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Appendix K - Biology

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Natural Resource Survey Report in Support of the Draft Environmental Impact Statement for the Marine Corps Relocation Initiative to Various Locations on Guam

Pre-Final

Revision 1

June 29, 2010

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives Contract Number N62742-06-D-1870, TO 0016 and TO 0007 Mod 4

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List of Acronyms and Abbreviations

AAFB	Andersen Air Force Base
ac	acre
AFB	Air Force Base
°C	Celsius
cm	centimeter
CNMI	Commonwealth of the Northern Mariana Islands
dbh	diameter at breast height
DoD	Department of Defense
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EOD	Explosive Ordnance Disposal
ERA	Ecological Reserve Area
ESA	Endangered Species Act
FAA	Federal Aviation Administration
GCWCS	Guam Comprehensive Wildlife Conservation Strategy
GDAWR	Guam Division of Aquatic and Wildlife Resources
GEDCA	Guam Economic Development and Commerce Authority
GPS	Global Positioning System
ha	hectare
HAPC	Habitat Area of Particular Concern
JGPO	Joint Guam Program Office
km	kilometer
m	meter
m^2	square meter
m/ha	meter per hectare
NAVFAC	Naval Facilities Engineering Command
NCTS	Naval Computer and Telecommunications Station
NMD	Non-metric Multidimensional Scaling
NMS	Naval Munitions Site
NR	Natural Resources
PVC	polyvinyl chloride
RH	relative humidity
sq cm	square centimeter
sq m/ha	square meter per hectare
SOGCN	Species of Greatest Conservation Need
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VCP	variable circular plot
yr	year

1 Introduction

Under a Naval Facilities Engineering Command (NAVFAC) contract for Architect-Engineer Services for Environmental Planning to Support Strategic Forward Basing Initiatives and in support of the Marine Corps Relocation Initiative to Various Locations on Guam, the TEC Joint Venture received Task Order (TO) 0016 with subsequent modifications and TO 0007 Mod 04 for Natural Resources (NR) Surveys on Guam. The purpose of these TOs is to provide the necessary data to support the Environmental Impact Statement (EIS) for the Joint Guam Program Office actions relating to the relocation of the Marines by filling existing data gaps identified in the *Final Natural Resources Survey and Assessment Report of Guam and Certain Islands of the Northern Mariana Islands* (NAVFAC, 2007). Natural resource surveys were conducted on Department of Defense (DoD) and non-DoD lands on Guam (Figure 1-1).

This report provides a summary of the natural resource surveys performed under the TOs. The detailed survey reports developed by the TEC JV team members are found in this report's appendices.

1.1 DoD Lands and non–DoD Lands Considered

To meet the anticipated increase in personnel and to support proposed training activities, construction is planned at numerous military properties and non-DoD lands on Guam. DoD lands included the following: Andersen Air Force Base (AAFB), including AAFB Finegayan and Potts Junction; Andersen South; Air Force Barrigada; Navy Barrigada; North Finegayan; South Finegayan; Navy Main Base, including Inner Apra Harbor, Camp Covington, and Orote Point; and the Naval Munitions Site (NMS). Non-DoD lands included the Harmon Annex, Route 1 River Crossings, Route 15 Lands, Proposed Option Road A, and the former Federal Aviation Administration (FAA) Parcel. Figure 1-2 identifies the locations of these parcels on Guam.

1.2 Natural Resources Surveys

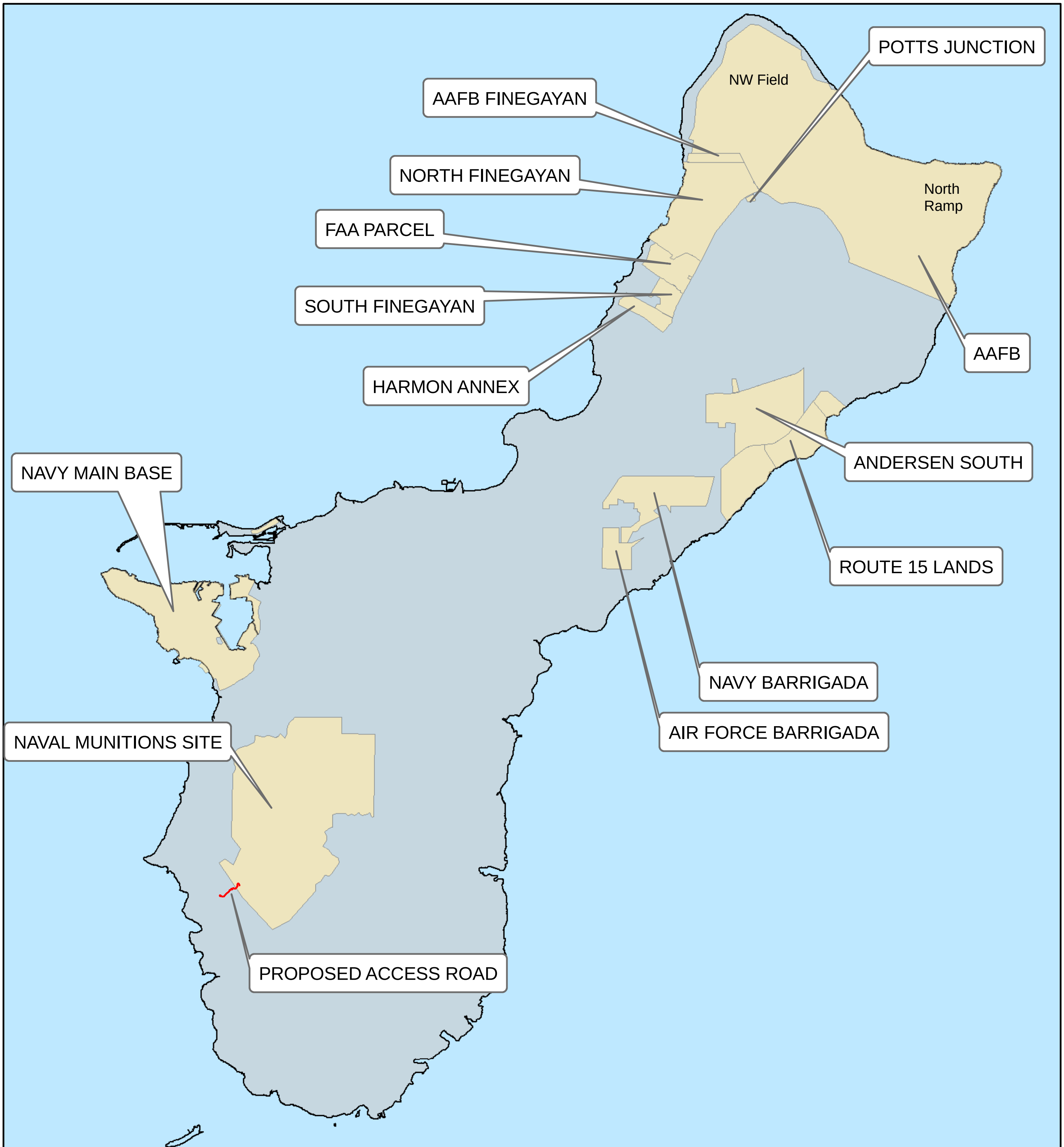
In order to assess the potential impacts to natural resources resulting from the buildup on DoD lands and non-DoD lands, a variety of natural resource surveys were conducted. These surveys included avian, butterfly, fruit bat, reptiles and amphibians (herpetofauna), marine waters, tree snail, and vegetation. Appendix A contains the descriptions of many species that were observed during the surveys. Table 1-1 identifies the surveys that were performed at each location. For each survey type a detailed technical report was prepared and these are provided in Appendices B through I.

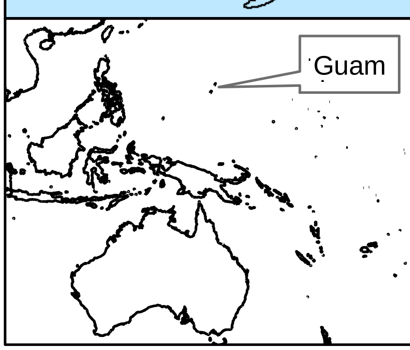
1.3 Structure of the Report

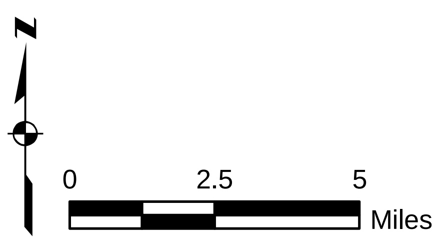
Chapter 1 is this introduction. Chapter 2 identifies the methodologies that were utilized for each survey. Survey methodologies were generally conducted in an identical manner on each parcel; although, if there was a change in methodologies, the differences are noted. Chapters 3 through 13 provide a summary of the results of the natural resources surveys that were conducted on each

Location of Guam and Northern Mariana Islands

Figure 1-1







DoD Lands & Non DoD Lands

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 1-2

parcel. The detailed survey reports provided by the project team are found in Appendices B through I.

Table 1-1

Natural Resources Surveys Conducted on Each Parcel

Property	Survey						
	Avian	Butterfly	Fruit Bat	Herpeto-fauna	Marine	Tree Snail	Vegetation
Air Force							
Andersen AFB	√	√		√		√	
AAFB Finegayan	√			√			√
Potts Junction	√						√
Andersen South	√	√		√		√	√
Air Force Barrigada	√	√		√			√
Navy							
Main Base							
Inner Apra Harbor					√		
Oscar and Papa Wharves					√		
Polaris Point	√			√	√		√
Camp Covington Wetlands	√						
Orote Point	√			√			√
NMS	√			√		√	√
NORTH Finegayan	√			√		√	√
South Finegayan	√			√			√
Navy Barrigada							
Non-DoD							
NMS Proposed Access Road Option A	√			√		√	√
Former FAA Parcel	√			√		√	√
Route 15 Lands*	√		√	√		√	√
Route 1 Crossings	√			√		√	√
Harmon Annex**							

Notes: *Route 15 Valley not surveyed due to access issues.
** The Harmon Annex was not surveyed as similar habitat exists on nearby parcels.

2 Methods

In order to support the EIS analysis, a field program was conducted to collect necessary data not available through past studies. The field program gathered data on vegetation, herpetofauna, avifauna, tree snails, butterflies, fruit bats, and marine species occurring within specified DoD and non-DoD lands.

The field program was originally proposed in the Guam Natural Resource Surveys Draft Sampling Plan (AECOM, 2007) and finalized in the *Guam Natural Resource Surveys Pre-Final Sampling Plan, Revision 1* (AECOM, 2008) based on Navy comments. Field surveys for fruit bats and butterflies were performed using protocols approved by the Navy and not incorporated in the sampling plan. Field studies commenced following the approval of this document.

The data collected as part of the field program will be included in the EIS to assist in the assessment of potential impacts to the following: federally threatened, endangered, and candidate species and their habitats; species of biological or cultural significance; and to terrestrial and aquatic habitats from the development of infrastructure for proposed basing and training facilities.

A key component of the field effort was to survey several terrestrial transects on each property. Table 2-1 shows the number and length of transects that were surveyed on each parcel. The transects were placed within each parcel to provide representative converge of the various habitats and natural resources surveyed. The length of each individual transect is identified in Table 2-1 and within the various natural resource survey reports provided in the appendices.

2.1 Herpetofauna

Two separate efforts documented herpetofauna on DoD and non-DoD parcels. One effort, completed by the TEC JV biologists surveyed herpetofauna on ten parcels. The other effort, which was completed by NAVFAC Pacific biologists, surveyed herpetofauna on three parcels. A description of the methods used for each effort is provided in Subchapters 2.1.1 and 2.1.2.

2.1.1 Herptofauna Survey - Andersen AFB; Andersen South; Navy Barrigada; FAA Property; NMS; North Finegayan; Orote Point; RT15 Lands; South Finegayan; and Proposed Access Road Option A

Herpetological surveys were conducted between the February 17, 2008 and October 21, 2009 on the following locations: AAFB; Andersen South; Navy Barrigada; FAA Property; NMS; North Finegayan; Orote Point; RT15 Lands; South Finegayan; and Proposed Access Road Option A. The surveys were conducted on the 10 parcels and 53 transects. The surveys were conducted nocturnally (targeting gecko species) and diurnally (targeting skink species) to increase the possibility of encountering as many species as possible within appropriate habitats along survey transects within each parcel. Multiple transects were established to survey each parcel's habitats (e.g., forest, grassland, etc.). The surveys were performed by up to three biologists on each transect utilizing both glue-board and visual surveys, as described below. The herpetofauna survey reports that further details the methods are located in Appendix B**.**

Table 2-1

Number and Length of Terrestrial Survey Transects for Each Parcel

Site	Number of Transects	Total Transect Length (m)	Length of Individual Transects
DoD Parcels			
Andersen AFB	7	2,100	Transect 1 is approx. 183 m in length. Transects 2 and 3 are 305 m in length. Transect 4 is approx. 427 m in length. Transects 5, 6, and 7 are 400 m in length.
Andersen South	7	1,150	Transects 1 – 6 are 152 m in length. Transect 7 is 500 m in length.
Air Force Barrigada	3	550*	Transect is Approximately 5050 m in length
Main Base - Orote Point	4	375	Transects 1 and 2 are 76 m long. Transects 3 and 4 are 152 m long.
Main Base – Polaris Point	2	650*	East Transect is approximately 400 m in length. West East is approximately 250 m in length
Main Base – Camp Covington Wetlands	1	1,700*	Transect is 1,700 m in length.
NMS	11	3,795	Transect 1 is approximately 1,000 m in length. All other transect are approximately 137 m long.
Navy Barrigada	3	550	Transects 1 and 2 are 152 m in length. Transect 3 is 250 m in length.
North Finegayan	9	1,700	Transects 1-8 are 133 m in length. Transect 9 is approximately 516 m in length
South Finegayan	2	150	Transects 1 and 2 are 76 m in length
Non-DoD Parcels			
Former FAA Parcel	3	450	Transects 1 -3 are 152 m in length.
Route 15 Lands	3	1,300	Transect 1 is approximately 250 m in length. Transect 2 is approximately 550 m in length. Transect 3 is approximately 500 m in length.
Route 15 Valley**	1	500	Transect is 500 m in length
AAFB Finegayan	2	1,000	Transects are 500 m in length
NMS Proposed Access Road	No formal transects were utilized for this parcel. Surveys occurred within discontinuous forested areas.		
Notes: * Length approximated. ** Parcel not surveyed due to access issues.			

2.1.1.1 Glue-Board Surveys

Glue-board surveys were conducted to capture small, cryptic species that may be more difficult to identify from a brief encounter during a visual survey. Size of the animal, placement of the trap, habitat type, and weather all have varying effects on the probability of capturing reptiles using glue boards. On each transect, two “mouse” glue boards were set at 15 meter (m) intervals, one on the ground and one in a nearby tree; if a tree was not available, only a ground trap was used at that particular station. All glue boards were set in the shade adjacent to and approximately 1 m from the transect. If rain was heavy or persistent, trapping was aborted.

The times at which traps were set, checked, and removed on each transect were recorded. During diurnal glue-board surveys, traps were checked no more than four hours from opening, but were usually checked after two hours. If mortality rates were greater than 15 percent, traps were repositioned to a more protected location to reduce mortality. During nocturnal glue-board surveys, traps were left open for no more than 14 hours unless mortality rates were greater than 20 percent, in which case traps were closed earlier. The aim was to maintain mortality rates below 10 percent.

When checking traps, personnel returned to the beginning of the transect without disturbing the transect. Traps were checked in the same order as they were set. Humane removal of individuals from glue boards was imperative. When removed, animals were released slowly from the boards so that the glue released with minimal strain. If for some reason the glue was less yielding, a thin line of vegetable oil was applied to the attachment location.

2.1.1.2 Visual Surveys

Visual surveys were performed to identify species that might not be captured on a glue board. Visual surveys were conducted both nocturnally and diurnally. Day surveys commenced between 0800 and 1000 hours and night surveys between 1830 and 2030 hours. Search speed was set at approximately 0.5 kilometers per hour. All visual surveys were conducted by two trained biologists simultaneously, each assigned to opposite sides of a transect. If the transect was too narrow, searchers were staggered, but not further apart than 4 m.

When a species was encountered, the time, location along the transect, species, rain, and perch information were all recorded. Any unidentified individuals were captured where possible to aid in identification. In some instances, photographs were taken to verify identification and to document interesting occurrences.

2.1.2 Herptofauna Survey - AAFB Finegayan, Air Force Barrigada, and Polaris Point

Herpetofauna surveys were conducted by NAVFAC Pacific biologists on AAFB Finegayan, North Finegayan, Air Force Barrigada, and Polaris Point between August and November 2008.

Reptiles and amphibians were sampled by visual surveys on transects and glue board, trapping on the same transects. Visual surveys were performed during the morning and evening hours. Adhesive traps were placed every 15 m on the transect up to 15 traps. One trap was placed on the ground and one was stapled to the nearest tree at approximately breast height. Ground traps were placed between 0800 am and 0900 am and left out for four hours. Tree traps were placed at the same time but left overnight. Tree traps were checked in the late afternoon so that lizards could be removed before nightfall. For more information regarding this survey, refer to Appendix C.

2.2 Vegetation

Qualitative and quantitative vegetation surveys were conducted on DoD and non-DoD parcels. Descriptions of the surveys are provided below. The vegetation survey reports that further detail the methods of the surveys, the dates each parcel was surveyed, etc., are located in Appendix D.

2.2.1 Qualitative Surveys

General walk-over surveys (qualitative) were conducted from July 7 to July 9, 2009 and December 9, 2009 to January 20, 2009 at the following parcels:

- AAFB (the specific task was to document the presence of host plants for butterfly species that are candidates for listing under the Endangered Species Act (ESA).
- North Finegayan, NMS Almagosa Basin, and the proposed NMS Proposed Access Road.
- Route 15 upper plateau lands (Firing Range Option A lands being considered in the EIS).

Surveys consisted of walking transect lines in areas where the identities of specific vegetation communities were uncertain, where edges of certain mapped community types were uncertain, or in areas where specific activities are proposed (e.g., the proposed Access Road Option A and Andersen AFB, where new utility lines are proposed).

Plants specifically searched for are Federal- or Guam-listed species or are those identified in the Guam Comprehensive Wildlife Conservation Strategy as species of greatest conservation concern (GDAWR 2006). Also searched for were host plants for ESA-candidate butterfly species. Plant names referred to in the text are based on Raulerson (2006).

2.2.2 Quantitative Surveys

Two separate efforts documented herpetofauna on DoD and non-DoD parcels. One effort, completed by Navy contractor biologists, surveyed herpetofauna on ten parcels. The other effort, which was completed by NAVFAC Pacific biologists, surveyed herpetofauna on three parcels. A description of the methods used for each effort is provided in Subchapters 2.2.2.1 and 2.2.2.2.

2.2.2.1 Vegetation Survey - Andersen AFB; Andersen South; Navy Barrigada; FAA Property; NMS; North Finegayan; Orote Point; RT15 Lands; South Finegayan; and Proposed Access Road Option A

The goal of the quantitative vegetation surveys is to locate Federal- or Guam-listed species or ones identified in the Guam Comprehensive Wildlife Conservation Strategy as species of conservation concern and to characterize the habitat types through a visual walk and conducting a point-quarter survey over the entire length of each transect. Vegetation surveys were conducted using the following methods:

- Quantitative surveys were performed along several transects within each parcel. Along each transect, stations were placed at a minimum of every 50 m to identify species. At each station, quarter plots were placed, and the tree that was greater than 2 centimeters diameter at breast height (cm dbh) closest to the transect in each quarter was measured at dbh.

- Within a 5-m radius around the station plot, the presence or absence of ungulate sign (deer and pigs) was noted and vegetation was counted and identified to species for tree seedlings that were smaller than 2cm dbh.

- Ground cover was assessed with a 50-cm by 50-cm polyvinyl chloride (PVC) square grid or quadrat frame. At each station the frame was dropped in one of the cardinal directions approximately 1 m from the station center. The types of ground cover recorded were litter (dead vegetation), rock, bare soil, or live vegetation.

- All observations were recorded in a field log book or on data sheets.

Quantitative surveys were performed by Navy Contractor biologists during February, March, and April of 2008.

2.2.2.2 Vegetation Survey - AAFB Finegayan, Air Force Barrigada, and Polaris Point

In addition, vegetation surveys were conducted by NAVFAC Pacific biologists on AAFB Finegayan, Air Force Barrigada, and Polaris Point between August and November, 2008. The results of those surveys are provided in Appendix C.

2.3 Butterfly Surveys

From September 28 to October 2, 2009 and January 25 to 31, 2010, butterfly surveys were conducted on three transects at Andersen AFB, one transect on Andersen South, and one transect on Air Force Barrigada. The butterfly survey consisted of two methods: timed counts and baited traps. Descriptions of these methods are provided in the sections below. A butterfly survey report is provided in Appendix (E).

2.3.1 Timed Counts

Timed counts were conducted along linear transects within each of the three parcels. At 30-m intervals, two biologists stood back-to-back and enumerated the observations of all butterfly species within a 5-minute period. The areas investigated along the transect consisted of 20-m diameter circle plots. The biologists communicated with each other frequently throughout the survey period so as not to count the same individual butterfly twice.

2.3.2 Baited Traps

Two baited traps were placed on each transect during daylight hours. The bait consisted of a mixture of mashed ripe bananas, apple cider, sugar, and yeast (Photo 2-1). At the end of the trapping period, which lasted approximately six hours, the traps were checked, and captured butterflies were noted and then released.

Photo 2-1 A baited butterfly trap hanging on a survey transect.

2.4 Marine Surveys

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault. Apra Harbor is a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers — the Apalacha and Atantano — drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974). Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and fill by the U.S. Navy since 1945 (Paulay et al., 2001). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom.

2.4.1 Marine Fauna and Flora Survey – Inner Apra Harbor

The specific objectives of the marine surveys were the following:

- Quantitative assessments of corals.
- Quantitative assessment of select macro-invertebrates.
- Fish census.
- Assessment of essential fish habitat (EFH).
- Assessment of endangered species (including federally listed, proposed for listing, and candidate species, as well as those similarly listed or otherwise recognized by Guam) to include abundance and preferred habitat, if any.

- A subjective evaluation of survey areas using the four criteria for Habitat Areas of Particular Concern (HAPCs):
    1. The ecological function provided by the habitat is significant.
    2. The habitat is sensitive to human-induced environmental degradation.
    3. Development activities are, or will be, stressing the habitat type.
    4. The habitat is rare.

Survey methods are summarized below and further details can be found in the marine survey report in Appendix F. Three separate marine survey efforts were conducted: Inner Apra Harbor; Oscar and Papa Wharves; and Polaris Point. Studies of the Inner Harbor occurred between May 21 and May 29, 2008. Marine surveys of Oscar and Papa Wharves occurred in March 2010. The methods for each effort are described in the following subchapters.

The general ecological condition of an approximately 145 ha area was assessed by a modified manta tow method. Two observers were towed behind a boat piloted along the 6,188-m boundary of the study area. Visibility was limited to less than 5 m because of high turbidity of the water. The locations and general surface coverage of corals were noted by the observers. Based upon these observations, three sites (Abo Cove, Transect 1, and Transect 2) were selected for benthic surveys, and five sites (Wharves S, T, U, V, and X) were selected for surveys of vertical wharf faces. A 100-m transect line was established along the 2-m isobath at Abo Cove. For Transects 1 and 2, in open areas of the harbor floor away from wharves or the shoreline, a global positioning system (GPS) tracking unit in a waterproof housing was towed by a diver swimming along the harbor floor. Lengths of the tracks were calculated with SigmaScan Pro 5.0 (SPSS, Inc., 1999). At Wharves S, V, and X, 100-m transects were established. At Wharves T and U, 50-m transects were established, because access to larger wharf areas was not granted. GPS coordinates were recorded for the ends of all transects.

Both Oscar and Papa Wharves are obstructed by large shipyard facilities that limited access to wharf faces. During the survey period, two large crane barges were moored at Oscar Wharf while a large dry dock occupies virtually all of Papa Wharf's main face. Therefore, transect lengths were limited to a 50-m stretch of wharf face at Oscar Wharf and a 50-m stretch of wharf face at the back of Papa Wharf where this wharf s with Romeo Wharf. GPS coordinates were recorded for transect locations at each wharf.

Benthic Cover - Benthic quadrats were surveyed along transects established for coral, invertebrate, and fish surveys. Six transects, each 50 m long, were established at a fixed depth (3–5 m) throughout Inner Apra Harbor. The percentage cover of algae, corals, and sponges in five 0.25-square meter (m^2) quadrats was quantified *in situ* for each transect. Macrophotographs of the representative species were taken. Voucher specimens of algae were collected to establish a reference collection of algae from Inner Apra Harbor. *In situ* cover estimates of turf algae were troubled by poor visibility and, therefore, removed from the data set prior to analysis.

Corals - Coral communities were assessed quantitatively along the transects by an observer using the point-quarter method of Cottam et al. (1953). Points were established 3 to 10 m apart on each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals.

Macroinvertebrates – All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines at Abo Cove and Wharves S, T, U, V, and X were identified and enumerated by an observer swimming along the transect line. For this study, conspicuous is defined as being larger than 50 millimeters (mm) in size and as being clearly visible to an observer without the need for overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line.

Fishes – Fish were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. At Abo Cove, the line was deployed along the bottom as the diver observed and counted fishes. Along wharf faces, three transects were run (where possible): just below the surface (subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5 m above or below the principal transect line were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the transect line were counted.

At two stations located in open areas of the harbor away from wharves or the shoreline, GPS tracking was used to census fishes. Here, one diver utilized a GPS unit set on timed-tracking mode and towed above him in a waterproof housing and recorded all benthic species observed within 1 m to either side of an imaginary line directly in front of the diver (Colin and Donaldson, in review). Observations were recorded during the course of the swim just above the bottom substrate. Pelagic species could not be observed because of poor visibility. Fishes were identified to species. Reference photographs and video were taken with an underwater digital camera or underwater digital video camera, but image quality tended to be extremely poor because of turbid conditions.

EFH - Extremely poor visibility on transects at all stations limited the ability to collect data on EFH. Underwater photographs taken along the transect line to estimate benthic structure used by different species were essentially useless. Similarly, measures of rugosity (benthic structural complexity), limited to the edge of a shallow reef at Abo Cove, were made under near-zero visibility and were fraught with error. Therefore, it was possible only to make qualitative descriptions of habitats used by fishes.

2.5 Avian Surveys

Four surveys were conducted during 2008, during the following periods: February 16-25; March 27 - April 6; June 24-28; and December 9-19. In 2009, additional surveys were conducted during July 16-19 and September 21-24. Both roadside and forest bird surveys were utilized to characterize avian communities at various sites. The avifauna survey report that further details the methods of the surveys is located in Appendix G.

In addition, surveys were conducted by NAVFAC Pacific biologists on AAFB Finegayan, Air Force Barrigada and Polaris Point between August and November 2008 (Appendix C).

2.5.1 Roadside Survey

A modified point-count methodology, in conjunction with a line transect (i.e., existing roadways) was used to enumerate bird detections (Bibby et al., 2000) for the roadside surveys. Total numbers of species detections (no direction or distance data were collected) were recorded (either by visual observations or song, or both) within one 3-minute survey period at each pre-determined station; no surveys were replicated. In order to minimize double-counting, survey stations were positioned a minimum of 150 m apart. All surveys were conducted either during the morning from sunrise to 1000 hours, or in the evening after 1700 hours.

For the Air Force Barrigada, AAFB Finegayan, and Polaris Point parcels, the roadside bird surveys methodologies varied from the avian surveys conducted on other parcels. Because the sites varied in size, the avian surveys consisted of a point count survey along each transect (count stations every 100 m on the transect) and/or, depending on the site, a roadside breeding bird type survey. Surveys started between 0600 and 0700 hours and were completed by 1100 hours. Due to the small size of the areas surveyed the number of stations at each site was fewer than 10. For the breeding bird surveys avian identification was performed along roadside survey routes. Each survey route utilized available Base roadways in areas planned for development. Sampling locations (i.e., stops) were at approximately 500-m intervals. At each stop, an 8-minute point count was conducted. During the count, every bird seen within a 0.25-mile radius or heard was recorded.

2.5.2 Forest Bird Survey

In forested habitat, bird detections were enumerated using a point-count methodology along variable-length straight-line transects (Bibby et al., 2000). Survey stations were placed a minimum of 150 m apart so as to minimize double-counting. All bird species were recorded (by either visual observations or song, or both) within one 8-minute survey. All station surveys were conducted during the morning hours from sunrise to 1000 hours. As in the roadside surveys, no surveys were replicated. Although direction and distance measurements were recorded, only relative abundance among species will be discussed.

For the Air Force Barrigada, AAFB Finegayan, and Polaris Point the forest bird surveys methodologies, varied from the avian surveys conducted on other parcels. Forest birds were surveyed using the variable circular plot (VCP) method (Scott et al. 1986). All birds seen or heard during an 8-minute count period at each station were recorded with the detection type (audio, visual, or combined detection) and the distance to the bird when first detected, estimated to the nearest meter. Observations between stations were not recorded.

2.5.3 Endangered Avian Species

Although all avian surveys recorded any ESA-listed, Guam-listed, or other species of concern, two species warranted specific survey efforts.

Mariana Swiftlet (*Aerodramus bartschi*)

During the station-count surveys for Mariana fruit bats, observers also searched for the ESA- and Guam-listed endangered Mariana swiftlet. Searches were used to determine whether this species utilized the areas for foraging, movement between foraging areas, and roosting or nesting. In addition to noting the occurrence of the swiftlets (if they occurred), all avian species heard or observed were recorded during fruit bat station-count surveys.

Mariana Common Moorhen (*Gallinula chloropus guami*)

The Camp Covington wetland on Navy Main Base was identified as a habitat requiring species-specific surveys to determine whether the ESA-listed endangered Mariana common moorhen was present. Eleven listening stations were strategically positioned around the wetland habitat. Surveys were conducted during the morning hours from sunrise to 1000 hours. Survey stations were placed a minimum of 150 m apart so as to minimize double-counting. All moorhen detections (visual or auditory) were recorded within one 8-minute survey; no surveys were replicated.

2.6 Tree Snail Surveys

Surveys for partulid tree snails were designed to locate, identify, and assess the distribution and abundance of partulid tree snails on DoD and non-DoD lands proposed for use under the EIS. Tree snail surveys occurred in 2008 and September, October, and December, 2009, and in January, 2010. Surveys targeted four species of partulid tree snail (Gastropoda: Partulidae):

- Fat Guam Partula tree snail (*Partula gibba*)
- Guam or Pacific tree snail (*Partula radiolata*)
- Mt. Alifan tree snail (*Partula salifana*)
- Fragile tree snail (*Samoana fragilis*)

Three of these tree snails (humped tree snail, Guam tree snail, and fragile tree snail) are federal candidate species for listing under the ESA (U.S. Fish and Wildlife Service [USFWS], 2010). The Government of Guam lists all four species as endangered (Guam Department of Aquatic and Wildlife Resources [GDAWR], 2006).

2.6.1 Locations

Tree-snail surveys were carried out along select transects situated at nine locations on Guam: AAFB, Andersen South, Air Force Barrigada, Former FAA parcel, Route 15 Lands, North Finegayan, South Finegayan, NMS, and Proposed Access Road Option Road A. To increase the possibility of detecting the four target species, transects were set up within habitat containing known host plants known to be used by partulid tree snails.

2.6.2 Methods

Three survey methods were used to determine the presence of tree snails at each survey location: general visual surveys, detailed visual surveys, and quadrat surveys. These methods are specifically designed to target partulid tree snails and are adapted from those utilized in previous tree snail assessments (Hopper and Smith, 1992; Smith et al., 2008). A description of each method follows.

- **General visual surveys -** General visual surveys involved up to two trained observers walking each transect searching likely tree snail habitat for the presence of snails. During the general visual survey period, observers also noted specific areas that included an abundance of known partulid host plants, and areas where detailed visual surveys would subsequently occur. Information on known partulid host plant species was obtained from Hopper and Smith (1992). Host species for the tree snails are identified as the following: *Alocasia macrorrhiza, Annona reticulata, Asplenium nidus, Barringtonia asiatica, Cocos nucifera, Cycas micronesica, Derris trifoliata, Hernandia nymphaeifolia, , Intsia bijuga, Mammea odorata, Neisosperma oppositifolia, Phymatodes scolopendria, Pandanus dubius, Piper guamensis,* and *Triphasia trifolia*

- **Detailed visual surveys** – These were conducted at locations along each transect where known partulid host plants were abundant. At each location, observers intensively examined the leaves and stems of known partulid host plants for up to 30 minutes. If live tree snails were observed, quadrat surveys (see below) were completed. Following each plant examination, leaf litter was investigated for partulid shells for up to 10 minutes. If snail shells were observed, the location and condition of the shell (e.g., weathering, fragmentation, color intensity or bleaching) that may indicate recent presence of the snails were noted. If live partulid tree snails or their empty shells were found during the detailed visual survey period, the location was recorded as supporting tree snails.

- **Quadrat surveys** - If live partulid tree snails were located within the 30-minute detailed visual survey period, four 25-m^2 quadrats were established under the densest understory, as determined by a spherical densitometer. All partulid tree snails occurring within the quadrats and to a height of 2 m were identified to species, and their shell length and height measured to the nearest 0.1 mm with sliding vernier calipers. Host plant species and vertical height of the host plant to 0.5 m were recorded for each partulid tree snail observed.

During the quadrat surveys, temperature (in degrees Celsius [°C]), relative humidity (RH), and air movement (by the Beaufort scale) were measured with miniature probes in microhabitats inhabited by partulid tree snails to quantify inhabited microhabitat features (Crampton, 1925). Temperature, humidity, and air-movement measurements were also taken in uninhabited areas to assess their suitability for supporting tree snail populations. Comparisons of data from inhabited and uninhabited forest will provide a clearer characterization of suitable microclimatic conditions suitable for tree snail survival. The tree-snail survey report that further details the methods of the surveys is located in Appendix H.

2.7 Fruit Bat Surveys

2.7.1 Survey Locations

Mariana fruit bat surveys were conducted from locations positioned in forest areas containing known Mariana fruit-bat roosting and foraging vegetation. The survey locations were situated on the east side of Route 15 in the northeast region of Guam, stretching from the Lumuna area through the Asdonlucas area south to Pagat Point. In addition NAVFAC Biologists performed surveys on North Finegayan, Orote Point and Navy Barrigada (NAVFAC, 2008). These locations were not associated with any of the designated transects used for vegetation, bird, tree snail, or herpetological surveys.

2.7.2 Methods

Station-count surveys (Utzurrum et al., 2003) were conducted to determine the presence of solitary Mariana fruit bats, locate aggregations or colonies, and assess the location of fruit bat flight paths. Surveys were carried out between 0510 and 0745 hours. Each location was surveyed four times, twice each by two trained observers. The survey locations were chosen as vantage points that provided wide and unimpeded views of potential fruit-bat habitat and flight paths. Binoculars and a spotting scope were used to detect and count fruit bats at each location.

While carrying out station-count surveys for Mariana fruit bats, the observers collected anecdotal observational data on the phenological phases (flowering and fruiting) of plants, focusing on species that may be used as food sources by Mariana fruit bats. The fruit bat survey report, which includes details of the survey methods, is provided in Appendix I.

2.8 River Crossing Investigations

Investigations occurred at the crossings of five rivers that flow under Marine Corps Drive (Route 1). All of the rivers empty into the shallow bays of Guam's western coast and ultimately the Philippine Sea. At these five crossings, the bridges require modification as some do not meet current load requirements and all are not rated for Anti-Ballistic Missile (ABM) transport. These study areas for the river crossings included terrestrial and aquatic habitats 30.5 m upstream and downstream of the bridges. The riverine habitats were also identified through snorkel surveys, in which the benthic substrate, fish, and floral populations were noted. Also, avian surveys were performed in the vicinity of the bridge locations.

3 Andersen AFB

Herpetofauna, butterfly, vegetation, avian, and tree snail surveys were conducted on Andersen AFB (AAFB). Three study areas comprise the main portion of Andersen AFB: Northwest Field, North Ramp, and the proposed utility corridors along Route 9. The locations of the transects in these three areas are shown on Figures 3-1, 3-2, and 3-3, respectively.

At AAFB, seven transects were surveyed. Two transects were set in degraded forest in the North Ramp area (Figure 3-1), with the shrub *Wickstroemia elliptica* being the dominant species, but also containing *Morinda citrifolia* and *Hibiscus tiliaceus* trees. Two transects (Figure 3-2) were located in the Northwest Field Area in native limestone forest habitat predominated by *Guamia mariannae, Aglaia mariannensis, Premna obtusifolia, Neisosperma oppositifolia*, and *Pandanus tectorius* trees. The final three transects were located within the southern portion of the facility at proposed utility corridors near the base boundary with Route 9 (hereafter referred to as the Route 9 Boundary Transects) (Figure 3-3).

Herpetofauna, vegetation, and avian surveys were also conducted on two other parcels associated with the AAFB. These parcels are AAFB Finegayan and Potts Junction (Figure 3-4).

3.1 Herpetofauna Surveys

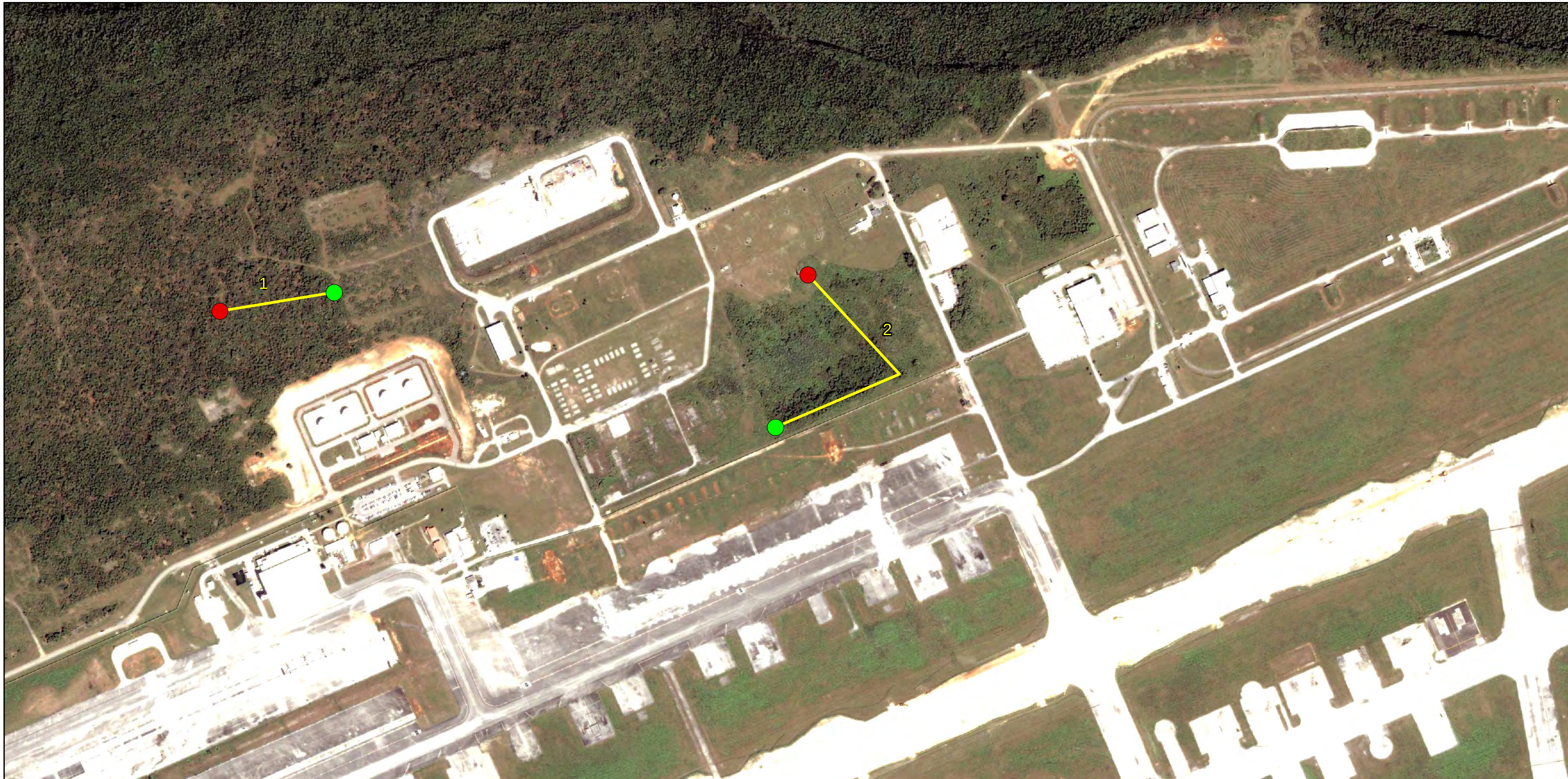
Two survey efforts identified herptofauna associated within the select areas of AAFB. Subchapter 3.1.1 identifies herptofauna observed within the Northwest Field, North Ramp, and proposed utility corridors along Route 9. Subchapter 3.1.2 identifies herptofauna observed within AAFB Finegayan.

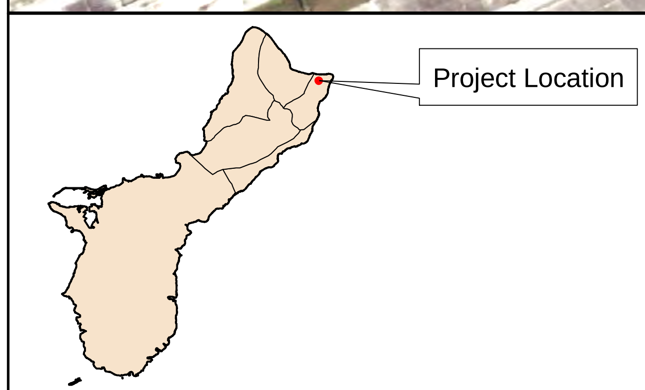
3.1.1 Herpetofauna – Northwest Field, North Ramp, and Proposed Utility Corridors

Nine herpetofauna species were captured or observed on AAFB. Table 3-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

The capture of moth skink (Photo 3-1), a Guam-listed endangered species, at AAFB is noteworthy. The distribution and abundance of this native skink on Guam is unknown, due to the variability of information presented by authors. The skink was captured on Transect 7, Station 16.

The continued widespread presence of the curious skink and the brown treesnake, as well as other introduced amphibian species, is of concern because of each species' potentially deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of the other introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).





Beginning Transect Point

End Transect Point

Transect Lines

N

0 200 400 Feet

0 200 400 Meters

Andersen AFB North Ramp

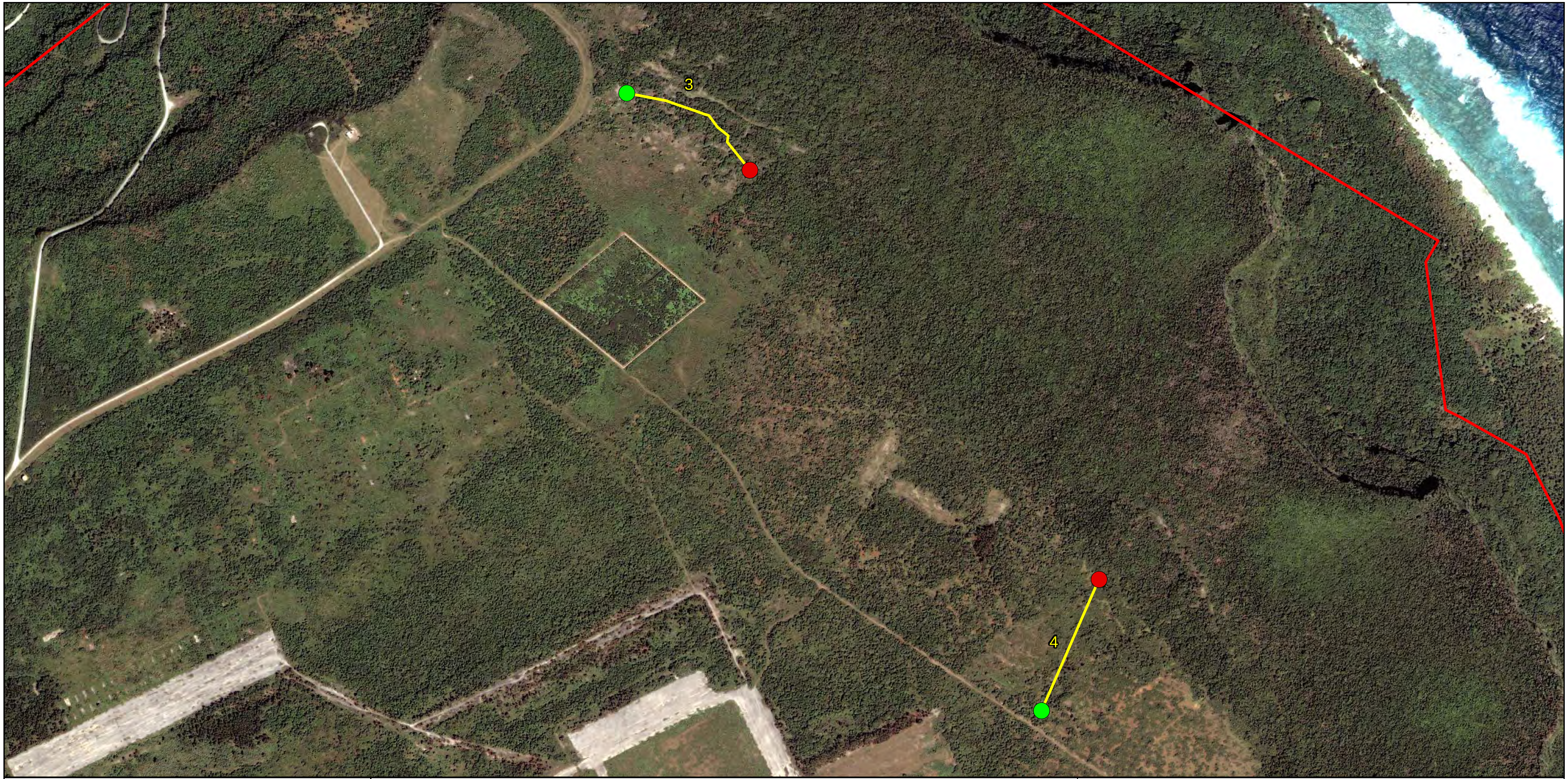
Transect Map

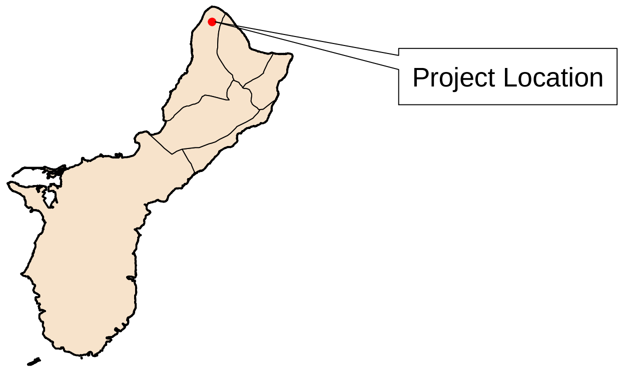
Prepared By: TEC Inc. Joint Venture

A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Exhibit 3-1





Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400 Meters

Andersen AFB Northwest Field

Transect Map

Prepared By: TEC Inc. Joint Venture
A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Figure 3-2

Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400

Meters

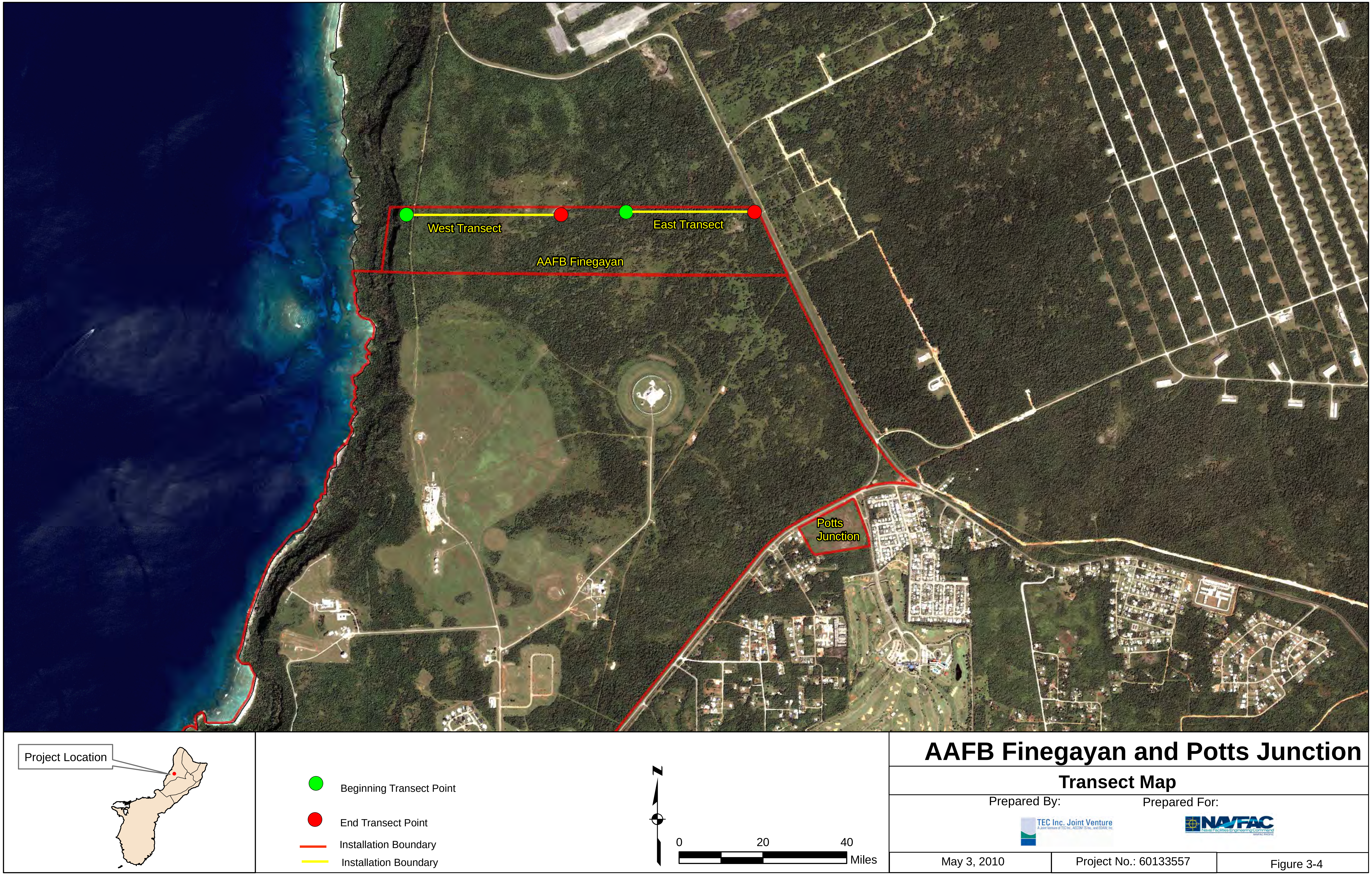
Andersen AFB - Utility Corridors

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 3-3



AAFB Finegayan and Potts Junction

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 3-4

Table 3-1

Herpetofauna Captured or Observed on Andersen AFB

Group	Species	Status
Skinks	*Curious skink (Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Geckos	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
	Brahminy blind snake (*Ramphotyphlops braminus*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced
Note: *Identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Endangered/ Species of Greatest Conservation Need (SOGCN) (GDAWR, 2006).		

Photo 3-1 Moth skink, *Lipinia noctua*

3.1.2 Herptofauna – AAFB Finegayan

In 2008, the NAVFAC Pacific biologists performed herpetofauna surveys along two transects in AAFB Finegayan (Figure 3-4). The transects were identified at Transect East and Transect West. Table 3-2 identifies the herptofauna that were observed.

Table 3-2

Herpetofauna Captured or Observed on AAFB Finegayan

Group	Species	Status
Skinks	Curious skink (Carlia ailanpalai)	Introduced
	Pacific blue-tailed skink (Emoia caeruleocauda)	Native
	Moth skink (Lipinia noctua)	Native*
Geckos	House gecko (Hemidactylus frenatus)	Introduced
	Mutilating gecko (Gehyra mutilata)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Amphibians	Marine toad (Rhinella marinus)	Introduced
Note: *Identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Endangered/ Species of Greatest Conservation Need (SOGCN) (GDAWR, 2006).		

3.2 Vegetation Survey

On the AAFB, vegetation surveys were performed within along Transects 5, 6, and 7 proposed utility corridors (Subchapter 3.2.1), the AAFB Finegayan (Subchapter 3.2.2) and the Potts Junction Property (Subchapter 3.2.3).

In addition to the qualitative survey performed as part of this work, the Air Force previously performed a more in-depth vegetation survey (Andersen AFB, 2008). The results of this study indicated that in east AAFB, the North Ramp project area consists primarily of developed land, but there are small areas of mixed herbaceous scrub and mixed limestone forest- in the northern portion of the site. The South Ramp project area consists primarily of developed land, but there are small areas of *Ochrosia mariannensis* edge and mixed herbaceous scrub habitats in the eastern portion of the site (Andersen AFB, 2008).

In West AAFB, Northwest Field (NWF), the Munitions Storage Area (MSA), and surrounding areas consist primarily of mixed limestone forest, *Vitex*-dominated forest, mixed herbaceous scrub, mixed shrub, *Casuarina equisetfolia* forest, and developed land (Andersen AFB. 2008).

3.2.1 Vegetation – Proposed Utility Corridors

A qualitative vegetation survey was performed within areas of proposed utility lines on AAFB (Transects 5, 6, and 7). A primary purpose of this survey was to determine if there were any host plants for the two federal-candidate butterfly species *Hypolimnas octocula mariannensis* and *Vagrans egista*. These host plants (*Elatostema calcareum*, *Procris pedunculata*, and *Maytenus thompsonii*) were not observed on any of the transects. Transects were in disturbed limestone forests ranging from highly degraded to somewhat degraded with a primarily indigenous understory.

Two *Tabernaemontana rotensis* trees were observed on Transect 6 in flower and fruit. *Tabernaemontana* is considered an SOGCN by the Government of Guam (GDAWR, 2006).

Several trees of the uncommon *Geniostoma micranthum*, an endemic species, were observed on Transect 7. For more in-depth analysis of the vegetation on Andersen AFB, please refer to Appendix D.

3.2.2 Vegetation – AAFB Finegayan

In 2008, the NAVFAC Pacific biologists performed quantitative surveys along Transect East and Transect West in AAFB Finegayan (Figure 3-4). The results for both transects are as follows:

Transect East – On the transect the number of trees per hectare (ha) was calculated at 3,183 trees/ha. The mean dbh (cm) (with 95 percent confidence interval) was calculated to be 10.86 (9.11-12.61). *Vitex parviflora, Pandanus tectorius, and Spathodea campanulata* were the dominant species in the tree layer. Chart 3-1 identifies the species composition along the transect. *Sida* sp., *Piper guahamense*, *Polypodium punctatum*, *Chromo odorata*, and *Chamaecrista nictitans* were the dominant non-woody species. Ungulate impacts were quite extensive at the site and appear to be causing fragmentation of the habitat.

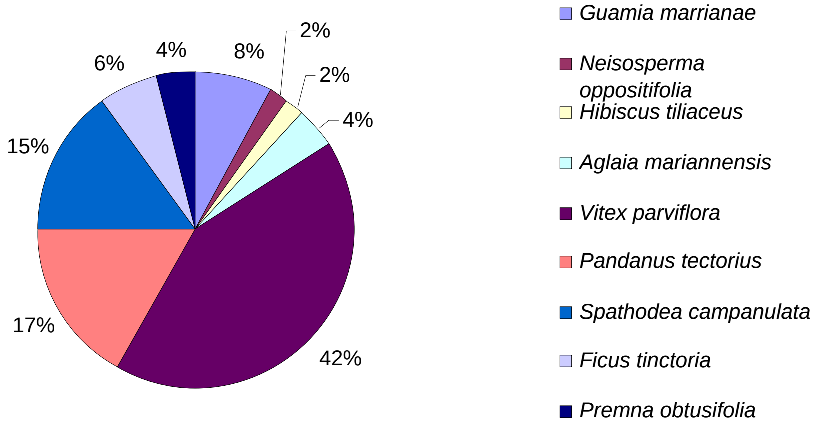


Chart 3-1 Tree Species Composition at AAFB Finegayan, East Transect

Transect West – On the transect the number of trees per hectare (ha) was calculated at 3,695 trees/ha. The mean dbh (cm) (with 95 percent confidence interval) was calculated to be 6.46 (4.85-11.31). *Vitex parviflora and Hibiscus tiliaceus* were the dominant species in the tree layer. Chart 3-2 identifies the species composition along the transect. *Piper guahamense*, *Polypodium punctatum*, *Chromo odorata*, *Stachytarpheta urticifolia*, and *Chamaecrista nictitans* were the dominant non-woody species. It was observed during the survey that deer and pigs are having a pronounced effect on the habitat, preventing regeneration of many native tree species and reducing diversity.

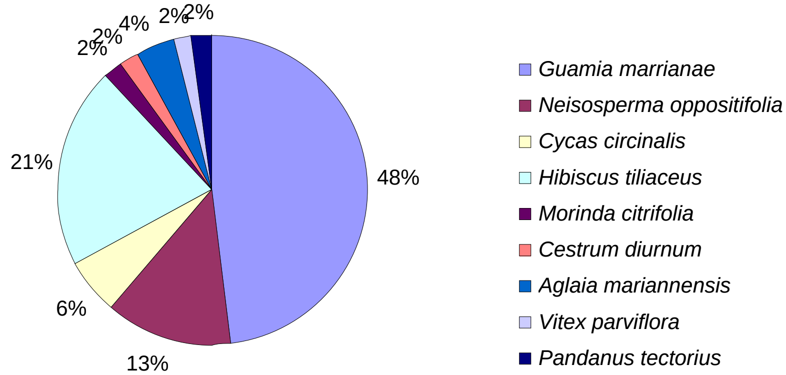


Chart 3-2 Tree Species Composition at AAFB Finegayan, West Transect

3.2.3 Vegetation – Potts Junction Property

In July, 2009, a qualitative study was performed on the Potts Junction parcel (Figure 3-4). The parcel is dominated by a highly disturbed shrub/grassland vegetation community with few native species. Much of the site is low vegetation including *Bidens alba*, *Passiflora suberosa*, and *Fimbristylis cymosa* with patches of grass including *Pennisetum purpureum*, *Pennisetum polystachion*, and *Saccharum spontaneum*. There are patches of trees or shrubs including *Buddleja asiatica*, *Spathodea campanulata*, *Hibiscus tiliaceus*, and *Leucaena leucocephala* and some patches of the fern *Pteris vittata*. There are some *Cocos nucifera* trees near the boundary with the Starts Golf Course.

3.3 Butterfly Survey

A butterfly survey was performed in the wet season (September, 2009) and at the start of the dry season (January, 2010) on Transects 5, 6, and 7 (Figure 3-3). The survey consisted of timed counts and baited traps.

The transects were located in a forested area with a canopy 6-12 m in height with moderate to dense undergrowth. On Transect 5, between the 130 m and 190 m mark, a clearing presents a break in the forest canopy and is vegetated with grasses and a few small isolated trees.

3.3.1 Timed Counts

Five butterfly species were identified during the timed counts:

- Lemon Emigrant (*Catopsilia pomona*)
- Monarch (*Danaus plexippus*)
- Blue-banded King Crow (*Euploea eunice*)
- Blue Moon (*Hypolimnas bolina*)
- Common Mormon (*Paplio polytes*)

None of the five species are considered endangered or threatened, and these species are fairly well distributed throughout Guam and portions of the Mariana Islands (Schreiner and Nafus, 1997). Table 3-3 identifies the numbers of individuals and species observed within the various sampling plots on Andersen AFB in September 2009 and January 2010.

In September 2009, the Common Mormon and Blue-banded King Crow were the two most common butterflies sighted. The Common Mormon and the Blue-banded King Crow comprised 46 and 43.6 percent of the total sightings at AAFB, respectively. Approximately 62 percent (57 of 92 sightings) of the total sightings of the Blue-banded King Crow occurred within two plots along Transect 5 associated with a road cut.

In January 2010, the Blue-banded King Crow and the Common Mormon were the two most common butterflies sighted, comprising 64.5 and 24.8 percent of the total sightings, respectively. Similar to the September findings, a majority of the total sightings on the Blue-banded King Crow (152 of 182 [83.5 percent]) occurred within the first 120 m of Transect A. These sightings also comprised 53.9 percent of the total sightings on AAFB.

The January sightings total of 282 individuals is approximately one-third higher than the September total of 211. Although there were two additional species sighted in September (Blue Moon and Monarch), the total number of individuals of these two species was only three. All of the species sighted are widely distributed throughout the Mariana Islands.

The Mariana Eight-Spot butterfly (*Hypolomnas octocula mariannensis*) and the Mariana wandering butterfly (*Vagrans egistina*), which are both candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973, were not observed on any transect. Moreover, the host plants for this species (refer to Subchapter 3.2.1) were also not observed on AAFB.

3.3.2 Baited Traps

Two baited traps were placed on the transects in the morning and retrieved in the late afternoon. On Transect 5, the traps were placed within a forested area in the beginning of the transect (September 2009 and January 2010) and a second trap was placed within a clearing in the September survey and near the end of the transect in the January survey. On Transects 6 and 7, the traps were placed in forested areas at the beginning and the end of the transects in both the September and January surveys.

No butterflies were captured in the baited traps on AAFB in September 2009. In January 2010, one Blue-banded King Crow was captured on Transect 6.

Table 3-3

Butterfly Sightings on AAFB – Transects 5, 6, and 7

Transect	September 2009						January 2010			
	Distance on Transect	Species					Distance on Transect	Species		
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant
5	10		1				0		40	
	40						30	1	9	
	70	1	4				60		28	
	100	2	6				90	1	24	
	130	2	29	2	2		120		51	
	160	3	28	4		1	180	2		
	190						220	1	1	
	230						250	1		
	260						280	3		
	290	1					310	3	1	
	320	1					340	2	2	
	350						370	2		
	380	2					400	2	4	
	TOTAL	**12**	**68**	**6**	**2**	**1**	**TOTAL**	**18**	**160**	
	Percent of Sightings	**13.5**	**76.4**	**6.7 p**	**2.3**	**1.1**	Percentage of Sightings	**10.1**	**89.9**	**0**
6	0						0			
	30						20	1		
	60	2					50	2		1
	90	8	2	3			80	2		
	120	8		1			110	2	1	
	150	3		2			140	1		
	180	5		1			170	3		6
	210		3	1			200	3		3
	240	1		3			230	2		7
	270	2					260		1	
	300	3		1			290	2		1
	330	2					320	2		4
	360	6					350	2		6
	390	5	17				380	3	1	1
	TOTAL	**45**	**22**	**12**	**0**	**0**	**TOTAL**	**25**	**3**	**29**
	Percent of Sightings	**57.0**	**27.9**	**15.2**	**0.00**	**0.00**	Percent of Sightings	**43.9**	**5.3**	**50.9**
7	0	2		1			0	3		
	30						30	2	1	
	60	1					60	2	2	
	90	1					90	5		
	120	3					120	1		
	150	2					150	2	4	
	180	3	2				180	1	6	
	210	4					210	4	1	
	240	4					240	1	1	
	270						270	4		1
	300	8					300	2		
	330	6					340		1	
	360	4					370			
	390	2					400		3	
	TOTAL	**40**	**2**	**1**	**0**	**0**	**TOTAL**	**27**	**19**	**1**
	Percent Sightings	**93.0**	**4.7**	**2.3**	**0**	**0**	Percent Sightings	**57.4**	**40.4**	**2.1**
Total	Individual s sighted	**97**	**92**	**19**	**2**	**1**	Individuals sighted	**70**	**182**	**30**

3.4 Avian Surveys

Avian surveys were performed within the Northwest Field, North Ramp, and Proposed utility corridors (Subchapter 3.4.1); AAFB Finegayan (Subchapter 3.4.2) and the Potts Junction parcel (Subchapter 3.4.3)

3.4.1 Avian Survey – Northwest Field, North Ramp, and Proposed Utility Corridor.

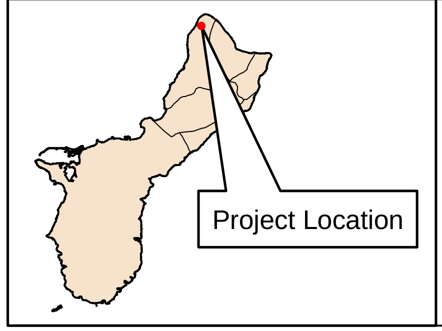
Within AAFB, roadside avian surveys were performed at the Northwest Field (Figure 3-5) and North Ramp (Figure 3-6), and forest bird surveys were performed at Northwest Field, North Ramp, and on the proposed utility corridors along Route 9 (Figure 3-4). Table 3-4 lists the species observed.

With the exception of the Micronesian starling, all other observed species are common to Guam. Table 3-5 specifies the resident status of the observed species. The nomenclature follows Gill et al. (2008). For more information on the avifauna survey and results, refer to Appendix G.

Table 3-4

Species Identified During Roadside and Forest Bird Surveys -- AAFB

Base / Parcel	Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
NW Field	Roadside Survey	17	Black Francolin (41) Island Collared Dove(~~15~~) (11) Yellow Bittern (2)	3	54
	Forest Bird Survey	8	Black Francolin (17) Island Collared Dove (6) Black Drongo (1) Eurasian Tree Sparrow (4)	4	28
North Ramp	Roadside Survey	6	Black Francolin (14) Island Collared Dove (4) Black Drongo (11) Eurasian Tree Sparrow (7)	4	36
Proposed Utility Corridors	Forest Bird Survey	12	Island Collared Dove (1) Black Drongo (1) Yellow Bittern (1) Micronesian Starling (1)	4	4



Installation Boundary

Roadside Survey Point

N

0 200 400

Meters

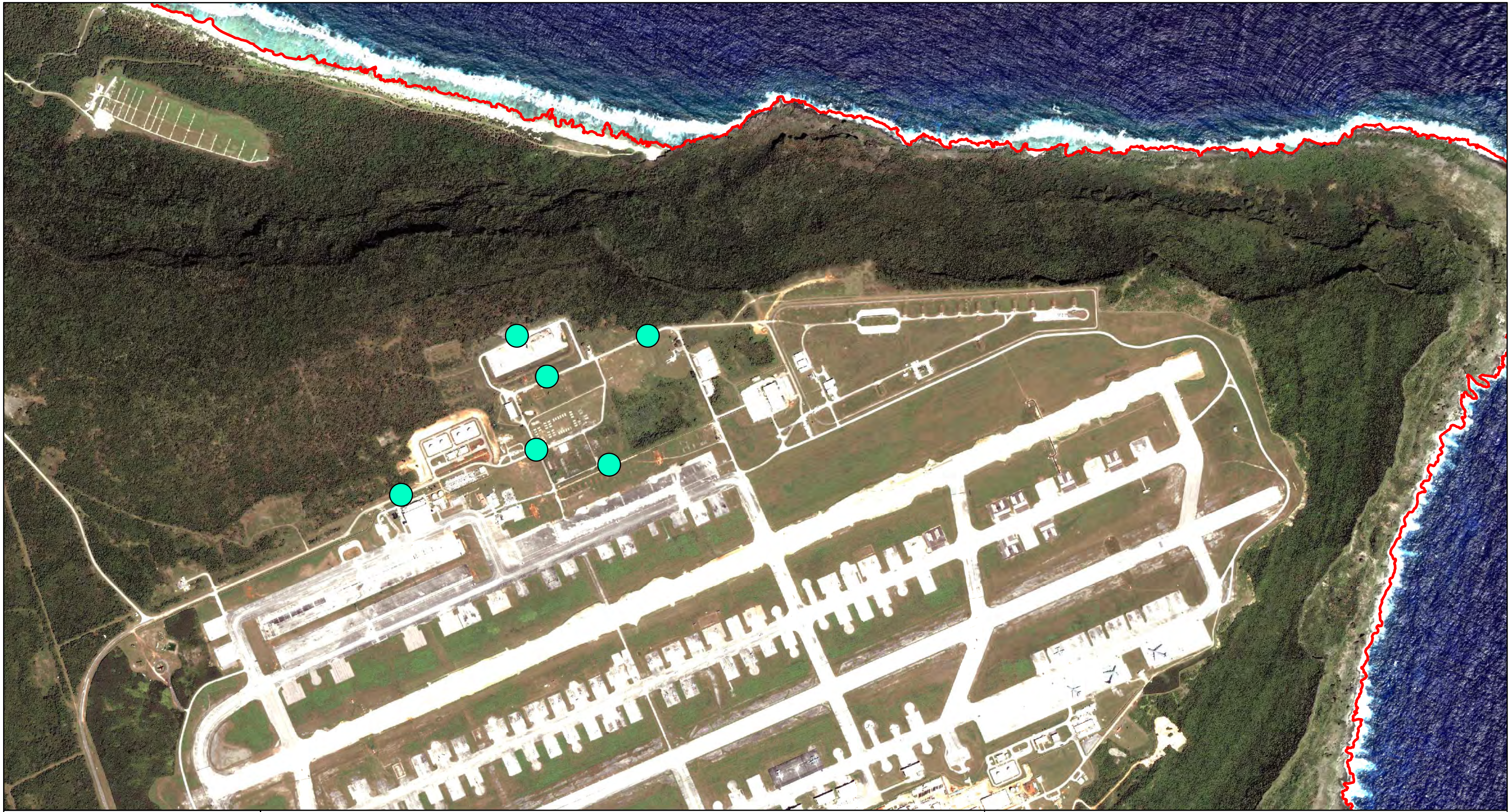
Andersen AFB Northwest Field

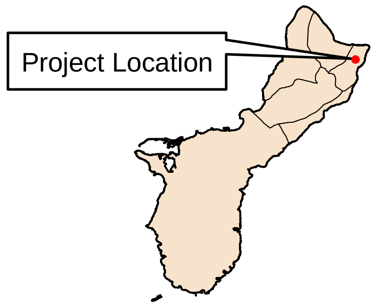
Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 3-5





Installation Boundary

Roadside Survey Point

N

0 200 400
Meters

Andersen AFB North Ramp

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 3-6

Table 3-5

Residence Status of Avifaunal Species Identified during Roadside and Forest Bird Surveys - AAFB

Species	Residence Status[1]
Yellow Bittern *(Ixobrychus sinensis*)	Common native resident - breeding
Island Collared Dove *(Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo *(Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow *(Passer montanus*)	Common introduced resident - breeding
Black Francolin *(Francolinus francolinus*)	Common introduced resident - breeding
Micronesian Starling *(Aplonis opaca*)	Guam-listed endangered species Uncommon native resident - breeding
Note: [1] Reichel and Glass 1991.	

3.4.2 Avian Survey - AAFB Finegayan

NAVFAC Pacific biologists performed an avian survey on two transects within AAFB Finegayan. The results of the survey are presented in Table 3-6. All four observed species are common introduced residents the island of Guam.

Table 3-6

Avian Species Detected During AAFB Finegayan

Avian Species	Status on Guam
Black Drongo *(Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow *(Passer montanus*)	Common introduced resident - breeding
Philippine Turtle Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Chicken (*Gaullus* sp.)	Common introduced resident - breeding
Note: Status and nomenclature follow Wiles, 2005.	

3.4.3 Avian Survey - Potts Junction Property

On July 16, 2009, a site reconnaissance was performed to identify avian species within the Potts Junction parcel. Only two introduced resident species were identified. Table 3-7 identifies the avifauna that were observed. Both observed species are common introduced residents the island of Guam.

Table 3-7

Avian Species Detected During Potts Junction Survey

Avian Species	Status on Guam
Black francolin (*Francolinus francolinus*)	Introduced resident, breeding
Island collared-dove (*Streptopelia bitorquata*)	Introduced resident, breeding
Note: Status and nomenclature follow Wiles, 2005.	

3.5 Tree Snail Surveys

General and detailed visual surveys were completed on Transects 5, 6, and 7 at AAFB (Figure 3-3). No living partulid tree snails or their shells were observed during any of the surveys conducted along the transects.

Table 3-8

Partulid Tree Snail General and Detailed Visual Survey Results on Department of Defense Lands, Guam - AAFB

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	Number of Partulid Tree Snails Observed
October 12, 2009	October 23, 2009	5	400	0
October 1, 2009	October 2, 2009	6[1]	400	0
September 25, 2009	September 25, 2009	7	400	0
[1] Manokwar flatworms (*Platydemus manokwari*) recorded along the transect.				

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen at all five transects. Additionally, live introduced Manokwar flatworms (*Platydemus manokwari*) were observed along Transect 6.

No partulid tree snails were observed on the transects on AAFB. However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Because no live partulid tree snails were observed during either the general or detailed visual survey, no quadrat surveys were completed. Therefore, temperature, humidity, and air-movement measurements were not taken in areas not inhabited by tree snails.

The presence of flatworms on AAFB is of note, especially since the species was not targeted during the tree-snail surveys and is more likely seen nocturnally when these flatworms are active; flatworms were likely present but undetected at all locations. This flatworm is known to feed on juvenile partulid tree snails in the wild on Guam and Pacific tree snails in captivity, and is believed to be the primary threat to the continued existence of partulid tree snails on Guam, the Northern Mariana Islands, and potentially Oceania (Hopper and Smith, 1992). These authors reported that on Guam, where flatworm abundance was high, partulid tree-snail colonies were rapidly declining.

For more information on the tree snail survey, refer to Appendix H.

3.6 Threatened/Endangered Species and Species of Concern

Several threatened and endangered and Guam-listed SOGN species were identified on AAFB during the natural resource surveys. These species are identified in the following sections.

3.6.1 Herptofauna

During the herptofauna survey, a moth skink was captured on Transect 7, Station 16. Also, a moth skink was observed on AAFB Finegayan. The skink is a Guam-listed endangered species.

3.6.2 Vegetation

During the qualitative vegetation survey, two *Tabernaemontana rotensis* trees were observed on Transect 6. The species is considered an SOGCN species on Guam.

3.6.3 Avifauna

No federally listed endangered or threatened avian species were identified during any of the surveys. One Guam listed endangered species, Micronesian starling, was recorded from the Forest Bird Survey along the Route 9 survey (Transect 6; Station 3) on September 24, 2009. This species was also observed in the same area the day before when the transect was being established.

It is also of note that the federally endangered Mariana crow was not detected during the surveys. Critical habitat has been designated north of AAFB on the Guam National Wildlife Refuge (Figure 3-8). Critical habitat has been designated for the Guam Micronesian Kingfisher north of AAFB on the Guam National Wildlife Refuge (Figure 3-9)

3.6.4 Fruit Bats

On January 28, 2010 on AAFB, a federally listed threatened Mariana fruit bat (*Pteropus mariannus mariannus*) (locally known as fanihi), was sighted. The fruit bat was observed during the day roosting in a *Guamia* tree on Transect 6 at the 50 m station.

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4 Andersen South

Herpetofauna, vegetation, butterfly, avian, tree snail, and fruit bat surveys were conducted on Andersen South. Seven transects were surveyed within Andersen South (Figure 4-1): Transects 1 through 3 were within the central area; Transect 4 was in the southwestern sector; Transects 5 and 6 were in the northwestern sector; and Transect 7 was located in the southeast sector. Transect 7 was established as to provide data for the anticipated relocation of Route 15.

All seven Andersen South transects were surveyed for herpetofauna. Four of the seven transects were located in forest where *Guamia mariannae, Aglaia mariannensis, Neisosperma oppositifolia*, and *Premna obtusifolia* were dominant. Two were in degraded *Leucaena leucocephala*-dominated forest, and one was in non-forested, grassy habitat that traversed pavements.

4.1 Herpetofauna Surveys

A total of nine herpetofauna species were captured or observed on Andersen South. Table 4-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 4-1

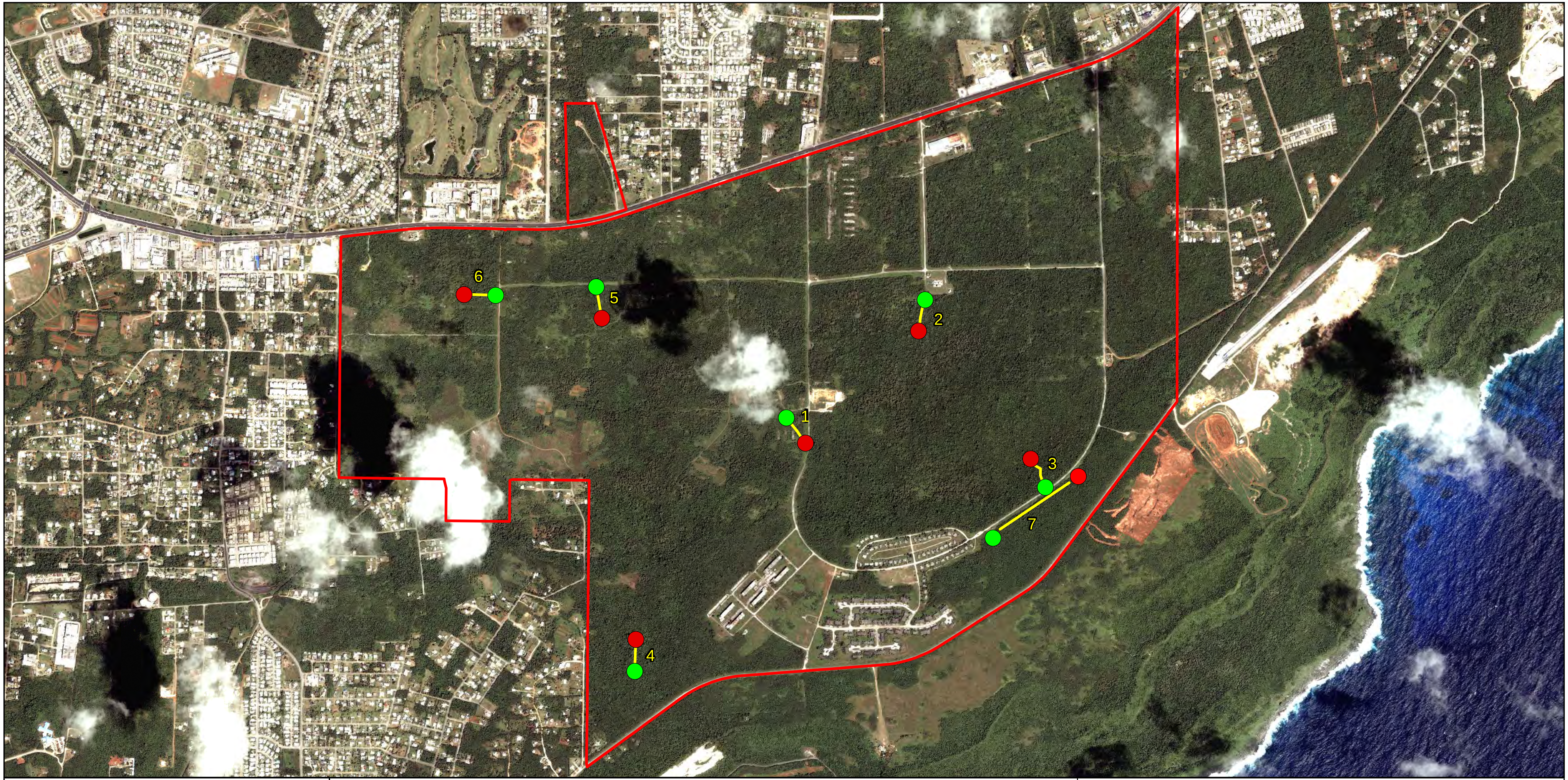
Herpetofauna Captured or Observed on Andersen South

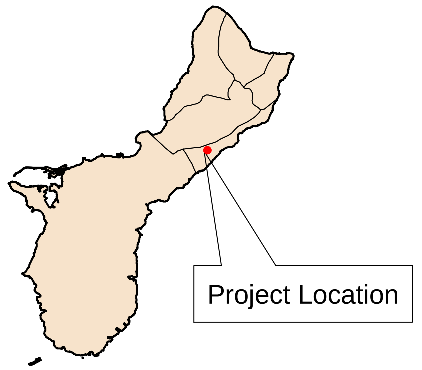
Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
	Brahminy blind snake (*Ramphotyphlops braminus*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced

The continued widespread presence of the brown treesnake and curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of the other introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

4.2 Vegetation

Quantitative surveys were performed along seven transects in the forested sectors (Figure 4-1). The results of the survey are provided in the following subchapters.





Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400 Meters

Andersen South

Transect Map

Prepared By: TEC Inc. Joint Venture

A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

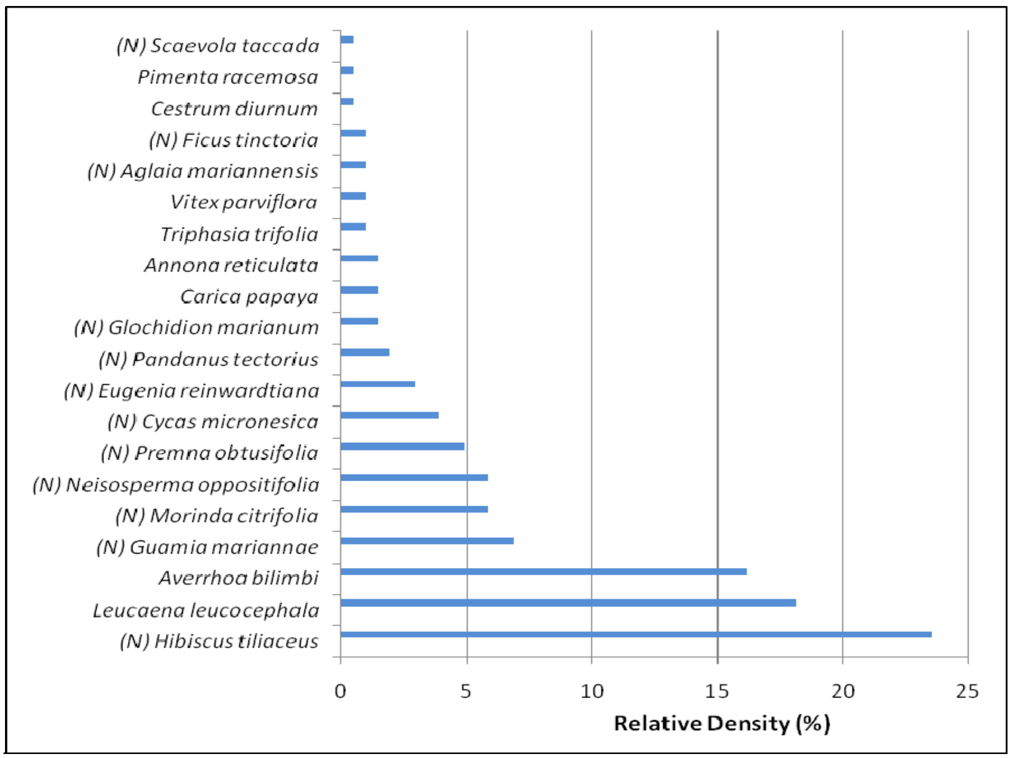
May 3, 2010	Project No.: 60133557	Figure 4-1

4.2.1 Trees

A total of 20 tree species were identified on the transects, of which 12 are native to Guam (Chart 4-1). The overall density for the six transects was calculated at 21.96 trees per 100 m^2. The native pago (*Hibiscus tiliaceus*) is an important species in these forests. Pago had the highest relative density (approximately 24 percent) and highest frequency among species, with specimens quantified on five of the six transects. Pago was also the third most dominant species at Andersen South, following the introduced pickle tree (*Averrhoa bilimbi*) and endemic paipai (*Guamia mariannae*). *Averrhoa bilimbi* and another introduced species, tangantangan (*Leucaena leucocephala*), followed pago with the next highest frequencies. *Averrhoa bilimbi* was common along the transects in the central sector, but it was recorded on every transect at Andersen South. Aside from pickle tree, other non-native species in the survey, such as papaya (*Carica papaya*) and custard apple (*Annona reticulata*), produce edible fruits that are likely dispersed by ungulate activity.

Chart 4-1

Relative Density of Tree Species at Andersen South, Transects 1-6
(N = native)



Native Guam tree species had a collective relative density of 60 percent along the Andersen South transects. Molave tree (*Vitex parviflora*) is a rapidly spreading introduced species that is becoming dominant in many of Guam's forests (Department of Agriculture, 2005), but *Vitex* accounted for less than 2 percent of the relative density at Andersen South, with only two specimens quantified on the transects. The introduced Bay Rum Tree (*Pimenta racemosa*), a relative of allspice (*P. dioica*), was encountered in the northwestern sector. Although this single tree was the only specimen quantified at Andersen South (Transect 5), it was fairly large, with a basal area of over 1,700 square centimeters (cm^2). Bay-rum can be invasive, particularly in southern Guam.

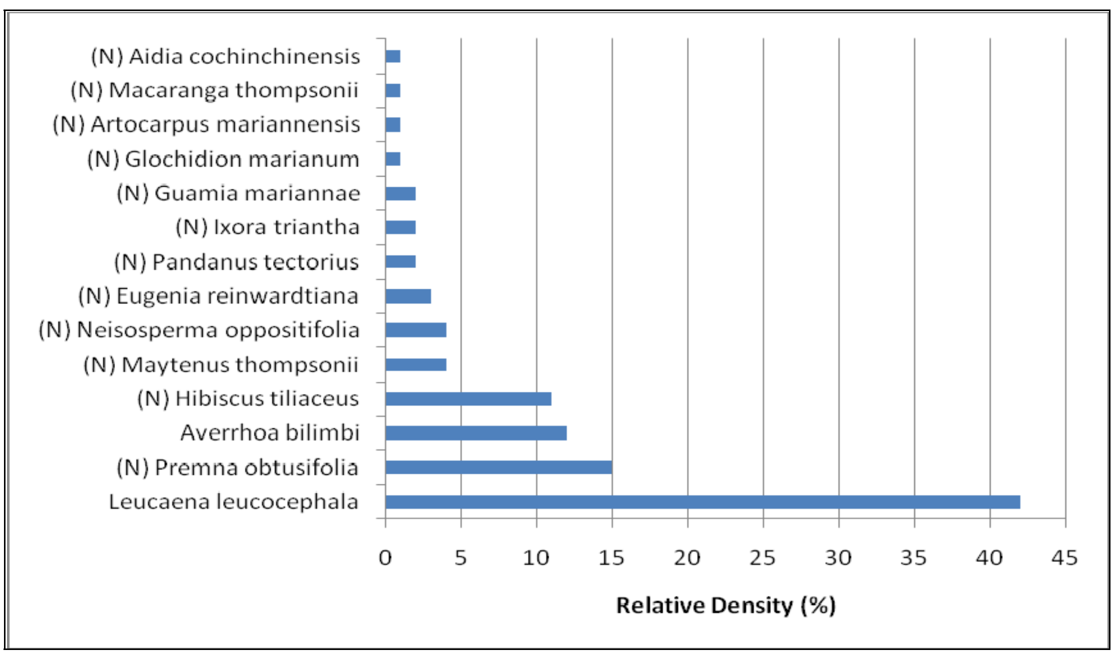
One species that was noticeably absent or present only in low numbers at Andersen South is dugdug or dokdok, the native seeded breadfruit (*Artocarpus mariannensis*). A few trees were seen but not surveyed on Transect 4. Dugdug is a characteristic species of native limestone forests in northern Guam (Fosberg, 1960). Specimens of native breadfruit were observed in other sectors of Andersen South (i.e., east of Transect 1) that were not included in the sampled areas. The recruitment and distribution of seeded breadfruit at Andersen South may be affected by typhoons and ungulate activity, as in other areas of the island.

For Transect 7, the overall density for this transect was calculated at 3,300 trees per hectare. Fourteen species of tree were encountered throughout the survey. The introduced *Leucaena leucocephala* had the highest relative density (approximately 42 percent) of all species (Chart 4-2). Tangantangan and *Averrhoa bilimbi* were the only introduced tree species encountered in this survey, yet accounted for approximately 54 percent of the relative density and 41 percent of the relative dominance of all species combined. *Premna obtusifolia* was the most encountered native tree species and had the highest relative density (approximately 15 percent) of all native species.

In addition, a vegetative survey was performed for the host plants (*Procris pedunculata* and *Elatostema calcareum*) for the Mariana eight-spot butterfly (*Hypolimnas octocula mariannensis*) and the host plant (*Maytenus thompso*nii) for the Mariana Wandering Butterfly (*Vagrans egistina*). Only individuals of *Maytenus thompsonii* were observed on Andersen South.

Chart 4-2

Relative Density of Tree Species at Andersen South, Transect 7
(N = native)



4.2.2 Seedlings

Plots conducted at stations along the six transects quantified more native than introduced seedlings of woody species. Native species had a mean density of approximately 4 seedlings/m^2; in comparison, introduced species had a mean density of less than 2 seedlings/m^2.

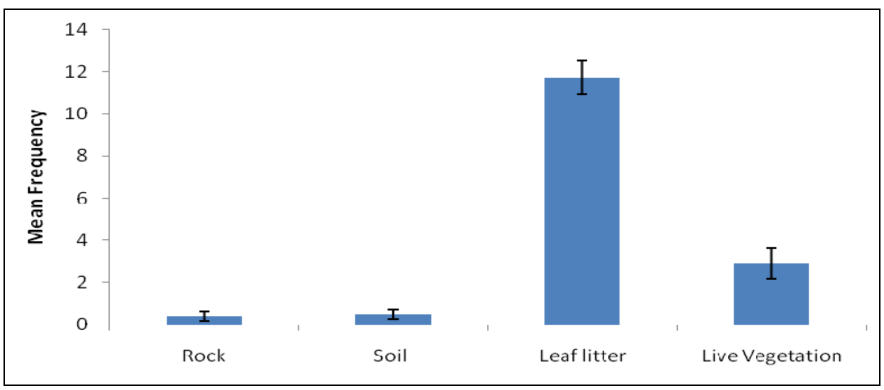
4.2.3 Habitat Quality

The habitat quality at Andersen South may be described through the level of ungulate activity, percentage of native species, and overall species richness. Of the six transects, the calculated species richness was highest for Transect 4. The forest along Transect 4 is the most intact among the six areas sampled in terms of canopy. The native species ratio is also higher than at other Andersen South transects, with 10 of the 14 tree species either native or endemic to Guam or the Northern Mariana Islands.

The ground cover at Andersen South was quantified for all transects. For Transects 1-6, calculations showed that, of the four categories of cover, leaf litter had the highest mean frequency, at 11.7 (Chart 4-3). Transects in the central sector of Andersen South had high levels of leaf litter mostly beneath pickle tree stands. The measure of ungulate activity for all transects revealed that rooting and rubbings were the most common observations, with mean frequencies of 0.59 and 0.50, respectively. For Transect 7, the frequencies for rock, soil, leaf litter, and live vegetation were 4, 37, 40, and 15, respectively.

Chart 4-3

Mean Frequency of Ground Cover along all Transects at Andersen South



Threatened/Endangered Species and Species of Concern

No species listed as threatened or endangered were identified within Andersen South during the current survey.

Species of Concern

The only species of concern identified within Andersen South during the current survey was the native cycad or fadang (*Cycas micronesica*) (Photo 4-1). The GDAWR lists fadang among the island's SOGCNs because of the threat from the introduced Asian cycad scale (GDAWRDA, 2006). Both healthy and injured cycads were noted in the survey. Seven specimens were quantified, with the highest density of cycads observed on Transect 4, at 3.61 trees per 100 m^2.

Incidental species that are not regulated or managed under local or federal law were also noted on the transects. These included water root orchid or saiyaihayon, tall shield orchid (*Nervilia aragoana*), and Z*euxine fritzii*, an inconspicuous ground orchid.

4.3 Butterfly Survey

On Andersen South, the butterfly survey was conducted on Transect 7 (Figure 4-1). The forest canopy is approximately 10 m in height, with moderate to heavy undergrowth.

4.3.1 Timed Counts

Three butterfly species were identified during the timed counts in September 2009 and January 2010. These were:

- Lemon Emigrant, *Catopsilia Pomona.*
- Blue-banded King Crow, *Euploea Eunice.*
- Common Mormon, *Paplio polytes.*

None of the three species observed on Andersen South are considered endangered or threatened and all are widely distributed in the Mariana Islands. Table 4-2 identifies the numbers of individuals and species observed within the various sampling plots on Andersen South in September 2009 and January, 2010.

On Andersen South the Common Mormon was the most numerous sighted butterfly in both September 2009 and January 2010, comprising 88.8 and 56.3 percent of the total sightings, respectively. The numbers of butterflies sighted, on average, also decreased between September and January. This reduction in abundance may be the result of natural cycles in butterfly population, the relatively short observation periods involved, or other factors.

The Mariana Eight-Spot butterfly and the Mariana wandering butterfly, which are both candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973, were not observed on any transect. Moreover, the host plants for these species were not observed along the transects during the vegetation surveys.

4.3.2 Baited Traps

Butterfly traps were set at the 0 and 470 meter mark on the transect. The baited traps were placed on each transect during daylight hours. No butterflies were captured on Andersen South.

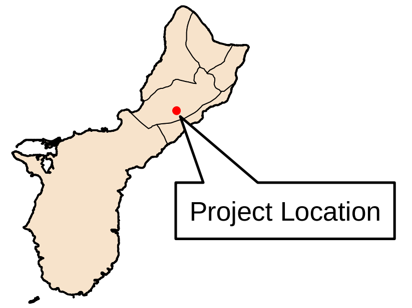
Table 4-2

Butterfly Sightings on Andersen South Transect 7 – September 2009 and January 2010

September 2009				January 2010			
Distance on Transect	Species			Distance on Transect	Species		
	Common Mormon	Blue-banded King Crow	Lemon Emigrant		Common Mormon	Blue-banded King Crow	Lemon Emigrant
0	3			0	3	3	
20	4			30		1	
40	2			60			
60	4			90	3		1
80	4	1	2	120	3	1	
100			1	150	1		
120	6			180			
140	16			210	2		
160	10	1		240	1	1	1
180	2			270		2	
200	4			300			
220	4			330		1	
240	4			360	1		
260	1			390	2		
280	3			420	1	2	
300	3	2		450	1		
320	3		1	480		1	
340	4						
360	3						
380	3	2	1				
400	2						
420	1		1				
440	3						
460	1						
480	3						
500	2						
TOTAL	**95**	**6**	**6**	**TOTAL**	**18**	**12**	**2**
Percent of Sightings	**88.8**	**5.6**	**5.6**	Percent of Sightings	**56.3**	**37.5**	**6.3**

4.4 Avian Surveys

In addition to the forest bird surveys along the seven transects on Andersen South, roadside bird surveys (Figure 4-2) were also conducted in the morning. Table 4-3 lists the species identified during the surveys.



Installation Boundary

Roadside Survey Point

N

0 200 400 Meters

Andersen South

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 4-2

Table 4-3

Species Identified during Roadside and Forest Bird Surveys – Andersen South

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	21	Eurasian Tree Sparrow (5) Black Francolin (4) Pacific Golden Plover (1) Island Collared Dove (2) Yellow Bittern (1)	5	13
Forest Bird	10	Pacific Golden Plover (1) Island Collared Dove (1) Yellow Bittern (1) Black Francolin (3)	4	6

All of the observed species are common to Guam. With the exception of the Pacific golden plover, all the observed species breed on Guam (Table 4-4). For more information on the avifauna survey and results, refer to Appendix G.

Table 4-4

Residence Status of Avifaunal Species Identified during the
Roadside and Forest Bird Surveys – Andersen South

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native - breeding
Common Pigeon (*Columba livia*)	Common introduced resident - breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding[2]
Notes: * Reichel and Glass 1991; **Johnson et al. 2006.	

4.5 Tree Snail Surveys

A general survey and a detailed visual survey were completed on Transect 7 on October 1, 2009 and October 9, 2009, respectively. No living partulid tree snails or their shells were observed during any of the surveys conducted along the transect. Because no live partulid tree snails were observed during either the general or detailed visual survey, no quadrat surveys were completed. Therefore, temperature, humidity, and air-movement measurements were not taken in areas not inhabited by tree snails.

No partulid tree snails were observed on Andersen South during the survey. However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen along the transect.

4.6 Threatened and Endangered Species

No federally-listed or Guam-listed threatened or endangered species or species of concern were identified on Andersen South. The native cycad (*Cycas micronesica*), a Guam SOGCN, was the only species of concern identified within Andersen South during the current surveys. The plant was observed on several transects with the highest density occurring on Transect 4.

5 Air Force Barrigada

On Air Force Barrigada (sometimes referred to as Air Force Communications Annex Barrigada), natural resource surveys preformed included herpetofauna, vegetation, and avian surveys. Figure 5-1 identifies the locations of the ecological transects. At Air Force Barrigada, one transect was surveyed.

5.1 Herpetofauna Surveys

Reptiles and amphibians were sampled by visual surveys on transects and glue board trapping on the same transects. Four species of reptiles and one amphibian species were documented (Table 5-1).

Table 5-1

Observed Herpetofauna - Air Force Barrigada

Group	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Geckos	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubrus*)	Native
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
Notes: It is likely that brown tree snakes, monitor lizards, and mutilating geckos are also present on Air Force Barrigada.		

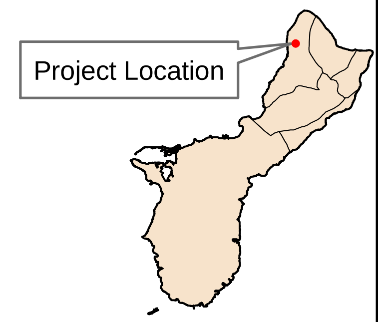
5.2 Vegetation Survey

On Air Force Barrigada the number of trees per hectare (ha) was calculated at 6,309. The mean dbh (with 95 percent confidence interval) was calculated to be 4.50 cm (range 3.85-5.15 cm). *Leuceana leucocephala* comprised the entire tree layer and *Polypodium punctatum*, *Stachytarpheta urticifolia*, and *Chromlaenao odorata* were the dominant non-woody species.

5.3 Avian Survey

An avian survey was performed by NAVFAC Pacific biologists on Air Force Barrigada (Appendix C). Three introduced, resident breeding species were identified. The identified species were the following:

- Black francolin
- Island collared dove
- Chicken



- Transect Lines
- Installation Boundary
- Avian Roadside Observation Stations
- Beginning Transect Point
- End Transect Point

N

0 100 200 Meters

Air Force Barrigada

Transect Map & Avian Roadside Survey Location Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 5-1

No threatened or endangered bird species were documented.

5.4 Threatened/Endangered Species and Species of Concern

No threatened/endangered species or species of concern were observed on Air Force Barrigada during the course of the surveys.

6 Navy Barrigada

On Navy Barrigada, natural resource surveys performed included herpetofauna, butterfly, vegetation, avian, and tree-snail surveys. Figure 6-1 shows the locations of the ecological transects.

Three transects were surveyed at Navy Barrigada. The transects were located in forested habitats where *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Guamia mariannae*, and *Aglaia mariannensis* were the most common species.

6.1 Herpetofauna Surveys

Seven herpetofauna species were captured or observed on Navy Barrigada. Table 6-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 6-1

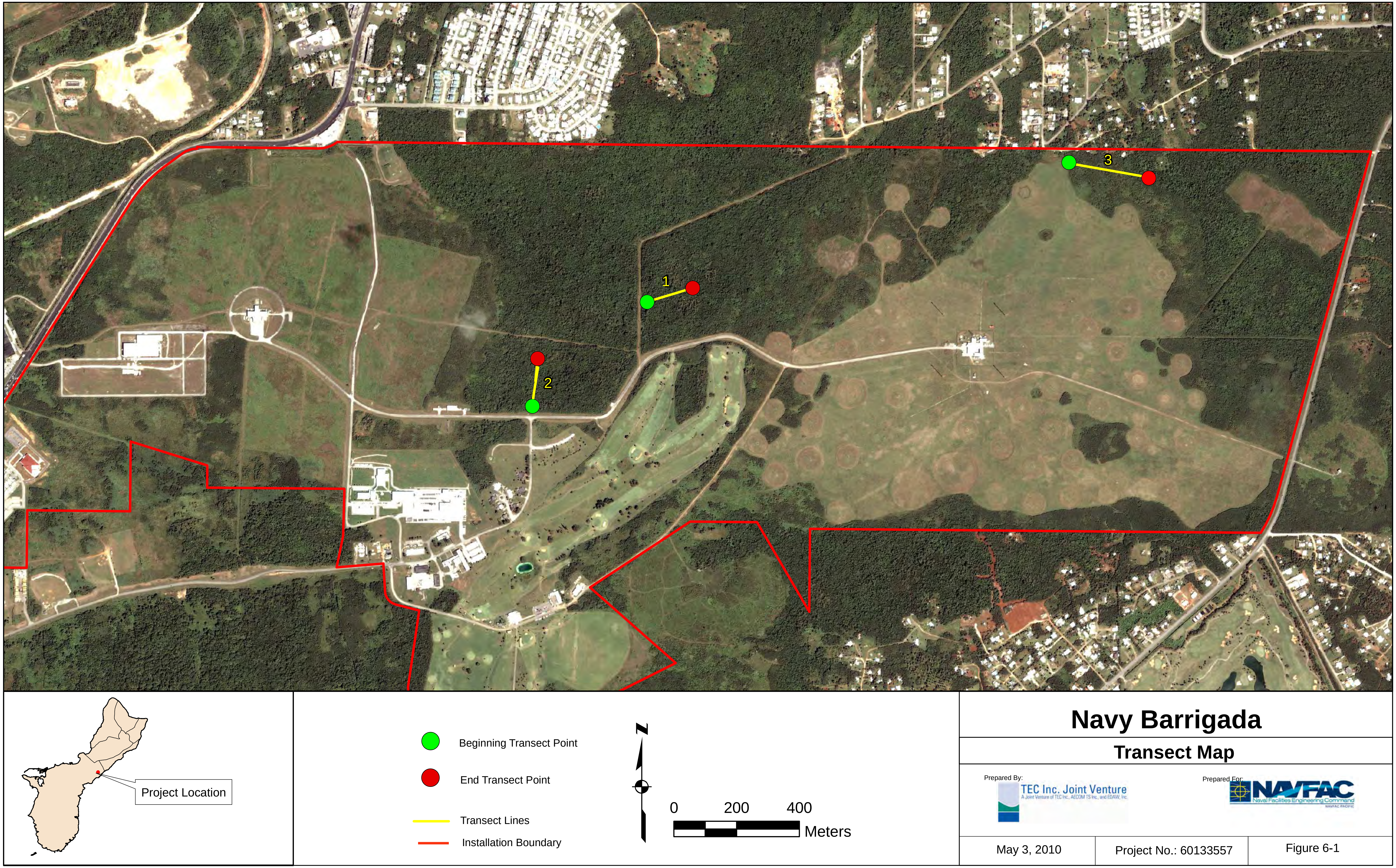
Herpetofauna Captured or Observed on Navy Barrigada

Group	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenat*us)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutil*ata)	Native
Amphibians	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced
	Hong Kong whipping frog (*Polypedates megacephalus*)	Introduced

The continued widespread presence of curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the ability of the introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

6.2 Vegetation

Much of Navy Barrigada is comprised of improved and unimproved roads, open fields, and weedy vegetation, with the remaining forested areas mainly concentrated around Mount Barrigada between two antenna fields. The goal of the vegetation surveys is to locate endangered plant species or species of concern and to characterize the habitat types through a visual walk and conducting a point-quarter survey over the entire length of each transect.



1
2
3
Project Location
Beginning Transect Point
End Transect Point
Transect Lines
Installation Boundary
N
0
200
400
Meters
Navy Barrigada
Transect Map
Prepared By:
TEC Inc. Joint Venture
Prepared For:
NAVFAC
Naval Facilities Engineering Command
May 3, 2010
Project No.: 60133557
Figure 6-1

Quantitative surveys were performed along three transects in the forested sectors: Transect 1 along an east-west axis near the toe of Mt. Barrigada; and Transect 2 along a north-south axis to the southwest of Transect 1. Both transects were within a limestone forest community west of the antenna field. A third transect, Transect 3, was located in limestone forest east of the antenna field.

6.2.1 Trees

Tree density, dominance, and frequency were quantified using the point-center quarter method; the results were summarized for both transects. A total of 20 species were quantified along the transects. The highest dominance observed was for the banyan tree (*Ficus prolixa*), an overstory species with numerous aerial roots that contribute to its large footprint. The species with the second- and third-highest dominances were pago (*Hibiscus tiliaceus*) and fagot (*Neisosperma oppositifolia*), which typically occupy the overstory. All three species are native to Guam.

The point-center quarter observations revealed the highest frequencies were for pago, followed by fagot and paipai (*Guamia mariannae*), which is a native forest understory species. Two introduced species – custard apple (*Annona reticulata*) and lemonchina (*Triphasia trifolia*) – had the next-highest frequency values. Although they are not native components, these species have become naturalized in other limestone forests around the island.

Native species had a combined relative density of approximatley 77 percent, far exceeding the relative density of introduced species for both transects at Navy Barrigada. The overall density of trees was calculated at 43.55 trees per 100 m^2 (Chart 6-1). The native species pago, fagot, and paipai had the three highest relative densities (approximately 29 percent, 14 percent, and 9 percent, respectively).

The overall density for Transect 3 was calculated at 4,632 trees per hectare. Seven species of tree were encountered throughout the survey. The introduced *Annona reticulata* and *Leucaena leucocephala* had the two highest relative densities of all species observed (Chart 2), and were the only introduced species encountered throughout the survey. Together, these two species accounted for approximately 58 percent of the relative density and 47 percent of the relative dominance. *Hibiscus tiliaceus* was the most encountered native tree species and had the highest relative density (approximately 17 percent) and relative dominance (approximately 31 percent) of all native species.

6.2.2 Seedlings

A comparison of the woody seedling density revealed a higher density for Transect 2. The density of woody seedlings was greater in Transect 2 than in Transect 1. Both transects, however, showed markedly higher densities of native over introduced species.

Chart 6-1

Relative Density of Tree Species, Navy Barrigada Transects 1 and 2
(N = native)

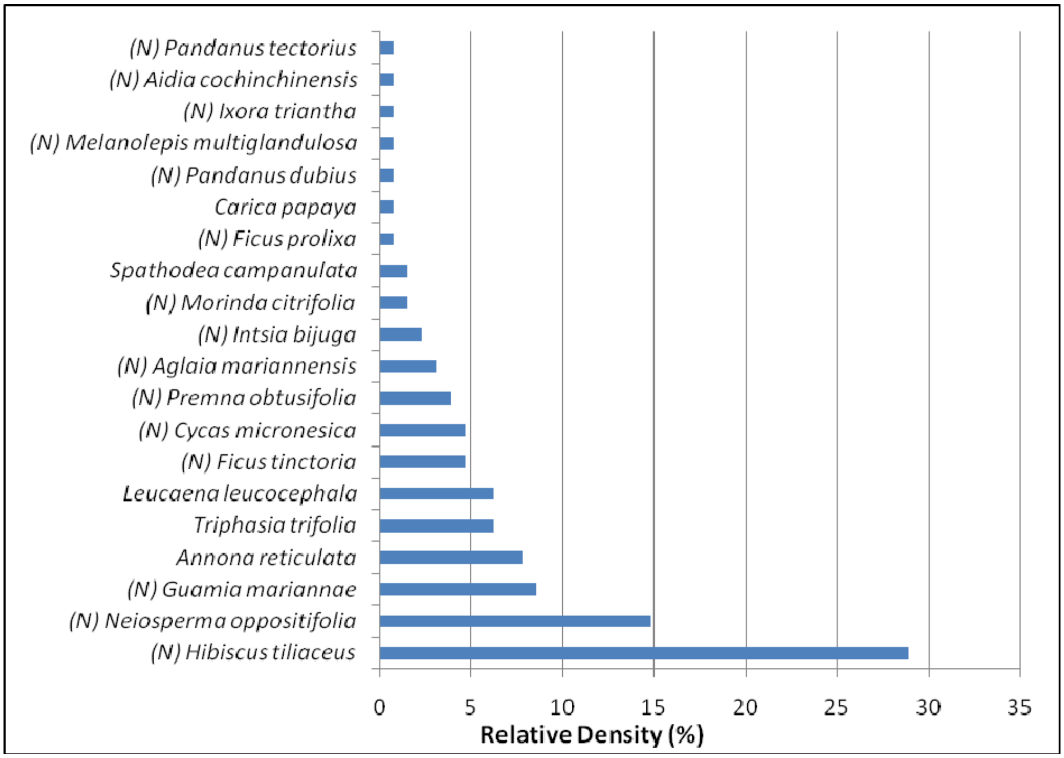
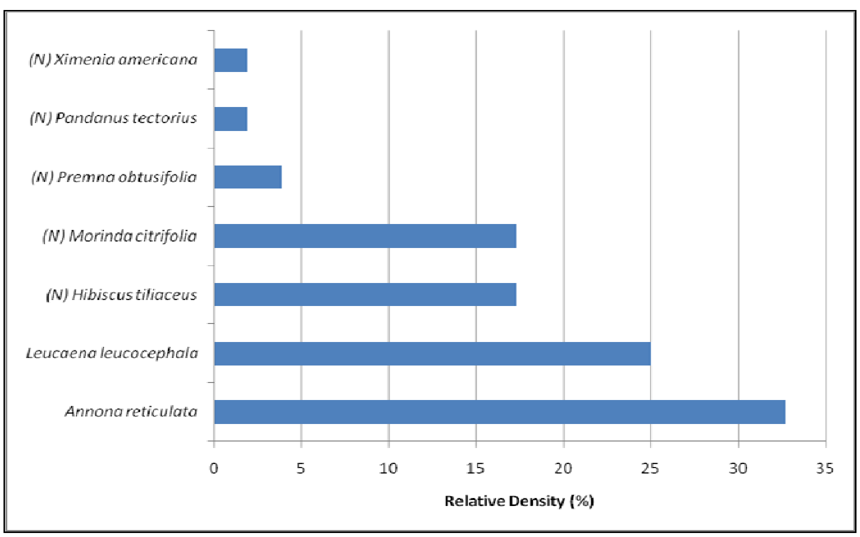


Chart 6-2

Relative Density of Tree Species, Navy Barrigada Transect 3
(N = native)



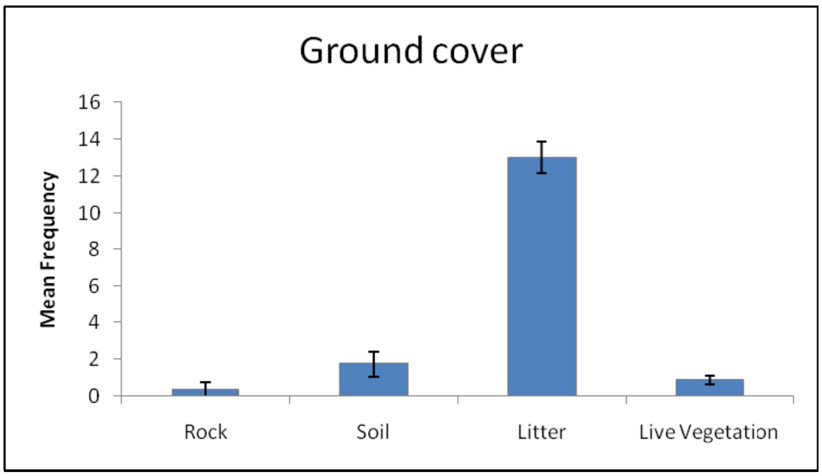
6.2.3 Habitat Quality

The habitat quality at Navy Barrigada may be described through the level of ungulate activity, percentage of native species, and overall species richness.

There was no ungulate activity quantified at the transect stations during the survey. Transects 1 and 2 had a higher level of species abundance than did transect 3. The ground- cover observations revealed a high frequency of leaf litter. Bare soil, rock, and live vegetation had relatively low mean frequencies for Transects 1 and 2 (Chart 6-3). For Transect 3, rock, bare soil, litter, and live vegetation had frequescies of 2,16, 22, and 8, respectively.

Chart 6-3

Ground Cover Frequencies in the Study Plots for Transects 1 and 2



6.2.3.1Threatened and Endangered Species and Species of Concern

Threatened and Endangered Species

In an earlier survey, BioSystems Analysis, Inc. (1989) identified no threatened or endangered species at Navy Barrigada. Likewise, no plant species listed as threatened or endangered were identified within Navy Barrigada during the current survey.

Live specimens of the Pacific tree snail (*Partula radiolata*) were found on fagot (*Neisosperma oppositifolia*) along Transect 2 in the central sector (Photo 6-1). The Pacific tree snail is listed as endangered on the local and federal endangered species lists.

Species of Concern

The current survey found one species of concern – fadang (*Cycas micronesica*) - which is considered a SOGCN by the GDWAR (Photo 6-1). Fadang was found along Transects 1 and 2, with densities of 3.81 and 0.61 trees per 100 m^2, respectively. Specimens were not in good health and were often topped by epiphytes, such as Bird's Nest Fern (*Asplenium nidus*). BioSystems Analysis, Inc. (1989) cited fadang among the dominant species in the limestone forest at Navy Barrigada.

Photo 6-1 *Cycas micronesica* in limestone forest along Transect 2, Navy Barrigada.

6.3 Butterfly Surveys

On Navy Barrigada, one 250-m transect (Transect 3, depicted on Figure 6-1) was surveyed. This transect is located in a forested area, with a canopy of approximately 6-8 m or tall with several small clearings on or near the transect. The forested area is located adjacent to a large, maintained grass field associated with communication towers. The transect began approximately 15 m from the forest's edge.

6.3.1 Species Observed

Four butterfly species were identified during the timed counts. The species were as follows:

- Blue-banded King Crow
- Blue Moon
- Common Mormon
- Common Evening brown

None of the four species are considered endangered or threatened, and all are fairly well-distributed throughout Guam and the Northern Mariana Islands. For a description of each species, refer to Appendix E.

Table 6-2 identifies the numbers of individuals and species observed within the various sampling plots on Navy Barrigada in September, 2009, and January, 2010.

On Navy Barrigada, the Common Mormon was the most frequently observed butterfly in September and January, comprising 73.2 and 52.5 percent of the total sightings, respectively. The numbers of individuals and species showed little variation between September and January.

The Mariana Eight-Spot butterfly (*Hypolomnas octocula mariannensis*) and the Mariana wandering butterfly (*Vagrans egistina*), which are both candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973, were not observed on the transect.

Table 6-2

Butterfly Sightings at Navy Barrigada – September 2009 and January 2010

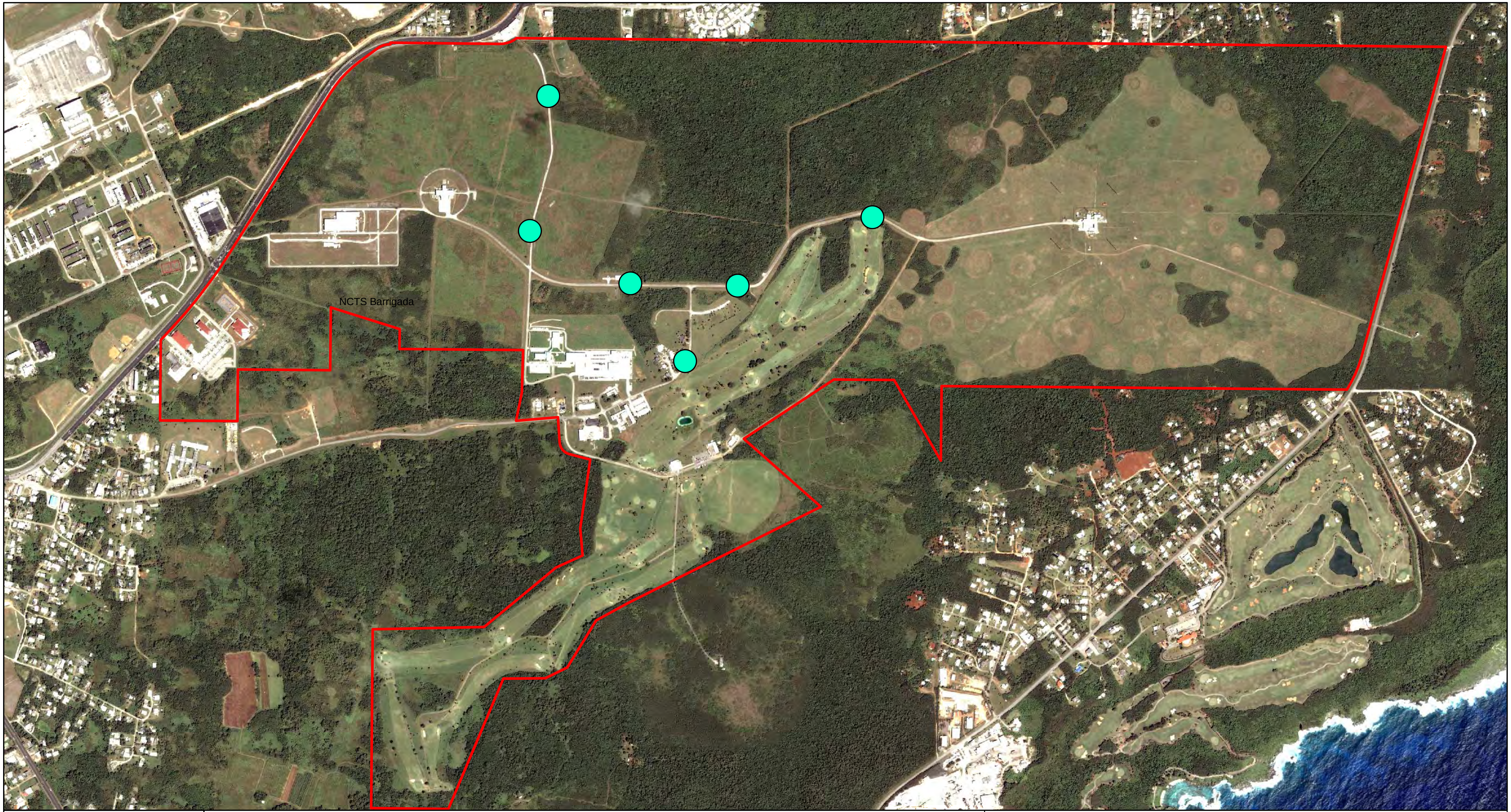
September 2009				January 2010				
Distance on Transect	Species			Distance on Transect	Species			
	Common Mormon	Blue-banded King Crow	Blue Moon		Common Mormon	Blue-banded King Crow	Blue Moon	Evening Brown
0	2	6		0	2	6		1
30	2	2		30	3			
60	7			60	2	1		
90	7	2	1	90	7		1	
120	3			120	1	2		
150	2			150	4	3		
180	2			180		4		
210	1			210	-	-	-	-
240	4			240	2	1		
TOTAL	**30**	**10**	**1**	**TOTAL**	21	17	**1**	**1**
Percent of sightings	**73.2**	**24.4**	**2.4**	Percent of sightings	**52.5**	**42.5**	**2.5**	**2.5**

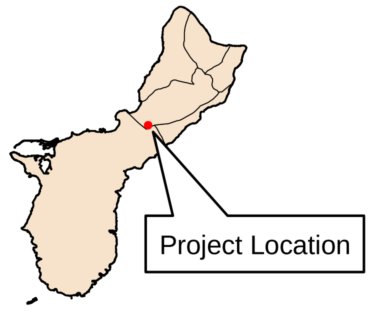
6.3.2 Baited Traps

Two baited traps were placed on the transect during daylight hours. The trap was placed at the start of the transects, and at approximately the 60 meter mark near a clearing. Two individuals of evening brown butterfly were captured in September 2009. In January 2010, one evening brown was captured.

6.4 Avian Surveys

On Navy Barrigada, roadside surveys (Figure 6-2) were conducted in the evening and forest bird surveys were conducted in the morning. Table 6-3 lists the species identified as part of the surveys.





Installation Boundary

Roadside Survey Point

0 200 400 Meters

Navy Barrigada

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 6-2

All of the observed species are common to Guam. Table 6-4 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna survey and results, refer to Appendix G.

Table 6-3

Species Identified during Roadside and Forest Bird Surveys – Navy Barrigada

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	6	Pacific Golden Plover (18) Black Drongo (9) Western Cattle Egret (8) Island Collared Dove (6) Eurasian Tree Sparrow (6) Black Francolin (3) Yellow Bittern (3)	7	53
Forest Bird	4	*- none -*	*- none -*	*- none -*

Table 6-4

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – Navy Barrigada

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native - breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]
Western Cattle Egret (*Bubulcus ibis*)	Common visitor – not breeding
Notes: * Reichel and Glass 1991; **Johnson et al. 2006.	

6.5 Tree Snail Surveys

General and detailed visual surveys were conducted on Transect 3 at Navy Barrigada (Figure 6-1). No living partulid tree snails or their shells were observed (Table 6-5).

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen on the transects. Additionally, live introduced Manokwar flatworms (*Platydemus manokwari*) were observed along Transect 3 (Table 6-5). Because no live partulid tree snails were observed during general or detailed visual surveys, no quadrat surveys were completed; therefore, temperature, humidity, and air movement measurements were not taken in areas not inhabited by tree snails.

Table 6-5
Partulid Tree Snail General and Detailed Visual Survey Results on Department of Defense Lands, Guam – Navy Barrigada

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	Number of Partulid Tree Snails Observed
September 29, 2009[1]	October 29, 2009[1]	3[2]	250	0
October 7, 2009[1]	November 6, 2009[1]	3[2]	250	0

1 Survey was completed over the course of two days due to poor weather conditions.
2 Flatworms recorded along the transect.

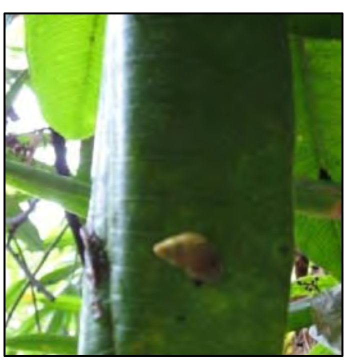
No partulid tree snails were observed. However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

The presence of flatworms on Navy Barrigada is of note – especially since the species was not targeted during the tree-snail surveys. As flatworms are more likely to be seen nocturnally when they are active, flatworms were likely present but undetected at all locations. This flatworm is known to feed on juvenile partulid tree snails in the wild on Guam and Pacific tree snails in captivity, and is believed to be the primary threat to the continued existence of partulid tree snails on Guam, the Mariana Islands, and potentially Oceania (Hopper and Smith, 1992). The authors reported that on Guam where flatworm abundance was high, partulid tree snail colonies were rapidly declining.

6.6 Fruit Bat Surveys

NAVFAC biologists surveyed two locations on Navy Barrigada in May 2008. No bats were sighted during this survey. For more information on the fruit bat survey and results, refer to Appendix I.

6.7 Threatened and Endangered Species



No threatened or endangered avifauna, butterfly, herpetofauna species or fruit bats were identified on Navy Barrigada. No partulid snails were identified as part of the tree snail survey; however, during the vegetation survey, live specimens of the Pacific tree snail, *Partula radiolata* were found on a fagot, *Neisosperma oppositifolia* plant along Transect 2 in the central sector (Photo 6-2). The Pacific tree snail is listed as endangered on the local and federal endangered species lists. Moreover, several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Photo 6-2 *Partula radiolata* on Neisosperma leaf at Transect 2, Navy Barrigada.

7 North Finegayan

On North Finegayan, natural resource surveys performed included herpetofauna, vegetation, avian, and tree-snail surveys. Figure 7-1 identifies the locations of the nine ecological transects where the surveys were performed. Also, for vegetation surveys, additional transects and survey locations were utilized. The location of these transects and other survey locations are presented when discussed in the respective discipline.

Nine transects were surveyed at North Finegayan. All nine transects were located in secondary forest, dominated by *Pandanus tectorius*, *Guamia mariannae*, *Vitex parviflora*, and *Hibiscus tiliaceus*.

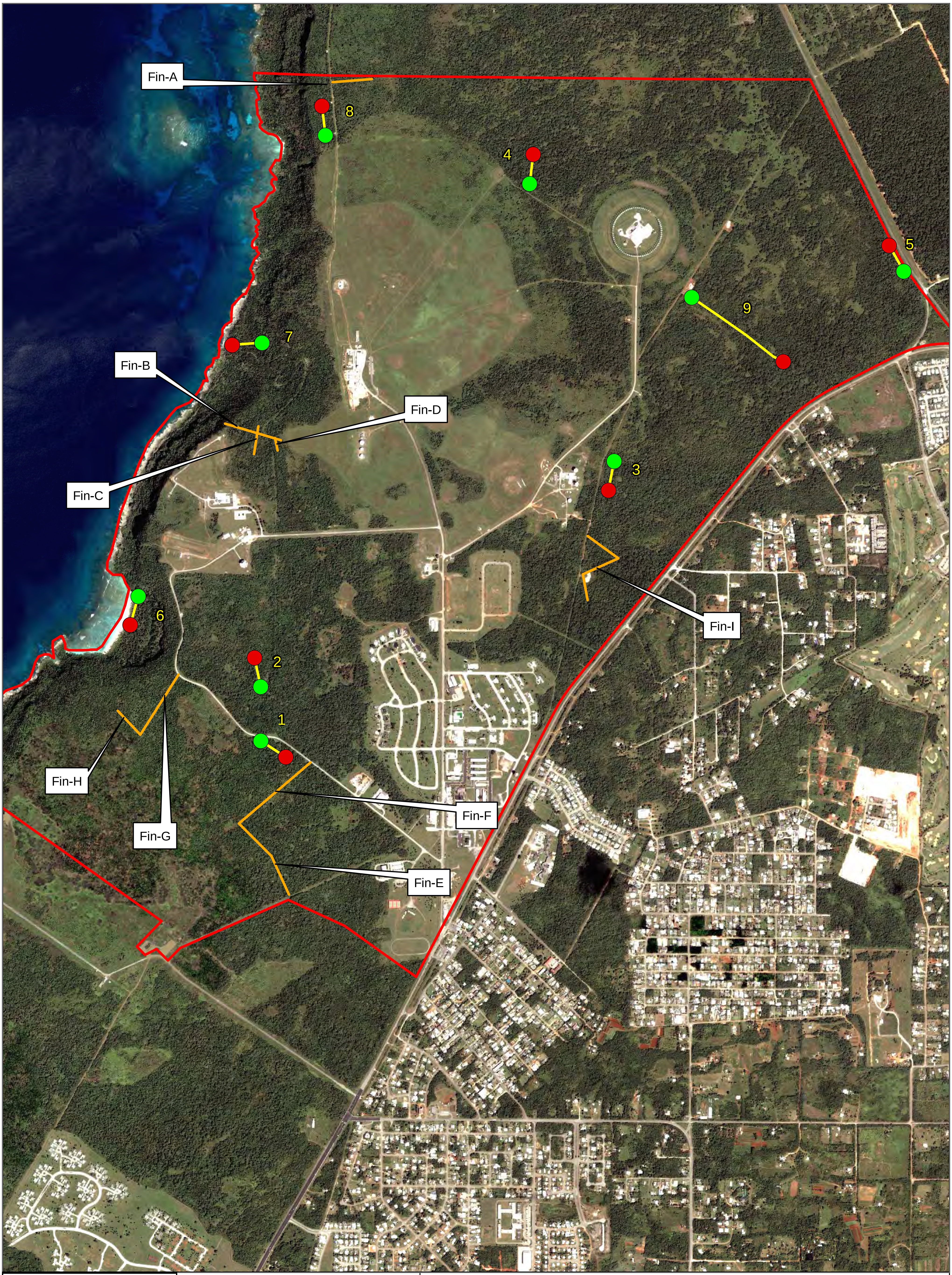
7.1 Herpetofauna Surveys

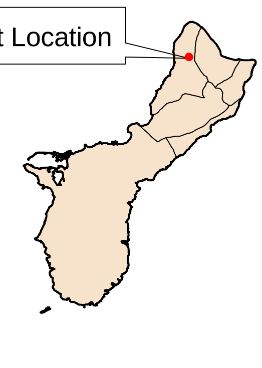
Ten herpetofauna species were captured or observed on North Finegayan. Table 7-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 7-1

Herpetofauna Captured or Observed on North Finegayan

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutilata*)	Native
	Pacific slender-toed gecko (*Nactus pelagicus*)	Native*
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Pre-historic
Amphibian	Marine toad (*Rhinella marinus*)	Introduced
Notes: * This species is identified by the Guam Comprehensive Wildlife Conservation Strategies (GCWCS) as SOGCN/Endangered - species of with the highest conservation value.		





Beginning Transect Point
End Transect Point
Quantitative Transects
Qualitative Transects
Installation Boundary

N

0 200 400
Meters

North Finegayan

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 7-1

The capture of two Guam- listed endangered species (i.e., moth skink and Pacific slender-toed gecko [Photo 7-1]) is noteworthy. The distribution and abundance of this native skink on Guam is unknown, due to the variability of information presented by authors. The Pacific slender-toed gecko is a rarely seen gecko. The moth skink was captured on Transect 9, Station 17. The pacific slender-toed Gecko was captured on Transect 9 at stations 9, 15, 16, 24, 28, 30, and 34.This study added records of the species at North Finegayan.

Photo 7-1 Photo of the Pacific slender-toed gecko, *Nactus pelagicus*

The continued widespread presence of the brown treesnake and curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of the introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a). For more information on the herpetofauna survey and results, please refer to Appendix B.

7.2 Vegetation

Vegetation surveys on North Finegayan consisted of the following:

- Quantitative Survey - The current quantitative survey areas at North Finegayan comprised three vegetation types: limestone forest, coconut grove, and disturbed/weed community. A disturbed/weed plant community occurred at forest edges and in patches within the forest.

- Qualitative Survey - A qualitative survey was conducted in North Finegayan. The full vegetation survey report is provided in Appendix D.

7.2.1 Quantitative Survey

7.2.1.1 Trees

Native species comprised nearly three-quarters of the relative density of tree species in the six transects in the limestone forest at upper North Finegayan (Chart 7-1). Thirteen of the 19 species (or approximately 68 percent) encountered on the transects were native trees. It is notable that *Vitex parviflora*, an introduced species, is a dominant component of these forests in terms of basal area, absolute dominance, and frequency. *Vitex* had the highest relative density (about 22 percent), followed by native kafu or screwpine (*Pandanus tectorius*) and endemic paipai (*Guamia mariannae*) trees, with densities of about 17 percent each. *Vitex* is a Philippine species that was introduced to Guam prior to 1970 (Stone, 1970) and has since become a common component of its forests (Donnegan et al., 2002).

In the forests of the southern sector (Transects 1 and 2), the three species with the highest relative densities were *Guamia mariannae*, *Pandanus tectorius*, and *Neisosperma oppositifolia*, which collectively accounted for 62 percent of the overall density. Native species had a combined density of 87 percent; two of these species, *Guamia* and *Aglaia*, are endemic to the Mariana Islands, and had a combined density of 27 percent. The non-native element was composed of *Triphasia trifolia* and *Vitex parviflora*, with a combined density of 13 percent.

Non-native species (*Vitex*, *Cestrum*, and *Triphasia*) accounted for 45 percent of the relative density in the limestone forest of the north-central sector of North FinegayanNorth Finegayan (Transects 3 and 4). Native species made up slightly more than half of the overall density, but endemic species (*Guamia* and *Aglaia*) accounted for only 8 percent of the relative density.

The limestone forest in the northeastern sector of North Finegayan (Transect 5) contained similar relative densities of the introduced *Vitex* and the endemic *Guamia* trees. *Vitex parviflora* and African tulip (*Spathodea campanulata*) trees were the non-native species, with a combined relative density of about 32 percent. The three endemic species (*Guamia*, *Eugenia palumbis,* and *Maytenus thompsonii*) accounted for about 30 percent of the relative density.

Transect 6, located along the coast of the Haputo Ecological Reserve Area (ERA) embayment, was located within a coconut (*Cocos nucifera*) grove. A disturbed/weed plant community occurred at forest edges and in patches within the forest. The area is located close to sea level below the limestone plateau of the main annex. Nonag (*Hernandia peltata*), an indigenous tree, had a relative density of about 22 percent; coconut palms comprised the remainder of the trees (Chart 7-2).

The west-central sector of North Finegayan in the vicinity of Pugua Point (Transect 7) contains limestone forest with a native species density of 66 percent and a pronounced *Merrilliodendron megacarpum* component (Chart 7-3). *Merriolliodendron megacarpum* is an indigenous species found in only a few localities on Guam because of its restricted habit. Non-native species accounted for 34 percent of the relative density; *Annona*, *Triphasia*, and *Carica* are successful introductions that have long been naturalized in native forests. Endemic species (*Guamia* and *Aglaia*) accounted for 14 percent of the relative density. The native cycad, *Cycas micronesica*, had a low density of only 3 percent.

Chart 7-1

Relative Density of Tree Species in Transects 1 to 5 and Transect 8, North Finegayan
(N = native)

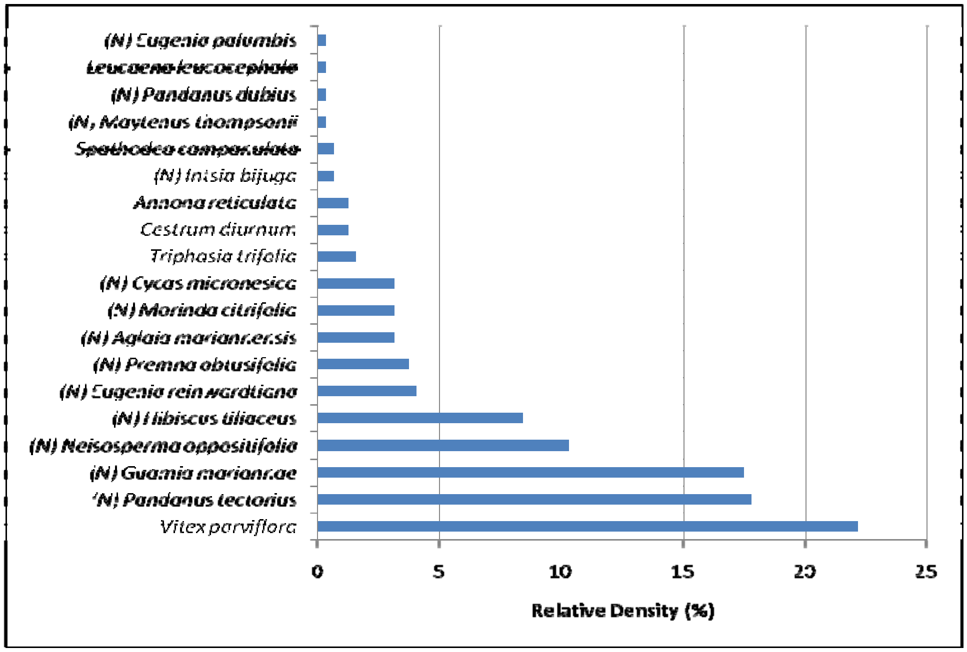


Chart 7-2

Relative Density of Tree Species on Transect 6 – North Finegayan
(N = native)

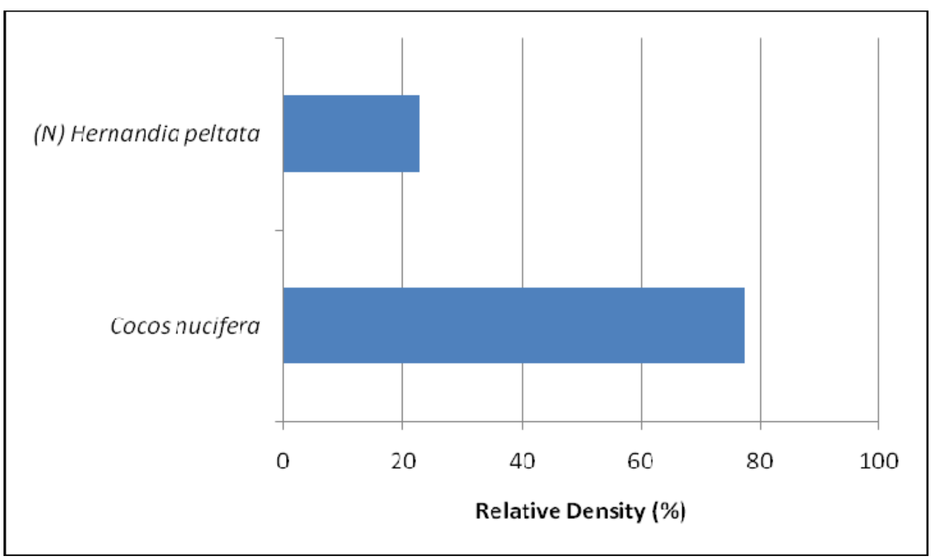
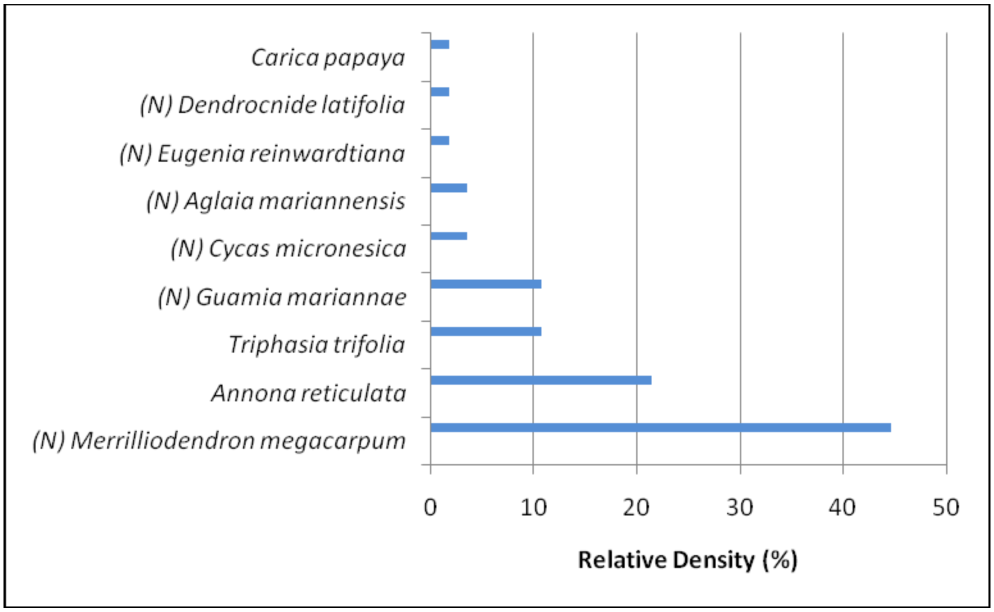


Chart 7-3

Relative Density of Tree Species on Transect 7 – North Finegayan.
(N = native)



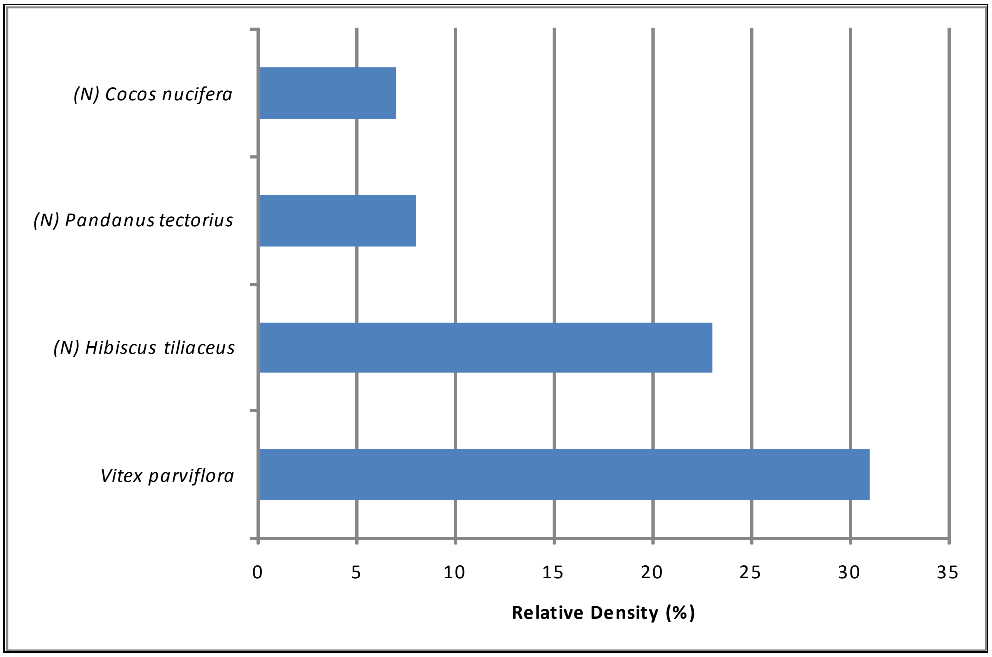
The limestone forest along Transect 7 in lower North Finegayan is a distinctive community composed of a stand of faniok (*Merrilliodendron megacarpum*) trees that provide habitat for the Pacific tree snail (*Partula radiolata*). The forest is situated close to sea level along the base of an escarpment and overlies karstic limestone substrate. From north to south, the site transitions from faniok-dominated forest to a more mixed community.

Transect 8 in the North Finegayan annex was a coconut (*Cocos nucifera*) grove in the Haputo ERA embayment along the western coast. The area is located close to sea level below the limestone plateau of the main annex. Nonag (*Hernandia peltata*), an indigenous tree, had a relative density of about 22 percent; coconut palms comprised the remainder of the trees along this transect.

Transect 9 sampled a forested area on the east side of the parcel. The overall density for this transect was calculated at 1,435 trees per hectare. Only four species of tree were encountered throughout the survey. The introduced *Vitex parviflora* was the most dominant species encountered along this transect, and the only introduced species observed. *Vitex parviflora* had a relative density of 55 percent (Chart 7-4) and a relative dominance of 93 percent. *Hibiscus tiliaceus* and *Pandanus tectorius*, together, had a relative density of 44 percent, yet only accounted for approximately 6 percent of the relative dominance within the transect. One individual of *Cocos nucifera* was encountered.

Chart 7-4

Relative Density of Tree Species on Transect 9 – North Finegayan
(N = native)



7.2.1.2 Seedlings

The percentage of native woody seedlings quantified along the transects exceeded 80 for Transects 4 and 8 in the northern and northwestern sectors on the upper plateau, and for Transect 7 along the west-central coast. Elsewhere, less than 60 percent of the seedlings were native.

The mean woody seedling density for all transects at North Finegayan was slightly higher for native species (1.71 seedlings per m^2) than for introduced species (1.12 seedlings per m^2).

7.2.1.3 Habitat Quality

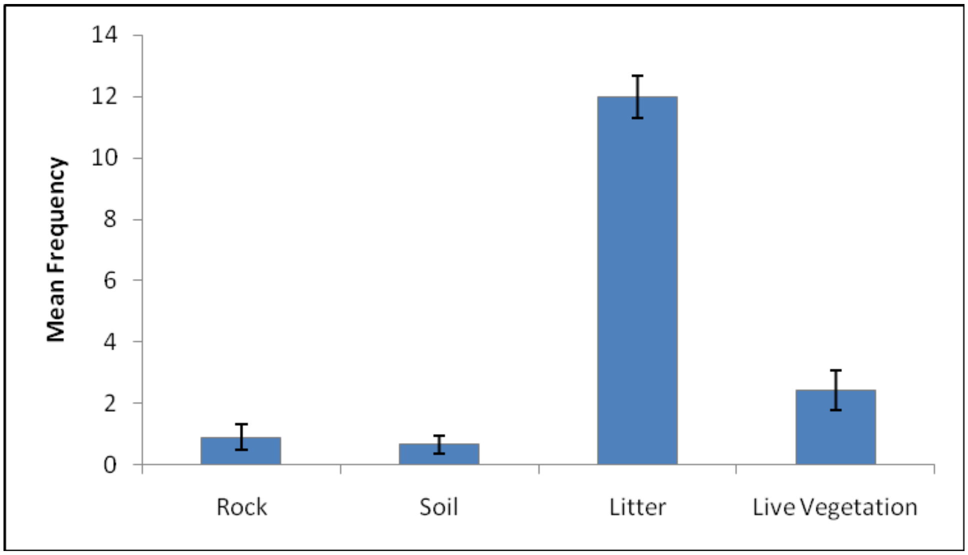
Certain aspects of the plant communities may provide a general indication of the quality of the habitat at North Finegayan. These include ungulate activity, presence of erosion, the percentage of native plant species, and overall species richness.

Analysis of individual transects revealed significantly lower species richness in the coconut grove of Transect 6 compared to all other sites. This transect was in the lower plateau and lacked many of the woody species observed in the remaining seven transects. Similar species richness values were observed for Transect 5 in the northeastern sector and for Transect 8 in the northwestern sector, which are both on the upper plateau.

The ground cover along Transects 1-8 at North Finegayan showed a high mean frequency of litter and relatively low mean frequencies of bare soil and rock (Chart 7-5). Along Transect 9, the rock, soil, litter, and live vegetation frequencies were 0, 1, 71, and 18, respectively. Thus, for all transect on North Finegayan, litter comprised the overwhelming majority of ground cover, with live vegetation being the second most common ground cover. Rock and soil was rarely encountered as ground cover.

Chart 7-5

Mean Frequency of Ground Cover along Transects at North Finegayan



Ungulate activity was observed most frequently in the form of rubbings on tree trunks and browsing. Soil disturbance, such as wallows, was less frequently observed at North Finegayan. An example of the type of ungulate disturbance observed at North Finegayan- is shown in Photo 7-2. Ungulates, most likely feral pigs, have toppled a fadang (*Cycas micronesica*) specimen, possibly to feed on the pith material in the trunk.

Photo 7-2 Ungulate damage to *Cycas micronesica*, Transect 8, North Finegayan

7.2.2 Qualitative Survey

On January 15, 2010 a qualitative survey was performed on eight transects (Figure 7-1) located in a secondary forest in the northeast portion of North Finegayan. No listed or rare species were observed. A small patch of *Procris pedunculata,* the host plant for the Mariana Eight-spot Butterfly, was observed scattered in one area of cockscomb limestone. The cockscomb limestone area also has some large (rising to nearly 6 m in height) *Cycas micronesia*, a SOGCN plant species. For more information on the results of this survey, refer to Appendix D.

7.2.3 Threatened and Endangered Species and Species of Concern - Vegetation

Threatened and Endangered Species

None of the locally-listed or federally-listed endangered plants were detected during the current survey in North Finegayan.

Species of Concern

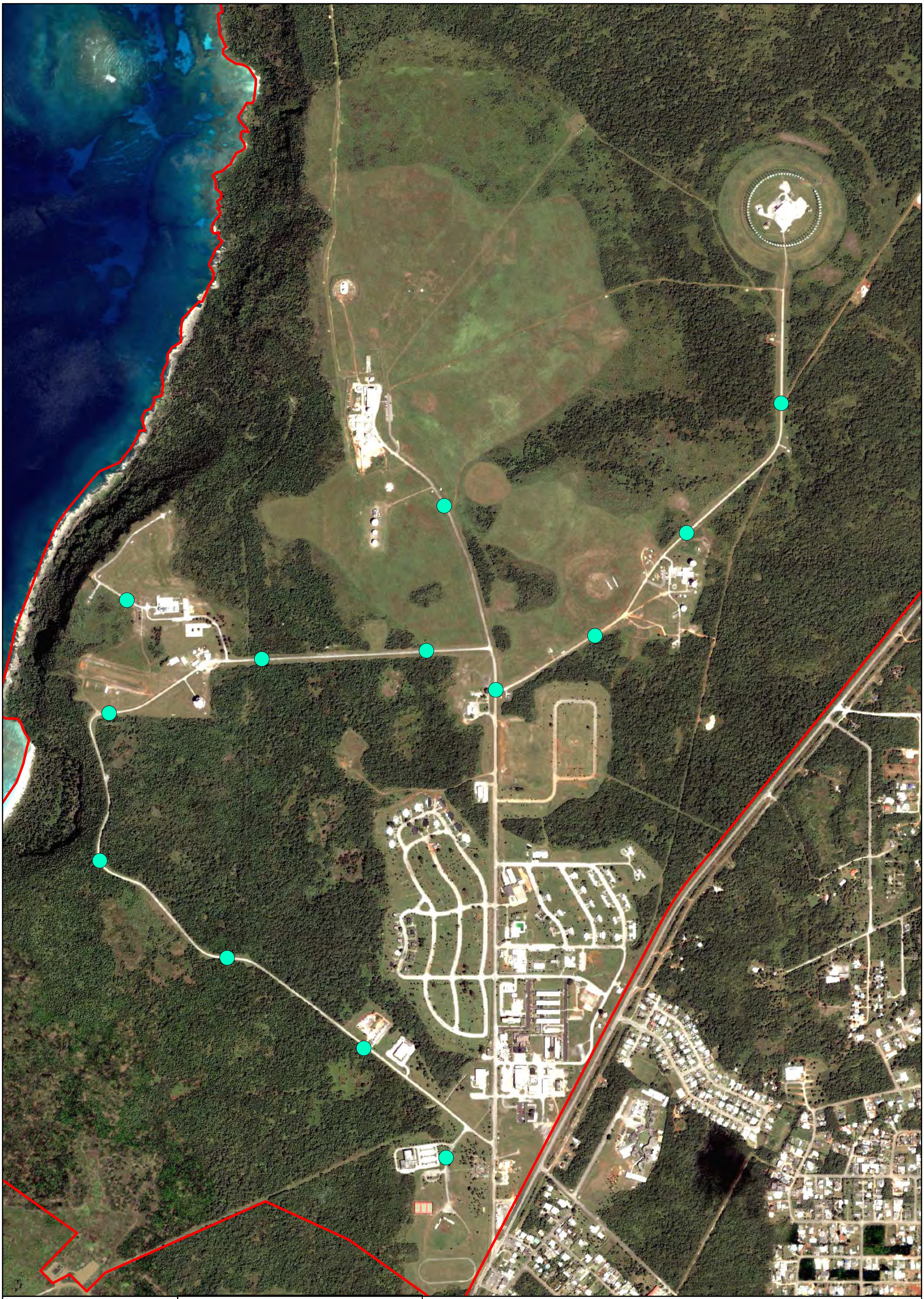
Species of concern are those plants that have biological or cultural significance as determined by recognized authorities or regulatory agencies. The Guam Department of Agriculture/ Division of Aquatic and Wildlife Resources currently lists three plants among the SOGCNs for the island, based on certain criteria.

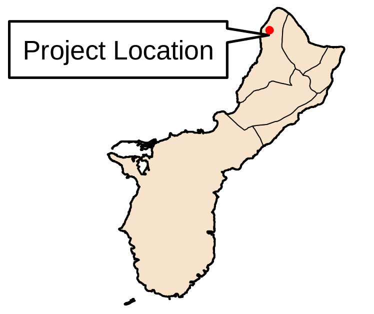
Two SOGCNs are present at North Finegayan: faniok (*Merrilliodendron megacarpum*), fadang (*Cycas micronesica*). According to the *Guam Comprehensive Wildlife Conservation Strategy*, faniok is threatened by herbivory, typhoons, and development (Department of Agriculture, 2005). A faniok stand is present along Transect 7 close to sea level in the west-central sector of the installation. Fadang is typically distributed over limestone and volcanic substrates, but populations island wide are in decline from infestation by the Asian cycad scale (*Aulacaspis yasumatsui*) (Department of Agriculture, 2005). Fadang was quantified only on Transect 7 in the west-central sector and on Transect 8 in the northwestern sector of the upper plateau. These areas also had the most native tree species among those surveyed.

7.3 Avian Surveys

Forest bird surveys (Figure 7-1) and roadside surveys (Figure 7-2) were conducted in the morning. Table 7-2 identifies the species observed as part of the surveys.

All of the observed species are common to Guam. Table 7-3 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna survey and results, refer to Appendix G.





Installation Boundary

Roadside Survey Point

0 200 400

Meters

North Finegayan

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 7-2

Table 7-2

Species Identified During Roadside and Forest Bird Surveys – North Finegayan

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	13	Pacific Golden Plover (53) Black Francolin (13) Eurasian Tree Sparrow (7) Island Collared Dove (6) Black Drongo (2)	5	81
Forest Bird	17	Island Collared Dove (7) Black Francolin (2) Eurasian Tree Sparrow (1)	3	10

Table 7-3

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – North Finegayan

Avifaunal Species	Residence Status[1]
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]

Notes:

[1] Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. ‘*Elepaio*, 51(1): 3-10.

[2] Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M. 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

7.4 Tree Snail Surveys

In 2008 a survey was performed on North Finegayan centered on the southern area and at Haputo Beach, and along the cliff line at Pugua Point in the central western area of the base (Appendix H; Smith et. al., 2008). The only colonies found were at Haputo Beach and Pugua Point. At Pugua Point the colony was made up of *Samoan fragilis* and *Partula radiolata* while the colony Comprised both *Partula gibba* and *Partula radiolata* at Haputo Beach.

In addition, a general and detailed visual survey was completed on Transect 9 at North Finegayan (Table 7-4). No living partulid tree snails (or their shells) were observed during any of the surveys conducted along the transect. No partulid tree snails were observed on Transect 9 in North Finegayan, but since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed.

Table 7-4

Partulid Tree Snail General and Detailed Visual Survey Results on Department of Defense Lands, Guam — North Finegayan

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	Number of Partulid Tree Snails Observed
21 January 2010	21 January 2010	NFIN - 9	500	0
Note: Because no live partulid tree snails were observed during general or detailed visual surveys, no quadrat surveys were completed; therefore, temperature, humidity, and air movement measurements were not taken in areas not inhabited by tree snails.				

Shells of the introduced Giant African Snail (*Achatina fulica*) and both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen along the transect.

7.5 Fruit Bat Surveys

NAVFAC biologists surveyed three locations over 10 days on North Finegayan from February to June 2008. Two bats were observed during this survey, one below the cliff line of the Haputo reserve and the other crossing Route 3A. For more information on the fruit bat survey and results, refer to Appendix I.

7.6 Threatened and Endangered Species

No federally-listed threatened or endangered avifauna, butterfly, herpetofauna, or tree snail species were identified at North Finegayan. However as noted above the federally threatened Fruit Bat was sighted at North Finegayan.

The capture of two Guam- listed endangered species (i.e., moth skink and Pacific slender-toed gecko occurred on North Finegayan. The moth skink was captured on Transect 9, Station 17. The pacific slender-toed Gecko was captured on Transect 9 at stations 9, 15, 16, 24, 28, 30, and 34.

Two SOGCN plant species are present at North Finegayan: faniok (*Merrilliodendron megacarpum*) and fadang (*Cycas micronesica*). According to the *Guam Comprehensive Wildlife Conservation Strategy*, faniok is threatened by herbivory, typhoons, and development (Department of Agriculture, 2005). *Procris pedunculata*, the host plant for the Mariana Eight Spot butterfly was observed scattered at North Finegayan.

The Haputo Ecological Reserve Area provides habitat for the Pacific tree snail (*Partula radiolata*) and the last remaining colony of Mariana tree snails (*Samoana fragilis*) on Guam. These species are among the endemic tree snails locally-listed as endangered and federally-listed as candidate species.

8 South Finegayan

On South Finegayan, the natural resource surveys performed included: herpetofauna, vegetation, and avian surveys. Figure 8-1 identifies the locations of the natural resource surveys' transects. On South Finegayan, both transects consisted primarily of *Hibiscus tiliaceus* and *Leucaena leucocephala*; bare ground was also common.

8.1 Herpetofauna Surveys

A total of five herpetofauna species were observed on South Finegayan. Table 8-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 8-1

Herpetofauna Observed on South Finegayan

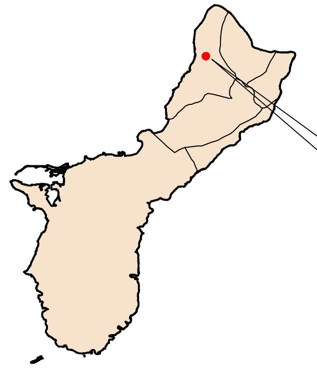
Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Amphibian	Marine toad (*Rhinella marinus*)	Introduced

The continued widespread presence of the curious skink as well as of other introduced amphibian species is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential for the introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a). For more information on the herpetofauna survey and results, please refer to Appendix B.

8.2 Vegetation

8.2.1 Trees

Calculation of the relative density of tree species on South Finegayan shows that the non-native *Vitex*, tangantangan, and papaya (*Carica papaya*) comprise 67 percent of the trees, with the remaining five species, all of which are native species comprising 33 percent; none are endemic to Guam or the other Northern Mariana Islands. The low native tree component may be attributed to past clearing activities at the site, which is adjacent to a fenced area enclosing what appears to be a hazardous waste remediation site. For more information on the vegetation survey and results, please refer to Appendix D.



Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400 Feet

0 200 400 Meters

South Finegayan

Transect Map

Prepared By: TEC Inc. Joint Venture

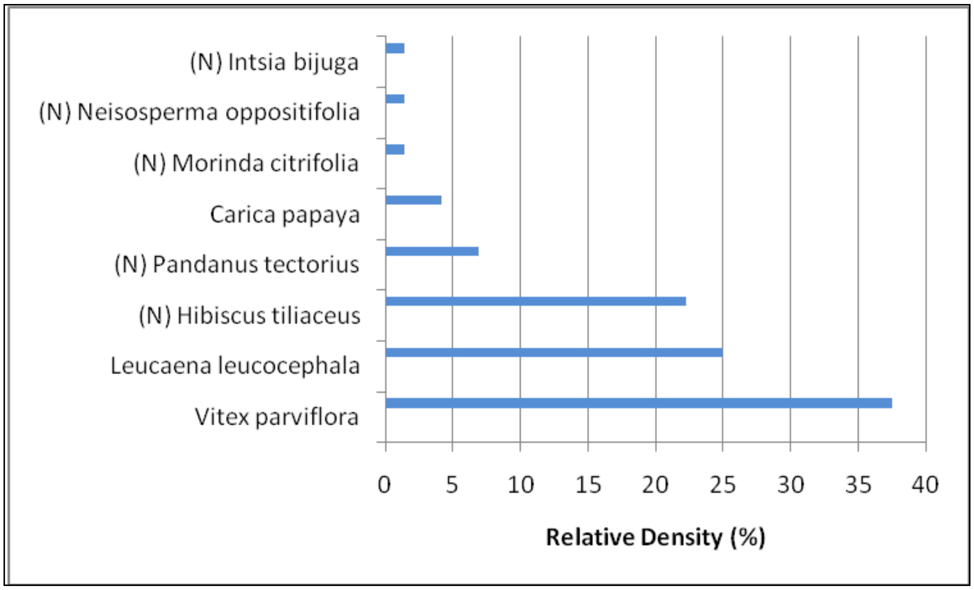
A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC Naval Facilities Engineering Command NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Figure 8-1

Chart 8-1

Relative Density of Trees at South Finegayan – Transects 1 and 2
(N = native)

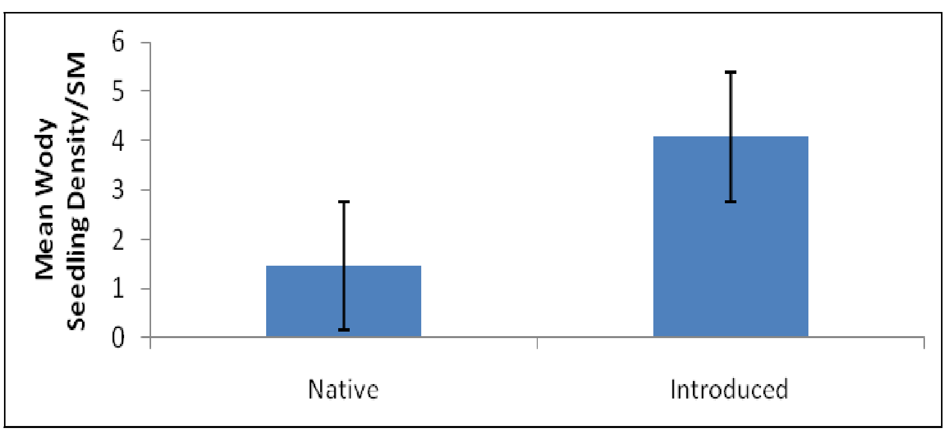


8.2.2 Seedlings

The mean woody seedling density at South Finegayan was lower for native species (1.46 seedlings/m^2) than for introduced species (4.06 seedlings/m^2). Chart 8-2 illustrates this difference between native and introduced seedling density. As can be seen in the figure, there are substantial variation in the number of seedlings per square meter along the transects.

Chart 8-2

Seedling Density of Woody Species at South Finegayan



8.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at South Finegayan. These include ungulate activity, presence of erosion, the percent of native plant species, and overall species richness.

Ungulate activity at South Finegayan fell into two categories: rubbings and soil disturbance. The ground cover at South Finegayan was primarily in the form of litter. Little live vegetation was detected.

8.2.4 Threatened and Endangered Species and Species of Concern -

No species listed as threatened or endangered, either by the Federal or local government, were observed along the transects at South Finegayan. Moreover, no species of concern were observed along the transects.

8.3 Avian Surveys

On South Finegayan, forest bird surveys (Figure 8-1) and roadside surveys (Figure 8-2) were conducted in the morning. Table 8-2 identifies the species observed as part of the surveys.

Table 8-2

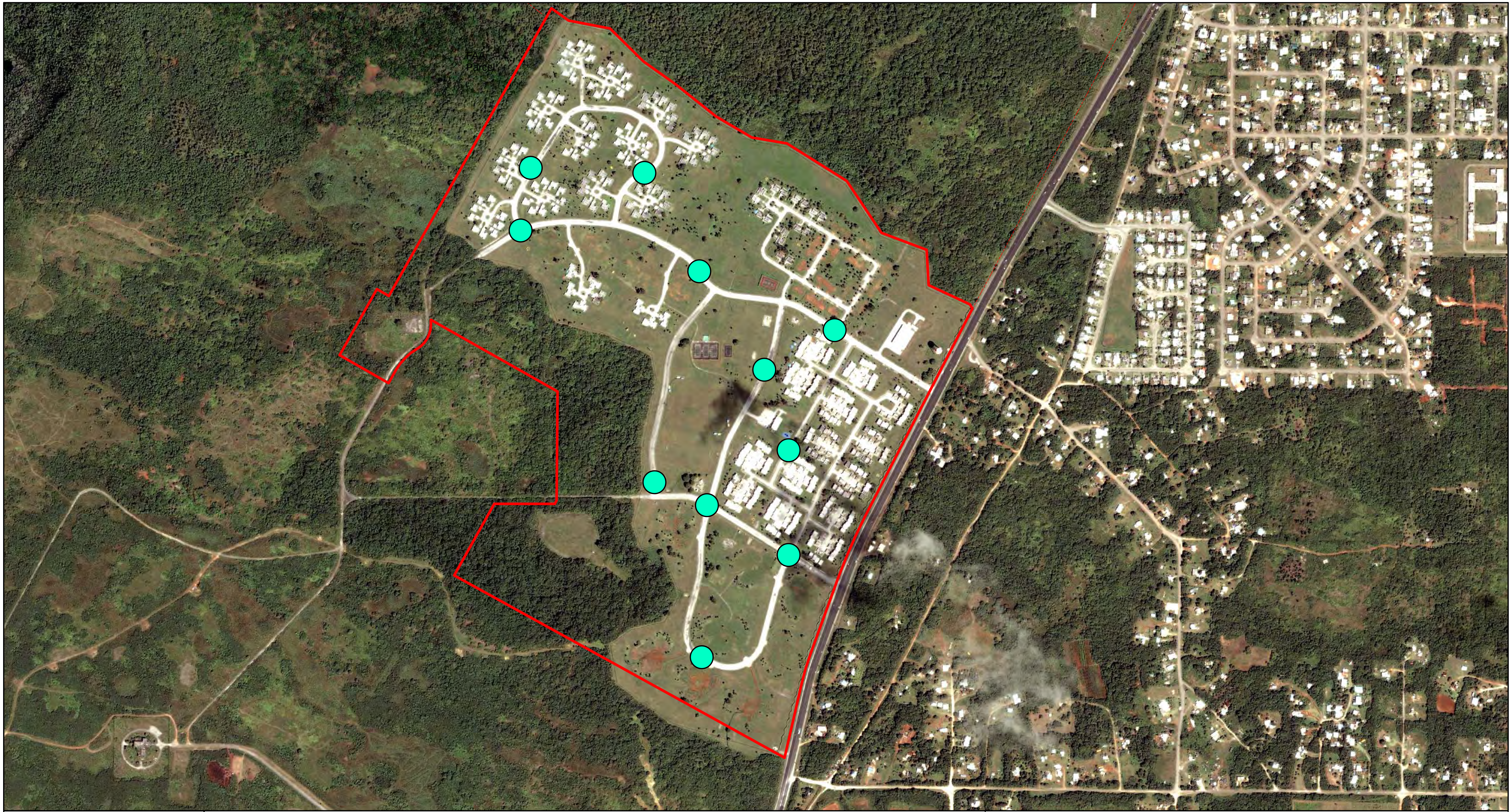
Species Identified During Roadside and Forest Bird Surveys – South Finegayan

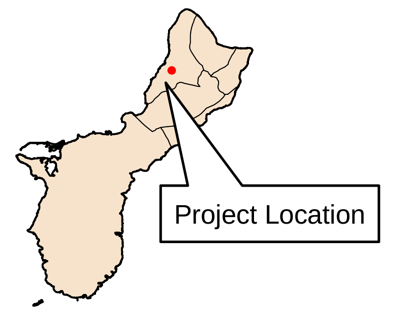
Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	11	Pacific Golden Plover (53) Island Collared Dove (28) Black Drongo (16) Eurasian Tree Sparrow (14) Common Pigeon (3) Yellow Bittern (1)	5	115
Forest Bird	4	Island Collared Dove (4)	1	4

All of the observed species are common to Guam. Table 8-3 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna survey and results, refer to Appendix G.

8.4 Threatened and Endangered Species

No threatened or endangered species were identified on South Finegayan during the natural resource surveys.





Installation Boundary

Roadside Survey Point

0 200 400 Meters

South Finegayan

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 8-2

Table 8-3

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – South Finegayan

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native – breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident – breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident – breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident – breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]

Notes::
[1] Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.

[2] Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M. 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

9 Main Base – Orote Point and Inner Apra Harbor and Polaris Point

The natural resource surveys on Main Base were in both terrestrial and aquatic habitats. The terrestrial habitats surveys were Orote Point, Polaris Point, and the Camp Covington Wetlands. The aquatic habitat that was surveyed consisted of portions of Inner Apra Harbor.

Subchapter 9.1 documents the herpetofauna survey conducted within Orote Point and Polaris Point. Subchapters 9.2 and 9.3 discuss the vegetation and avian surveys, respectively, conducted at Orote Point and Polaris Point. The locations of the survey sites are identified on Figure 9-1. In-water marine surveys associated with Inner Apra Harbor are documented in Subchapter 9.4. The locations of the survey sites in Inner Apra Harbor are identified on Figure 9-2.

Five transects were surveyed at Orote Point (Figure 9-1). *Guamia mariannae*, *Aglaia mariannensis*, *Ficus tinctoria*, *Triphasia trifolia*, and *Pandanus tectorius* dominated Transects 1, 2, 3a, and 3b. Transect 4, located below the Spanish Steps toward the beach, was almost entirely *Cocos nucifera*. Two northwest-southeast running transects were surveyed within the vegetated areas of Polaris Point.

9.1 Herpetofauna Surveys

Herptofauna surveys were conducted on Orote Point and Polaris Point. The results of the surveys are provided in Subchapters 9.1.1 and 9.1.2, respectively.

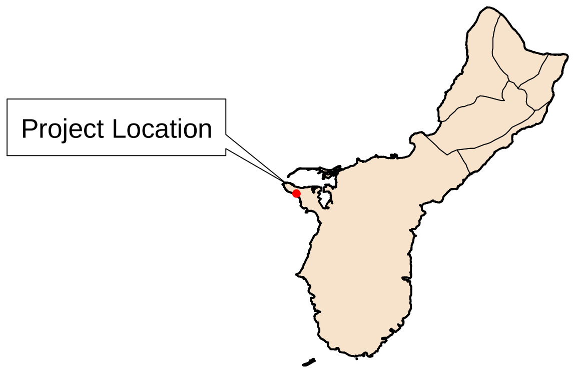
9.1.1 Orote Point

A total of seven herpetofauna species were captured or observed on Orote Point. Table 9-1 lists the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 9-1

Herpetofauna Captured or Observed on Orote Point

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced



Beginning Transect Point

End Transect Point

Transect Lines

Installation Boundary

N

0 200 400 Meters

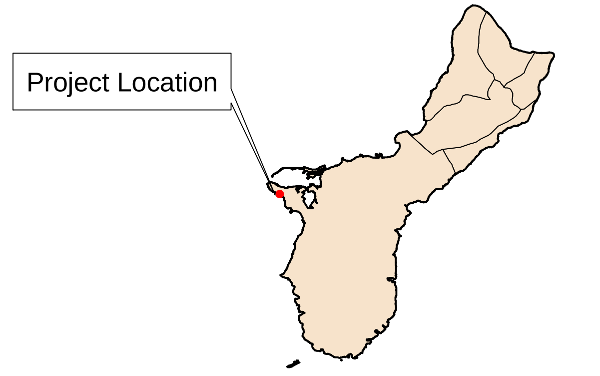
Main Base - Orote Point

Transect Map

Prepared By: TEC Inc. Joint Venture
A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Figure 9-1



Legend

Inner Apra Harbor Survey Area

Installation Boundary

N

0 0.5 1 Miles

Main Base - Inner Apra Harbor

Marine Survey Area Map

Prepared By: TEC Inc. Joint Venture

A Joint Venture of TEC Inc., AECOM TS Inc., and EDAW, Inc.

Prepared For: NAVFAC

Naval Facilities Engineering Command

NAVFAC PACIFIC

May 3, 2010	Project No.: 60133557	Figure 9-2

The continued widespread presence of the brown treesnake and the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential for introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

9.1.2 Polaris Point

In 2008, the NAVFAC Pacific biologists performed herpetofauna surveys along two transects in Polaris Point (Figure 9-1). Table 9-2 identifies the herptofauna that were observed. Eight herptofauna species were identified at Polaris Point. The species observed include the endangered moth skink and five introduced species.

Table 9-2

Herpetofauna Captured or Observed on Polaris Point

Group	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Geckos	House gecko (*Hemidactylus frenatus*)	Introduced
	Mutilating gecko (*Gehyra mutilata*)	Native
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced

Note: *Identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Endangered/ Species of Greatest Conservation Need (SOGCN) (GDAWR, 2006).

9.2 Vegetation

Vegetation surveys were performed on Orote Point and Polaris Point. On Orote Point, quantitative surveys were performed along a transect in the upper plateau to the west of the old runway in the southern sector of Orote. The area has a rugged limestone karst topography.

On Polaris Point, a qualitative vegetation survey was performed by Navy biologists in 2008. Subchapter 9.2.2 details the results of the survey at Polaris Point.

9.2.1 Orote Point

9.2.1.1 Trees

Surveys were performed along a transect in the upper plateau to the west of the old runway in the southern sector of Orote. The area has a rugged limestone karst topography.

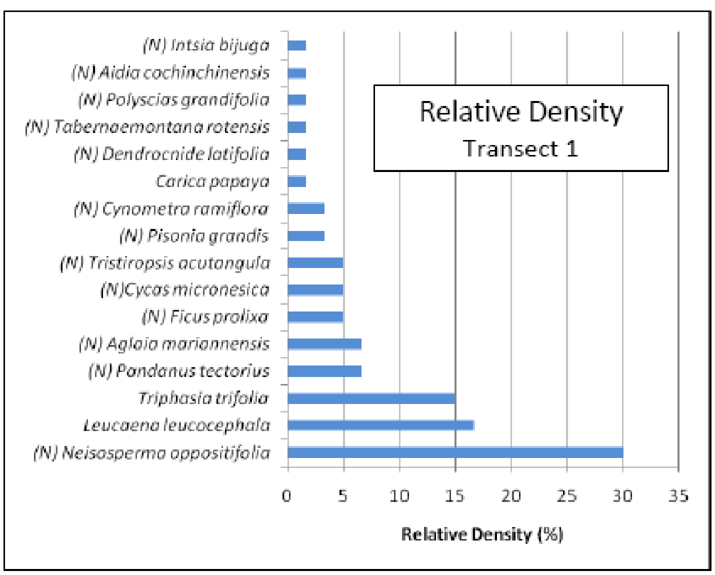
Based on the transect results, the overall density in this sector of Orote is approximately 5,030 trees per ha. The limestone forest was characterized by native fagot (*Neisosperma oppositifolia*) trees, which comprised 28 percent of the relative density, or approximately 1,414 trees per ha. The next highest densities were for the well-established but non-native trees tangantangan (*Leucaena leucocephala*) and Lemon China (*Triphasia trifolia*), with densities of 16 percent and 14 percent, respectively. Collectively, introduced species, including papaya (*Carica papaya*), comprised 33 percent of the relative density (Chart 9-1). The remaining 67 percent of the relative density comprised native species, including the Mariana Islands endemic species *Aglaia marianennsis* and *Tabernaemontana rotensis*.

Absolute cover or dominance was highest for native *Ficus rolix, at* 20.84 m^2/ha, *Pisonia grandis, at* 16.20 m^2/ha, and *Tristiropsis acutangula*, at 15.93 m^2/ha; each had total basal areas exceeding 2,000 cm^2. These species occupy the uppermost canopy of the forest. In comparison, non-native *Leucaena leucocephala*, *Triphasia trifolia*, and *Carica papaya*, which occupy the forest understory, had relatively modest absolute cover values less than 3 m^2/ha.

Absolute frequency was led by native fagot (*Neisosperma oppositifolia*), a mid- to upper-canopy tree, with a value of 56.25. The naturalized species, *Triphasia trifolia* and *Leucaena leucocephala*, had the next highest absolute frequencies, at 37.50 each. *Leucaena* is well-distributed on Orote Point, forming buffers between the periphery of the forest and cleared areas. *Leucaena* had a density of 59.23 trees per 100 m^2 (5,923 trees per ha) and an absolute frequency of 75 in forests sampled near the Kilo Wharf extension project on the northern coast of the Point.

Chart 9-1

Relative Density of Trees along Orote Point Transect 1
(N = native)



9.2.1.2 Seedlings

The woody seedling composition in plots at Orote Point consisted of about 84 percent native seedlings, with a seedling density of 4.04 seedlings/m^2. Introduced seedlings comprised approximately 15 percent, with a density of 0.76 seedlings/m^2.

The native woody seedling density seemed to reflect the higher relative density of native tree species quantified in the point-center quarter transect.

9.2.1.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at Orote Point. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. The species richness curve does not show a definite asymptote to indicate that richness has leveled off.

The mean frequency of ground cover in four categories was calculated based on quadrats. The mean frequencies for the categories of rock and vegetative litter were close to one another; live vegetation was very low, and no bare soil was observed in quadrats.

Orote Point is considered free of ungulates because of its topography and relative isolation. Nonetheless, the area was surveyed for soil disturbance or other activity attributed to ungulates, but no ungulate sign was recorded at Orote Point along the vegetation transect.

9.2.1.4 Threatened and Endangered Species and Species of Concern – Orote Point

Threatened and Endangered Species

Guam's only federally-listed plant species, the fire tree or trongkon guafi (*Serianthes nelsonii*), is known to occur only at the northern tip of the island (USFWS, 1994). BioSystems Analysis, Inc. (1989) identified ufa-halomtano (*Heritiera longipetiolata*), an endangered species by the Guam ESA (5 GCA, Chapter 63), as the only listed species within Orote Peninsula. No specimens of *Heritiera longipetiolata* were found in the 2008 survey, which sampled the forest on the southern region of the Peninsula opposite the ammunition wharf.

Notable Species and Species of Concern

The following species of concern were identified within Orote Point during the current survey:

- *Tabernaemontana rotensis* (Apocynaceae) is an endemic tree with distribution limited to the islands of Guam and Rota. The species was proposed for federal listing under the U.S. Endangered Species Act but this candidacy status was removed in 2004. *Tabernaemontana* is considered an SOGCN by the Government of Guam (Department of Agriculture, 2006). One live specimen of *Tabernaemontana* was encountered in the current vegetation survey, which appeared to be a healthy tree with a basal area of 26.96 cm^2. No flowers, fruits, or seedlings were observed.

- *Pisonia grandis* (Nyctaginaceae) is an indigenous tree considered important to the recovery of the Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*) as nesting habitat. A density of 157 trees per ha was calculated for the survey at Orote.

- *Cycas micronesica* (Cycadaceae) is listed by the Guam Department of Agriculture as an SOGCN. This native cycad is under threat by an introduced insect, the Asian scale (*Aulacaspis yasumatsui*).

- *Tristiropsis acutangula* (Balsalminaceae) is an indigenous tree of limited distribution on Guam. Orote had the highest density of *Tristiropsis* (approximately 236 trees *per ha*) *among all DOD* and non-DOD lands investigated in the current survey.

- *Zeuxine fritzii* (Orchidaceae) is an indigenous ground orchid found on forest floors. Feral pigs are known threats because of their rooting activities.

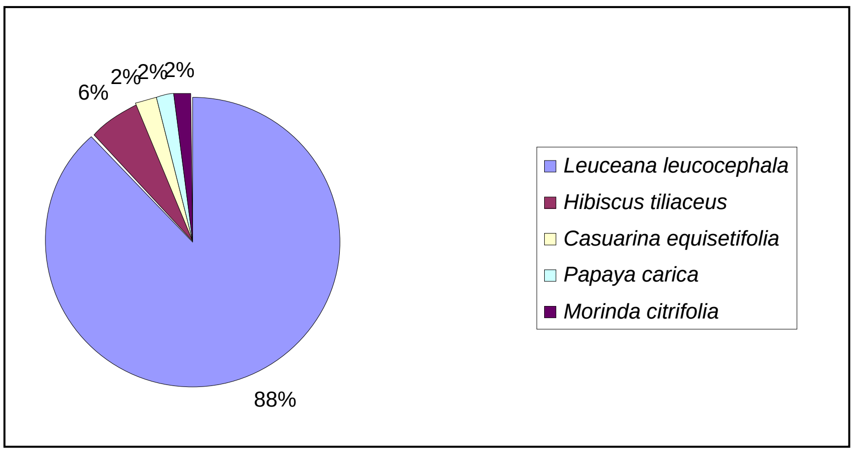
9.2.2 Polaris Point

9.2.2.1 Trees

At Polaris Point the number of trees per hectare (ha) was calculated at 5,004 trees/ha. The mean dbh (cm) (with 95 percent confidence interval) was calculated to be 6.12 (5.03-7.21). *Leuceana leucocephala* comprised 88 percent of the tree layer Chart 9-2 identifies the species composition along the transect.

Chart 9-2

Tree Species Composition at Polaris Point



9.2.2.2 Threatened and Endangered Species – Polaris Point Plant Species

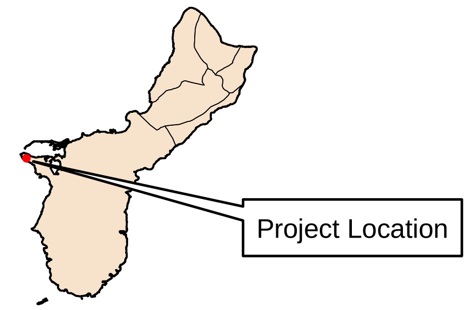
No threatened and endangered species or species of concern were identified at Polaris Point.

9.3 Avian Surveys

On the Main Base, avian surveys occurred on Orote Point, Polaris Point, and the Camp Covington Wetlands.

9.3.1 Orote Point

On Orote Point, both roadside (Figure 9-3) and forest bird surveys (Figure 9-1) were conducted in the morning. Table 9-3 lists the species observed as part of the surveys.



Orote Point

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 9-3

Table 9-3

Species Identified During the Roadside and Forest Bird Surveys – Orote Point

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	5	Pacific Golden Plover (50) Black Francolin (12) Whimbrel (11) Island Collared Dove (1) Black Drongo (4)	5	78
Forest Bird	8	Island Collared Dove (1) Yellow Bittern (1) Black Francolin (1)	3	3

All of the observed species are common to Guam. Table 9-4 specifies the resident status of the observed species. The nomenclature follows Gill et al. 2008. For more information on the avifauna survey and results, refer to Appendix G.

Table 9-4

Residence Status of the Avifaunal Species Identified during the Roadside and Forest Bird Surveys – Orote Point

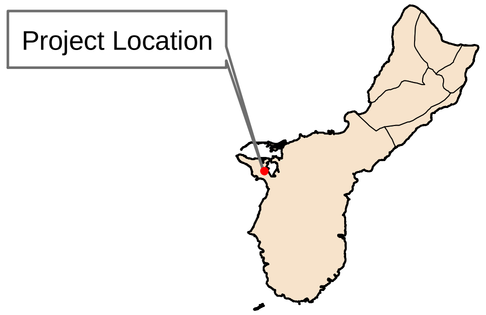
Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native – breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident – breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident – breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident – breeding
Whimbrel (*Numenius phaeopus*)	Common visitor – not breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]

NOTES:
1 Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. ‘*Elepaio*, 51(1): 3-10.

2 Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M., 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

9.3.2 Polaris Point

On Polaris Point, aviafauna surveys were conducted by NAVFAC Pacific biologists along two transects (Figure 9-4). Four species were observed and are provided in Table 9-5.



Transect Lines
Moorhen Survey Transects
Installation Boundary
Avian Roadside Observation Stations

N

0 200 400
Meters

Main Base Camp Covington & Polaris Point

Avian Survey Location Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 9-4

Table 9-5

Avian Survey Results – Orote Point

Avifaunal Species	Residence Status[1]
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native – breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident – breeding
Philippine Turtle Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Brown noddy (*Anous stolidus*)	Uncommon resident to Guam, nests in numbers on Cocos Island [3]

NOTES:
1 Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.

2 Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M., 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

3 USGS, 2010

Three of the species observed in the survey at Polaris Point are common to Guam. However, on species, the brown noddy, nest in numbers on nearby Cocos Island but have not successfully nested on Guam since the brown tree snake populations peaked in the 1970s and 1980s (USGS, 2010).

9.3.3 Avian Endangered Species Survey

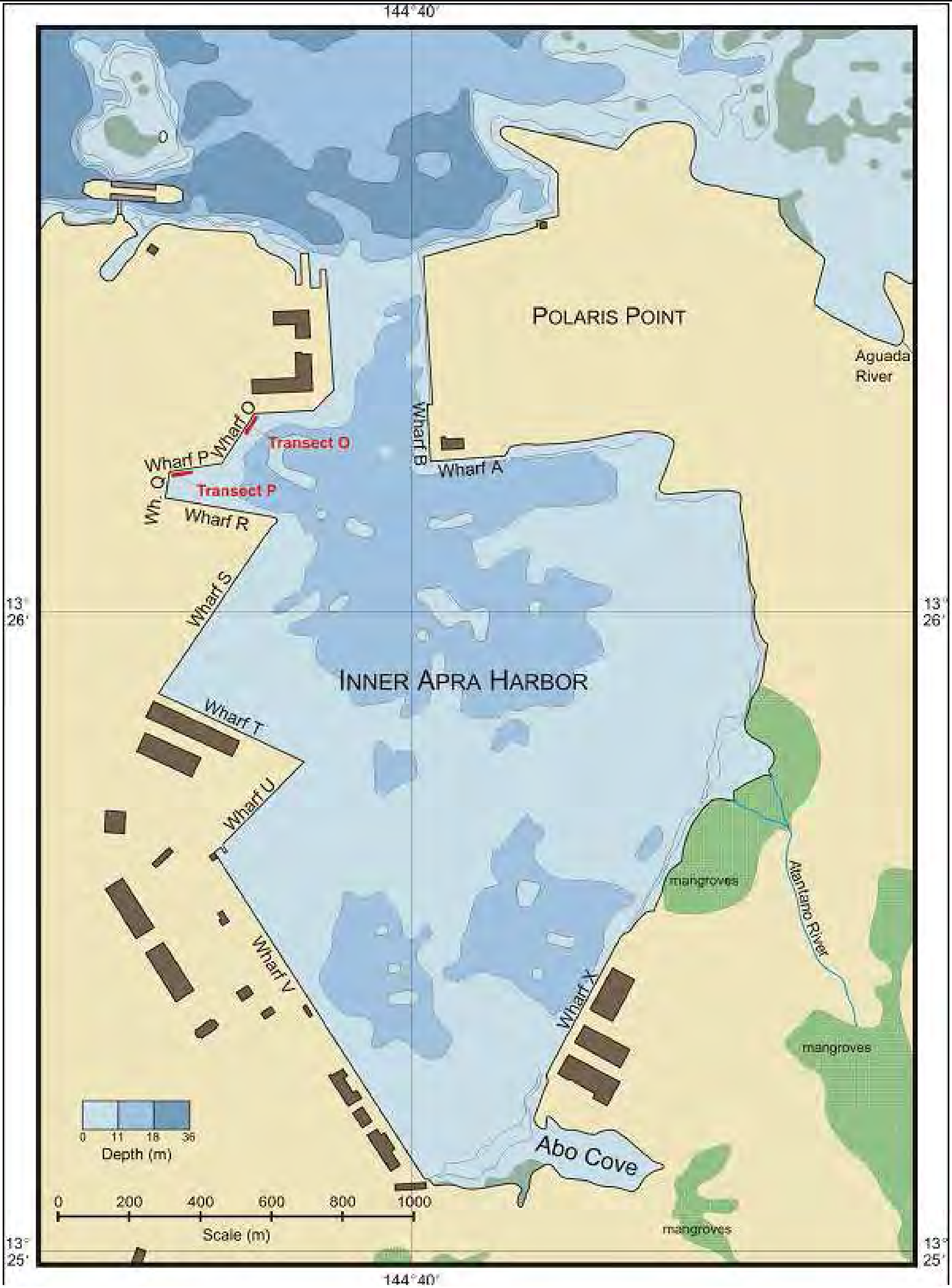
The Camp Covington wetland (Figure 9-4) was identified as a habitat resource requiring special surveys to determine whether the federally endangered Mariana Common Moorhen (*Gallinula chloropus*) was present. Eleven listening stations were strategically positioned around the wetland habitat. Surveys were conducted during the morning hours from sunrise to 1000 hours.

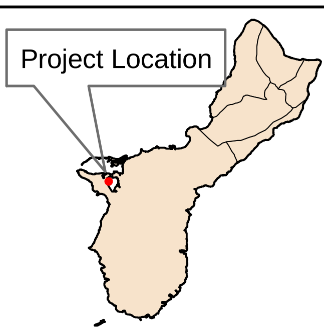
Survey stations were placed a minimum of 150 m apart to minimize double-counting. All moorhen detections were recorded (by visual observation or by song) within one 8-minute survey; no surveys were replicated. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

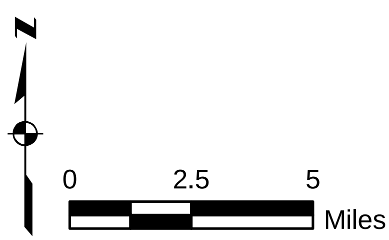
No federally endangered Mariana Common Moorhens were detected during the Endangered Species Survey conducted at the Camp Covington wetland complex.

9.4 Inner Apra Harbor

Within Apra Harbor, marine investigations occurred along the wharves of Polaris Point, Oscar and Papa Wharves (Figure 9-5), and Abo Cove and Wharves S, T, U, V and X (Figure-9-6). Marine surveys were accomplished through visual observation of scientists.







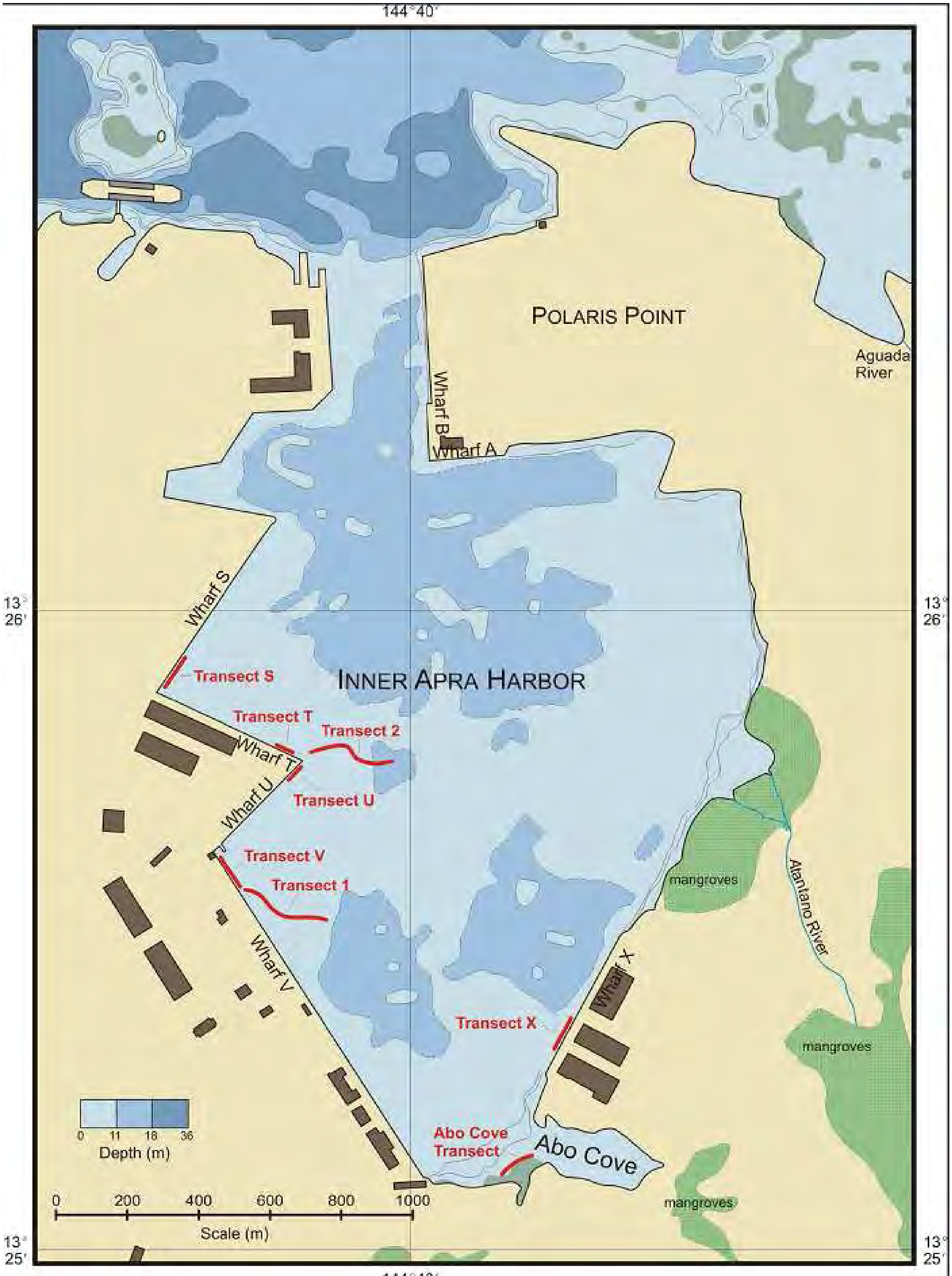
Oscar & Papa Wharves Marine Survey Transects

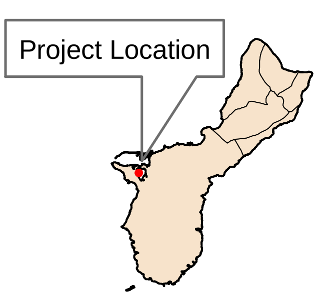
Transect Map

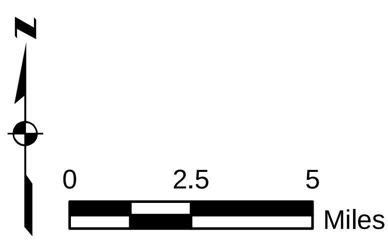
Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 9-5







Inner Apra Harbor
Marine Survey Transects

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC Naval Facilities Engineering Command

May 3, 2010	Project No.: 60133557	Figure 9-6

9.4.1 Benthic Cover

9.4.1.1 Oscar and Papa Wharves

Mean surface coverage of the vertical substrate along the transects at Oscar and Papa Wharves is presented in Figure 9-5. The harbor floor not sampled. Substrate coverage was divided into seven abiotic and biotic features at the sites. The mean biotic coverage in ten quadrat samples was 20.63 percent at Oscar Wharf and 55.63 percent at Papa Wharf. Sponges were the predominant biotic cover organisms at Oscar Wharf, ranging from 0–18.75 percent cover; macroalgae were predominant at Papa Wharf, ranging from 12.5–62.5 percent cover (Chart 9-3).

9.4.1.2 Abo Cove and Wharves S, T, U, V and X

A total 70 benthic taxa were recorded and quantified during this study. The total number of taxa recorded is low compared to benthic surveys in other parts of the harbor. The average species richness of the quadrats is also low compared to similar studies in other parts of Guam. There was a large difference in the total number of species and in species richness between quadrats from Abo Cove and the wharf transects. The most authentic “natural” site (Abo Cove) is significantly less taxon-rich than the wharf sites.

Turbidity and sediment deposition are most likely the most important causal factors for this difference. *Caulerpa verticillata* is a green alga that copes well with increased levels of sedimentation and reduced salinities. Exceptionally large specimens of this alga were found in Abo Cove, probably a result of relatively low herbivore pressure. The distribution of the seagrass species *Halophila japonica* also seems to be restricted to Abo Cove in the inner harbor.

Turbidity is high throughout the inner harbor, but the vertical orientation of hard substrates (and probably ship activity) at the wharves results in a lower amount of sediment deposition, favoring the growth of epilithic biota adapted to low-light conditions. Although very different from Abo Cove, the benthic assemblages of the wharves contain interesting taxa as well. Some of the taxa recorded here do not appear in the most recent taxonomic treatises for Guam. For example, the very abundant *Celleporaria sibogae* and the rather uncommon *Lichenopora* sp. are most likely new bryozoan records for Guam, as this group has been virtually unstudied in the region (Paulay, 2003). Diversity measures mimic the differences in species richness between the inner harbor sites. Sponges contribute most to the benthic diversity of the wharves. A number of these probably also constitute new records for Guam, and others are infrequently encountered elsewhere around the island as they are typically confined to deep water, caves, or other cryptic habitats.

As with taxonomic richness and diversity, the benthic assemblages of Abo Cove differ significantly from the wharf sites in having a low overall biotic cover. This is a direct result of the Abo Cove site being a mostly horizontally oriented sedimentation flat. In contrast, the biotic assemblages of the wharves are best developed on the shallow vertical surfaces. It is important to note, however, that corals are the main constituents of the biotic assemblages at Abo Cove, while the wharves are predominantly covered by crustose algae and sponges.

9.4.1.3 Polaris Point

-Subconsultant has not provided data for in-water surveys at Polaris Point -

9.4.2 Corals

9.4.2.1 Oscar and Papa Wharves

Species richness was highest at Oscar Wharf, where six species occurred on the transect; only three species occurred on the transects at Papa Wharf. *Leptastrea purpurea*, *Pocillopora damicornis* and *Porites lobata* were the most frequently observed species. Three species, *Dendrophyllia* sp., *Psammocora haimeana*, and *Porites rus* occurred on the transect only at Oscar Wharf.

9.4.2.2 Abo Cove and Wharves S, T, U, V and X

A total of 13 species of scleractinian corals encountered on six transects in Abo Cove and Wharves S, T, U, V, and X. An additional 13 species of scleractinian corals were observed on substrates adjacent to the transects. Two species of non-scleractinian anthozoans were also recorded. Therefore, a cumulative total of 28 species of corals and related organisms, representing 11 families and 13 genera, was observed at the study site. This count represents a minimum, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species.

Species richness was highest at X-ray Wharf, where eight species occurred on the transect; only four species occurred on transects at Above Cove and Tango, Uniform, and Victor Wharves. *Porites lutea* and *Pocillopora damicornis* were the most common species, occurring on five of the six transects. Seven species occurred on only one transect, and three of these species were represented by single observations.

Poritid corals were predominant in coverage, averaging some 83 percent relative coverage on transects. Similarly, *Porites* spp. occurred at high frequencies on transects, although smaller species, such as *Pocillopora damicornis* and *Leptastrea purpurea*, exhibited high frequencies as well. The harbor floor consists of fine-grain sediments unsuitable for settlement by coral larvae. Consequently, few corals were encountered on Transects 1 and 2 on the harbor floor. Small colonies of *Porites lutea* were observed on scattered pieces of debris and old pilings that provided the only hard substrate available for settlement of larvae. With the exception of what appeared to be the remains of an old pier extending perpendicularly from Victor Wharf, the amount of debris was greater near the wharves. No corals were observed on the harbor floor at distances of 20 m or more.

The fourth root-transformed relative coral coverage data were analyzed by non-metric multidimensional scaling (NMDS). The two-dimensional NMDS plot shows the biotic affinities between the sites (low stress) and reveals differences not only between Abo Cove and the wharf sites, but between Sierra Wharf and the four remaining wharves. Uniform Wharf and X-ray Wharf cluster together, as do Tango Wharf and Victor Wharf. Coral communities on the four southern wharves are more similar to each other than to either Sierra Wharf or Abo Cove.

9.4.3 Macroinvertebrates

9.4.3.1 Oscar and Papa Wharves

Seventeen species of solitary macroinvertebrates were encountered on the transect at Papa Wharf, and 12 species were recorded on the transect at Oscar Wharf. As noted at other sites in Inner Apra Harbor (Smith et al., 2008), 100 percent of the macroinvertebrates encountered on the transects were suspension feeders. Bivalve mollusks (seven species) and solitary ascidians (eight species) dominated the macroinvertebrate fauna at both wharves, and mean densities were generally greater at Papa Wharf. The bivalves *Malleus decurtatus* and *Spondylus squamosus* were remarkably more abundant at Papa Wharf, as was the ascidian *Rhopalaea circula*. Mean densities ranged from less than 1.0 individual/20 m^2 (several species) to 55 individuals/20 m^2 (*Spondylus squamosus* at Papa Wharf). Spondylid bivalves occurred at the greatest density encountered at both sites

9.4.3.2 Abo Cove and Wharves S, T, U, V and X

Twenty species of solitary macroinvertebrates in four phyla were encountered on the transects, and ten additional species were observed in areas adjacent to the transects. Three of the species on transects occurred as single observations, and one species, *Phallusia nigra*, is reported as non-indigenous (Paulay et al., 2001a; Lambert, 2002, 2003). The greatest diversity (i.e., 16 species, or 80 percent of the diversity on transects) was found on the vertical face at Victor Wharf (Transect V), and the least (i.e., eight species) on the coral reef at Abo Cove (Transect A). Bivalve mollusks and ascidians dominated the macroinvertebrate fauna in terms of both diversity and density. Remarkably, 100 percent of the macroinvertebrate species encountered on transects were suspension feeders. Of the total 30 species of solitary macroinvertebrates, all but three are suspension feeders – the three being detritus feeders. The predominance of suspension feeders in lagoonal environments, such as the inner harbor, may be a result of nutrient enrichment by terrestrial runoff and the extended residence time of waters in the lagoon.

Densities of solitary macroinvertebrates ranged from less than one individual of a species to more than 90 individuals/10 m^2, with bivalve mollusks and ascidians being predominant. The hammer oyster *Malleus decurtatus* occurred in the greatest densities (up to 9.3 oysters/ m^2 at Victor Wharf), with thorny oysters, *Spondylus* spp., and jewel box clams, *Chama* spp., also abundant. Among ascidians, *Rhopalaea circula* reached a density of 6.3 individuals/ m^2 at Tango Wharf. The greatest total density was observed at Victor Wharf (Transect V), where there were 143.7 macroinvertebrates/10 m^2; the lowest total density was 4.4 macroinvertebrates/10 m^2 at Abo Cove. As noted above for benthic coverage, this pattern may be explained by the greater availability of hard substrate for post-larval settlement on the vertical faces of the wharves, as compared to the sediment-laden horizontal substrate on the reef at Abo Cove.

The harbor floor is largely depauperate of epibenthic macroinvertebrates. The substrate of the harbor consists predominately of a sticky, fine silt/mud sediment that is easily resuspended. Observed species were associated with debris that provided hard substrate, with the exception of the detritivorous snail *Bittium* sp. Generally, the volume of debris, and therefore the number of macroinvertebrates, diminished with distance from the wharves. Although few epibenthic macroinvertebrates were observed on the harbor floor, large numbers of burrow openings were present, indicating an abundance of infaunal organisms.

Comparison of macroinvertebrate community structure across transects by cluster analysis indicates considerable contrast for horizontal and vertical substrates. The macroinvertebrate community on vertical faces of the wharves form a single large clade that is distinctly different than the community inhabiting the horizontal substrate at Abo Cove. As noted for benthic cover, the similarity between Uniform Wharf and Victor Wharf is high. However, for solitary macroinvertebrates, X-ray Wharf is more similar to these communities than to the community at Tango Wharf. The Abo Cove macroinvertebrate community is distinctly different from the communities on the wharf faces, which clustered together.

Possibly the most abundant solitary invertebrates were neither epibenthic nor conspicuous. The pelagic thecosomate gastropod cf. *Styliola subula* was abundant in surface waters adjacent to all surveyed wharves.

9.4.4 Fish

9.4.4.1 Oscar and Papa Wharves

Thirty-five species of fishes were observed on transects surveyed at both wharves. As with other sites within the Inner Apra Harbor surveyed previously (Smith et al., 2008), this low level of species richness represents an impoverished fish fauna (there are about 1,000 species of reef and near-shore fishes reported from the Mariana Islands; Myers and Donaldson, 2003; unpublished data). Components of this fauna, however, are indicative of protected, turbid lagoons or bays of Guam, of which there are relatively few compared to clear water reefs, and thus constitute a relatively unique assemblage of fishes.

Two invasive species were observed at both wharves. One, *Neopomacentrus violescens* (Pomacentridae, damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). This species was found more recently on Tango, Uniform and X-ray Wharves (Smith et al., 2008). The second species, *Amblygliphididon ternatensis* (Pomacentridae), was reported from Sierra, Tango, Uniform and Victor Wharves. These damselfishes occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999).

Species richness (the number of species observed) ranged from 15 (n = 57 individuals) at Oscar Wharf to 29 (n = 1347 individuals) at Papa Wharf. Generally, species richness was greater on or adjacent to mid-wall and top-wall transects at both wharves, where corals, hanging debris, and oyster shells provided shelter for various species, but especially damselfishes, cardinalfishes and juvenile butterflyfishes. Bottom-transects at both wharves had the lowest number of species and individuals. These included burrowing gobies (mainly *Oplopomus oplopomus*) and transient snappers (*Lutjanus fulvus*).

9.4.4.2 Abo Cove and Wharves S, T, U, V and X

Sixty-two species of fishes were observed on transects surveyed within the Apra Inner Harbor. While this number indicates an impoverished fish fauna (there are approximately 1,000 species of reef and nearshore fishes known from the Mariana Islands; the fauna seems representative of protected, turbid lagoons or bays of Guam. Further, at least three species appear to be invasive or new records for Guam and the Mariana Islands. These species are the following: *N. eviolescens, A. ternatensis* and *Rhamdia cypselurus* (Apogonidae; cardinalfishes). These species has not been reported previously from the Mariana Islands. All three species occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999).

Species richness between stations ranged from 2 (harbor floor, Transect 2) to 29 (UniformWharf–bottom, Transect UB). Generally, species richness was greater on the bottom at stations, where debris provided shelter for various species. Some wharf walls (mid-depth transects), however, supported relatively high numbers of species, as well.

Densities of fish species refers to the number of individuals/$m^{2.}$ Small, structure-associated cardinalfishes had the greatest density among stations. *Apogon lateralis* (Apogonidae) densities where high at Sierra Wharf ($20/m^2$ at mid-depth and $4.4/m^2$ at subsurface depth), Victor Wharf, Uniform Wharf, and X-ray Wharf ($2.06/m^2$ at mid-depth). Another cardinalfish, the apparently invasive *Rhabdamia cypselerus*, had relatively high densities at Sierra Wharf and Tango Wharf. Both species tended to occur in aggregations of several individuals. The invasive damselfish, *Amblyglyphididon ternatensis* (Pomacentridae), was relatively dense at Victor Wharf ($2.24/m^2$ at mid-depth) and Sierra Wharf ($1.16/m^2$ at subsurface depth). This species occurred in aggregations as well; many were juveniles. Densities of other species were low to very low and ranged from $0.0033/m^2$ to $1.0/m^2$.

9.4.5 Summary

9.4.5.1 Oscar and Papa Wharves

As shown in a previous study (Smith et al., 2008), the artificial and most anthropogenically-impacted habitats, wharves, might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 19 species of scleractinian corals, and an additional two taxa including a stony hydrozoan and an octocoral. The predominant corals were *Pocillopora damicornis*, *Porites lobata*, and *Leptastrea purpurea.* The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea purpurea* (Amesbury et al., 1977). Coral species (Smith et al., 2008; this report).

Macroinvertebrates communities on the vertical surfaces of Oscar and Papa Wharves were only moderately diverse, with species observed on or near transects. This pattern is consistent with that reported for similar localities within the inner harbor (Smith et al., 2008). For corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surfaces. Macroinvertebrate assemblages on both wharves were dominated by suspension feeding species, which comprised 100 percent of the species occurring on transects and 90 percent of all species observed.

The species richness and diversity of the fish faunas of Oscar and Papa Wharves, like elsewhere in the inner harbor (Smith et al., 2008), are relatively low compared to habitats elsewhere on Guam. These fauna are highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves and jetsam and debris (pilings, frames, storage units, etc.), and the microhabitats found on or adjacent to these were utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (e.g., bilge water), and became established at each of the wharves. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

9.4.4.2 Abo Cove and Wharves S, T, U, V and X

This study shows a clear difference between the most authentic inner harbor habitats at Abo Cove and the manmade wharfs (Chart 9-4). Ironically, the artificial and most anthropogenically impacted habitats of the wharfs might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges.

The coral fauna of the study area consisted of 30 species, or about 10 percent of the coral fauna of Guam (see Randall, 2003). The predominant corals were massive *Porites* spp., one of which exceeded 1 m in diameter at Abo Cove. The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves.

Macroinvertebrates communities in the inner harbor were only moderately diverse, with 30 species observed on or near transects. As for corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surface. On the harbor floor, macroinvertebrates were limited to scattered debris that provided the only hard substrate available. Macroinvertebrate assemblages in the inner harbor were dominated by suspension feeding species, which comprised 100 percent of the species occurring on transects and 90 percent of all species observed. Except for a single species of marine snail, no macroinvertebrates were observed on the soft sediments of the harbor floor.

The species richness and diversity of the fish fauna within the Inner Harbor are relatively low compared to habitats elsewhere on Guam. However, the fauna are highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves, and the microhabitats found on or adjacent to those wharves was utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the stations. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

Perhaps the only unusual species present at most or all stations are the bottom dwelling, burrowing goby species that may be specific only to sand bottoms in back bay or estuarine areas. The extent of the distribution of these species is not well known, however, because of the generally poor visibility encountered in such areas (i.e., Inner Apra Harbor and Sasa Bay in western Guam, and the estuaries of the Pago, Ylig, and Talofofo Rivers in eastern Guam).

9.5 Fruit Bat Surveys

NAVFAC biologists surveyed one location on Orote Point during this survey in April 2008. No Fruit bats were observed. For more information on the fruit bat survey and results, refer to Appendix I.

9.6 Threatened and Endangered Species

No federally-listed threatened or endangered avifauna were identified on the Navy Main Base. However, a Guam-listed endangered species: moth skink (herptofauna) was observed on Polaris Point.

During the marine survey, a green turtle was observed from the boat in waters between Abo Cove and the southern end of Victor Wharf. *Chelonia mydas* is listed as a threatened species under the federal ESA. The observed individual was small (0.5–1.0 m carapace length).

Because of the fine-grained, muddy composition of the shoreline of Inner Apra Harbor, the beaches in the vicinity are not considered as potential nesting sites for endangered and threatened marine turtles known to occur in the seas around Guam. The nearest documented nesting beaches are near Gabgab Beach, in the outer harbor. Therefore, it is assumed that the individual sighted was foraging.

Chart 9-3

Percent Coverage of Algae, Sponges (Porifera), Corals (Cnidaria), and other Covertypes at Oscar and Papa Wharves

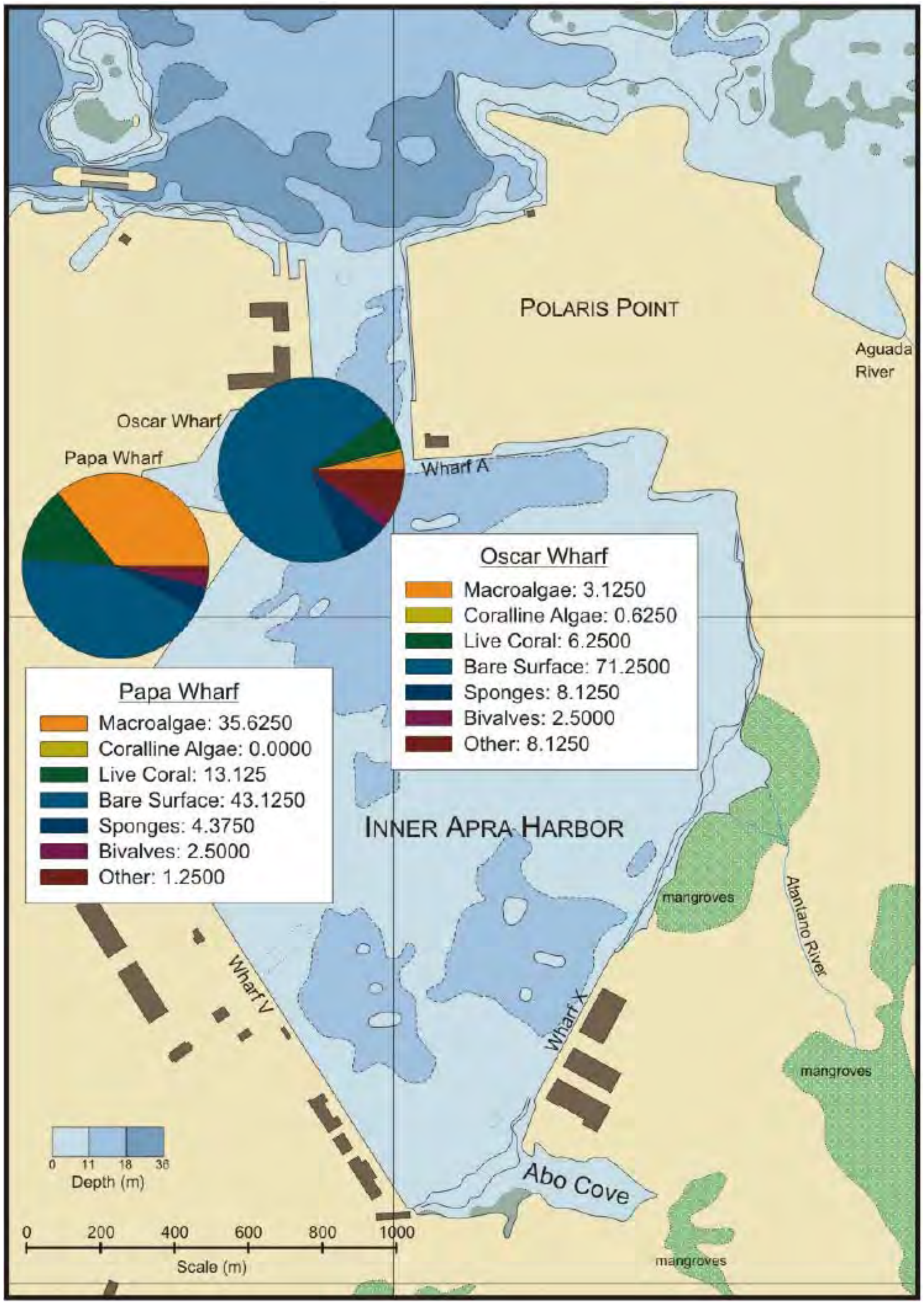
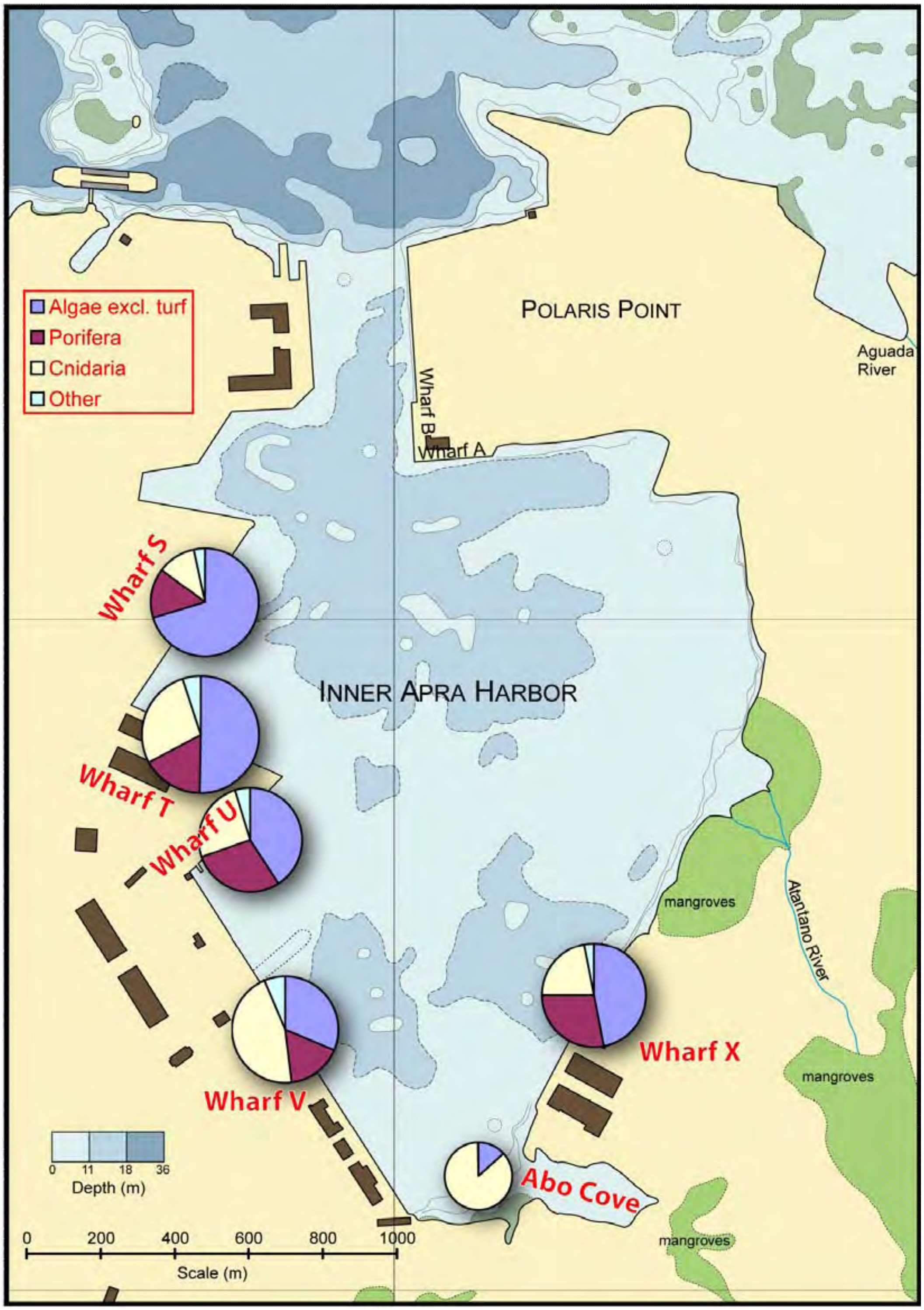


Chart 9-4

Percent Coverage of Algae, Sponges (Porifera), Corals (Cnidaria), and other Covertypes at Abo Coves and Wharves S, T U, V, and X



10 Naval Munitions Site

On Naval Munitions Site (NMS, formerly known as Naval Magazine) and along the Proposed Access Road Option A, natural resource surveys performed included herpetofauna, vegetation, and avian surveys. Figure 10-1, NMS – Northern Transects Map, and Figure 10-2, NMS – Southern Transects Map, show the locations of the ecological transects. Figure 10-3 identifies the location of Proposed Access Road Option A.

At the NMS, eleven transects were surveyed. Ten of the eleven transects were situated almost entirely in native forest consisting of *Premna obtusifolia*, *Aglaia mariannensis*, and *Guamia mariannae*. Some transects passed over streams and swampy ground where *Cocos nucifera*, *Pandanus tectorius*, and *Hibiscus tiliaceus* were dominant. One transect was dominated by *Miscanthus floridulus*.

10.1 Herpetofauna Surveys

At NMS, herpetofauna surveys were conducted within the NMS and within a corridor for the potential Proposed Access Road Option A. The results of the surveys within the NMS are presented in Subchapter 10.1.1. The results of the surveys conducted within the proposed access road corridor are presented in Subchapter 10.1.2.

10.1.1 NMS - Results

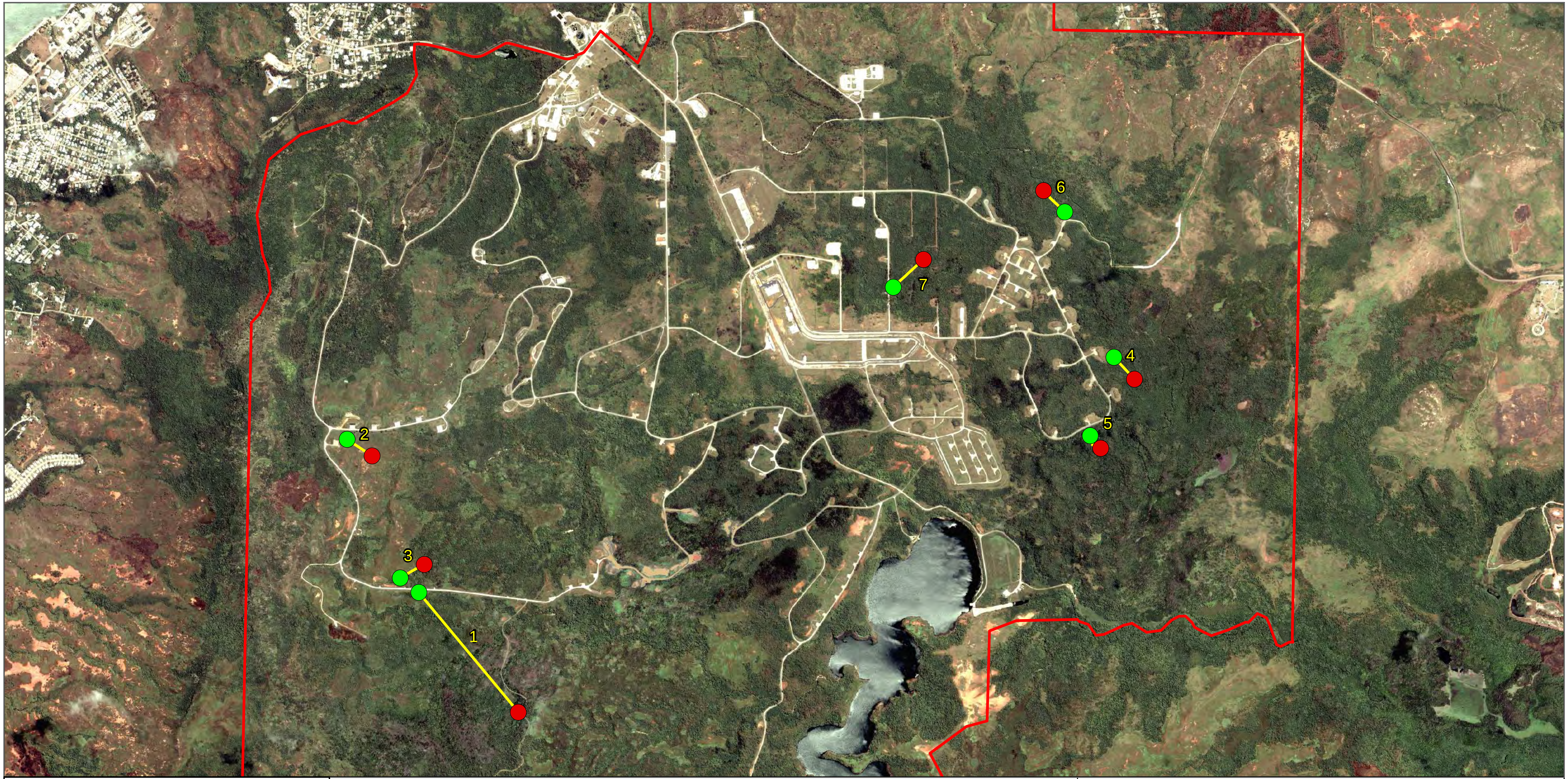
Six herpetofauna species were captured or observed on NMS. Table 10-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

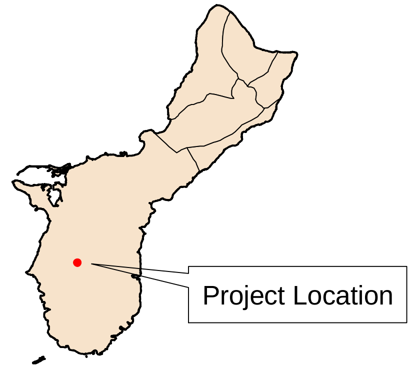
The capture of moth skink and Pacific slender-toed gecko at NMS is noteworthy. The distribution and abundance of this native skink on Guam is unknown, due to the variability of information presented by authors. Since the transect on which the species was caught was the only transect not to be visually searched at night, the number of moth skink detected during this survey might have been higher if a night search had been conducted.

The continued widespread presence of the brown treesnake and the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a).

10.1.2 Proposed Access Road Option A

This site consisted of three transects in forested areas, situated alongside the trail leading into the top NMS (Figure 10-3). The first two were in degraded forest of *Leucaena leucocephala*, *Hibiscus tiliaceus*, and *Flagellaria indica*. The third, at the highest elevation, was primarily native forest; *Pandanus tectorius* and *Aglaia mariannensis* were common at this location.





Beginning Transect Point

End Transect Point

Quantitative Transects

Qualitative Transects

Installation Boundary

N

0 400 800

Meters

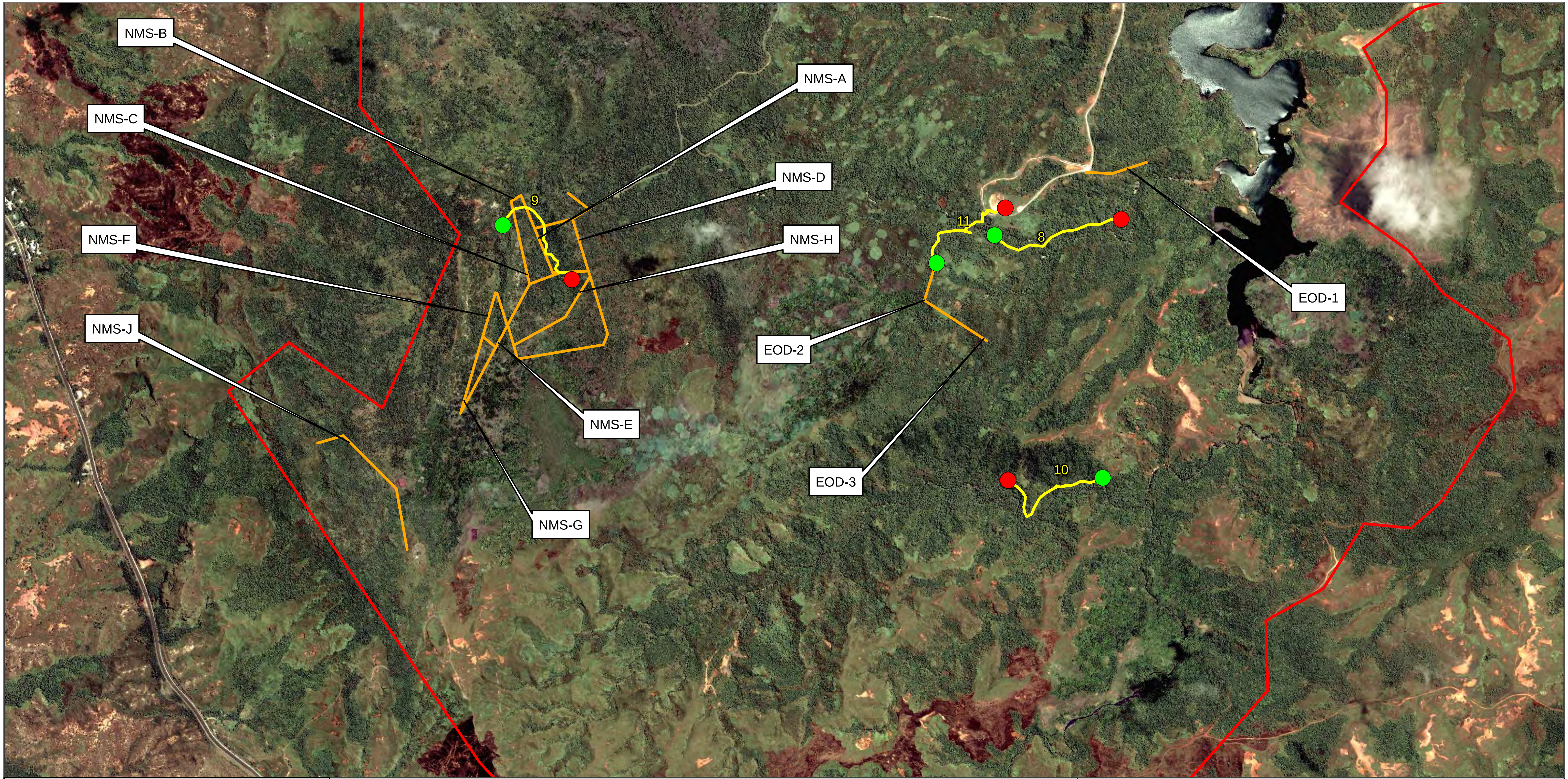
Naval Munitions Site

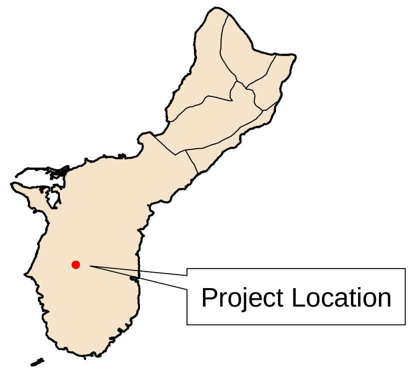
Northern Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-1





Beginning Transect Point

End Transect Point

Quantitative Transects

Qualitative Transects

Installation Boundary

N

0 400 800
Meters

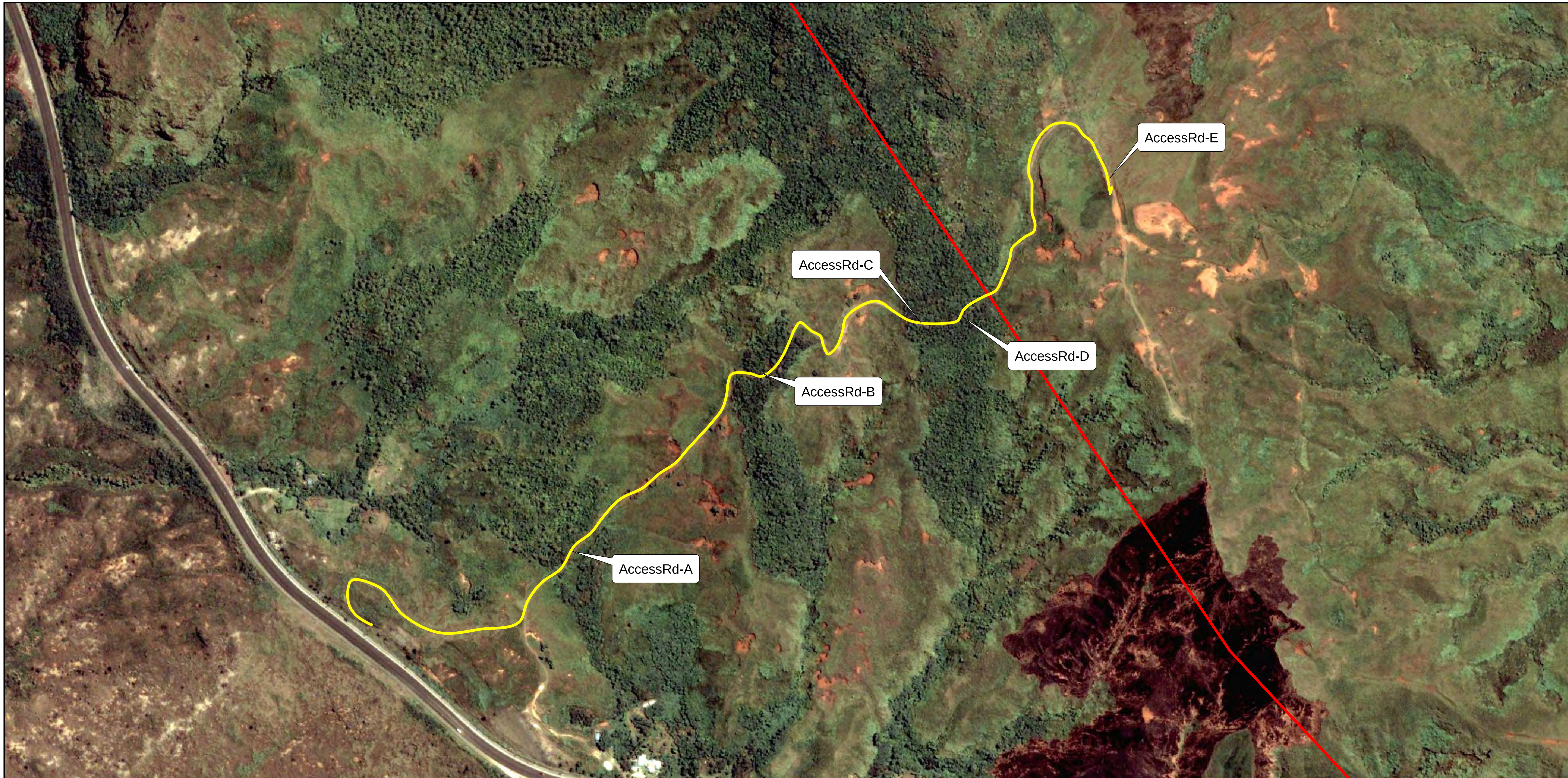
Naval Munitions Site

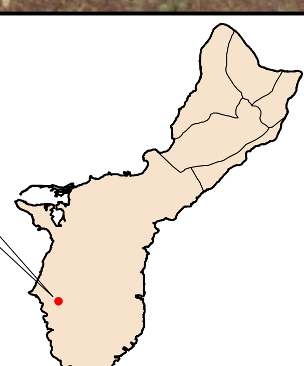
Southern Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010 | Project No.: 60133557 | Figure 10-2





Potential Access Road

Installation Boundary

0 200 400 Feet

Potential Access Road Option A

Survey Areas

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-3

Table 10-1

Herpetofauna Captured or Observed on NMS

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
	Moth skink (*Lipinia noctua*)	Native*
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
	Mourning gecko (*Lepidodactylus lugubris*)	Native
	Mutilating gecko (*Gehyra mutilata*)	Native
	Pacific slender-toed gecko (*Nactus pelagicus*)	Native*
Snake	Brown treesnake (*Boiga irregularis*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Eastern dwarf tree frog (*Litoria fallax*)	Introduced
	Crab-eating frog (*Fejervarya cancrivora*)	Introduced
	Gunther's Amoy frog (*Sylvirana guentheri*)	Introduced
Notes: * This species is identified by the Guam Comprehensive Wildlife Conservation Strategies (GCWCS) as SOGCN/Endangered - species of with the highest conservation value.		

Four herpetofauna species were captured or observed within the Proposed Access Road Option A area. Table 10-2 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

The continued widespread presence of *Carlia fusca* as well as other introduced amphibian species is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a).

Table 10-2

Herpetofauna Captured or Observed on Proposed Access Road Option A

Guild	Species	Status
Skinks	Curious skink (*Carlia fusca*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House Gecko (*Hemidactylus frenatus*)	Introduced
Amphibians	Marine Toad (*Rhinella marinus*)	Introduced

10.2 Vegetation

10.2.1 Quantitative Surveys

Quantitative surveys were performed along transects in ravine forest, limestone forest, and a savanna grassland community. Due to the size of the NMS surveys, transects are divided into the northern and southern sectors, as described below.

- **Northern Sector** (Transects 1 through 7).
  - In the northwestern portion of NMS, ravine forest was sampled along Transects 1 and 3, which both cross stream channels. Transect 1 was the longest, and traversed the most variable terrain, of the seven transects conducted in northern NMS.
  - Transect 2 sampled a grassland; thus, no data are presented with respect to trees (e.g., species, density, etc.).
  - Transects 4, 5, and 6, were in the vicinity of stream channels.
  - In the north-central sector, which is near active and former operations areas, Transect 7 sampled a ravine forest.

- **Southern Sector** (Transects 8 through 11).
  - In the southern sector of NMS, Transects 8 and 11 sampled the ravine forest and coconut grove surrounding the Explosive Ordnance Disposal (EOD) Range.
  - Transect 9 sampled the faniok (*Merrilliodendron megacarpum*) forest around Mount. Almagosa.
  - Transect 10 sampled ravine forest along the Sadog Gagu River, which drains into Fena Reservoir.

10.2.1.1 Northern Sector

Native species accounted for approximately 70 percent of the relative density among the 11 tree species quantified along Transect 1 (Chart 10-1). The overall density for this transect was calculated at approximately 1,203 trees per ha. The native kafu or screwpine (*Pandanus tectorius*) had the highest relative density (over 50 percent) and was the most dominant species among the 11 tree species encountered on the transects.

The ravine forest sampled in Transect 3 had a density of approximately 1,700 trees per ha. Betelnut palms (*Areca catechu*), which are thought to be an aboriginal introduction, had the highest relative density (29 percent) among the seven species on the transect (Chart 10-2). Aside from betelnut and *Vitex parviflora*, the transect was made up of native species that accounted for approximately 67 percent of the relative density.

The transects in the northeastern sector (Transects 4 through 6) revealed a calculated density of approximately 5,261 trees per ha. The native kafu (*Pandanus tectorius*) had the highest cover and third-highest relative density (about 17 percent) among the 11 tree species in the transects (Chart 10-3). The introduced and often invasive BayRum Tree(*Pimenta racemosa*) had the highest relative density (about 20 percent), followed closely by native pago (*Hibiscus tiliaceus*) with about 19 percent. Both native gulos (*Cynometra ramiflora*) and introduced Lemon China (*Triphasia trifolia*) had densities of about 16 percent. These five species each had relative densities exceeding 15 percent; in contrast, on Transect 1 the relative density of kafu was slightly more than 50 percent and the densities of each of the remaining species were less than 14 percent.

Chart 10-1

Relative Density of Trees Along Transect 1 – NMS
(N = native)

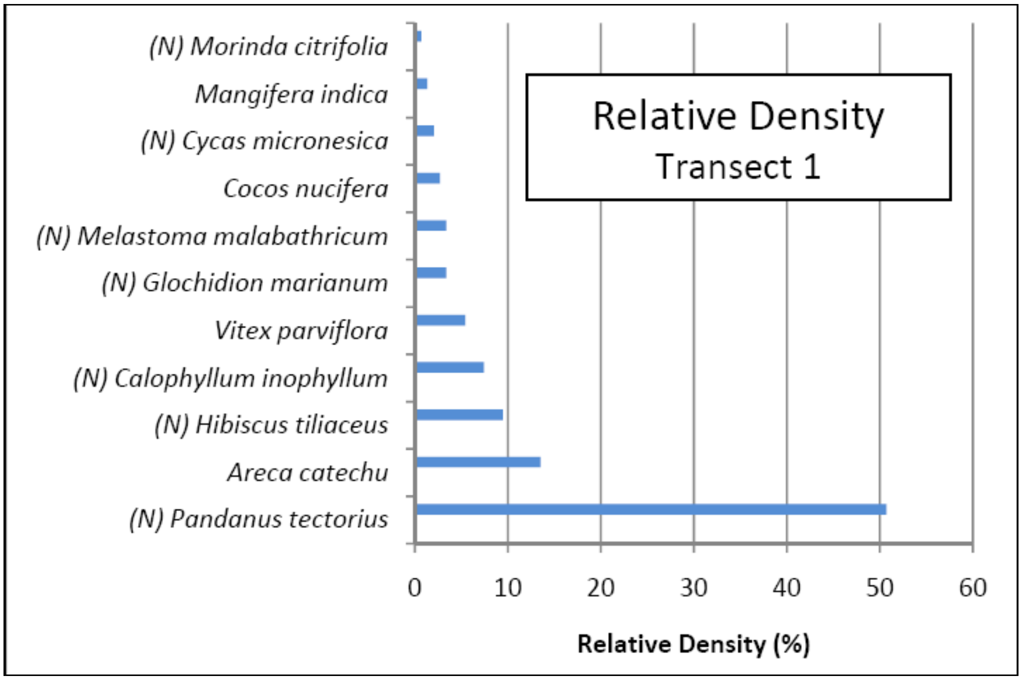


Chart 10-2

Relative Density of Trees Along Transect 3 – NMS
(N = native)

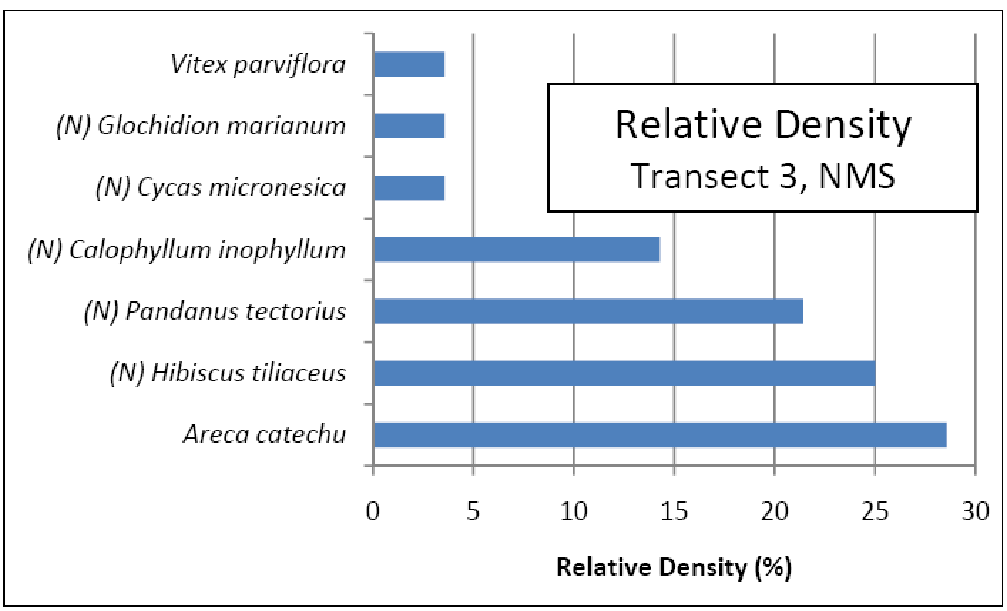
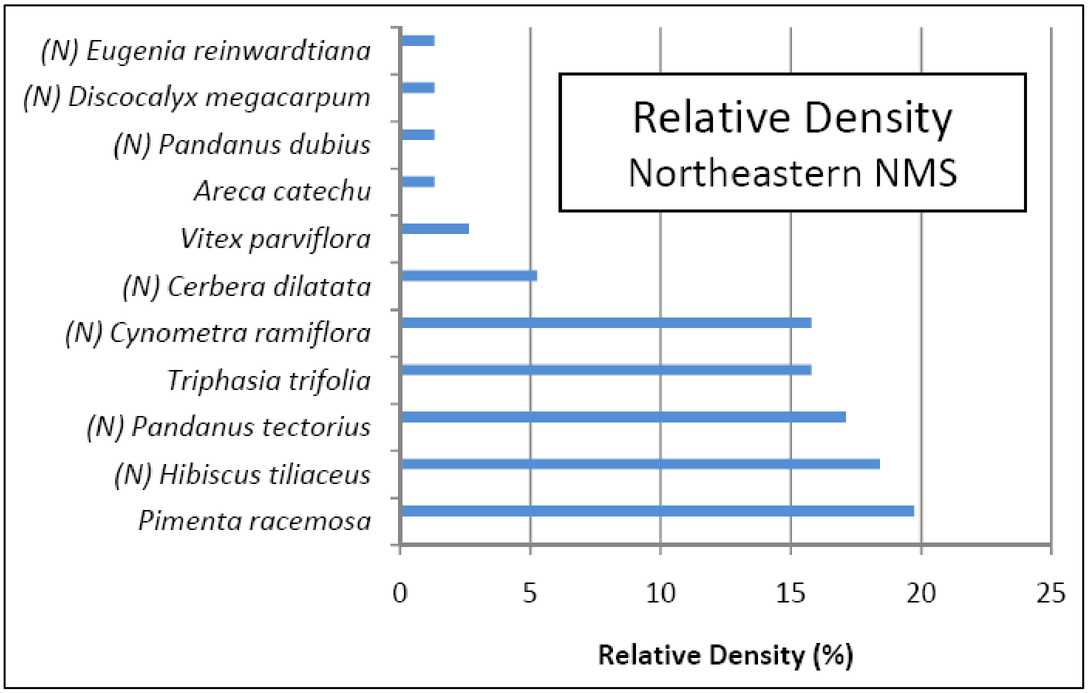


Chart 10-3

Relative Density of Trees Along Transects 4, 5, and 6 – NMS
(N = native)



The ravine forest sampled along Transect 7 had a calculated density of approximately 1,791 trees per ha. The four highest relative densities were for species native to Guam, and ranged from about 33 percent to 10 percent. Introduced species accounted for less than 13 percent of the relative density among the nine species on the transect (Chart 10-4).

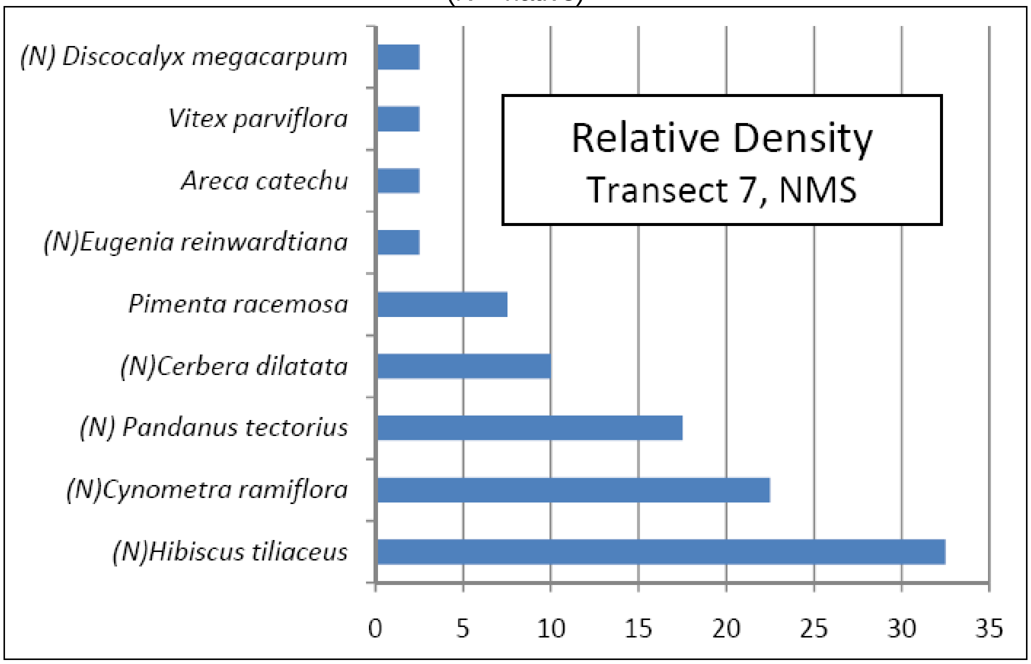
10.2.1.2 Southern Sector

Transect 9 sampled the ravine forest in the valley slopes surrounding Mt. Almagosa. The overall density was calculated at approximately 2,637 trees per hectare. The forest is characterized by the dominant faniok (*Merrilliodendron megacarpum*) trees that comprised over 63 percent of the relative density (Chart 10-5). Faniok had an absolute cover of 21.31 m^2/ha, well above any other species on the transect.

Transect 10 sampled the ravine forest along the Sadog Gagu River in the southern sector of the annex. Point-center quarter results revealed an overall tree density of approximately 1,474 trees per ha. Two introduced and naturalized species, coconut (*Cocos nucifera*) and Milla (*Vitex parviflora*), outranked all other species, with cover values of 13.46 m^2/ha and 8.02 m^2/ha, respectively. *Vitex* also had the highest relative density (28 percent), followed by the betelnut palm or pugua (*Areca catechu*) (22 percent) (Chart 10-5). The overall relative density of native species was approximately 33 percent, which is lower than the densities observed in ravine forest transects in the northern sectors of the annex.

Chart 10-4

Relative Density of Trees Along Transect 7 – NMS
(N = native)



The ravine forest in the southwestern sector of the annex was sampled along Transects 8 and 11, located south and west of the explosive ordnance disposal (EOD) range, respectively. The survey revealed an overall density of about 1,500 trees per ha. Coconut (*Cocos nucifera*) and betelnut palms were dominant with native kafu (*Pandanus tectorius*) in terms of density, dominance and frequency (Chart 10-6).

The remaining species had low relative densities. The native cycad or fading (*Cycas micronesica*) was represented by two specimens with a mean basal area of 630 cm^2; both trees were sampled on Transect 8.

10.2.2 Seedlings

The study plots analyzed in the northern NMS revealed a lower native woody seedling density of approximately 1.83 seedlings/m^2 compared with introduced seedlings, which had a density of about 2.44 seedlings/m^2. Transect 4 in the northeastern sector had a particularly high density of bay-rum (*Pimenta racemosa*) seedlings, which contributed to the higher overall density of introduced seedling species. Bay-rum appears to be thriving in the northeastern sector, possibly in part because of its prolific seed production.

The southern sector of NMS had a native woody seedling density of about 17.19 seedlings/m^2. This was higher than the density of introduced seedlings, which was approximately 1.06 seedlings/m^2. Native mapunao (*Aglaia mariannensis*) trees were prolific seedling producers on Transect 9, which contributed to the higher native seedling density in southern NMS.

Chart 10-5

Relative Density of Trees Along Transect 9 – NMS
(N = native)

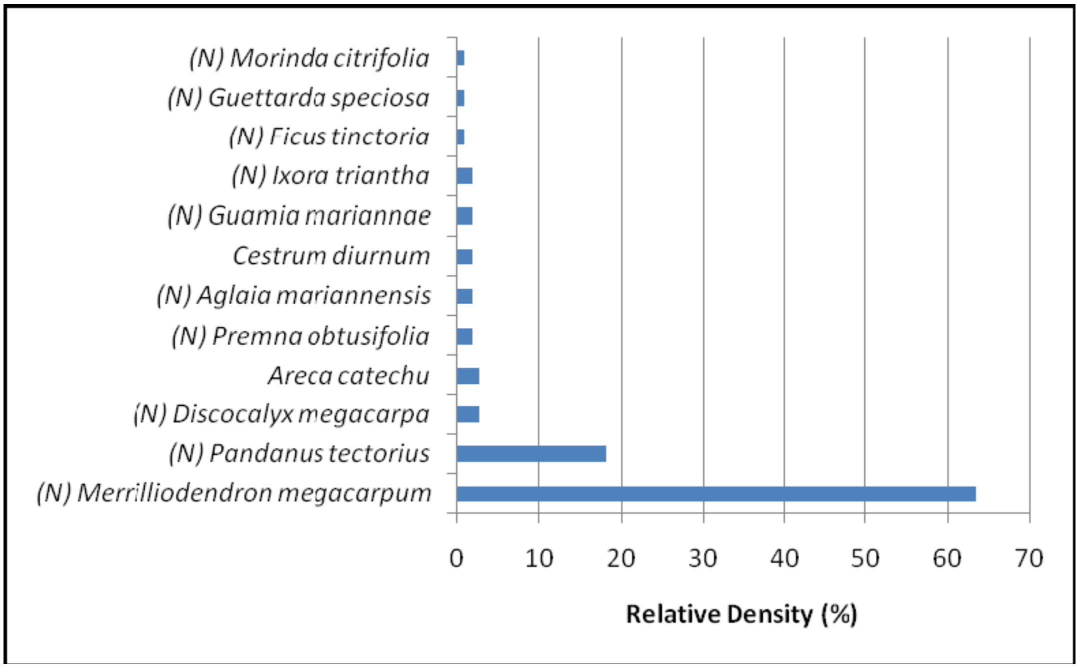


Chart 10-6

Relative Density of Trees Along Transect 10 – NMS
(N = native)

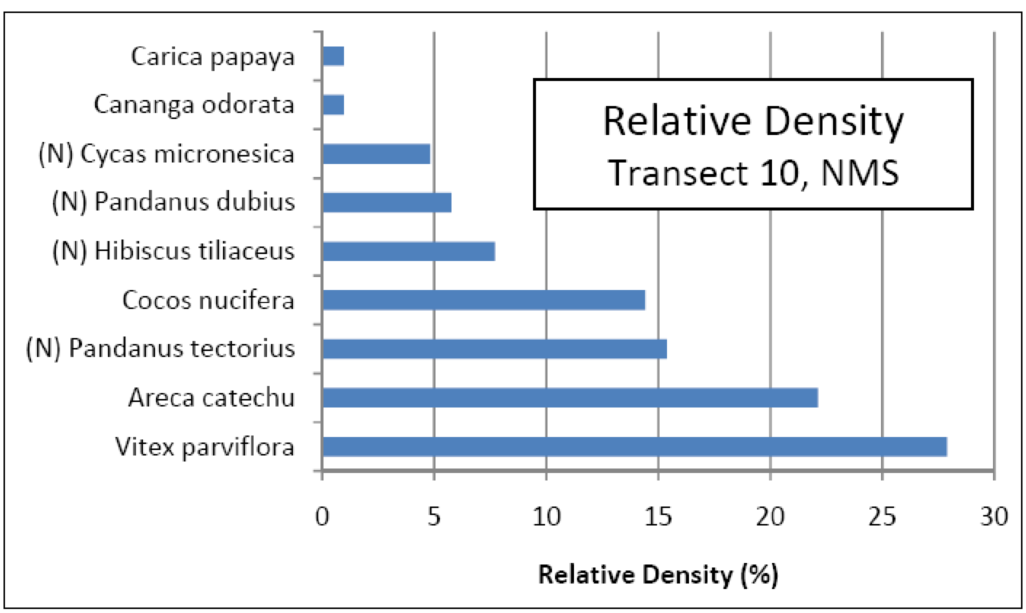
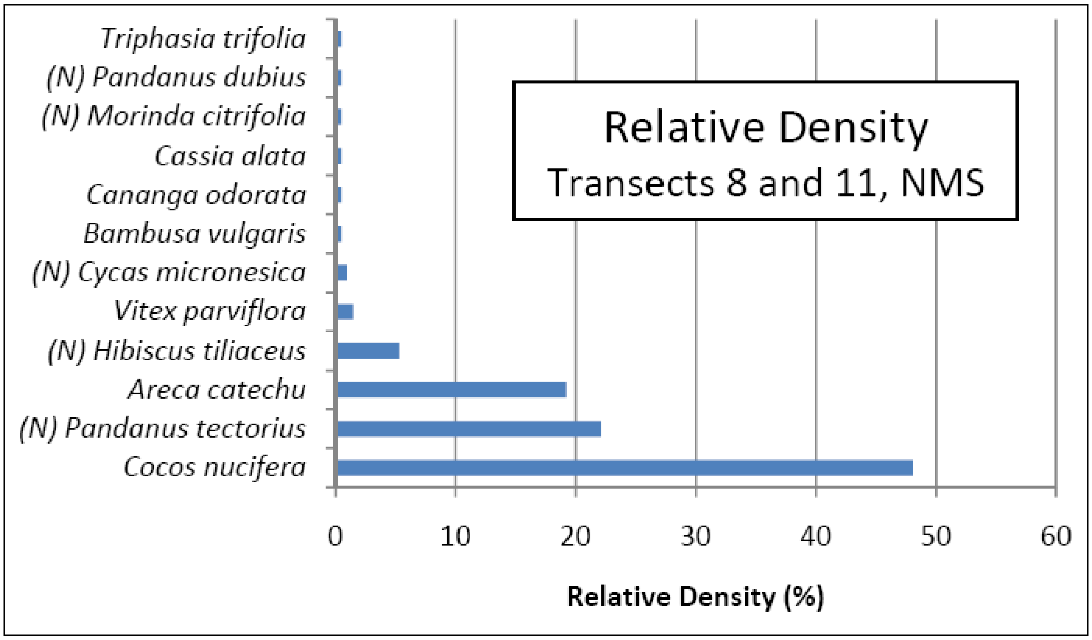


Chart 10-7

Relative Density of Trees Along Transects 8 and 11 – NMS
(N = native)



10.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at NMS. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. Among the transects sampled in the northern sector of NMS, species richness was highest for Transect 5, followed by Transects 7, 1, 6, 3, and 4, respectively. Transect 1 and Transect 7 appear to have similar points of inflection; rarefaction would indicate that richness is similar among these transects, although fewer samples were obtained for Transect 7.

Species richness curves indicate a higher species richness for Transect 9 in the *Merrilliodendron megacarpum* forest than for other transects in the southern sector of NMS (Transects 8, 10, and 11). Transect 9 also had the highest relative density of native versus introduced species among all transects at NMS.

Overall, the lowest species richness in the southern sector of NMS was along Transect 11 in the ravine forest west of the EOD Range, which contained only seven tree species. This forest contains a high proportion of coconut (*Cocos nucifera*) (approximately 55 percent of the relative density) among mostly kafu (*Pandanus tectorius*), betelnut (*Areca catechu*), and pago (*Hibiscus tiliaceus*) trees. In the northern sector of NMS, the lowest species richness was observed along Transect 4; only five species were sampled on this transect, which contained similar relative densities of native and introduced species.

Ungulate activity was quantified at stations along Transects 1 through 11. Soil disturbance, such as rooting, had the highest mean frequency, followed by browsing. Erosion, vegetation damage and other disturbance from wild pigs (*Sus scrofa*), deer (*Cervus unicolor*), and carabao (*Bubalis*

bubalis) are considered major problems at NMS. The ungulate activity was especially conspicuous along Transect 11 in the southern sector of NMS, where active wallows, rooting, and live feral pigs were observed.

10.2.4 Threatened and Endangered Species and Species of Concern

10.2.4.1 Threatened and Endangered Species

The only federally- or locally-listed species identified at NMS by BioSystems Analysis, Inc. (1989) was the tree fern tsatsa (*Cyathea lunulata*), which is locally protected as an endangered species. However, no tree ferns or other listed species were observed at NMS during the current survey.

10.2.4.2 Species of Concern

The Guam Department of Agriculture lists fadang (*Cycas micronesica*) among the six plant SOGCNs (Department of Agriculture, 2005). This was the only SOGCN observed during the current survey. In the northern sector of NMS, fadang had a relative density of less than 4 percent on Transects 1 and 3; it was not sampled on other transects in the northern sector of NMS. In the southern sector of NMS, fadang appeared only on Transects 8 and 10, where it had relative densities of approximately 2 percent and 4 percent, respectively.

BioSystems Analysis, Inc. (1989) cited the presence of several rare but unprotected species at NMS. These species were the following:

- *Thelypteris warburgii*, a fern indigenous to Guam and Papua New Guinea that occurs only at NMS along the Bonya, Tolaeyuus and Maemong Rivers. *T. warburgii* is also considered a species of concern by the USFWS (USFWS, 2005).
- *Eria rostiflora*, an epiphytic orchid found only at NMS.
- *Coelogyne guamensis*, an epiphytic orchid found locally only at NMS.
- *Nervilia platychila*, a ground orchid found locally only at NMS.
- *Maesa* sp., a tree found locally only at NMS.
- *Fagraea berteriana*, a native tree found locally only at NMS.
- *Merrilliodendron megacarpum*, a native tree with limited distribution on Guam.

With respect to these species of concern, the findings of the current surveys were as follows:

- *Thelypteris warburgii* was identified near Transects 5 and 6, with only one plant at each site.
- *Fagraea berteriana* - a few specimens of were observed along Transects 1 and 9, some of which were flowering and fruiting.
- *Merrilliodendron megacarpum* was quantified in the forest stands along Transect 9 around Mount Almagosa.

The following uncommon species were also noted along transects at NMS, although they are not regulated or managed by the federal or local authorities: *Hedyotis laciniata*, an endemic herb of the savannas; *Tuberolabium* (*Trachoma*) *guamensis*, an endemic epiphytic orchid found on Guam and Rota; and *Luisia teretifolia*, an indigenous epiphytic orchid found on Guam and Rota.

10.2.5 Qualitative Survey

10.2.5.1 NMS

A qualitative survey was performed on twelve transects within the NMS (Figure 10-1). Three separate *Merrilliodendron megacarpum* stands were mapped totaling 10 acres (4 hectares). In addition, numerous other smaller scattered patches of *Merrilliodenron megacarpum* were noted in the area. Several uncommon species were observed including *Dishidia puberula* and *Coelogyne guamense*, the latter an orchid species found primarily in the branches of large trees on high limestone ridges and found on Guam, Rota, and Palau (Raulerson and Rinehart, 1992).

10.2.5.2 Proposed Access Road

A qualitative vegetative survey was performed along the Proposed Access Road Option A. The proposed access road would follow an existing foot trail that traverses savanna vegetation with a few stands of forest in minor valleys. The area surveyed was within approximately 25 m of either side of the trail. *Merrilliodendron megacarpum* forest, an uncommon forest type on Guam, was present and dominated a portion of the small forest on either side of the trail at the highest forest stand encountered along the trail. On both sides of the trail, the *Merrilliodendron megacarpum* forest did not appear to extend much, if at all, beyond the survey corridor. No threatened or endangered or rare species were observed.

10.3 Avian Surveys

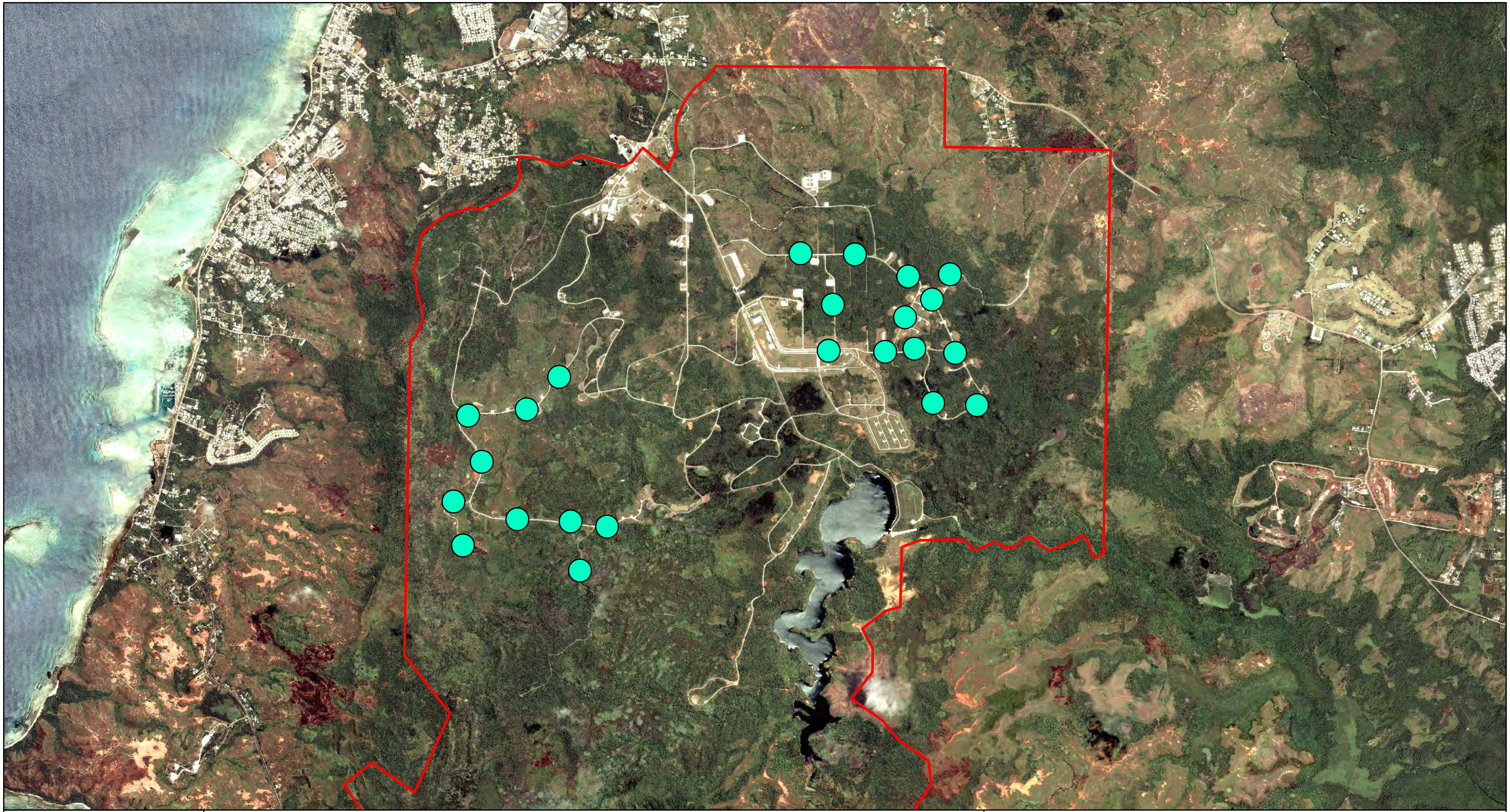
On the NMS, roadside bird surveys (Figure 10-4) and forest bird surveys were conducted in the morning. Table 10-3 lists the species observed as part of the surveys.

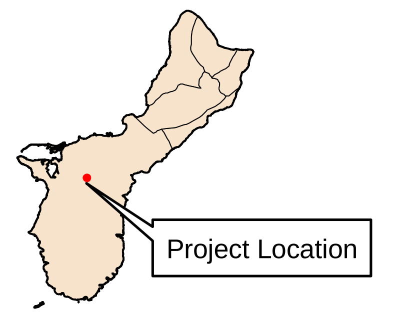
Table 10-3

Species Identified during Roadside and Forest Bird Surveys – NMS

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Roadside	23	Island Collared Dove (13) Black Francolin (11) Pacific Golden Plover (6) Black Drongo (3) White Tern (2)	5	35
Forest Bird	29	Black Francolin (8) White Tern (3) Island Collared Dove (2) Yellow Bittern (1) Grey-tailed Tattler (1)	5	15

With the exception of the white tern, all of the observed avian species are common to Guam. Although the white tern is uncommon, it does breed on Guam. Table 10-4 specifies the resident status of the observed species. The nomenclature follows Gill et al., 2008. For more information on the avifauna species below, refer to Appendix A.





Installation Boundary

Roadside Survey Point

N

0 200 400 Meters

Naval Munitions Site

Roadside Survey Points

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 10-4

Table 10-4

Residence Status of Avifaunal Species Identified during the Roadside and Forest Bird Surveys – NMS

Avifaunal Species	Residence Status[1]
White Tern (*Gygis alba*)	Uncommon, native resident - breeding
Yellow Bittern (*Ixobrychus sinensis*)	Common resident native - breeding
Island Collared Dove (*Streptopelia bitorquata*)	Common introduced resident - breeding
Black Drongo (*Dicrurus macrocercus*)	Common introduced resident - breeding
Eurasian Tree Sparrow (*Passer montanus*)	Common introduced resident - breeding
Black Francolin (*Francolinus francolinus*)	Common introduced resident - breeding
Pacific Golden Plover (*Pluvialis fulva*)	Common visitor – not breeding [2]
Grey-tailed Tattler (*Tringa brevipes*)	Common visitor – not breeding

Notes:
1 Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. ‘*Elepaio*, 51(1): 3-10.

2 Residence status obtained from Johnson, O.W., Goodwill, R. & Johnson, P.M., 2006, Wintering ground fidelity and other features of Pacific Golden-Plovers *Pluvialis fulva* on Saipan, Mariana Islands, with comparative observations from Oahu, Hawaiian Islands. *Wader Study Group Bull.* 109: 67–72.

10.4 Tree Snail Surveys

In 2008 a survey was performed at select locations in the Naval Munitions (Appendix H; Smith et. al., 2008). Two colonies of partulid snails were found near Kitts Road. Only *Partula radiolata* were found at the two locations.

Additional surveys were conducted along four transects in the southern Naval Munitions site however the **--Subconsultant has not provided data for these tree snail surveys --**

10.5 Threatened and Endangered Species

No federally-listed threatened or endangered avifauna, herpetofauna, tree snail, or vegetation species were identified on the NMS.

Two Guam-listed SOGCN amphibians (moth skink and Pacific slender-toed gecko) were identified on NMS. The moth skink was identified on Transect 1, Stations 18, 47, and 50; Transect 10, Station 14; and Transect 11, Station 18. The Pacific slender-toed gecko was observed on Transect 8, Station 18; Transect 10, Stations 17 and 22; and Transect 11, Station 19. Fadang (*Cycas micronesica*), a SOGCN plant species was observed on Transects 1and 3 within the northern section of NMS and Transects 8 and 10 in the southern section of NMS.

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11 Route 1 River Crossings

Five bridges along Route 1require structural upgrades as some are not structurally sound to carry current loads and to support the ABM Transports. At these five locations, both avian and in-stream surveys were conducted. The five bridges cross the following rivers from south to north: the Atantano, Aquada, Sasa, Asan, and Agana. Figure 11-1 depicts the locations of the river crossing study areas.

At each river crossing, scientists measured the width of the stream bed at the upstream and downstream location of the river's crossing under Route 1. The depth was also measured immediately upstream and downstream of Route 1. Finally, within 50 m upstream and downstream of the bridge, the benthic substrate, flow, the height and composition of river banks, fish species utilizing the area, and the general ecological setting were also recorded. Avian surveys were performed at the five river crossings; however, no avifauna were observed at any location.

The investigations were conducted twice, first during the rainy season of 2009, when some areas were obscured due to turbid water conditions, and second during the dry season (in January 2010), when water conditions were less turbid.

11.1 Atantano River

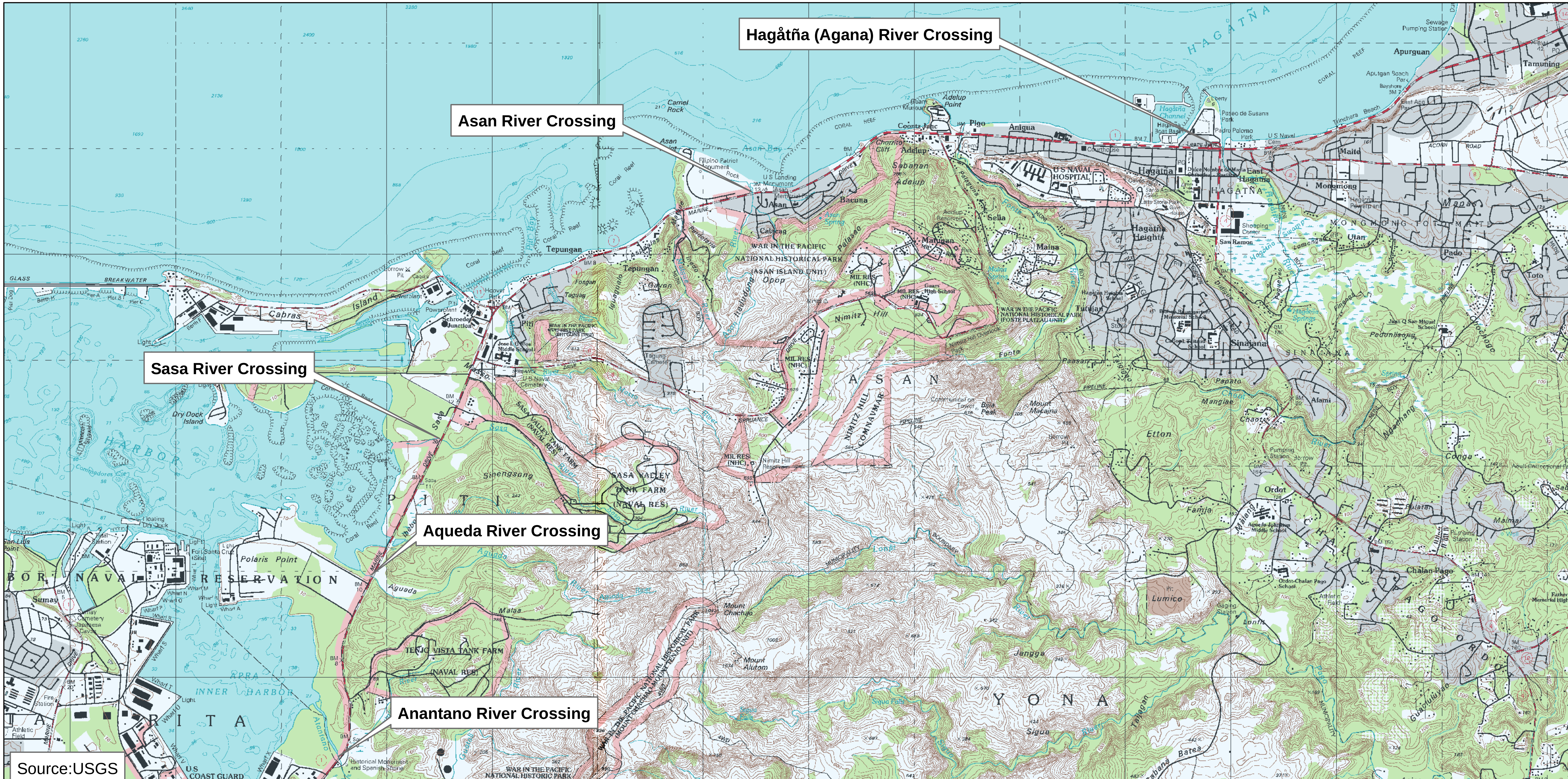
The Atantano River crossing of Route 1 is located approximately 0.7 kilometers (km) north of the main gate of the Apra Harbor Naval Reservation. The areas immediately adjacent to the banks are largely undeveloped. The crossing is approximately 0.5 km upstream of the river's confluence with Inner Apra Harbor.

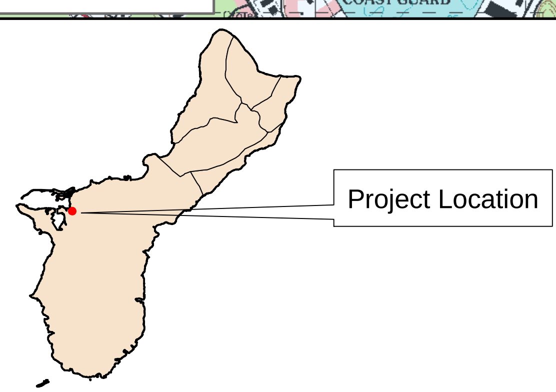
At the Route 1 crossing, the Atantano River is 13.2 m wide and 2 m deep at the downstream location and 13.4 m wide and 2.8 m deep at the upstream location. Immediately downstream of Route 1, the river's banks consist of vertical sheet piling encrusted with marine life. Further downstream, woody vegetation is present to the edge of the bank.

Upstream of the bridge, the river banks consist of vertical eroded earthen banks approximately 1.3 m in height. Immediately adjacent to the bridge, the tops of the banks are cleared, but further upstream woody vegetation occurs to the edge of the banks. Photos 11-1 and 11-2 illustrate the views downstream and upstream from the bridge, respectively.

Due to turbid conditions in September 2009, no in-water observations of marine life or benthic substrate were conducted. In January 2010, snorkel surveys were performed within the river. The benthic substrate consisted of silty sand with some isolated rocks. No submerged aquatic vegetation was observed within the study area. Marbled eel (*Anguilla marmorata*) and rock flagtail (*Kuhlia rupestris*) were the only fish observed within the river. Both species are native to Guam.

In 2008, a Biological and Habitat Assessment of the Atantano River conducted by GDAWR indicated that the river has the largest and best developed mangrove swamp on Guam (GDAWR, 2008). The report also acknowledged that the river experiences perturbations from adjacent





Route 1 River Crossings

River Crossings Map

Prepared By: Prepared For:

TEC Inc. Joint Venture

NAVFAC

May 3, 2010	Project No.: 60133557	Figure 11-1

shipping, docking, and oil refinery facilities. The assessment also indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

Photo 11-1 Looking downstream from Route 1 at the Atantano River.

Photo 11-2 Looking upstream form Route 1 at the Atantano River.

- Fish – Native species include: Common Glass Fish (*Ambassis buruensis*), Dusky Sleeper (*Eleotris fusca*), Rock Flagtail *(Kuhlia rupestris*), snappers *(*Family Lutjanidae), Silver Moony (*Monodactylus argenteus*), Bluespot mullet (*Moolgarda seheli*), Bandfin mullet goby (*Mugilogobius cavifrons*), mudskipper (*Periophthalmus argentilineatus*), Bigmouth Goby (*Redigobius bikolanus*), gobies (*Stenogobius sp.*), Feathered River-garfish (*Zenarchopterus dispar*). Introduced species include: Mosquitofish (*Gambusia affinis*) and Guppy (*Poecilia reticulata.*

- Invertebrates. Native species include: Ninja Shrimp (*Caridina serratirostris*), Shrimp (*Caridina sp.*), Tahitian Prawn (*Macrobrachium lar*), Snail (*Neritina squamipicta*), and *Thiara granifera.* Invasive species included leeches, Class Clitellata.

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

11.2 Aquada River

The Aquada River crossing of Route 1 is located approximately 3.1 km north of the Atantano River. The areas adjacent to the banks are largely undeveloped. The crossing is approximately 0.2 km upstream of the river's confluence with Apra Harbor.

At the Route 1 crossing, the Aquada River is 9.2 m wide and 3.4 m deep at the upstream location and 9.1 m wide and 3.2 m deep at the downstream location. Approximately 15 m upstream of the bridge, the river narrows to less than 1 m wide and less than 0.3 m deep. During the time of the investigation the stream had an imperceptible flow and was choked with vegetation due to a downstream logjam that had backed up the flow. Photos 11-3 and 11-4 illustrate the views downstream and upstream from the bridge, respectively.

Upstream of the bridge a forested area dominates the landscape (Photo 11-5). Within the forest, numerous drainage channels were observed. The channels were mostly dry during the investigation but evidence of hydrology (e.g., sediment staining of vegetation, drift lines, and water-stained leaves) indicated that these channels do convey surface water to the Aquada River during wetter periods of the year.

Downstream of the bridge, the river pools and is approximately 9 m wide and 15 m long; the pool then empties into a swiftly-flowing stream that is less than 1 m wide. On the southern bank of the pool, a strip of hydrophytic vegetation is present. Downstream of the pool, the river is swift-flowing, clear, with a rocky bottom. This portion of the river flows through a forested area dominated by palms and bamboo (Photo 11-6). The forested area has a hummocky surface.

Due to turbid conditions in September 2009, no in-water observations of marine life or benthic substrate were conducted. In January 2010, it was determined that damming of the water by logs had caused stagnant conditions. Due to safety concerns, no snorkel surveys were performed. From the bank, flagtail fish were observed swimming in the river. Upstream and downstream of the bridge, in the portions of the river that are narrower and with increased flows, native species such as gobies (*Awaous* sp., *Stenogobius* sp., and *Sicyopus* sp.) likely utilize the river as habitat.

In 2008, a Biological and Habitat Assessment of the Aquada River was conducted by GDAWR (GDAWR, 2008). The assessment indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

- Fish –species include: Giant Marbled Eel (A*nguilla marmorata*) and Goby (S*icyopus spp*.);
- Invertebrates. Native species include: Green Lace Shrimp (*Atyoida pilipes*), shrimp *(Caridina sp.*), Malaysian Trumpet Snail (*Melanoides tuberculata*), snail (*Neritina pettiti*), Mayfly larvae, Dragonfly Larvae, and Pyralid caterpillars.

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-3 Looking downstream from Route 1 at the Aquada River.

Photo 11-4 Looking upstream from Route 1 at the Aquada River. Note the high water and waterbody choked with vegetation.

Photo 11-5 Looking further upstream from Route 1. During the time of the investigation (January 2010), the river flowed through a 5-m wide, vegetation-choked stream bed. The river was approximately 0.3 m foot wide and 0.2 m deep.

Photo 11-6 Looking further down stream at the wetland area south of the bridge. The wetland is dominated by palms and bamboo. The river (see photo) is narrow and swift flowing.

11.3 Sasa River

The Sasa River crossing of Route 1 is located approximately 1.6 km north of the Lagaus River. The land areas adjacent to the banks are largely undeveloped. The crossing is approximately 0.7 km upstream of the river's confluence with Apra Harbor.

At the Route 1 crossing, the Sasa River is 7.4 m wide and 0.1 m deep at the upstream location and 5.6 m wide and 0.45 m deep at the downstream location. Approximately 5 m upstream of the bridge a logjam measuring some 20 m long was observed. Further upstream from the logjam, the river continues to be broad and shallow, with a flat, sandy-gravel bottom with numerous gravel bars. During the time of the investigations, the river's flow was estimated at 0.22 meters per second (mps).

Downstream of the bridge, the river is shallow, with a flat sandy bottom with gravel and cobbles. Approximately 25 m downstream, a logjam occurred. The river's banks are earthen, 1.2 m high, and vertical. Photos 11-7 and 11-8 illustrate the views upstream and downstream from the bridge, respectively.

Upstream and downstream of the bridge forested areas occur. Downstream of the bridge within the study area, the vegetation is low and denser, whereas upstream of the bridge large bamboo stands line the river banks (Photo 11-9). No submerged aquatic vegetation was observed in the study area, although some filamentous green algae were observed on rocks immediately downstream of the bridge.

No fish were observed during the surveys. However, the riverine habitat is similar to other rivers on the islands that support fish species such as Guam goby (*Awaous guamensis*), rock flagtail (*Kuhlia rupestris*), other gobies (*Sicyopterus* and *Stiphodon sp.*), and marbled eel (*Anguilla marmorata*).

In 2008, a Biological and Habitat Assessment of the Sasa River conducted by GDAWR indicated that the river does incur impacts from adjacent shipping, docking, and oil refinery facilities (GDAWR, 2008). The assessment also indicated that a variety of fish species utilize the river as habitat. A list of these species are the following:

- Fish – Native species include: Engel's mullet (*Moolgarda engeli*), Bandfin Mullet Goby (*Mugilogobius cavifrons*), Mudskipper (*Periophthalmus argentilineatus*), Feathered River-garfish (*Zenarchopterus dispar*). Invasive species included the Mozambique tilapia (*Oreochromis mossambicus*).

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-7 Looking upstream from Route 1 at the Sasa River.

Photo 11-8 Looking downstream from Route 1 at the Sasa River.

Photo 11-9 Looking upstream at the Sasa River. Here the stream is shallow and swift flowing with coarse-grained sediments comprising the river bed. Note the near vertical banks and large bamboo stands that line the river.

11.4 Asan River

The Asan River is located 0.6 km east of Asan Point. Upstream, residential and commercial developments occur along the river banks. Downstream, the banks are managed as the river flows through a national park. The crossing is approximately 100 m upstream of the river's confluence with Asan Bay.

The Asan River is 13.8 m wide and up to 1 m deep at the upstream location and 14.1 m wide and up to 1 m deep at the downstream location. Upstream of the bridge, wing walls occur along the banks. The land areas adjacent to the banks are developed with residential and commercial properties. The river is tidally influenced, with a flat, sandy bottom.

Downstream of the bridge, the river is tidally influenced and shallow, with a flat, sandy bottom. During periods of higher tides, wave action occurs within the river south of the bridge. Species that inhabit this area include flagtails, eels, snapper, puffer, and goat fish. Photos 11-10 and 11-11 illustrate the views downstream and upstream from the bridge, respectively. Land areas adjacent to the banks downstream of the bridge are mowed lawns comprising the National Park.

In 2008, a Biological and Habitat Assessment of the Asan River conducted by GDAWR indicated that the river is channelized and heavily developed (GDAWR, 2008). The assessment also indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

- Fish – Native species include: Giant Marbled Eel (*Anguilla marmorata*), Dusky Sleeper (*Eleotris fusca*), Rock Flagtail *(Kuhlia leucisus*), River Gobies *(Stiphodon spp.*). Introduced species included the Mozambique Tilapia (*Oreochromis mossambicus*).

- Invertebrates. Native species include: Ninja Shrimp (*Caridina serratirostris*), Shrimp (*Caridina sp.*), Tahitian Prawn (*Macrobrachium lar*), Snail (*Neritina pulligera*), Snail (*Neritina variegata*), (*Septaria porcellana*), *and* (*Thiara granifera*).

Upstream of the bridge, no fish species were observed. Downstream of the bridge, observed species included species common to shallow, coastal flats, such as wrasses (Family Labridae), Guam goby, eels, pufferfish (Family Tetraodontidae), acute-jawed mullet (*Neomyxus leucisus*), and damselfish (Family Pomacentridae). In addition, in January 2010, small crabs (Decapods) were observed in shallow-water areas along the banks.

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-10 Looking downstream from Route 1 at the Asan River. Note the river's confluence with Asan Bay and the Philippine Sea in the distance.

Photo 11-11 Looking upstream from the Route 1 at the Asan River. Note the outfalls and engineered banks.

11.5 Agana River

The Agana River is located approximately 2.2 km east of the Fonte River. The Agana River's banks are occupied by commercial and recreational properties associated with the City of Hagatna. The crossing is approximately 100 m upstream of the river's confluence with Agana Bay.

At the Route 1 crossing, the Agana River is 10.6 m wide and up to 0.7 m deep at the upstream location and 10.7 m wide and up to 0.4 m deep at the downstream location. Upstream of the bridge, the river has a swift flow and a flat, sandy bottom with boulders. The banks are vertical concrete walls with outfall pipes. Photos 11-12 and 11-13 depict the upstream and downstream habitats, respectively.

Downstream of the bridge, the river has a swift flow with a flat, sandy bottom with boulders. The banks are vertical concrete walls with outfall pipes. Species identified included the Guam goby, damselfish, snapper, flagtail, angelfish, yellow lip emperor (*Lethrinus xanthochilus*), diamond-scale mullet (*Liza vaigiensis*), acute-jawed mullet (*Neomyxus leucisus*), and keeltail needlefish (*Platybelone argalus*).

In 2009, a Biological and Habitat Assessment of the Agana River conducted by GDAWR indicated that the river is heavily channelized and developed (GDAWR, 2008). The assessment also indicated that a variety of fish and invertebrate species utilize the river as habitat. A list of these species are the following:

- Fish – Native species include: Indonesian Shortfin Eel (*Anguilla bicolor* (Giant Marbled Eel (*Anguilla marmorata*) Guam Goby (*Awaous guamensis*) Dusky Sleeper (*Eleotris fusca*) Yellow Tail Mullet (*Ellechelon*, Rock Flagtail (*Kuhlia leucisus*) *False mullet Neomyxus leucisus*) river gobies (*Stiphodon spp.*) Feathered River-garfish (*Zenarchopterus dispar*. Introduced species include: Walking Catfish (*Clarias batrachus*) Common Carp (*Cyprinus carpio*) Mosquitofish (*Gambusia affinis*) Mozambique Tilapia (*Oreochromis mossambicus*) Guppy (*Poecilia reticulata*) and Tilapia (*Tilapia zillii*).

- Invertebrates. Native species include: Tahitian Prawn (*Macrobrachium lar*).

During the course of the natural resource survey, no avifauna were observed. Also, no chance observations of herptofauna or mammals were observed either during the survey.

Photo 11-12 Looking downstream for Route 1 at the Agana River. Here too, note the close proximity to the ocean.

Photo 11-13 Looking upstream from Route 1 at the Agana River.

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12 Route 15 Lands

The Route 15 Lands are immediately east of Andersen South. The Route 15 Lands comprise the plateau area and the Sasajyan Valley. Figure 12-1 identifies the locations of the ecological transects. Ecological surveys on the Route 15 Lands included vegetation, avian, and fruit bat surveys. Also, for the vegetation survey, additional transects and survey locations were utilized. The location of these transects and other survey locations are presented when discussed in the respective discipline. Surveys on the Sasajyan Valley transect were not possible because of access issues.

Two transects were located on top of the cliff line in limestone karst forest. The first started with native forest which included *Guamia mariannae, Aglaia mariannensis, Ficus tinctoria,* and *Triphasia trifolia* before opening up to a degraded forest with some *Leucaena leucocephala, Chromolaena ordata,* and *Stachytarpheta cayennensis.* The second transect traversed through similar native forest. The third was situated below the cliff line and consisted mostly of *Cocos nucifera.*

12.1 Herpetofauna

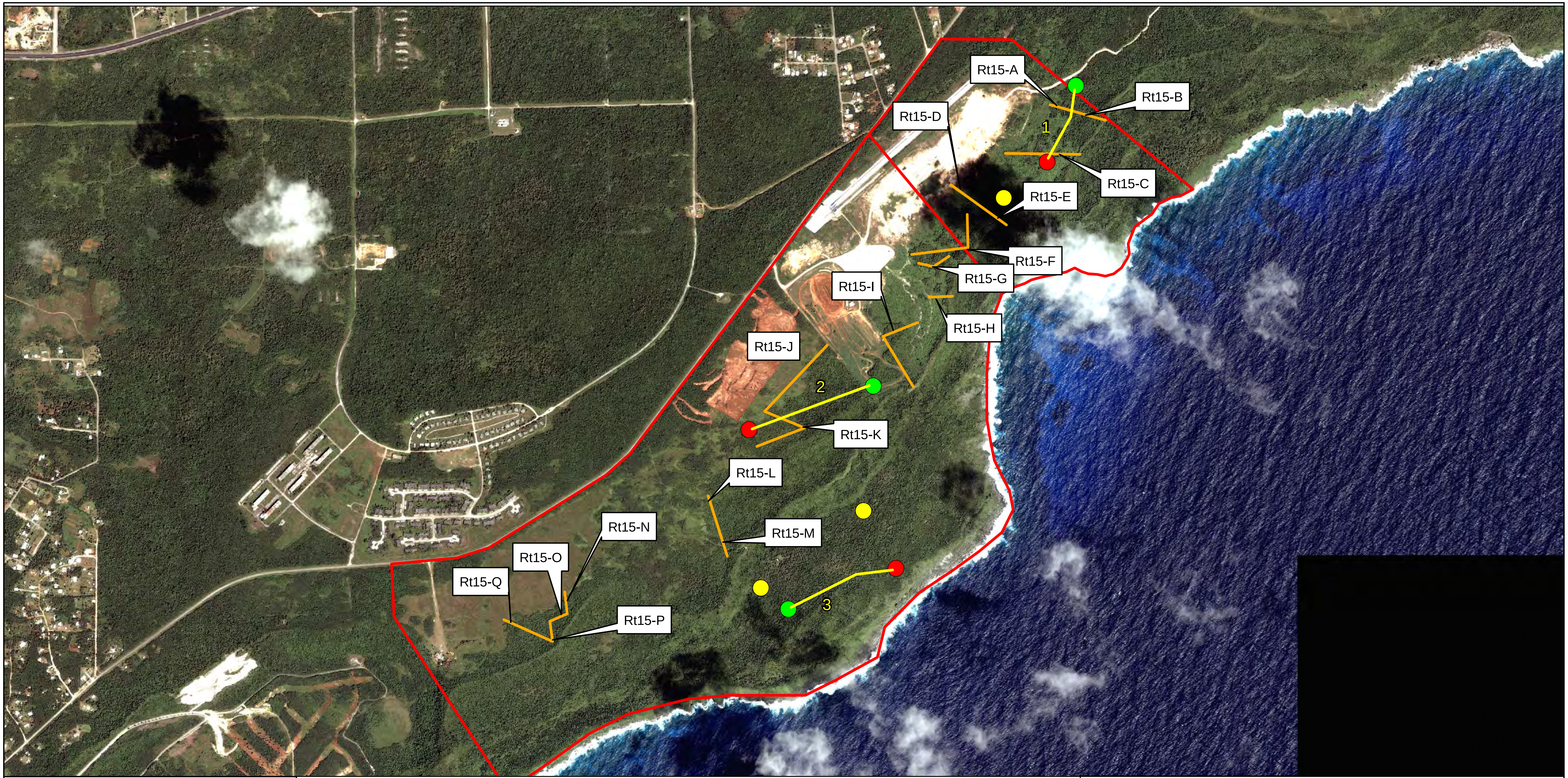
A total of six herpetofauna species were captured or observed on the Route 15 Lands. Table 12-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

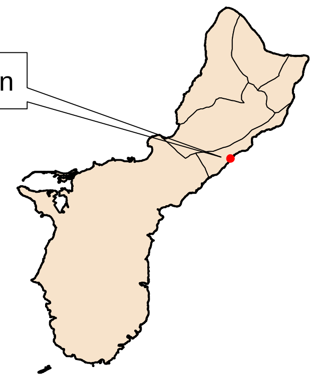
Table 12-1

Herpetofauna Captured or Observed on Route 15 Lands

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Gecko	House gecko (*Hemidactylus frenatus*)	Introduced
Snakes	Brown treesnake (*Boiga irregularis*)	Introduced
Other	Monitor lizard (*Varanus indicus*)	Introduced
Amphibians	Marine toad (*Rhinella marinus*)	Introduced
	Greenhouse frog (Eleutherodactylus planirostris)	Introduced
	Eastern dwarf tree frog (*Litoria fallax*)	Introduced

The continued widespread presence of the brown treesnake and the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential of these introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998; Christy et al., 2007a).





Beginning Transect Point
End Transect Point
Fruit Bat Survey
Quantitative Transects
Qualitative Transects
Installation Boundary

N

0 200 400
Meters

Route 15 Lands

Transect Map

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 12-1

12.2 Vegetation

Both quantitative and qualitative vegetation surveys were performed in the Route 15 Lands. The results of these surveys are provided in Subchapter 12.2.1 and 12.2.2, respectively.

12.2.1 Quantitative Survey

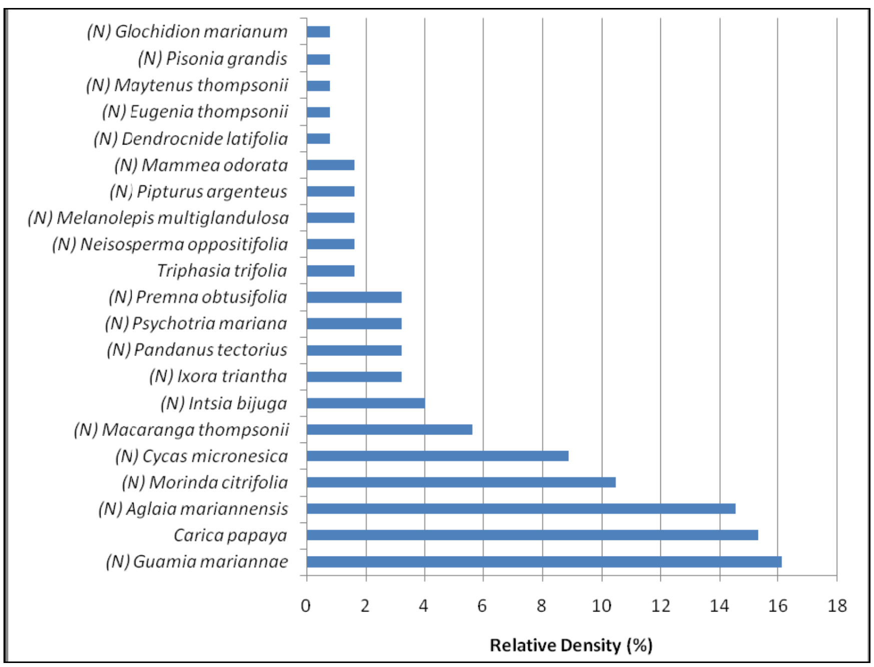
12.2.1.1 Trees

Surveys were performed along three transects in the limestone forest communities of the Route 15 Lands. Transect 1 was located in the northeastern sector of the Route 15 parcel along a north-south axis; Transect 2 was located to the south along a north-south axis; and Transect 3 was located along a north-south axis on a plateau below Transect 2.

The quantitative observations from the point-center quarter survey along Transect 1 revealed an absolute density of approximately 3,148 trees/ha. Native ading (*Cycas micronesica*) and ifil (*Intsia bijuga*), and introduced papaya (*Carica papaya*) were the most dominant species, with absolute cover values from 3.73 to 5.33 $m^{2/}$ha. Pengua (*Macaranga thompsonii*), a species endemic to the Mariana Islands, was the next most dominant species, with an absolute cover of 3.08 m^2/ha. The relative density was highest for paipai (*Guamia mariannae*), papaya, and mapunao (*Aglaia mariannensis*), with relative densities of approximately 16 percent, 15 percent, and 14.5 percent, respectively (Chart 12-1). These species also had the highest absolute frequencies, indicating that they are well-distributed along the transect.

Chart 12-1

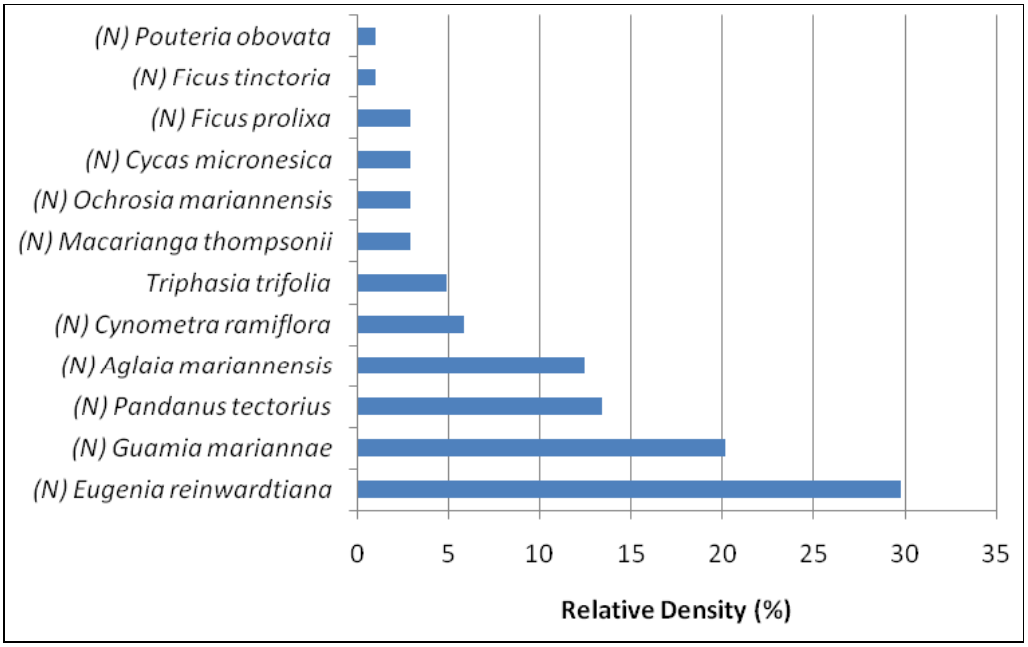
Relative Density of Trees Along Transect 1 – Route 15 Lands
(N = native)



Transect 2 had an absolute density of 4,566 trees per ha. This was the highest overall density among the three transects in the Route 15 project area. On this transect, the native a'abang (*Eugenia reinwardtiana*) was dominant, with an absolute cover of 8.19 m^2/ha and an absolute density of 1,321 trees/ha. A'abang was also well-dispersed, and had the highest frequency (57.69) among the 12 species on the transect (Chart 12-2). Pengua had an even higher absolute cover (5.13 m^2 per ha) than in Transect 1, although absolute density was lower, at 131.73 trees/ha. The relative density of trees was highest for a'abang, at nearly 30 percent, followed by paipai (*Guamia mariannae*) and kafu (*Pandanus tectorius*), at 20 percent and 13 percent, respectively. Fadang (*Cycas micronesica*) had a lower absolute density (131.73 trees/ha), absolute cover (218.61 cm^2), and absolute frequency (7.69) than in Transect 1.

Chart 12-2

Relative Density of Trees Along Transect 2 – Route 15 Lands
(N = native)



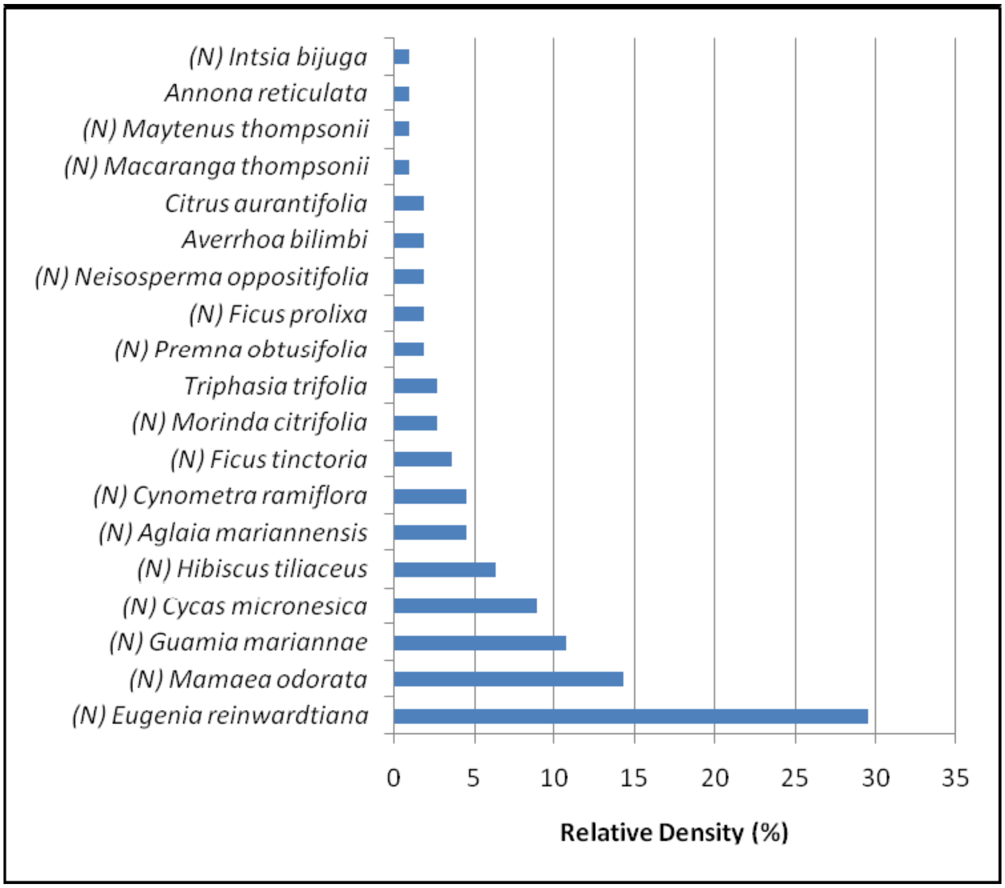
Transect 3, on the lower plateau, was closest to sea level of the three transects in the Route 15 Lands, but was further inland from the halophytic/xerophytic plant community along the coast. The absolute density was approximately 3,183 trees/ha (Chart 12-3). As in Transect 2, a'abang was a dominant component, with the highest absolute density (938 trees/ha).

12.2.1.2 Seedlings

The mean woody seedling density was calculated for the three transects at Route 15. Native seedlings exceeded mean density of 6 seedlings per m^2, compared with a mean density of approximately 1 seedling per m^2 for non-native species. Native seedlings outranked introduced seedlings in every transect, especially in Transect 1. The numbers of non-native seedlings were nearly equivalent to those of native seedlings along Transect 3, which can be attributed to the presence of naturalized introductions such as *Triphasia trifolia*, pickle tree (*Averrhoa bilimbi*), and custard apple (*Annona reticulata*), and some cultivated species, such as sweetsop (*Annona squamosa*) and citrus trees.

Chart 12-3

Relative Density of Trees Along Transect 3 – Route 15 Lands
(N = native)



12.1.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at the Route 15 study area. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. Species richness curves for Transects 1 and 3 indicate higher richness for these areas than for Transect 2 in the GEDCA parcel south of Lot 7161-R1.

Leaf and vegetative litter had the highest frequency (8.7) among the four categories of ground cover quantified on the three transects. Live vegetation (3.9), rock (2.3), and soil (1.0) had significantly lower frequencies. Limestone rock outcrops were prevalent along all three transects as a natural feature of the terrain.

Ungulate activity along all three transects was highest in the form of soil disturbance (0.4), such as rooting or wallows. Rubbing and signs of browsing had similar frequencies, each approaching 0.2, while other signs, such as scat, were least observed, with a frequency of around 0.1.

12.2.2 Qualitative Survey

A general pedestrian survey was conducted by two biologists on the Route 15 Lands. The survey involved walking along informal transects to document the plant community and record any notable species. The central portion of the parcel is a flat open expanse with a network of jeep trails through a weed/grassland community. The grassland is dominated by foxtail (*Pennisetum polystachion*) about 1 m high interspersed with assorted herbs such as horseweed (*Conyza canadensis*), buttonmint (*Hyptis capitata*) and ferns (*Nephrolepis hirsutula*). Scattered shrubs, such as lada (*Morinda citrifolia*) and aplokating (*Psychotria mariana*), also dot the landscape. Prior to clearing, the vegetation in the area most likely resembled the remnant limestone forest communities in this eastern sector of the island.

The grassland abruptly transitions into a thick stand of native pago (*Hibiscus tiliaceus*) trees towards the eastern sector. Naturalized species, such as lantana (*Lantana camara*), lemon China (*Triphasia trifolia*), and tangantangan (*Leucaena leucocephala*), are common within the stand. The composition is indicative of a mixed-shrub community, a sub-type of Fosberg’s (1960) weed community. Species typical of a limestone forest occur sporadically in the stand. These include fagot (*Neisosperma oppositifolia*) and fadang (*Cycas circinalis*). The invasive scarlet gourd vine (*Coccinia grandis*) drapes the pago branches, forming a tangled mass that obstructs passage. The understory, however, shows heavy disturbance by feral ungulates. Extensive rooting, rubbing, ripped and shredded tree trunks, and pig trails were observed. Further towards the eastern cliff line, the terrain becomes treacherous, as karst topography dominates the area. Limestone forest species also gradually dominate the composition of the plant community, which resembles the mixed moist forest described by Fosberg (1960). Succulent herbs, such as *Lapportea ruderalis*, and ground orchids, such as *Nervilia aragoana* and *Zeuxine fritzii*, are found on the limestone outcrops. The forest floor and outcrops are covered in a mossy layer. For more information regarding the qualitative survey, refer to Appendix D.

12.2.3 Threatened and Endangered Species and Species of Concern

12.2.3.1 Threatened and Endangered Species

A previous survey identified 22 ufa-halomtano (*Heritiera longipetiolata*) trees, with 184 associated seedlings (Duenas and Associates, Inc., 2000). This species is endemic to the Mariana Islands and is listed as endangered by the Government of Guam, which considers ungulate damage, typhoons, and infrequent flowering as major threats to the viability of the population (Department of Agriculture, 2006). Other threats appear to be present, since several of the trees in Lot 7161-R1 were infested with termites or ants, or were parasitized by other plants, such as strangling fig (*Ficus* spp.) (Duenas and Associates, Inc., 2000). Several trees were left intact within a designated conservation area at the Guam Raceway Park as a required condition of the Department of Agriculture. No Ufa-halomtano trees were observed on the transects; a single specimen was found near Transect 2 in the adjacent parcel. The tree was mostly dead, except for a 7-cm-diameter branch near the base. The main trunk had a dbh of 37 cm.

12.2.3.2 Species of Concern and Notable Species

The following species of concern were identified within the Route 15 Lands:

- *Cycas micronesica*, which is considered an SOGCN by the Government of Guam (Department of Agriculture, 2006). The island-wide populations are threatened by an introduced scale insect, *Aulocapsis yasumatsui*.

- *Elatostema calcareum* (Urticaceae) and *Procris pedunculata* (Urticaceae), which are indigenous succulent herbs that grow in limited habitats over limestone rock outcrops in moist limestone forest. These plants serve as host species for the Mariana Eight Spot butterfly (*Hypolimnas octocula*), which is listed as a species of concern by the USFWS. One butterfly was found along Transect 2 in the GEDCA parcel. Other species were noted, although they are not managed or protected by either the local or federal governments.

- *Zehneria* (*Melothria*) *guamensis* (Cucurbitaceae), which is a rare endemic vine. The species was found in one small area of Lot No. 7161-R1.

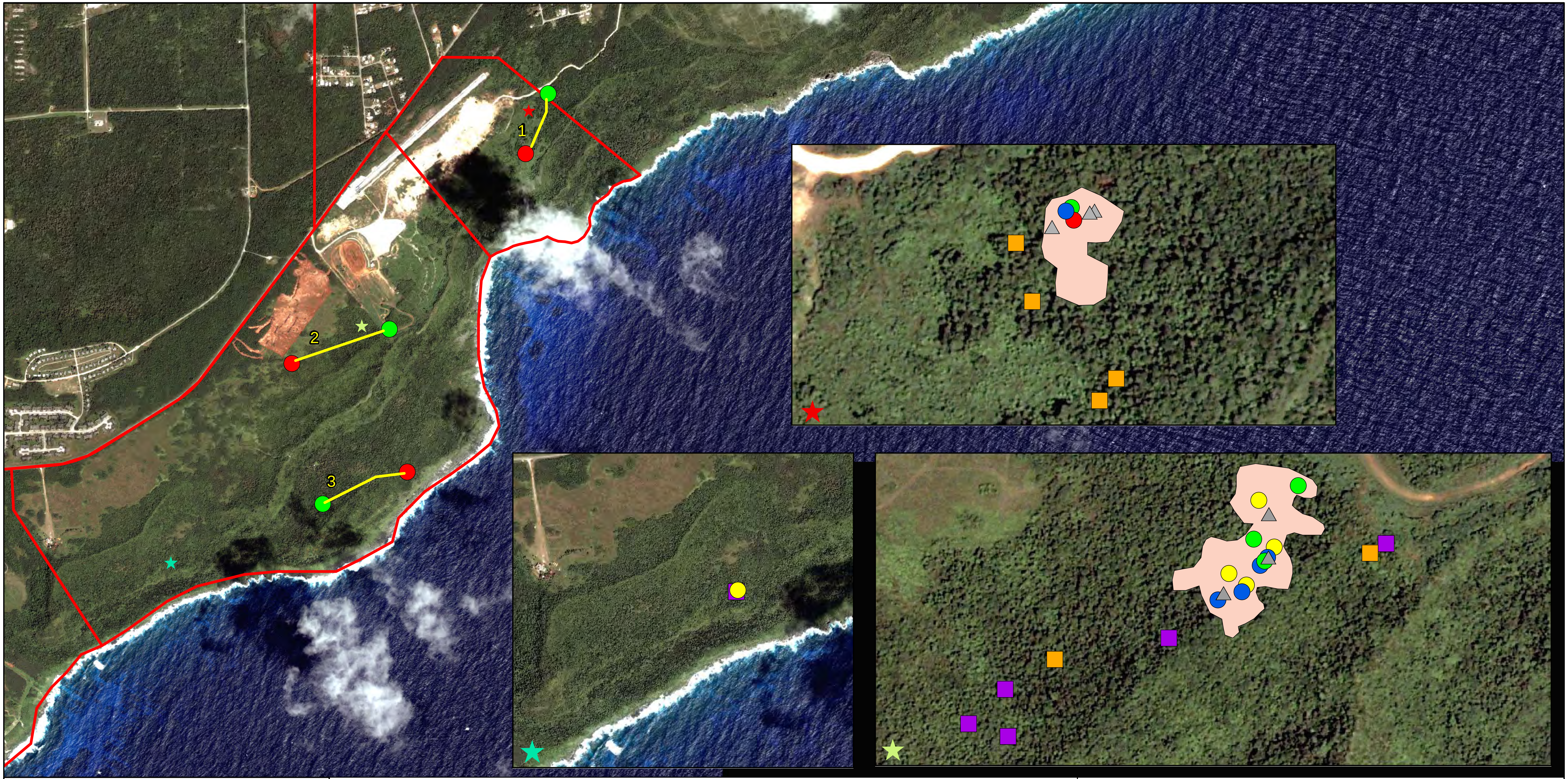
12.3 Butterfly Surveys

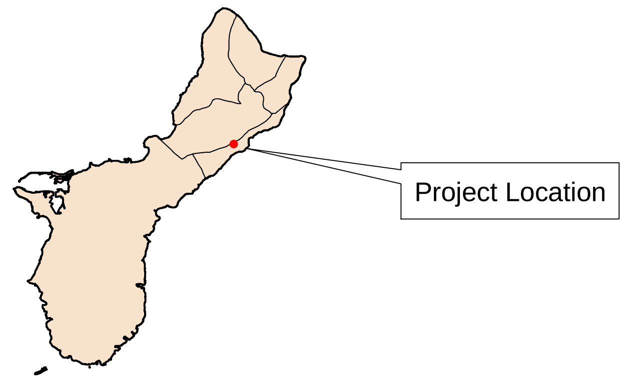
After the sighting of the Mariana Eight Spot butterfly on the Route 15 Lands during the vegetation surveys an in-depth survey was performed by two NAVFAC biologists. The survey report is provided in Appendix E.

The survey identified two areas that contained both host plants and Mariana Eight Spot butterflies on the Route 15 Lands and one location along the Pagat Trail (Figure 12-2). No butterflies of any species were observed in the bait pans. The survey results indicate that there is at least one population of the Mariana Eight Spot butterfly in the area. In addition, there are two areas that contain many of both host plant species, and which appear to be sustaining the butterfly population.

12.4 Avian Surveys

Forest bird surveys were conducted during the mornings. No avifauna were observed on the Route 15 Lands as part of the forest bird surveys. However, as part of the fruit bat survey, a survey was performed for endangered avian species, specifically the Mariana swiftlet. During the surveys, no endangered Mariana swiftlets were recorded. However, avian species that were identified in flight or vocalizing within habitat associated with the station count locations are shown in Table 12-2. No of the observed species are listed as threatened or endangered.





- Beginning Transect Point
- End Transect Point
- Transect Lines
- Installation Boundary
- Egg
- Butterfly
- Chrysalis
- Caterpillar
- Bait_pans
- Procris pedunculata
- Elatostema calcareum
- Mixed Host Plants

N

0 200 400 Meters

Route 15 Lands

Butterfly Survey Locations

Prepared By: TEC Inc. Joint Venture

Prepared For: NAVFAC

May 3, 2010	Project No.: 60133557	Figure 12-2

Table 12-2

Avian Species Detected during Mariana Fruit Bat Station Count Surveys in the Lumuna/Asdonlucas/Pagat Region, 6 - 22 October 2009.

Avian Species	Status on Guam
Black francolin (*Francolinus francolinus*)	Introduced resident, breeding
Yellow bittern (*Ixobrychus sinensis*)	Native resident, breeding
Pacific reef heron (*Egretta sacra*)	Native resident, breeding
Pacific golden-plover (*Pluvialis fulva*)	Migratory or wintering species, non-breeding
White tern (*Gygis alba*)	Native resident, breeding
Island collared-dove (*Streptopelia bitorquata*)	Introduced resident, breeding
Note: Status and nomenclature follow Wiles, 2005.	

12.5 Fruit Bat Surveys

Surveys for the Mariana fruit bat, locally known as fanihi, (*Pteropus mariannus mariannus*) were carried out in October 2009 in the Lumuna/Asdonlucas/Pagat region (adjacent to Route 15). The fruit bat survey report is provided in Appendix I.

Throughout the 20th century, the fruit bat population on Guam steadily declined. Illegal hunting appears to be the key reason for the fruit bat's dramatic decline on Guam, while habitat destruction and predation by introduced brown treesnakes (*Boiga irregularis*) may also be contributing factors (Wiles et al., 1989, Wiles et al., 1995, Morton and Wiles, 2002, Brooke, 2008).

The Mariana fruit bat was reclassified as a federally threatened species by the USFWS in 2005. The Government of Guam included the fanihi in the GCWCS as an SOGCN (GDAWR, 2006).

12.5.1 Survey Locations

Three survey locations (count stations) were situated on the east side of Route 15 in the northeast region of Guam, stretching from the Lumuna region through the Asdonlucas area south to Pagat Point (Figure 12-1).

The three locations were as follows:

- **Location 1 -** This count station was situated along the cliff line overlooking a forested basin below and mixed forest above.

- **Location 2 -** Count Station 2 was located along the cliff line and provided an unobstructed view of a forested basin below, as well as mixed forest above.

- **Location 3** - Count Station 3 was situated along the cliff line and afforded a clear view of a forested basin below, and mixed forest and a cleared region above.

12.5.2 Results

Fruit Bat Observations

Between October 6 and October 22, 2009, 12 station count surveys were completed at three locations (Table 12-3). No Mariana fruit bats were observed during any of the surveys.

The survey method utilized during this project relies on observing fruit bats in low light and daytime conditions. Any fruit bats that were using the area prior to or after the survey period would not have been detected. No fruit bats were observed during the 12 station count surveys. However, the survey area is suitable for the Mariana fruit bat to roost and forage because it is situated away from dense human habitation and includes several known Mariana fruit bat roosting and food tree species. The survey area is also close (within about 12.1 km) to the last remaining colonial roost location of fruit bats known on Guam. Therefore, it is possibile that fruit bats use the area for roosting and/or foraging as well as flight paths.

Table 12-3

Mariana Fruit Bat Station Count Results in the Lumuna/Asdonlucas/Pagat Region

Survey Date	Survey Location	Start Time	Stop Time	Number of Bats Observed
October 6, 2009	1	0545 h	0745 h	0
October 6, 2009	2	0545 h	0745 h	0
October 13, 2009	2	0525 h	0740 h	0
October 13, 2009	3	0530 h	0740 h	0
October 14, 2009	3	0515 h	0745 h	0
October 14, 2009	1	0530 h	0740 h	0
October 20, 2009	2	0510 h	0740 h	0
October 20, 2009	1	0520 h	0740 h	0
October 21,2009	3	0510 h	0740 h	0
October 21, 2009	2	0520 h	0740 h	0
October 22, 2009	1	0520 h	0740 h	0
October 22, 2009	3	0520 h	0740 h	0

At the time of the survey, there was loud noise associated with construction and rock-blasting activities on the property adjacent to survey location 3. The associated noise and possibility of hunting may prevent Mariana fruit bats from establishing permanent roosts in the area.

It is worth recognizing that three native, breeding resident avian species and one migratory avian species were detected flying above habitat associated with the survey area.

12.6 Tree Snail Surveys

- Subconsultant has not provided data for tree snail surveys on the Route 15 Lands -

12.7 Threatened and Endangered Species

No threatened or endangered avifauna, herpetofauna, or tree snail species were identified on the Route 15 parcels. Several Ufa-halomtano (*Heritiera longipetiolata*) trees were left intact within a designated conservation area at the Guam Raceway Park as a required condition of the Department of Agriculture. No Ufa-halomtano trees were observed on the transects; a single specimen was found near Transect 2 in the adjacent GEDCA parcel.

The Mariana Eight Spot butterfly (Photo 12-1) was sighted on the Route 15 parcel (Figure 12-2). As indicated in section 12.3, host plants for the butterfly do occur on the parcel.

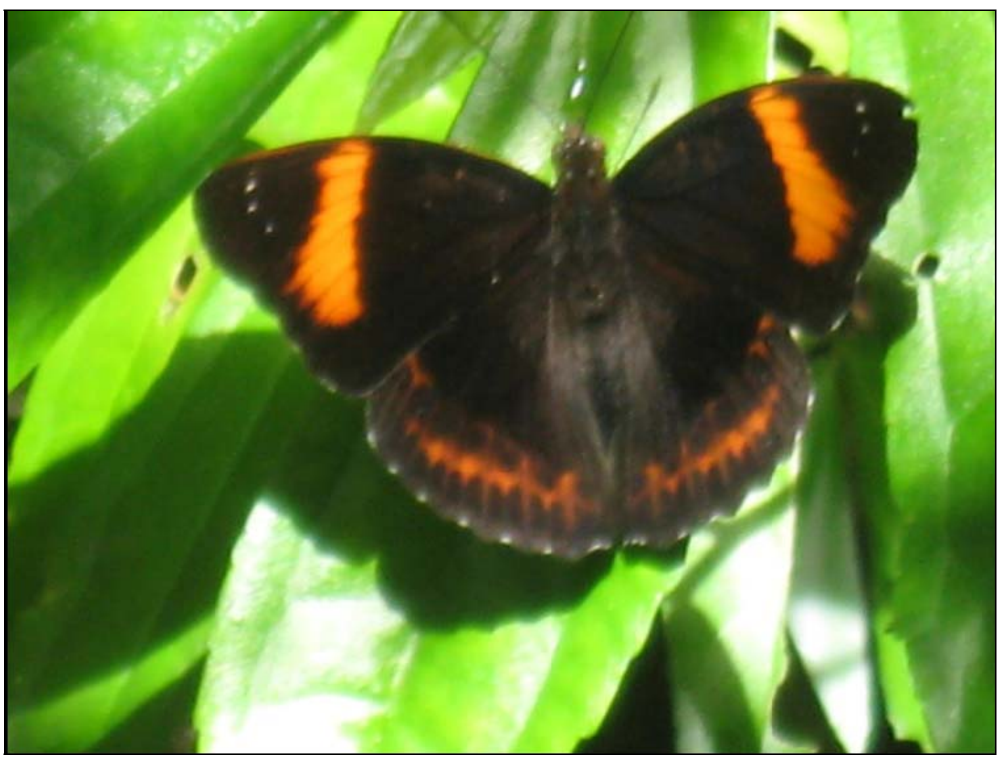


Photo 12-1 Mariana Eight-Spot Butterfly

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13 Former FAA Parcel

On the former FAA parcel, natural resource surveys performed included herpetofauna, vegetation, and avian surveys. Figure 13-1 shows the locations of the three natural resource survey transects.

FAA parcel transects were situated in a degraded forest of white lead tree (*Leucaena leucocephala*), *Coconut palm* (*Cocos nucifera*), and Sea hibiscus (*Hibiscus tiliaceus*).

13.1 Herpetofauna

Four herpetofauna species were captured or observed on the former FAA parcel. Table 13-1 identifies the species and their status. For more information on the herpetofauna survey and results, please refer to Appendix B.

Table 13-1

Herpetofauna Captured or Observed on the Former FAA Parcel

Guild	Species	Status
Skinks	Curious skink (*Carlia ailanpalai*)	Introduced
	Pacific blue-tailed skink (*Emoia caeruleocauda*)	Native
Amphibians	Greenhouse frog (*Eleutherodactylus planirostris*)	Introduced
	Marine toad (*Rhinella marinus*)	Introduced

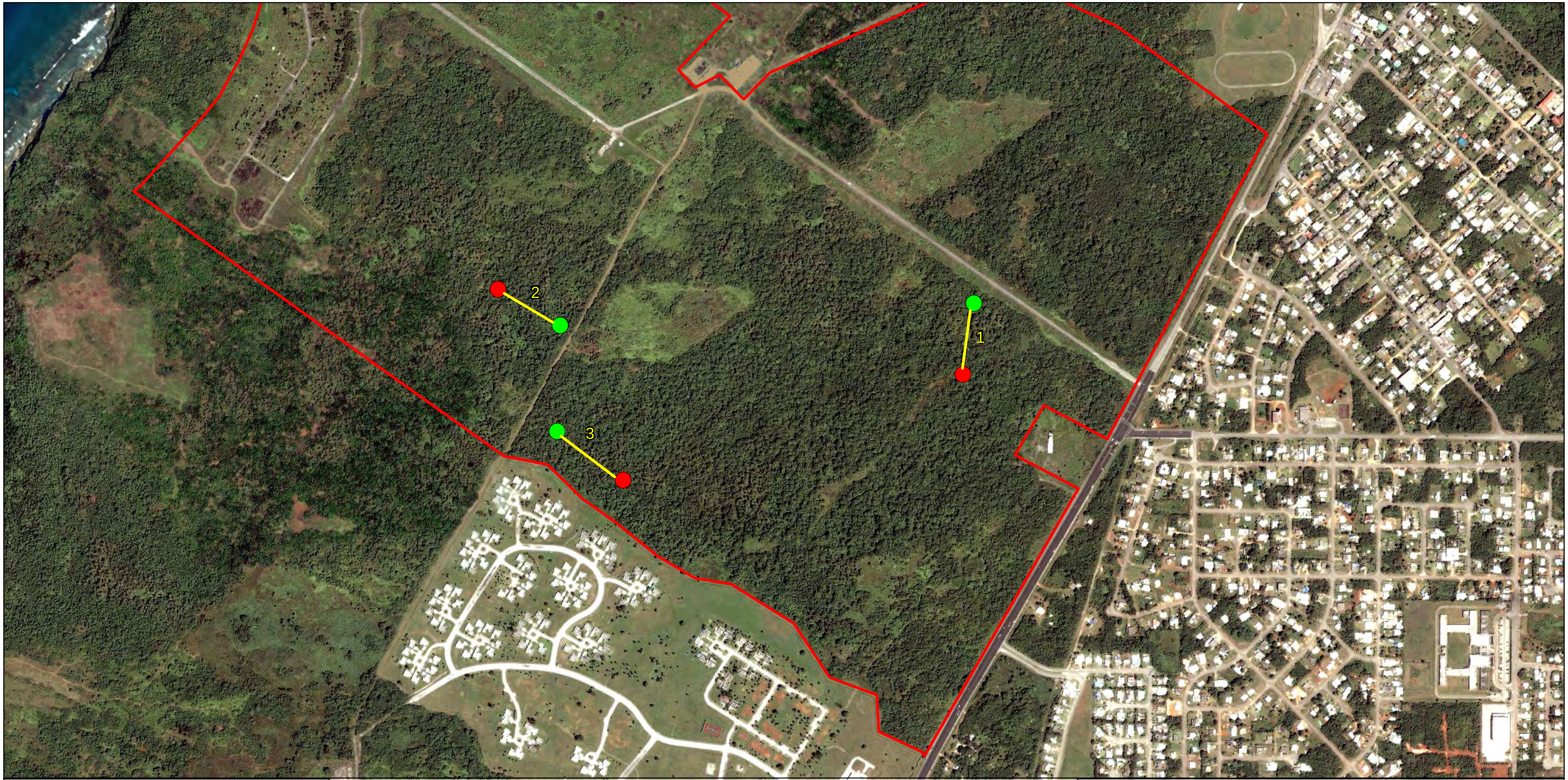
The continued widespread presence of the curious skink, as well as other introduced amphibian species, is of concern because of each species' potential deleterious impacts to Guam's native fauna (Rodda et al., 1999, Kraus et al., 1999, Wiles et al., 2003, Christy et al., 2007a). Of particular concern is the potential for these introduced species to serve as additional food sources for the brown treesnake (Fritts and Rodda, 1998, Christy et al., 2007a).

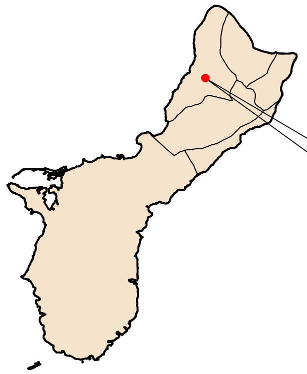
13.2 Vegetation

Quantitative surveys were performed using the point-center quarter method along three transects in the former FAA parcel. Transect 1 was located along a north-south axis in the eastern sector and Transects 2 and 3 were located along a northwest-southeast axis in the central-southern sector. The full vegetation survey report is provided in Appendix D.

13.2.1 Trees

Overall tree density among the three transects was lowest in the eastern sector (Transect 1), with 1,798 trees/ha and a total absolute cover of 25.85 m^2/ha. Pago (*Hibiscus tiliaceus*) was dominant, with the highest density (687.44 trees/ha) and absolute frequency (58.82), but this native species had a modest absolute cover of 2.03 m^2/ha. Pago occurred as a mid-canopy species and





- Beginning Transect Point (green dot)
- End Transect Point (red dot)
- Transect Lines (yellow line)
- Installation Boundary (red line)

N

0 200400 Feet

0 200 400 Meters

Former FAA Parcel

Transect Map

AECOM

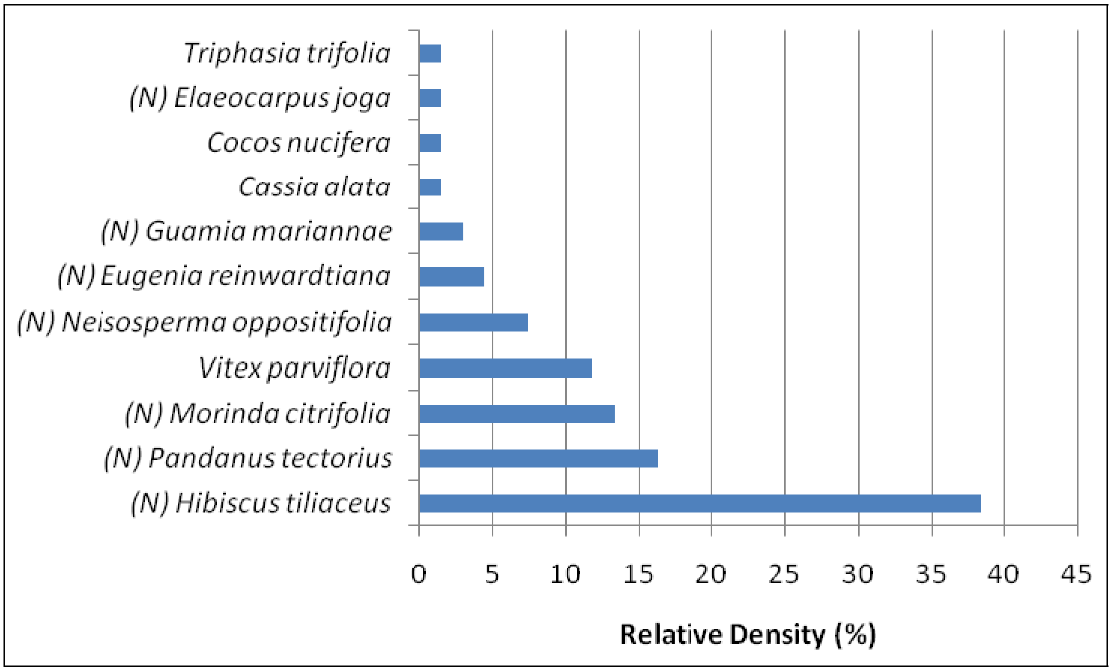
300 Broadacres Drive, Suite 350
Bloomfield, NJ 07003
www.aecom.com

May 3, 2010	Project No.: 60133557	Figure 13-1

comprised approximately 38 percent of the relative density among the 11 tree species encountered on Transect 1 (Chart 13-1). Native species had a much higher relative density (approximately 84 percent) than introduced species (approximately 16 percent). Aside from pago, kafu (*Pandanus tectorius*), lada (*Morinda citrifolia*) and *Vitex parviflora* had relative densities greater than 10 percent. Kafu and lada are native mid-canopy species; non-native *Vitex* occupied the upper canopy. Yoga (*Eleocarpus joga*), a native emergent canopy species, had the highest total basal area (4,126 sq cm) and absolute cover (10.91 m^2/ha), although only one specimen was encountered. *Eleocarpus* was not encountered along the other transects.

Chart 13-1

Relative Density of Trees Along Transect 1 – FAA Parcel
(N = native)

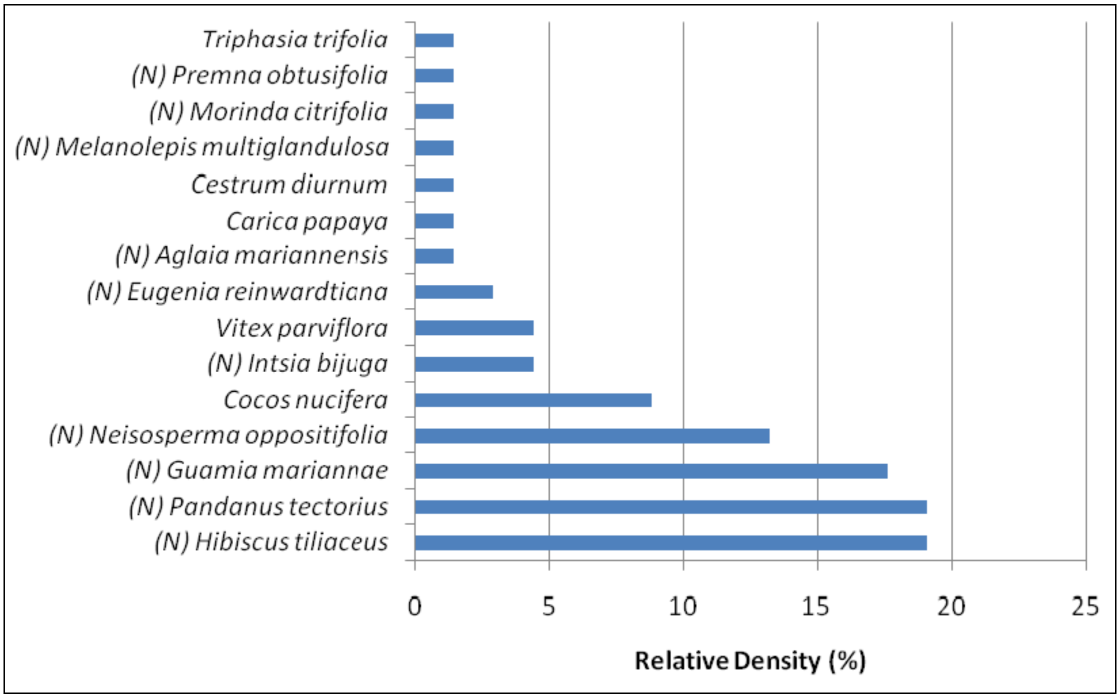


Transect 2 in the central-southern sector had the highest density among the transects, with 2,856.98 trees/ha and a total absolute cover of 24.86 m^2/ha. Both pago and kafu prevailed over other species with densities of 546.19 trees/ha and absolute frequencies of 47.06. These species, and paipai (*Guamia mariannae*) and fagot (*Neisosperma oppositifolia*), had relative densities exceeding 10 percent (Chart 13-2). Overall, native species had a higher relative density (about 82 percent) than introduced species (about 18 percent), which was similar to the proportion observed in the eastern sector along Transect 1. Two species, paipai and mapunao (*Aglaia mariannensis*), are endemic to the Mariana Islands.

Coconut (*Cocos nucifera*) was dominant overall in absolute cover (12.75 m^2/ha), followed by kafu, fagot and ifil (*Intsia bijuga*). *Vitex parviflora* was less dominant than in Transect 1 in density (126 trees/ha) and absolute cover (0.93 m^2/ha). The mean basal area of *Vitex parviflora* (73.91cm^2) was also the lowest observed among the transects.

Chart 13-2

Relative Density of Trees Along Transect 2 – FAA Parcel
(N = native)



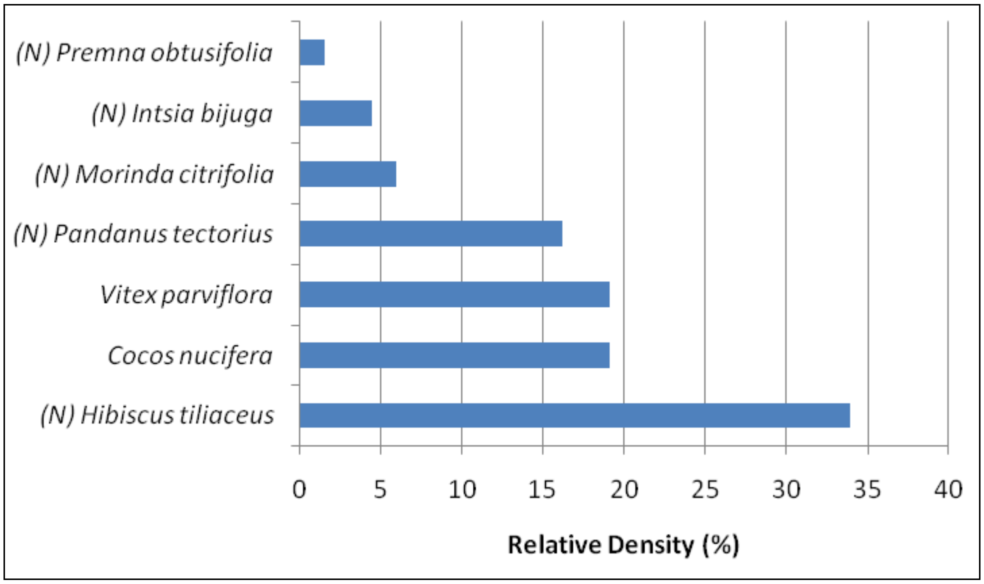
Transect 3 had an overall tree density of 1,868.79 trees/ha and a total absolute cover of 41.24 m^2/ha. The overall absolute cover was the highest among the three transects. Pago was consistently dominant among the transects, with the highest individual density (632.09 trees/ha) on Transect 3, and a relative density of about 33 percent (Chart 13-3). Pago also had the highest frequency among the seven species on Transect 3. Collectively, native species had a relative density of about 62 percent, which was the lowest proportion of native species among the three transects. Coconut comprised the bulk of absolute cover (20.52 m^2/ha) on Transect 3; both density (357 trees/ha) and absolute cover were higher than in Transect 2. *Vitex parviflora* had the next- highest absolute cover, and was as equally well-distributed along the transect as coconut, with an absolute frequency of 41.18.

13.2.2 Seedlings

The mean woody seedling density was significantly higher for native species (2.7 seedlings/m^2) than for non-native species (0.3 seedlings/m^2). The proportion of native to introduced seedlings was similar for Transects 1 and 2, and slightly lower for Transect 3. The seedling density reflects the higher native component observed in the relative tree densities along the transects.

Chart 13-3

Relative Density of Trees Along Transect 3– FAA Parcel
(N = native)



13.2.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat in the former FAA parcel. These include ungulate activity, the presence of erosion, the percentage of native plant species, and overall species richness. Species richness curves indicate that the highest tree species richness among the transects was along Transect 2, while Transect 3 had the lowest richness.

Leaf and vegetative litter comprised the highest mean frequency (5.6) among the four ground cover categories in the survey. Live vegetation had a similar frequency (5.0), while the limestone substrate and rocky terrain were reflected in the moderate frequency for rock (3.8). The lowest mean frequency was for bare soil (1.6).

Ungulate activity was encountered most frequently as soil disturbance, such as pig wallows and rooting. The mean frequency for soil disturbance appeared to be significantly higher than for rubbing and browsing on vegetation. Other signs of ungulate activity, such as scat, were not observed on the transects.

13.3 Avian Surveys

On the former FAA parcel, the forest bird survey was conducted in the mornings Table 13-2 identifies the species observed as part of the surveys. The nomenclature follows Gill et al. 2008. For more information on the avifauna survey and results, refer to Appendix G.

Table 13-2

Species Identified during the Forest Bird Survey – Former FAA Parcel

Survey Type	Number of Stations	Species and Number of Detections	Number of Species	Total Number of Detections
Forest Bird	6	Island Collared Dove*	1	7
Notes: * the Island Collard Dove's resident status is identified as "Common introduced resident – breeding" Residence status obtained from Reichel, J. D. and P. O. Glass, 1991, Checklist of the birds of the Mariana Islands. '*Elepaio*, 51(1): 3-10.				

13.4 Tree Snail Surveys

- Subconsultant has not provided data for tree snail surveys on the FAA Parcel -

13.5 Threatened and Endangered Species

No threatened or endangered avifauna, fruit bat, herpetofauna, tree snail, or vegetation species were identified on the former FAA Parcel.

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APPENDIX A

A SPECIES DESCRIPTIONS

During the course of the natural resources surveys on Guam, numerous species were observed. The text below provides descriptions of avifauna, butterfly, and herpetofauna species.

A1 Herpetofauna

A variety of herpetofauna were captured or observed during the herpetofauna surveys. Descriptions of each species are provided below. The species are listed in alphabetical order by scientific names; when available, the local Chamorro name is also provided.

A.1.1 Skinks

Curious skink, *Carlia fusca,* (Chamorro name: guali'ek halom tano') – The curious skink was initially introduced to Saipan in the 1960s, and then to Guam around 1968 (Rodda and Dean-Bradley, 2006). It is a brown terrestrial lizard, common and ubiquitous in all habitats on Guam (Vogt and Williams, 2004). Curious skinks grow to 70 mm in body length and lack a fifth toe on the front feet (USGS, 2005a; Zug 2004). This species feeds on insects and small lizards (Vogt and Williams, 2004) and is prey for the *Boiga irregularis* on Guam (Fritts and Rodda, 1998).

Pacific blue-tailed skink, *Emoia caeruleocauda* (Chamorro Name: guali'ek halom tano') – The Pacific blue-tailed skink is indigenous to the Mariana Islands, and on Guam can be found in all habitats (Vogt and Williams, 2004). It is mostly observed on the ground, but will climb shrubs and trees (Wiles et al., 1990). Juveniles have three stripes on their back and a bright blue tail, but as they grow the tail fades to brown (Wiles et al., 1990). Adult males tend to lose their stripes, but females will often retain theirs (Wiles et al., 1990). Pacific blue-tailed skinks are insectivorous and grow to 55 mm snout to vent (Vogt and Williams, 2004).

Moth skink, *Lipinia noctua* (Chamorro name: guali'ek halom tano') – Moth skinks are widespread across the western Pacific, although Guam is the only Mariana Island on which the species occurs. Two individuals were observed on Rota, but species status on the island is unknown (Rodda et al., 1991). Moth skinks are not common but can still be found in native forests in central Guam. As of the early 1990s, the species was known from Hilaan Point, Haputo Beach, and Acae Point along Guam's northwest coast (GDAWR, 2006). Moth skinks are one of the only diurnal, primarily arboreal species in the region (Rodda et al., 1991). The moth skink is a Guam-listed endangered species.

A1.2 Geckos

Mutilating gecko, *Gehyra mutilata* (Chamorro name: guali'ek) – The mutilating gecko is an insectivorous, tan/gray gecko with dark spots and thin skin that is easily sloughed or damaged (Vogt and Williams, 2004;, USGS, 2005a). The 64-mm-long mutilating gecko can be found in most natural habitats on Guam, in addition to the sides of houses and other structures (USGS, 2005a). It is also found on most islands in the Mariana archipelago (Vogt and Williams, 2004). There is uncertainty whether the mutilating gecko is native to Guam (e.g., USGS, 2005a and Vogt and Williams, 2004); for the purpose of this report, *Gehyra mutilata* is assumed to be native.

House gecko, *Hemidactylus frenatus* (Chamorro name: guali'ek) – The house gecko is very common on Guam in urban (Wiles et al., 1990) and natural habitats (Rodda and Dean-Bradley, 2006). This brown stripy gecko has a characteristic spiked tail and can grow to 60 mm body length (Vogt and Williams, 2004). House geckos feed primarily on insects, and are found on most islands in the Mariana archipelago (Vogt and Williams, 2004).

Mourning gecko, *Lepidodactylus lugubrus*, (Chamorro name: guali'ek) – The mourning gecko is a small insectivorous gecko found throughout Guam and most of the Mariana Islands (Vogt and Williams, 2004). It is observed in all habitats and quite often on houses (Wiles et al., 1990). The mourning gecko is light gray or tan with dorsal chevron banding (Vogt and Williams, 2004). The species is relatively small, attaining an average body length of 50 mm (Vogt and Williams, 2004). At night, these geckos can regularly be heard chirping to one another. Apart from *Nactus pelagicus*, *L. lugubrus* is the only other native reptile in the Mariana that is parthenogenic (USGS, 2005a).

Pacific Slender-toed Gecko, *Nactus pelagicus* (Chamorro name: guali'ek) - Unlike other geckos on Guam, Pacific slender-toed geckos are primarily ground-dwelling, and are mainly observed in rocky areas (Wiles et al., 1990). Captures of the Pacific slender-toed gecko have been rare since 1945. The decline of this species is possibly a result of the introduction of the brown treesnake (*Boiga irregularis*) and the musk shrew (*Suncus murinus*) (USGS, 2005a). The species is listed as endangered on Guam. Recent sightings have occurred in restricted areas in the northern limestone forests of Guam (Rodda, unpublished data). Rota and Tinian are known to support Pacific slender-toed geckos (USGS, 2005a).

A1.3 Snakes

Brown Tree Snake, *Boiga irregularis* (Chamorro name: kolepbla) – The brown treesnake can reach 3 m long, but on Guam averages around 1 m (Rodda et al., 1999). This snake inhabits all ecosystems; smaller snakes are usually observed in trees, larger ones on the ground (Rodda et al., 1999). The brown treesnake was introduced to Guam in the late 1940s, possibly on military cargo (Savidge, 1987). These snakes are directly responsible for the extirpation of numerous species of birds, and for the diminishing numbers of native lizards on the island (Savidge, 1987; Wiles et al., 2003). They feed on birds, small mammals, and lizards (Savidge, 1987). Brown treesnakes are native to northern Australia, Indonesia, the Solomon Islands, and New Guinea (Rodda et al., 1999).

Blind snake, *Ramphotyphlops braminus* – The blind snake reaches only 15 mm in length, is black in color, and often is confused with earthworms (Vogt and Williams, 2004). Blind snakes are parthenogenic (Vogt and Williams, 2004) and burrow in the dirt (fossorial), feeding on termites and ants (USGS, 2005b).

A1.4 Monitor Lizard

Monitor Lizard, *Varanus indicus* (Chamorro name: hilitai) – The presence of the monitor lizard in forested habitat on Guam is common, although it is possible that its abundance has declined in the last two decades. This decline may be a combined result of the introduction of the brown treesnake, which is capable of eating eggs and small juveniles, and of the poisonous marine toad, *Bufo marianus* (*Rhinella marianus*) (USGS, 2005). The monitor lizard is also found in numerous other locations, including Palau, New Guinea, the Caroline Islands, the Marshall Islands, the Solomon Islands, northern Australia, and throughout the Mariana Islands (Vogt and Williams, 2004).

A1.5 Frogs and Toads

Greenhouse frog, *Eleutherodactylus planirostris* – This species is nocturnal, but will readily move during rainy weather (Krauss et al., 1999).

Crab-eating frog, *Fejervarya cancrivora* – This species was accidentally introduced to Guam via an aquaculture shipment from the Philippines in 2002 (Christy et al., 2007b).

Eastern dwarf tree frog, *Litoria fallax* – A species native to Australia, it was introduced to Guam in 1968 (Christy et al., 2007a).

Hong Kong whipping frog, *Polypedates megacephalus* – This is an introduced species.

Marine toad, *Bufo marianus* (*Rhinella marinus*) – This species of toad has inhabited the island for the longest period of time, and is the only amphibian on Guam to be poisonous to animals that try to consume it (Vogt and Williams, 2004).

Gunther's Amoy frog, *Sylvirana guentheri* –This species was also introduced via the aquaculture trade from China, possibly as early as 2001 (Christy et al., 2007b).

A2 Tree Snails

A variety of tree snails were captured or observed during the surveys. Descriptions of each species are provided below. The species are listed in alphabetical order by scientific names.

Fat Guam Partula tree snail/Mariana Islands tree snail, *Partula gibba* - This species has a dark-colored body. The shell is light to dark brown. The shell's whorls darken between the apex and suture. The Mariana Islands tree snail is endemic species to Guam and the northern Mariana Islands. Currently, the status of this tree snail population is unknown. The Mariana tree snail prefers cool, shaded forest habitats with high humidity. This species occupies tree branches.

Guam or Pacific tree snail, *Partula radiolata.* - The Pacific tree snail has a tan to cream colored body and a shell with light and dark stripes. The snail is endemic to Guam. Currently, the population's status is unknown though it was found in the Mount Santa Rosa and Fadian Point. The Pacific tree snail prefers cool shaded forested areas with high humidity.

Mt. Alifan tree snail, *Partula salifana* – This species was first found on Guam in the 1920s in the west-central highlands region of the island.

Fragile tree snail, *Samoana fragilis* - This species was first discovered in 1820 and was considered uncommon. Currently, the fragile tree snail population remains uncommon. The species prefers cool shaded forest habitats with high humidity.

A3 Avifauna

A variety of avifauna were observed during the surveys. Descriptions of each species are provided below. The species are listed in alphabetical order by scientific names; when available, the local Chamorro name is also provided.

Micronesian starling, *Aplonis opaca* – (Chamorro name: sali), live in groups and nest in cavities. These black birds eat fruits, seeds and insects. Sali used to be found throughout Guam but predation by the kulepbla (brown treesnake) has restricted them primarily to Cocos Island, Andersen Air Force Base, parts of Agana, and certain coastal areas in the south (GDAWR, 2010).

Common Pigeon, *Columba livia* – sometimes referred to as Rock Dove, are common species to Guam and other continents.

Black Drongo, *Dicrurus macrocercus* – a native to Taiwan, this species was first introduced to Rota (CNMI) by the Japanese South Seas Development Company in 1935 in order to control destructive insects (Baker 1951). Since Rota lies approximately 50 km north of Guam, it is believed that the drongo either flew on its own accord or possibly was purposely introduced to Guam as the species first appeared in Northern Guam in the early 1960s (Engbring and Ramsey, 1984).

Black francolin, *Francolinus francolinus* - This species is a common introduced resident that has an established breeding population. A native to Southern Asia, this species was introduced as a game bird to Guam in 1961 (USFWS, 1984).

Grey-tailed tattler, *Heteroscelus brevipes* – The Grey-tailed Tattler is a medium-sized wader, with long wings and tail. Grey-tailed Tattlers breed in Siberia and on passage are seen along the East Asian-Australasian Flyway (the migration route to Australia). When non-breeding they are found in China, Philippines, Taiwan, Vietnam, Malay Peninsula, Indonesia, New Guinea, Micronesia, Fiji, New Zealand and Australia.

Whimbrel, *Numenius phaeopus* – Whimbrels are large shorebirds with long, curved bills. They are smaller in size than the similar-looking Long-billed Curlew, and their bills are shorter. Whimbrels nest in the tundra, not far from the tree line, in a variety of open habitats from wet lowlands to dry uplands. During migration, they use wetlands, dry, short grasslands, farmland (especially plowed fields), and rocky shores.

Eurasian tree sparrow, *Passer montanus* – an Old World native, was introduced to Guam from 1945-1960 and is commonly found in the urban areas (Engbring and Ramsey, 1984).

Pacific Golden Plover, *Pluvalis fulva* – This species is a common non-breeding visitor to Guam. The Pacific Golden Plover breeds on the Arctic tundra in western Alaska. It winters in South America and islands of the Pacific Ocean to India, Indonesia and Australia. In Australia it is widespread along the coastline. The species is found on muddy, rocky and sandy wetlands, shores, paddocks, saltmarsh, coastal golf courses, estuaries and lagoons (Birds in Backyards, 2010).

Island Collared Dove, *Streptopelia bitorquata* – a common introduced resident that has an established breeding population. A native to the Philippines, Borneo and surrounding islands, this species was believed to have been introduced by the Spanish perhaps as long as 200 years ago. (Engbring and Ramsey, 1984).

A4 Butterflies

A list of the species and a brief description of each species is provided below. The descriptions of the species are based on Schreiner and Nafus (1997). The species are listed in alphabetical order by scientific names.

Lemon migrant, *Catopsilia Pomona* – The species is found in the Mariana and Palau islands. The larvae feed on various species of the Shower tree, *Cassia* sp. The species is often found in moist open areas and engages in migratory flights.

Monarch, *Danaus plexippus* – This species' range includes the Americas, Australia and numerous Pacific Islands, including the Mariana Islands. In Micronesia, the species feeds on Milkweed, *Asclepias curassavica* and Crown flower (*Caltropis gigantean*). The species is a known migrant, capable of flying thousands of miles.

Blue-banded King Crow, *Euploea Eunice* – This species' range extends from India to Micronesia. The larvae feed on Ficus, *Ficus* sp., edible figs, and oleander. They are often sighted hanging on aerial roots of fig trees, other vegetation, or structures.

Blue Moon, *Hypolimnas bolina* – This species ranges from Madagascar to New Zealand, and is considered the most widely distributed butterfly in the world. The species is recorded as taking migratory flights from Australia to New Zealand.

Common Evening brown, *Melanitis leda* – In the Pacific, the evening brown butterfly occurs within the Mariana Islands and Caroline Island Chains. On Guam, the species has been found on corn, Guinea grass, and Napier grasses. The larvae also feed on grasses.

Common Mormon, *Paplio polytes* – This species is found throughout southeast Asia, the Philippines, Palau, Yap, and the Mariana Islands, although it is thought to be a recent arrival in the Mariana. Common Mormons are attracted to salt and frequently observed near puddles. They are also attracted to citrus trees found within the flowering plant tree family, Rutaceae.

APPENDIX B
Herpetological Surveys

Herpetological Surveys on Department of Defense Lands, Guam, In Support Of A Marine Corps Relocation Initiative To Various Locations On Guam. SWCA Environmental Consultants. June 21, 2010**.**

2010

HERPETOLOGICAL SURVEYS ON DEPARTMENT OF DEFENSE LANDS, GUAM, IN SUPPORT OF A MARINE CORPS RELOCATION INITIATIVE TO VARIOUS LOCATIONS ON GUAM

Photo credit: I. Chellman

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1.0 INTRODUCTION

Herpetological surveys were carried out as part of an extensive effort to locate, identify, and assess the distribution and abundance of Guam's herpetofauna on Department of Defense (DoD) and private lands. Survey methods were designed to target important or rare reptiles, excluding sea or turtles. Although survey methods did not target non-native reptiles or amphibians, their presence was recorded when observed. This report provides data on the presence of herpetofauna in various habitats throughout the survey locations.

1.1 Species Description, Distribution, and Status

The 23 known terrestrial herpetofauna (excluding turtles) on Guam can be divided into three main groups: lizards (including skinks, geckos, and monitor lizards), snakes, and amphibians (Table 1).

Skinks are small, smooth-skinned lizards with scales. Most are diurnal (active during the day), but can be observed at night when disturbed. Although these quick-moving species are often observed on the ground, they can climb trees if necessary. Some species lay eggs (ovipary) while others give birth to live young (vivipary).

Geckos are lizards with specialized toe pads, which enable them to climb almost any surface type. They are normally nocturnal (active at night), and can be heard eliciting chirping noises to one another.

Monitor lizards are larger-bodied than most skinks and geckos with powerful and well-developed limbs.

Amphibians are smooth-skinned vertebrates that include frogs, toads, salamanders, and caecilians. They typically undergo an aquatic and terrestrial stage during their life cycle. All amphibian species on Guam are non-native.

Native terrestrial herpetofauna on Guam were historically composed of skinks and geckos. Due to the island's isolated location, its native vertebrate fauna were limited to those that can either fly, such as birds and bats, or those capable of surviving long ocean journeys on floating vegetation. On Guam, native and endemic species are those that established prior to human settlement or without human assistance. Of the 11 native reptile species, only six are known to be currently present on Guam. The Pacific blue-tailed skink (*Emoia caeruleocauda*) and the mourning gecko (*Lepidodactylus lugubris*) are common. Mutilating gecko *(Gehyra mutilata)* is uncommon in many areas but locally common in others. The moth skink (*Lipinia noctua*), tide-pool skink (*Emoia atrocostata*), and Pacific slender-toed gecko (*Nactus pelagicus*) are rare and currently known only from restricted localities.

Table 1: Terrestrial reptile and amphibian species (excluding turtles) known to occur on Guam. "Status" denotes general distribution and abundance of each species. "Listing" refers to whether or not the species is locally listed, the level of listing, or whether it is non-native. The Guam Comprehensive Wildlife Conservation Strategy (GCWCS) identifies Species of Greatest Conservation Need (SOGCN) and Endangered as species of highest conservation value (GDAWR 2006). Species considered extinct are not included as SOGCN. Except for sea turtles, there are currently no reptile or amphibian species listed as federally endangered or threatened on Guam.

Common Name	Scientific Name	Chamorro Name	Status	Listing
Guam Listed Species				
Snake-eyed skink	*Cryptoblepharis poecilopleurus*	Guali'ek Halom Tano'	Unknown	SOGCN, Endangered
Azure-tailed skink	*Emoia cyanura*	Guali'ek Halom Tano'	Unknown	SOGCN, Endangered
Slevin's skink	*Emoia slevini*	Guali'ek Halom Tano'	Unknown	SOGCN, Endangered
Moth skink	*Lipinia noctua*	Guali'ek Halom Tano'	Locally restricted	SOGCN, Endangered
Micronesian gecko	*Perochirus ateles*	Guali'ek	Unknown	SOGCN, Endangered
Tide-pool skink	*Emoia atrocostata*	Guali'ek Kantun Tasi	Rare	Endangered
Oceanic gecko	*Gehyra oceanica*	Achiak	Unknown	Endangered
Pacific slender-toed gecko	*Nactus pelagicus*	Guali'ek	Locally restricted	Endangered
Native				
Pacific blue-tailed skink	*Emoia caeruleocauda*	Guali'ek Halom Tano'	Common	Not listed
Mutilating gecko	*Gehyra mutilata*	Guali'ek	Locally Common	Not listed
Mourning gecko	*Lepidodactylus lugubris*	Guali'ek	Common	Not listed
Non-native				
Brown treesnake	*Boiga irregularis*	Kolepbla	Common	Recent Introduction
Brahminy blind snake	*Ramphotyphlops braminus*	Ulo' Attilong	Common	Prehistoric Introduction
Monitor lizard	*Varanus indicus*	Hilitai	Locally abundant	Prehistoric Introduction
Curious skink	*Carlia ailanpalai*	Guali'ek Halom Tano'	Common	Recent Introduction
House gecko	*Hemidactylus frenatus*	Guali'ek	Common	Recent Introduction
Green anole	*Anolis carolinensis*	Guali'ek	Locally common	Recent Introduction
Marine toad	*Rhinella*(formally *Bufo*) *marinus*		Common	Recent Introduction
Greenhouse frog	*Eleutherodactylus planirostris*		Locally common	Recent Introduction
Crab-eating frog	*Fejervarya cancrivora*		Locally common	Recent Introduction
Eastern dwarf tree frog	*Litoria fallax*		Locally common	Recent Introduction
Gunther's Amoy frog	*Sylvirana guentheri*		Locally common	Recent Introduction
Hong Kong whipping frog	*Polypedates megacephalus*		Locally common	Recent Introduction

1.1.1 Federally Listed Species

Except for sea turtles, there are currently no reptile or amphibian species listed as federally endangered or threatened on Guam.

1.1.2 Guam Listed Species

Eight species of lizard are listed as Guam endangered species, either because they are rare with reduced populations, or have been potentially extirpated (USGS 2005). Of these, five are identified in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as Species of Greatest Conservation Need (SOGCN). Species considered extinct are not included as SOGCN.

1.1.2.1 Snake-eyed Skink
Scientific name: *Cryptoblepharis poecilopleurus*
Chamorro name: Guali'ek Halom Tano'
Status: Unknown
Guam listing: SOGCN, Endangered

The snake-eyed skink (also known as oceanic snake-eyed skink) has a body length of approximately 1.7 in (45 mm) and is usually found in coastal areas on rocks and shrubs (Vogt and Williams 2004). The eyelids are clear and fused, giving the appearance of being constantly open (USGS 2005). Overall coloration is tan to dark brown with light-colored spots on the sides (Vogt and Williams 2004). Three golden stripes on the back fuse to form two stripes on the tail, the middle stripe is of a more intense copper color than the bronze dorsolateral stripes (USGS 2005).

The last recorded snake-eyed skink on Guam was in 1969 (USGS 2005). However, four specimens were found on the small off-shore islet of Fofos (near Merizo) in the mid 1990s (Perry et al. 1998). This find may suggest a continued presence on Guam. The status of the snake-eyed skink on Guam is unknown but the species is still known to occur on Cocos, Saipan, Tinian, Rota, and most of the smaller northern Mariana Islands (USGS 2005).

1.1.2.2 Azure-tailed Skink
Scientific name: *Emoia cyanura*
Chamorro name: Guali'ek Halom Tano'
Status: Unknown
Guam listing: SOGCN, Endangered

The azure-tailed skink is endemic to Guam. The identification of this species can easily be confused with the Pacific blue-tailed skink (*Emoia caeruleocauda*). However, where they exist together, azure-tailed skinks are found on the forest edge and Pacific blue-tailed skinks are found in the forest interior (USGS 2005). The species reportedly specializes in hot, dry, open areas, particularly near the coast (McCoy 1980).

Historically, azure-tailed skinks occurred in southern Guam around the Geus River. Currently, the skink is thought to still occur on Cocos, but its status remains unknown (GDAWR 2006).

1.1.2.3 Slevin's Skink
Scientific name: *Emoia slevini*
Chamorro name: Guali'ek Halom Tano'
Status: Unknown
Guam listing: SOGCN, Endangered

The Slevin's (or Mariana) skink can reach up to 3 in (75 mm) in body length. It is usually brown or tan in color with white dorsal markings. The posterior two-thirds of the body can be bright orange (USGS 2005). Slevin's skinks are generally found on forest floors, tree trunks, and in old fields.

Slevin's skink was historically found throughout the island. However, it has not been observed on Guam since 1945. The species was known to occur on Cocos until the early 1990s; no recent sightings have been recorded in recent years. Populations of this species can still be found on the island of Sarigan, Guguan, Alamagan, Pagan, and Asuncion (GDAWR 2006).

1.1.2.4 Moth Skink
Scientific name: *Lipinia noctua*
Chamorro name: Guali'ek Halom Tano'
Status: Locally restricted
Guam listing: SOGCN, Endangered

Moth skinks reach around 2.1 in (55 mm) in body length and are usually brown to tan with a characteristic yellow spot on the head. This spot may be contiguous with a light-colored stripe on the dorsal surface and light spots on the flanks. The lips are marked with black and white bands and the belly is orange to yellow. Moth skinks are often found in low limbs and tree trunks. To escape predators, the skink is capable of breaking off its toes and tail (USGS 2005). The species is viviparous, which is not known in any other lizard species found in the Marianas (Vogt and Williams 2004). Moth skinks are one of the only diurnal, primarily arboreal species in the region (Rodda et al. 1991).

Although moth skinks are widespread across the western Pacific, Guam is the only island in the Marianas on which the species occurs. Two individuals were observed on Rota but species status on the island is unknown (Rodda et al. 1991). Moth skinks are not common but can still be found in native forests in central Guam. As of the early 1990s, the species was known from Hilaan Point, Haputo Beach, and Acae Point along Guam's northwest coast (GDAWR 2006).

1.1.2.5 Micronesian Gecko
Scientific name: *Perochirus ateles*
Chamorro name: Guali'ek
Status: Unknown
Guam listing: SOGCN, Endangered

The Micronesian gecko is large, reaching an average body length of 3.5 in (90 mm). Body coloration is usually brown to green with small black spots on the ventral surface. Defining physical attributes include a flattened, spiny tail and a reduced fifth toe (Vogt and Williams 2004). Similar to the oceanic gecko, the Micronesian gecko is closely associated with undisturbed habitat, primarily native limestone forest. However, a number of geckos have been found in untended coconut groves (Sabath 1981).

In 1969, the Micronesian gecko was considered common on Guam. However, the last specimen was collected in 1978. The current status is unknown. Other than Guam, the Micronesian gecko has been reported from Cocos, Tinian, Rota, and Saipan, where its status is also unknown (Rodda 2003).

1.1.2.6 Tide-pool Skink
Scientific name: *Emoia atrocostata*
Chamorro name: Guali'ek Kantun Tasi
Status: Rare
Guam listing: Endangered

Indigenous to the Mariana Islands, the tide-pool skink (also known as littoral skink) is found in coastal areas on rocks and shrubs, but is rarely seen. It has a mix of black and tan coloring, and grows to 3.3 in (85 mm) in body length. The species is tolerant of salt water and will use the ocean to move around and escape predators (Vogt and Williams 2004).

There have been reported sightings of tide-pool skinks on Guam in the vicinity of Inarajan Pools as recently as 2007 (Reed et al. 2007). A survey of the islets surrounding Guam conducted in the mid 1990s detected nine specimens on Agrigan Islet near Merizo, and Anae Islet near Agat (Perry et al. 1998).

1.1.2.7 Oceanic Gecko
Scientific name: *Gehyra oceanica*
Chamorro name: Achiak
Status: Unknown
Guam listing: Endangered

The oceanic gecko has light coloring, usually gray, tan, or dark brown, often with a white-spotted dorsal surface. It is the largest terrestrial lizard in the Marianas, reaching up to 4 in (100 mm) in body length. This species prefers poorly lit surfaces and is often most abundant in trees, vegetation, and stony outcrops. As a result, oceanic geckos are associated with undisturbed habitat and may be less tolerant of urbanization than other gecko species occurring in the Marianas (Sabath 1981). For the purpose of this report, the oceanic gecko is considered native although some authors argue the species is a recent arrival (Vogt and Williams 2004, Rodda unpublished data). Oceanic geckos still occur on the islands of Cocos, Rota, Tinian, Saipan, Guguan, Alamagan, and Asuncion where they appear common. The species has not been sighted on Guam in over a decade. The last verified observation was made on the University of Guam Campus in Mangilao (Rodda unpublished data).

1.1.2.8 Pacific Slender-toed Gecko

Scientific name: *Nactus pelagicus*
Chamorro name: Guali'ek
Status: Locally restricted
Guam listing: Endangered

The Pacific slender-toed gecko is gray, with dark bands and small bumps on its back and tail. A distinguishing feature of the species is its straight non-adhesive toes, which are thin compared to the large toe pads of other geckos (USGS 2005). Unlike other geckos on Guam, Pacific slender-toed geckos are primarily ground dwelling, mainly observed in rocky areas (Wiles et al. 1990). At night, the gecko can be found foraging on the ground and rocky substrates. This species is comprised only of females, and utilizes an asexual form of reproduction known as parthenogenesis (USGS 2005) whereby development of embryos occurs without fertilization by a male.

Captures of the Pacific slender-toed gecko have been rare since 1945. The decline of this species is possibly a result of the introduction of the brown treesnake (*Boiga irregularis*) and the musk shrew (*Suncus murinus*) (USGS 2005). Recent sightings have occurred in restricted areas in the northern limestone forests of Guam (Rodda unpublished data). Additionally, four specimens were found on the small southern off-shore islet Anae (near Agat) between 1994 and 1997 (Perry et al. 1998). Rota and Tinian are known to support Pacific slender-toed geckos (USGS 2005).

1.1.3 Species Native to Guam But Not Listed

1.1.3.1 Pacific Blue-tailed Skink

Scientific name: *Emoia caeruleocauda*
Chamorro name: Guali'ek Halom Tano'
Status: Common
Guam listing: Not listed

Juvenile Pacific blue-tailed skinks have three dorsal stripes and a bright blue tail. As they mature, the tail fades to brown. Adult males tend to lose their stripes, but females often retain them. Pacific blue-tailed skinks can grow to 2.1 in (55 mm) in body length (Vogt and Williams 2004).

On Guam, the Pacific blue-tailed skink can be found in all habitats throughout the island (Vogt and Williams 2004). They have been observed primarily on the ground, but will readily climb shrubs and trees (Wiles et al. 1990).

1.1.3.2 Mutilating Gecko

Scientific name: *Gehyra mutilata*
Chamorro name: Guali'ek
Status: Locally common
Guam listing: Not listed

The mutilating gecko is tan or gray with dark spots and a slightly flattened tail. The species has thin skin that is easily sloughed or damaged (Vogt and Williams 2004, USGS 2005). Body length averages about 1.6 in (42 mm).

The mutilating gecko is found in a variety of habitats, both forested and man-made. Its distribution on Guam is not fully known although it is considered patchy. The gecko is uncommon in some areas and locally abundant in others. Specimens have been collected from several offshore islets (Perry et al. 1998). The mutilating gecko is also known to occur on the islands of Cocos, Rota, Tinian, Saipan, Sarigan, Guguan, Alamagan, Pagan, and Agrihan (USGS 2005).

1.1.3.3 Mourning Gecko

Scientific name: *Lepidodactylus lugubris*
Chamorro name: Guali'ek
Status: Common
Guam listing: Not listed

The mourning gecko is light gray or tan with black bars on its back forming a chevron pattern. While primarily nocturnal, activity can also occur during the day in shaded locations (USGS 2005). At night, these geckos will vocalize and can regularly be heard chirping to one another. Mourning geckos are relatively small, attaining an average body length of 2 in (50 mm) (Vogt and Williams 2004). Reproduction in this species can occur via parthenogenesis (USGS 2005).

This species of gecko occurs throughout Guam in virtually all habitats. Other islands in the Marianas where the mourning gecko is present are Cocos, Rota, Tinian, Saipan, Alamagan, Agrihan, and Ascuncion (Vogt and Williams 2004).

1.1.4 Non-native Species

Although non-native species were not specifically targeted during this survey, captures or sightings of key species were documented whenever they occurred.

1.1.4.1 Brown Treesnake
Scientific name: *Boiga irregularis*
Chamorro name: Kolepbla
Status: Common
The brown treesnake on Guam averages around 3 ft (1 m), but can reach 9 ft (3 m) in length (Rodda et al. 1999). The snake was introduced to Guam in the late 1940s possibly on military cargo from the Admiralty Islands (Rodda et al. 1992). This snake is implicated in the extirpation of numerous species of birds and for diminishing numbers of native lizards on the island (Savidge 1987, Wiles et al. 2003). The brown treesnake is a generalist predator that will feed on birds, small mammals, and lizards (Savidge 1987).

The brown treesnake can be found in all habitats throughout Guam (Rodda et al. 1999).

1.1.4.2 Brahminy Blind Snake
Scientific name: *Ramphotyphlops braminus*
Chamorro name: Ulo' Attilong
Status: Common

The brahminy blind snake is inconspicuous and often confused with earthworms. Body size for this species reaches only 0.6 in (15 mm) in length, with a coloration that is solid black (Vogt and Williams 2004). The snake is an all female species that reproduces by means of parthenogenesis. Blind snakes are fossorial and feed on termites and ants (USGS 2005). This species is regarded as a prehistoric introduction but its mode of arrival to Guam is unknown. However, the species is known to be accidentally transported in flower pots (Vogt and Williams 2004).

The brahminy blind snake can be found in all habitats throughout Guam. Records of this species also exist from Rota, Tinian, Saipan, Anatahan, Sarigan, Alamagan, Pagan, and Agrihan, though it has potentially been established on all the Mariana Islands (Vogt and Williams 2004).

1.1.4.3 Monitor Lizard
Scientific name: *Varanus indicus*
Chamorro name: Hilitai
Status: Locally abundant

The monitor lizard on Guam is dark brown to black with yellow flecks. Body size can reach up to 4.9 ft (1.5 m). Monitor lizards are diurnal scavengers that feed on almost anything including insects, other species of lizards, small mammals, birds, eggs, crabs, and carrion (Dryden 1965). The establishment of the monitor lizard on Guam is thought to be prehistoric, coinciding with the arrival of ancient human inhabitants.

Presence of the monitor in forested habitat on Guam is common, although it is possible that its abundance has declined in the last two decades. This decline may be a combined result of the introduction of the brown treesnake, which is capable of eating eggs and small juveniles, and the introduction of the poisonous marine toad (USGS 2005). The monitor lizard is also found in numerous other locations, including Palau, New Guinea, Caroline Islands, Marshall Islands, Solomon Islands, northern Australia, and throughout the Mariana Islands (Vogt and Williams 2004).

<u>1.1.4.4 Curious Skink</u>
Scientific name: *Carlia ailanpalai*
Chamorro name: Guali'ek Halom Tano'
Status: Common

The curious skink was accidentally introduced to Guam and nearby Micronesian islands through the post-WWII transport of military supplies (Zug 2004). The first recorded specimen of the curious skink on Guam occurred in 1968. Native to the New Guinea region and Palau (Vogt and Williams 2004), the skink is a brown, terrestrial lizard that can be distinguished from other skinks by the lack of a fifth toe on the front feet (Zug 2004). Curious skinks grow to 2.8 in (70 mm) in body length. This species is primarily insectivorous but is known to feed on other small lizards (USGS 2005).

By the early 1990s, the curious skink was the most abundant skink on Guam and found in all habitats (McCoid 1993). It has been reported to be common in open and disturbed areas (Vogt and Williams 2004). The curious skink is also known to occur on the islands of Cocos, Saipan, and Tinian (USGS 2005).

<u>1.1.4.5 House Gecko</u>
Scientific name: *Hemidactylus frenatus*
Chamorro name: Guali'ek
Status: Common

The house gecko is very common in all habitats on Guam, particularly urban areas on buildings and fences and in natural habitats on branches and tree trunks (Rodda and Dean-Bradley 2006). Body color can vary from a light tan to dark brown with occasional dorsally-located stripes. Body length can reach 2.4 in (60 mm). A defining physical characteristic of this species is the spiked tail (Vogt and Williams 2004). The behavior of the house gecko is thought to possibly affect that of the mourning gecko (Vogt and Williams 2004).

No introduction date is known for this species, though implications of its presence exist prior to 1906 (Van Denburgh 1917 as referenced in McCoid 1993). McCoid (1993) described the house gecko as the most abundant gekkonid on Guam.

1.1.4.6 Green Anole
Scientific name: *Anolis carolinensis*
Chamorro name: Guali'ek
Status: Locally common

The green anole is usually bright green, but can change to brown depending on the surrounding environment (USGS 2005). Growing to 2.8 in (75 mm), males are generally larger than females. The males of this species also have a throat pouch (dewlap) that is used to display during courting behavior or when disputes over territory arise (Vogt and Williams 2004). Green anoles are diurnal and primarily feed on insects and spiders (Vogt and Williams 2004).

The introduction of the green anole to Guam was intentional, occurring in the mid-1950s as a means for insect control (Eldredge 1988). Its distribution on Guam has become locally common in urban areas, while populations have declined in forest habitat (Rodda et al. 1991). This habitat bias may be a result of predation by the brown treesnake (Rodda et al. 1999). Introductions of the green anole have also occurred on Rota, Saipan, and Tinian (Vogt and Williams 2004).

1.1.5 Amphibians

Guam has no native amphibian species. However, via accidental and intentional introductions, 13 species have found their way to Guam. Of these, eight are recorded as present, five of which are known to have established populations on the island (Government of Guam 1940, Christy et al. 2007b, Christy et al. 2007a). Species most likely to be encountered during surveys include the following:

Marine toad *(Rhinella marinus [formally Bufo]*) – Intentional introduction in 1937
Greenhouse frog (*Eleutherodactylus planirostris*) – Accidental introduction in 2003
Crab-eating frog (*Fejervarya cancrivora*) - Accidental introduction in 2002
Eastern dwarf tree frog (*Litoria fallax*) – Unknown introduction pathway in 1968
Gunther's Amoy frog (*Sylvirana guentheri*) - Accidental introduction around 2001
Hong Kong whipping frog (*Polypedates megacephalus*)

2.0 METHODS

2.1 Survey Locations

Herpetofauna surveys were undertaken at 11 locations on DoD and privately-owned lands on Guam (Table 2). Transects were set up within various habitat types to increase the possibility of detecting target species. General habitat descriptions of each survey location and corresponding transects are discussed below.

2.1.1 Andersen Air Force Base (7 transects)

Habitat type varied among transects from degraded forest (dominant species *Wikstroemia elliptica*, *Morinda citrifolia* and *Hibiscus tiliaceus*) to native limestone forest (predominately *Guamia mariannae*, *Aglaia mariannensis*, *Premna obtusifolia*, *Neisosperma oppositifolia*, and *Pandanus tectorius*).

2.1.2 North Finegayan (9 transects)

All nine transects were located in secondary forest, dominated by *Pandanus tectorius*, *Guamia mariannae*, *Vitex* sp., and *Hibiscus tiliaceus*.

Table 2: Herpetofauna surveys were carried out at 11 locations on DoD and private lands on Guam. Each site was designated a site-specific code. The number of transects and total length of transects varied between sites. Sites are ordered from north to south on the island.

Site	Site Code	Number of Transects	Total Transect Length (m)
Andersen Air Force Base	AAFB	7	2115
North Finegayan	NFIN	9	1720
South Finegayan	SFIN	2	150
Federal Aviation Administration	FAA	3	460
Andersen South	ANDS	7	1165
Route 15	RT15	3	1300
NCTS Barrigada	NBAR	3	555
Cabras	CABR	1	500
Orote Point	OROT	4	460
Naval Munitions Site	NMS	11	3830
Access Road – Option A	ACRD	3	400

2.1.3 South Finegayan (2 transects)

Both transects at this location consisted primarily of *Hibiscus tiliaceus* and *Leucaena leucocephala.* Bare ground was also common on each transect.

2.1.4 Federal Aviation Administration Parcel (3 transects)

FAA parcel transects were situated in degraded forest of *Leucaena leucocephala, Cocos nucifera*, and *Hibiscus tiliaceus*.

2.1.5 Andersen South (7 transects)

Four of the seven transects were located in forest where *Guamia mariannae, Aglaia mariannensis, Neisosperma oppositifolia*, and *Premna obtusifolia* were dominant. Two were in degraded *Leucaena leucocephala*-dominated forest and one in non-forest, grassy habitat that traversed pavements.

2.1.6 Route 15 (3 transects)

Two transects were located on top of the cliff line in limestone karst forest. The first started with native forest including *Guamia mariannae, Aglaia mariannensis, Ficus tinctoria, Triphasia trifolia* before opening up to a degraded forest with some *Leucaena leucocephala, Chromolaena odorata,* and *Stachytarpheta* sp. The second transect also traversed through similar native forest. The third was situated below the cliff line and consisted mostly of *Cocos nucifera.* Surveying of herpetofauna on the "Route 15 valley transect" was not possible because of access issues.

2.1.7 NCTS Barrigada (3 transects)

Transects were set in forested habitats where *Hibiscus tiliaceus*, *Leucaena leucocephala*, *Guamia mariannae*, and *Aglaia mariannensis* were common.

2.1.8 Cabras (1 transect)

The single transect was located in wetland. *Hibiscus tiliaceus*, *Spathodea campanulata*, and *Flagellaria indica* were common throughout.

2.1.9 Orote Point (4 transects)

Guamia mariannae, Aglaia mariannensis, Ficus tinctoria, Triphasia trifolia, and *Pandanus tectorius* dominated three of the four transects. The fourth, below Spanish Steps towards the beach, was almost entirely *Cocos nucifera*.

2.1.10 Naval Munitions Site (11 transects)

Ten of the eleven transects were situated almost entirely in native forest consisting of *Premna obtusifolia, Aglaia mariannensis,* and *Guamia mariannae.* Some transects passed over streams and swampy ground where *Cocos nucifera*, *Pandanus tectorius,* and *Hibiscus tiliaceus* were dominant. One transect was dominated by *Miscanthus floridulus.*

2.1.11 Access Road Option A at Mt. Jumullong (3 transect)

This site consisted of three transects in forest, situated along-side the trail leading to the top of Mt. Jumullong. Two transects were in degraded forest of *Leucaena leucocephala, Hibiscus tiliaceus, and Flagellaria indica.* The third, at highest elevation, was primarily native forest. *Pandanus tectorious and Aglaia mariannensis* were common at this location.

2.2 Herpetological Surveys

Herpetological surveys were performed by up to three herpetologists at each transect. Surveys were conducted nocturnally (targeting geckos) and diurnally (targeting skinks) on each transect to increase the possibility of encountering as many species as possible within each habitat. Reptiles and amphibians were documented by capture using glue board traps (traps) and/or visual surveys. Capturing individuals was valuable for identification of fast moving, cryptic or morphologically similar species. Visual surveys were intended to detect species that might not be trapped.

2.2.1 Trap Surveys

Day surveys commenced between 0730 and 0830, and night surveys between 1730 and 1830. If rain was present or imminent, trapping was delayed until the threat of rain ceased. On each transect, two non-scented Catchmaster™ mouse and insect glue board traps (henceforth referred to as traps) were set at 50 ft (15 m) intervals, one on the ground and one in a nearby tree. If no tree was available within 15 ft (5 m), only ground traps were used at that location. All traps were set in a shaded area approximately 3 ft (1 m) adjacent to the transect.

Tree traps were nailed to plants with a minimum diameter of 1.5 in (50 mm) at breast height (dbh), between 3 and 6 ft (1 - 2 m) high. Locations of traps were numbered and marked with flagging tape. Trap set and removal times were recorded along with time of each trap check. During the day, traps were generally checked within two hours (but never more than four hours) from opening. Traps were set for up to 12 hours overnight. A mortality level below 10 percent was considered acceptable. If mortality exceeded 10 percent, traps were repositioned or removed.

In order to decrease human disturbance along transects, traps were checked in the order in which they were set. Along with check time, the species type and number of individuals found on a trap were recorded. Non-target fauna and a change in weather conditions were also noted. Each animal was removed and placed into a correspondingly-numbered plastic bag until the trap was closed to prevent recapture. Once a trap was checked, it was closed or removed.

Individuals were removed from the traps slowly and carefully to minimize stress and physical damage. If removal was difficult, a small amount of vegetable oil was applied to decrease stickiness of the glue. Lizards that escaped but left their tail attached to the trap were recorded as a capture. When effectiveness of traps decreased due to dampness or an accumulation of debris or non target species, its location was noted and the trap replaced. Trapping was aborted in heavy or persistent rain and reopened when inclement weather passed. After completion of trap checks, individuals were released at their capture point.

Species caught by hand were recorded anecdotally.

2.2.2 Visual Surveys

Visual surveys were conducted both during the day and at night. Day searches commenced between 0800 and 1000 and night surveys between 1830 and 2130. A typical search speed of 0.2 to 0.4 mi/h was maintained. Any search speed variation was attributed to the density of the vegetation and abundance of species observed.

When a species was encountered, the information was chronicled on the data sheet. Species, perch taxon or substrate, and location were recorded. Any unidentified individual was captured where possible and photographed to aid in identification. Stop time and weather conditions were recorded at the completion of the visual surveys. Incidental observations and comments were also recorded.

3.0 RESULTS

Herpetofauna were surveyed along 53 transects at 11 locations between the 17th of February 2008 and the 21st of October 2009. Daytime and nighttime trap and visual surveys were carried out on all transects at all locations except NMS 1, where no nighttime visual survey was conducted due to safety concerns. Appendix 1 provides a full list of survey sites with transects and the associated date for each survey type.

Since transect length varied, results are presented as number of individuals or species recorded per meter (individuals/m or species/m). Amphibians were not considered a priority species; therefore abundance data are not included except where specifically noted.

3.1 Overall Results

Data presented in this section represent the combined results of trap and visual surveys; separate results for these surveys can be found in sections 3.2 and 3.3.

3.1.1 Individual and Species Abundance

A total of 2,900 individuals representing 15 herpetofauna species were recorded during trap and visual surveys along almost 13,000 meters of transect. The greatest number of individuals detected per meter was 0.50 (n = 275 individuals) at NBAR and 0.43 (n = 195 individuals) at OROT (Figure 1).

The highest number of species recorded per meter was 0.03 (n = 5 species) at SFIN (Figure 2). The location with the greatest number of species recorded was NMS (n = 11 species); however, since the total length of transects surveyed at NMS was high relative to other locations, the number of species per meter was the lowest recorded (0.003 species).

The highest number of native herpetofauna individuals recorded per meter was 0.21 (n = 118 individuals) at NBAR. Non-native individuals were most abundant at NBAR (0.28 individuals/m; n = 156) and OROT (0.28 individuals/m; n = 129) (Figure 3).

SFIN had the highest number of both native (0.013 species/m; n = 2) and non-native (0.02 species/m; n = 3) species recorded per meter (Figure 4). However, the locations with the most native herpetofauna species were NFIN (n = 5) and NMS (n = 5). The ANDS survey location contained the most non-native species (n = 7).

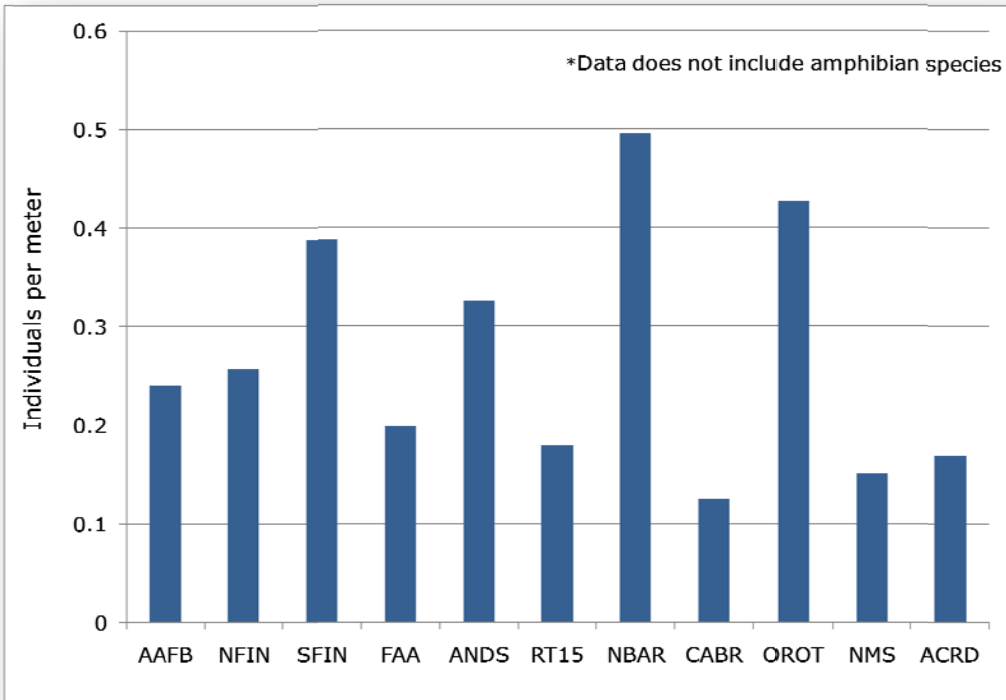

Figure 1. Number of herpetofauna individuals detected per meter at each survey location. See Table 2 for site code definitions.

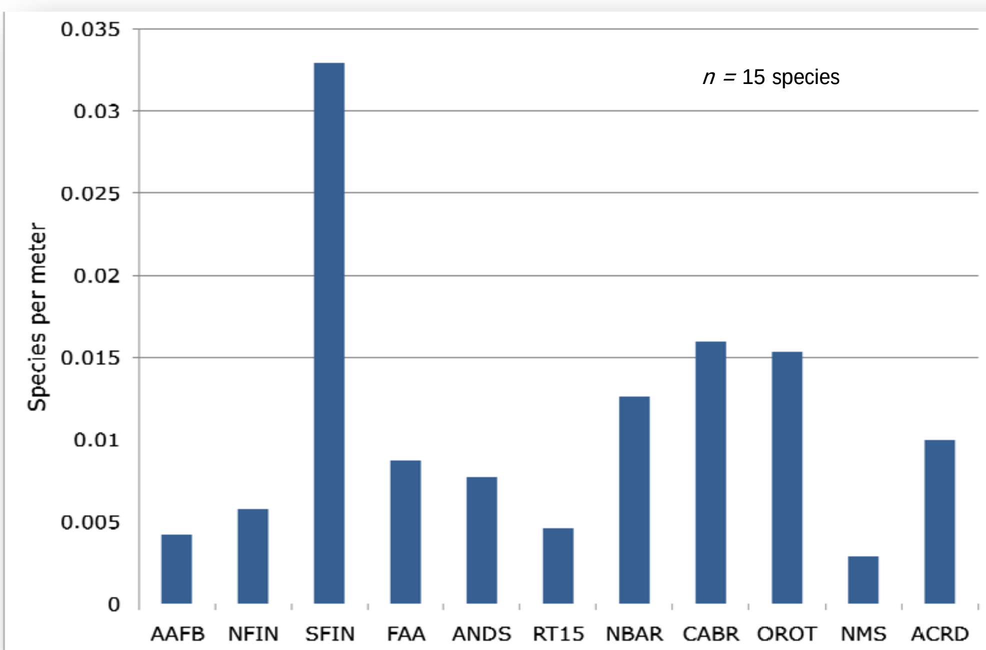

Figure 2. Number of species recorded per meter at each survey location. See Table 2 for site code definitions.

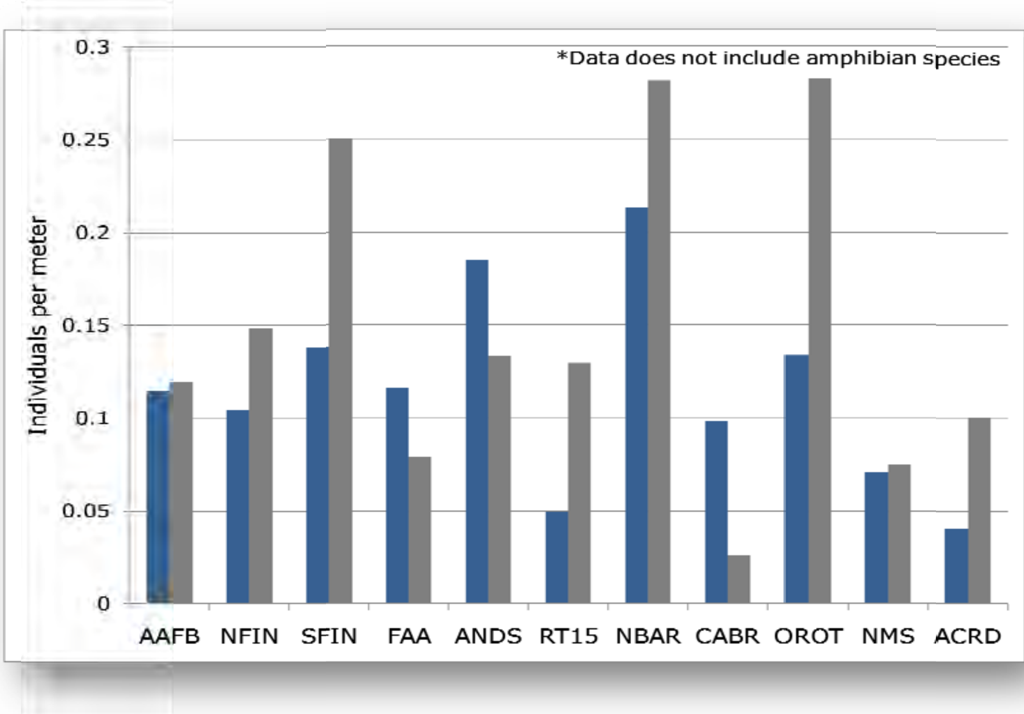

Figure 3. Number of native (blue) and non-native (grey) herpetofauna individuals recorded per meter at each survey location. See Table 2 for site code definitions.

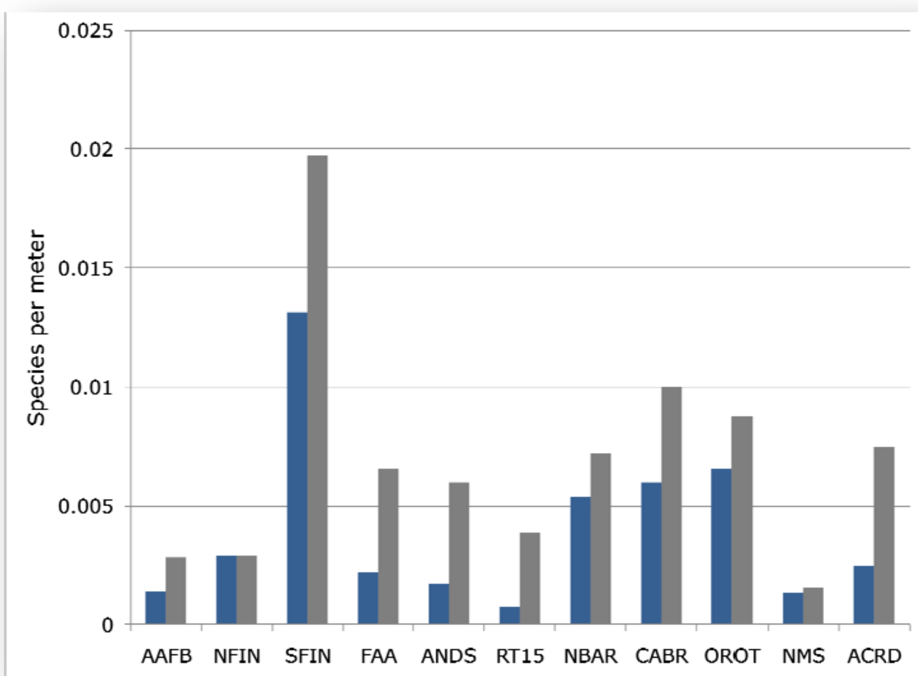

Figure 4. Number of native (blue) and non-native (grey) herpetofauna species recorded per meter at each survey location. See Table 2 for site code definitions.

3.1.2 Notable Species

Of the 15 herpetofauna species recorded during the surveys, five were native and ten non-native (Table 3). Two native skinks (moth skink and Pacific blue-tailed skink) and three native geckos (Pacific slender-toed gecko, mourning gecko, and mutilating gecko) were either captured or observed. The non-native curious skink and native Pacific blue-tailed skink were the only species observed and captured at all 11 survey locations. The house gecko and mutilating gecko were the most widespread of the geckos in the surveys, recorded at 10 and 8 of the 11 survey locations, respectively. The invasive brown treesnake was detected at seven survey locations and the marine toad at nine. An additional four amphibian species were recorded during the surveys. Gunther's Amoy frog, was observed at NMS after completion of a visual survey and while exiting the site.

Two Guam listed species were detected during the surveys: the moth skink (n = 8 individuals; Figure 5) at AAFB, NFIN, CABR, and NMS (Figure 7), and the Pacific slender-toed gecko (n = 14 individuals; Figure 6) at NFIN and NMS (Figure 7). Appendix 2 provides details associated with all moth skink and Pacific slender-toed gecko captures and observations.

Table 3. Herpetofauna detected at 11 locations during trap and visual surveys on DoD and privately-owned lands, Guam: 17 February 2008 - 21 October 2009. C = Captured; O = Observed. AAFB = Andersen Air Force Base; ANDS = Andersen South; NBAR = Barrigada; FAA = Federal Aviation Administration; NMS = Naval Munitions Site; NFIN = North Finegayan; OROT = Orote; RT15 = Route 15; SFIN = South Finegayan; CABR = Cabras; ACRD = Access Road Option A. The moth skink and Pacific slender-toed gecko (highlighted in blue) are both Guam listed species.

	Status	AAFB	NFIN	SFIN	FAA	ANDS	RT15	NBAR	CABR	OROT	NMS	ACRD
Skinks												
Snake-eyed skink	Native											
Pacific blue-tailed skink	Native	C,O	C,O	C,O	C, O	C,O	C,O	C,O	C,O	C,O	C,O	C,O
Tide-pool Skink	Native											
Slevin's skink	Native											
Azure-tailed Skink	Native											
Moth Skink	Native	C	C						C		C	
Curious skink	Non-native	C,O	C,O	C,O	C, O	C,O	C,O	C,O	C,O	C,O	C,O	C,O
Geckos												
Mourning gecko	Native		O					O		C	O	
Mutilating gecko	Native	C,O	C,O	C,O		C,O		C	C,O	C,O	C,O	
Pacific slender-toed gecko	Native		C,O								C,O	
Oceanic gecko	Native											
Micronesian gecko	Native											
House gecko	Non-native	C,O	C,O	O		C,O	C,O	O	O	O	C,O	O
Snakes												
Brown treesnake	Non-native	O	O			O	O		O	O	O	
Brahminy blind snake	Non-native	O				C						
Other												
Green anole	Non-native											
Monitor lizard	Non-native		O			C,O				O		

	Status	AAFB	NFIN	SFIN	FAA	ANDS	RT15	NBAR	CABR	OROT	NMS	ACRD
Amphibians												
Marine toad	Non-native	O	C,O	O	O	C,O	C,O		C,O		C,O	C,O
Greenhouse frog	Non-native	O			O	O	O	O				
Eastern dwarf tree	Non-native								O		O	
Crab-eating frog	Non-native										O	
Gunther's Amoy frog	Non-native										*	
Hong Kong whipping frog	Non-native							O				

* Gunther's Amoy frog observed off the transect following survey completion. Data not included in analysis.

Figure 5. Moth skink (*Lipinia noctua*) was recorded at four locations during the surveys. Photo: SWCA.

Figure 6. Pacific slender-toed gecko (*Nactus pelagicus*) was recorded at two locations during the surveys. Photo: SWCA.

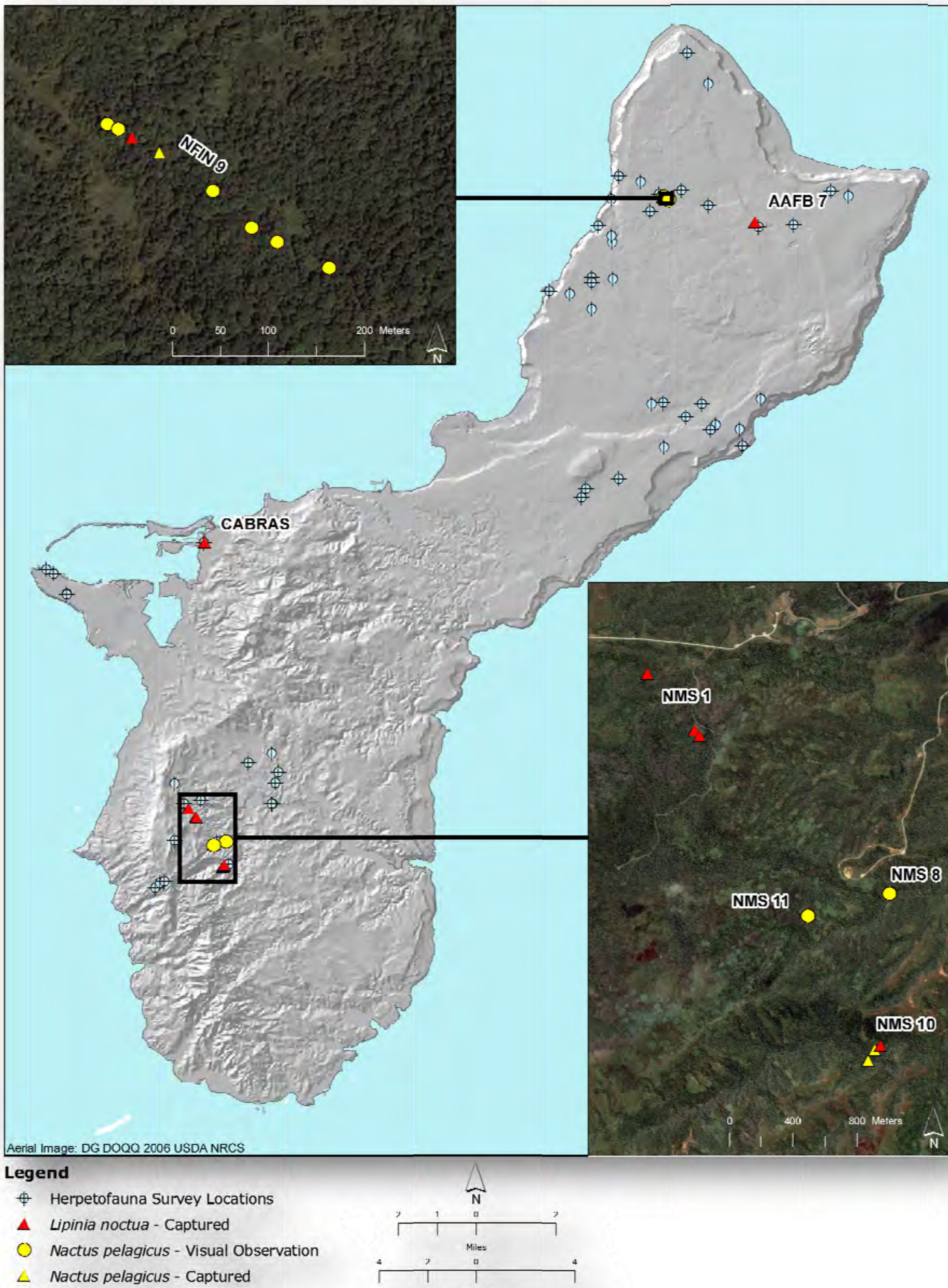

Figure 7. Herpetofauna survey locations where moth skinks (*Lipinia noctua*) and Pacific slender-toed geckos (*Nactus pelagicus*) were recorded during the surveys. See Table 2 for site code definitions.

3.2. Trap Surveys

3.2.1 Individual and Species Abundance

Ten species (*n* = 1,104 individuals) were captured during trap surveys at 11 locations. The highest number of individuals trapped was at AAFB (*n* = 227), whereas the most individuals trapped per meter was at SFIN (0.2; *n* = 31 individuals). Not only did SFIN have the highest number of individuals trapped per meter, the location also had the greatest number of species trapped per meter (0.02; *n* = 3 species). NFIN, ANDS, and NMS yielded the greatest number of species trapped (*n* = 7 at each location).

The locations with the most native herpetofauna species trapped were NFIN (*n* = 4) and NMS (*n* = 4). However, the highest number of native species trapped per meter was 0.013 (*n* = 2 individuals) at SFIN. The most non-native herpetofauna species trapped was at ANDS (*n* = 5), whereas the most non-native species captured per meter was at SFIN (0.007; *n* = 1 species).

The non-native curious skink and the native Pacific blue-tailed skink were the most frequently captured species during the surveys. These two skinks were captured at all 11 locations in high numbers (*n* = 539 curious skinks, *n* = 493 Pacific blue-tailed skinks). The most commonly trapped geckos were the native mutilating gecko (*n* = 20, captured at 8 locations) and the non-native house gecko (*n* = 21, captured at 5 locations).

Although only expected to be detected visually a monitor lizard was also caught by a glue board trap at ANDS (Figure 8). The individual had escaped between trap checks, but evidence of capture of foot scales left on the trap was recorded. It appears the monitor lizard became entangled in the trap attempting to depredate a curious skink.

A list of captured species by site can be found in Table 3.

3.2.2 Notable Species

By far the most important trap captures were those of the moth skink and Pacific slender-toed gecko. All eight moth skinks were captured on glue board traps at four sites: AAFB (*n* = 1), NFIN (*n* = 1), CABR (*n* = 1), and NMS (*n* = 5) (Table 3, Figure 7). In addition, four of the 14 Pacific slender-toed geckos detected during the surveys were trapped at two sites; NFIN (*n* = 2) and NMS (*n* = 2; Figure 7).

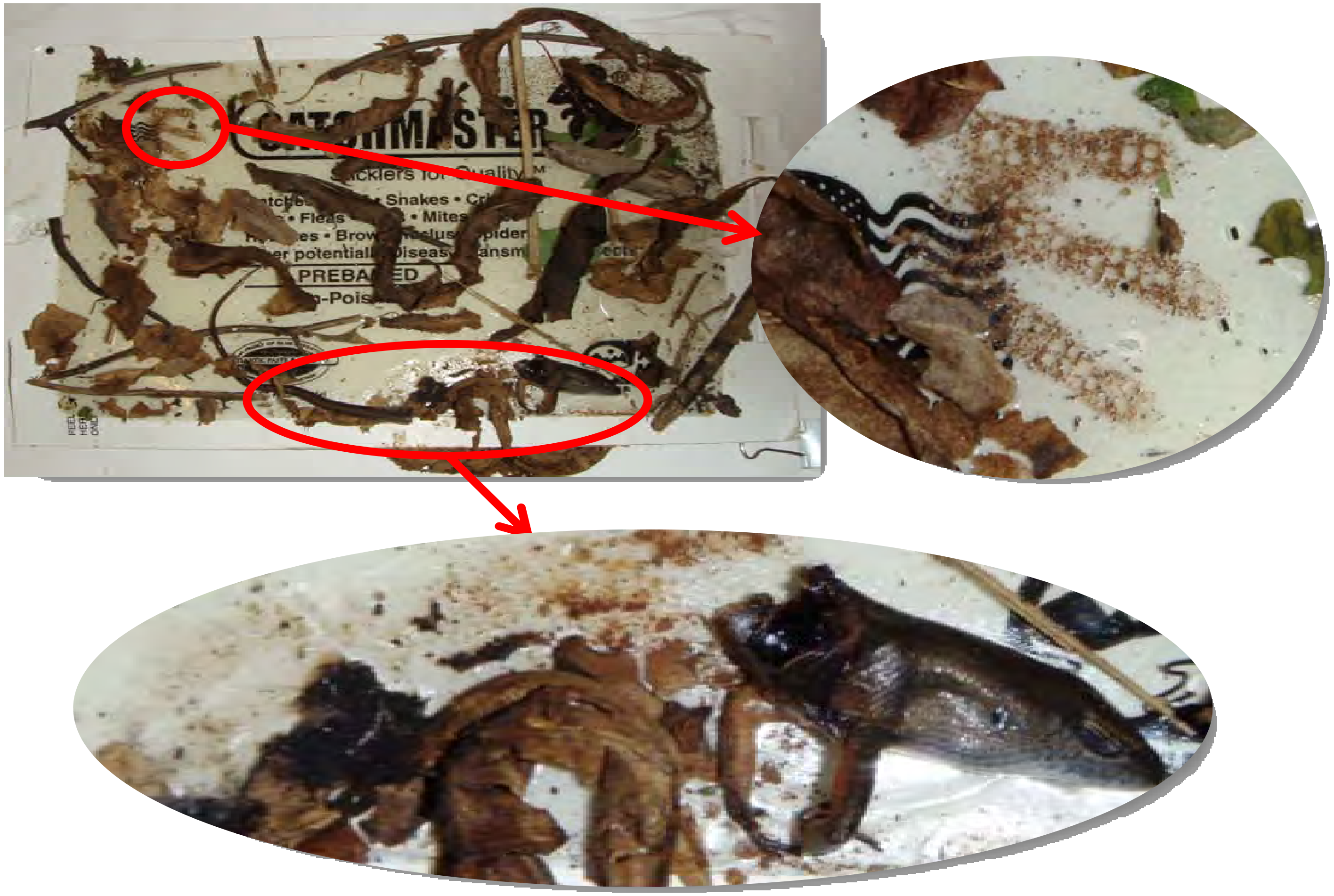

Figure 8**.** Evidence of a monitor lizard capture on a glue board on ANDS. Top circle shows monitor lizard foot scales. Lower circle shows the remains of a curious skink that appears to have been depredated by the lizard.

3.3 Visual Surveys

3.3.1 Individual and Species Abundance

A total of 1,796 herpetofauna individuals, comprising 14 species were observed during visual surveys at 11 locations (Table 3).

More individuals were observed per meter at NBAR than in any other location (0.39; *n* = 217 individuals). The most number of observed species was recorded at NMS (*n* = 10); however, the greatest number of observed species per meter was 0.03 (*n* = 5) at SFIN.

Four native species were observed during visual surveys at NFIN and NMS. However, the most native species observed per meter was at SFIN (0.013; *n* = 2 species). Six non-native species were observed at three locations: AAFB, ANDS, and NMS. Considering the area surveyed, the most non-native species observed per meter was at SFIN (0.02; *n* = 3 species).

3.3.2 Notable Species

The Pacific slender-toed gecko was observed at NFIN (*n* = 7) and NMS (*n* = 3).

The non-native curious skink and native Pacific blue-tailed skink were the most frequently observed species and sighted at all 11 survey locations. The non-native house gecko was the most commonly observed gecko; 95 individuals were visually detected at 10 sites. The native mutilating gecko was also frequently observed; 23 individuals were visually detected at seven locations.

Non-native marine toads (*n* = 9 locations) and greenhouse frogs (*n* = 5 locations) were relatively frequently observed. Both species were often observed in large numbers, particularly following rainfall. At several locations including AAFB and ANDS, greenhouse frogs were so abundant that numbers of individuals could not be determined. Other amphibians (eastern dwarf tree frog, crab-eating frog, and Hong Kong whipping frog) were also observed. A Gunther’s Amoy frog was observed on NMS after completion of a visual survey.

4.0 DISCUSSION

This survey of herpetofauna on Guam's DoD lands resulted in 16 species (including Gunther's Amoy frog, which was not recorded during the surveys); eleven non-native species and five native species. The continued widespread presence of the curious skink, marine toad, and brown treesnake, as well as five frog species recorded during this survey is distressing. This presence of non-native herpetofauna on Guam is a concern because of their deleterious impacts to Guam's native fauna by competition, as well as possibly serving as food sources for the brown treesnake (Christy et al. 2007a, b).

Native skinks and geckos not recorded during this survey include the snake-eyed skink, Slevin's skink, azure-tailed skink, tide-pool skink, oceanic gecko, and the Micronesian gecko. Nevertheless, this does not indicate these species are not present at any of the 11 localities surveyed. Seasonality (wet or dry season) and habitat type may have influenced the presence and/or absence of common, rare, and uncommon species during the surveys.

Capture of five Guam listed moth skinks at NMS, and one capture at AAFB, NFIN, and CABR are noteworthy. The official status of this native skink on Guam is unknown due to the variability of information presented by past authors. The number of moth skinks observed during this survey may have been higher if a nighttime visual survey was performed along the NMS 1 transect. However, due to safety concerns, this particular transect was only surveyed during daylight hours.

The Pacific slender-toed gecko is a rarely observed gecko that is listed on as endangered by the Government of Guam. This study provided additional records of the species at NFIN and NMS. Their presence at these sites is noteworthy and should be considered during future planning and development. When potential development projects arise at any of this study's 11 survey locations, consideration should be given to the suitability of the existing native and secondary forest not only for Guam's herpetofauna but other Guam species of concern.

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APPENDIX 1 SURVEY DATES AND LOCATIONS BY TRANSECT

Department of Defense and private lands were surveyed for herpetofauna species at 11 sites between the dates of the 17th of February 2008 and the 21st of October 2009.

Site	Transect	Search Type	Date
Andersen Air Force Base (AAFB)	1	Day Visual	11-Jun-2008
		Night Visual	10-Jun-2008
		Day Trap	11-Jun-2008
		Night Trap	11-Jun-2008
	2	Day Visual	18-Jun-2008
		Night Visual	18-Jun-2008
		Day Trap	18-Jun-2008
		Night Trap	19-Jun-2008
	3	Day Visual	18-Jun-2008
		Night Visual	18-Jun-2008
		Day Trap	18-Jun-2008
		Night Trap	19-Jun-2009
	4	Day Visual	11-Jun-2008
		Night Visual	10-Jun-2008
		Day Trap	11-Jun-2008
		Night Trap	11-Jun-2008
	5	Day Visual	12-Oct-2009
		Night Visual	14-Oct-2009
		Day Trap	14-Oct-2009
		Night Trap	15-Oct-2009
	6	Day Visual	1-Oct-2009
		Night Visual	14-Oct-2009
		Day Trap	14-Oct-2009
		Night Trap	15-Oct-2009
	7	Day Visual	12-Oct-2009
		Night Visual	14-Oct-2009
		Day Trap	14-Oct-2009
		Night Trap	15-Oct-2009
North Finegayan (NFIN)	1	Day Visual	5-Mar-08
		Night Visual	4-Mar-08
		Day Trap	8-Mar-08
		Night Trap	5-Mar-08
	2	Day Visual	5-Mar-08
		Night Visual	4-Mar-08

Site	Transect	Search Type	Date
North Finegayan (NFIN) cont.		Day Trap	8-Mar-08
		Night Trap	5-Mar-08
	3	Day Visual	9-Mar-08
		Night Visual	6-Mar-08
		Day Trap	7-Mar-08
		Night Trap	7-Mar-08
	4	Day Visual	9-Mar-08
		Night Visual	6-Mar-08
		Day Trap	7-Mar-08
		Night Trap	7-Mar-08
	5	Day Visual	5-Mar-08
		Night Visual	4-Mar-08
		Day Trap	8-Mar-08
		Night Trap	5-Mar-08
	6	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08
	7	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08
	8	Day Visual	9-Mar-08
		Night Visual	6-Mar-08
		Day Trap	7-Mar-08
		Night Trap	7-Mar-08
	9	Day Visual	21-Jul-09
		Night Visual	20-Jul-09
		Day Trap	20-Jul-09
		Night Trap	21-Jul-09
South Finegayan (SFIN)	1	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08
	2	Day Visual	13-Mar-08
		Night Visual	12-Mar-08
		Day Trap	13-Mar-08
		Night Trap	13-Mar-08

Site	Transect	Search Type	Date
Federal Aviation Administration (FAA)	1	Day Visual	21-Nov-08
		Night Visual	24-Nov-08
		Day Trap	21-Nov-08
		Night Trap	24-Nov-08
	2	Day Visual	21-Nov-08
		Night Visual	24-Nov-08
		Day Trap	21-Nov-08
		Night Trap	24-Nov-08
	3	Day Visual	18-Dec-08
		Night Visual	17-Dec-08
		Day Trap	18-Dec-08
		Night Trap	18-Dec-08
Andersen South (ANDS)	1	Day Visual	15-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	15-Apr-2008
		Night Trap	18-Apr-2008
	2	Day Visual	16-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	16-Apr-2008
		Night Trap	18-Apr-2008
	3	Day Visual	16-Apr-2008
		Night Visual	10-Jun-2008
		Day Trap	16-Apr-2008
		Night Trap	18-Apr-2008
	4	Day Visual	18-Apr-2008
		Night Visual	10-Jun-2008
		Day Trap	18-Apr-2008
		Night Trap	18-Apr-2008
	5	Day Visual	15-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	15-Apr-2008
		Night Trap	18-Apr-2008
	6	Day Visual	15-Apr-2008
		Night Visual	9-Jun-2008
		Day Trap	15-Apr-08
		Night Trap	18-Apr-08

Site	Transect	Search Type	Date
	7	Day Visual	9-Oct-09
Andersen South (ANDS) cont.		Night Visual	14-Oct-09
		Day Trap	14-Oct-09
		Night Trap	15-Oct-09
Route 15 (RT15)	1	Day Visual	19-Nov-08
		Night Visual	25-Nov-08
		Day Trap	19-Nov-08
		Night Trap	25-Nov-08
	2	Day Visual	19-Nov-08
		Night Visual	25-Nov-08
		Day Trap	19-Nov-08
		Night Trap	26-Nov-08
	3	Day Visual	2-Dec-08
		Night Visual	1-Dec-08
		Day Trap	2-Dec-08
		Night Trap	2-Dec-08
NCTS Barrigada (NBAR)	1	Day Visual	17-Feb-08
		Night Visual	18-Feb-08
		Day Trap	17-Feb-08
		Night Trap	18-Feb-08
	2	Day Visual	17-Feb-08
		Night Visual	18-Feb-08
		Day Trap	17-Feb-08
		Night Trap	18-Feb-08
	3	Day Visual	7-Oct-09
		Night Visual	20-Oct-09
		Day Trap	20-Oct-09
		Night Trap	21-Oct-09
Cabras (CABR)	1	Day Visual	24-Jun-09
		Night Visual	24-Jun-09
		Day Trap	24-Jun-09
		Night Trap	25-Jun-09
Orote (OROT)	1	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08
	2	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08

Site	Transect	Search Type	Date
Orote (OROT) cont.	3	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08
	4	Day Visual	25-Apr-08
		Night Visual	30-Apr-08
		Day Trap	25-Apr-08
		Night Trap	1-May-08
Naval Munitions Site (NMS)	1	Day Visual	1-Mar-08
		Night Visual	None
		Day Trap	22-Feb-08
		Night Trap	22-Feb-08
	2	Day Visual	23-Feb-08
		Night Visual	26-Feb-08
		Day Trap	23-Feb-08
		Night Trap	26-Feb-08
	3	Day Visual	23-Feb-08
		Night Visual	26-Feb-08
		Day Trap	23-Feb-08
		Night Trap	26-Feb-08
	4	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	21-Feb-08
		Night Trap	26-Feb-08
	5	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	21-Feb-08
		Night Trap	26-Feb-08
	6	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	20-Feb-08
		Night Trap	26-Feb-08
	7	Day Visual	21-Feb-08
		Night Visual	26-Feb-08
		Day Trap	20-Feb-08
		Night Trap	26-Feb-08
	8	Day Visual	9-Dec-08

Site	Transect	Search Type	Date
		Night Visual	8-Dec-08
Naval Munitions Site (NMS) cont.		Day Trap	9-Dec-08
		Night Trap	9-Dec-08
	9	Day Visual	11-Dec-08
		Night Visual	10-Dec-08
		Day Trap	11-Dec-08
		Night Trap	11-Dec-08
	10	Day Visual	8-Jan-09
		Night Visual	7-Jan-09
		Day Trap	7-Jan-09
		Night Trap	8-Jan-09
	11	Day Visual	9-Dec-08
		Night Visual	8-Dec-08
		Day Trap	9-Dec-08
		Night Trap	9-Dec-08
Access Road (ACRD)	ARCD-1	Day Visual	15-Jul-08
		Night Visual	14-Jul-08
		Day Trap	14-Jul-09
		Night Trap	15-Jul-09
	ARCD-2	Day Visual	15-Jul-08
		Night Visual	14-Jul-08
		Day Trap	14-Jul-09
		Night Trap	15-Jul-09
	ARCD-3	Day Visual	15-Jul-08
		Night Visual	14-Jul-08
		Day Trap	14-Jul-09
		Night Trap	15-Jul-09

APPENDIX 2 NOTABLE SPECIES DETECTION INFORMATION

Nactus pelagicus

Date	Transect	Location Easting	Location Northing	Number of individuals	Visual/Capture
12/8/2008	NMS 8	250139	1476478	2	Visual
3/30/2009	NMS 11	249630	1476337	1	Visual
7/20/2009	NFIN 9	268054	1503381	2	Visual
7/20/2009	NFIN 9	268232	1503256	1	Visual
7/20/2009	NFIN 9	268066	1503375	1	Visual
7/20/2009	NFIN 9	268165	1503310	1	Visual
7/20/2009	NFIN 9	268205	1503271	1	Visual
7/20/2009	NFIN 9	268286	1503228	1	Visual
1/8/2009	NMS 10	250051	1475481	1	Capture
1/8/2009	NMS 10	250010	1475411	1	Capture
7/21/2009	NFIN 9	268109	1503350	1	Capture
7/21/2009	NFIN 9	268054	1503381	1	Capture
			TOTAL	14	

Lipinia noctua

Date	Transect	Location Easting	Location Northing	Number of individuals	Visual/Capture
2/22/2008	NMS 1	248620	1477879	1	Capture
2/22/2008	NMS 1	248920	1477516	1	Capture
2/22/2008	NMS 1	248952	1477483	1	Capture
3/31/2009	NMS 11	249640	1476347	1	Capture
6/25/2009	Cabras	249272	1488964	1	Capture
7/20/2009	NFIN 9	268080	1503366	1	Capture
10/15/2009	AAFB 7	271845	1502281	1	Capture
1/8/2009	NMS 10	250087	1475509	1	Capture
			TOTAL	8	

APPENDIX C
Terrestrial Natural Resource Surveys

Terrestrial Natural Resources Surveys on Guam, In Support Of The Joint Guam Project Office Environmental Impact Statement. NAVFAC Pacific, Pearl Harbor, Hi. October 2009

TERRESTRIAL NATURAL RESOURCES SURVEYS ON GUAM, IN SUPPORT OF THE JOINT GUAM PROJECT OFFICE ENVIRONMENTAL IMPACT STATEMENT

Prepared by
S. Vogt, NAVFAC Pacific, Pearl Harbor, HI

October 2009

INTRODUCTION

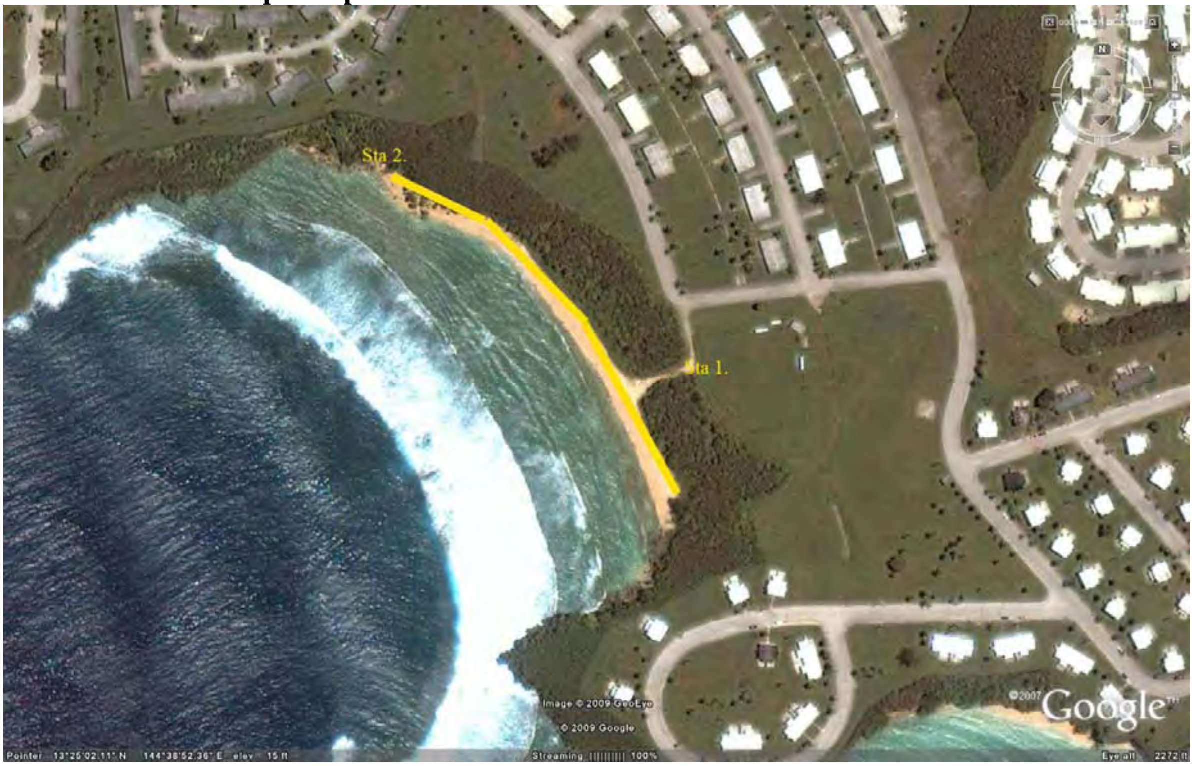
As part of the proposed transfer of U.S. Marines from Okinawa to Guam, natural resource surveys were performed in areas to be impacted as a result of this transfer. Avian, reptile, amphibian, and botanical surveys were performed in August, September, October and November, 2008.

STUDY SITES

Sites that were sampled include Dadi (Map 1) and Tipalao (Map 2) beach areas at the Naval Installation (Naval Base Guam), Air Force Barrigada (Map 3), Anderson Air Force Base (AAFB) Finegayan (Map 4), and Polaris Point (Map 5).

Map 1. Dadi beach area transects and bird count stations

Map 2. Tipalao beach area transects and bird count stations



Map 3. Air Force Barrigada transect and bird count stations

Map 4. AAFB Finegayan transects: bird count stations are on the transects

Map 5. Polaris point transect and bird count stations

METHODS

Bird Surveys

Because the sites varied in size, the avian surveys consisted of a point count survey along each transect (count stations every 100 meters [m] on the transect) and/or, depending on the site, a roadside breeding bird type survey. Surveys started between 0600 am and 0700 am and were completed by 1100 am. Due to the small size of the areas surveyed the number of stations at each site was less than 10.

For the breeding bird surveys avian identification was performed along roadside survey routes. Each survey route utilized available Base roadways in areas planned for development. Sampling locations (i.e., stops) were at ~500-m intervals. At each stop, an 8-minute point count was conducted. During the count, every bird seen within a 0.25-mile radius or heard was recorded.

Forest birds were surveyed using the variable circular plot (VCP) method (Scott et al. 1986). All birds seen or heard during an 8-minute count period at each station were recorded with the detection type (audio, visual or combined detection) and the distance to the bird when first detected, estimated to the nearest meter. Observations between stations were not recorded.

Reptile and Amphibian Surveys

Reptiles and amphibians were sampled by visual surveys on transects and adhesive, “sticky”, trapping on the same transects.

Visual surveys were performed during the morning and evening hours. Adhesive traps were placed every 15 meters on the transect up to 15 traps. One trap was placed on the ground and 1 was stapled to the nearest tree at ~breast height. Ground traps were placed between 0800 am and 0900 am and left out for 4 hours. Tree traps were placed at the same time but left over night. Tree traps were checked in the late afternoon so that lizards could be removed before nightfall.

Botanical Surveys

The goal of the vegetation surveys was to locate endangered plant species or species of concern through a visual walk over the entire transect length and a point-quarter survey. The point-quarter survey was performed, with stations every 50 m to identify to species and measure the nearest tree in each quarter greater than 2-cm diameter at breast height (dbh). At the point quarter station, the presence or absence of signs of ungulate (deer and pigs) activity within a 5-m radius around the station point was noted. Within this same 5-m radius, vegetation was counted and identified to species for tree seedlings that are smaller than 2-cm dbh. At each station ground cover was assessed with a 50 cm x 50 cm PVC square grid or quadrant frame, divided into a grid of 25 squares (use wire or string on the PVC frame), each 10 x 10 cm, providing 16 interior points where the grid lines intersected. At each station the frame was dropped in one of the cardinal directions approximately 1 meter from the station center. The types of ground cover that each intersecting gridline touched was recorded as follows: Litter (dead vegetation), rock, bare soil, and live vegetation.

RESULTS

Bird surveys

Nine bird species were documented although not all species were observed at any one site (Table 1). No threatened or endangered bird species were documented. There were not enough birds detected of any species to provide an estimate of population density or abundance.

Table 1. Bird species documented at survey sites

Species	*Dadi*	*Tipalao*	*Polaris Point*	*AAFB Finegayan*	*Air Force Barrigada*
Drongo	X	X	X	X	
Yellow Bittern			X		
White Tern		X			
Black Francolin					X
Tattler sp.		X			
Brown Noddy			X		
Eurasian Tree Sparrow	X	X		X	
Philippine Turtle Dove	X	X	X	X	X
Chicken				X	X

Reptile and Amphibian Surveys

Seven species of reptiles and one amphibian species were documented (Table 2). No federally threatened or endangered species were documented. Even though not all species were documented at all sites, it is assumed that all occur each site.

Table 2. Reptiles and amphibians documented at survey sites

Species	*Dadi*	*Tipalao*	*Polaris Point*	*AAFB Finegayan*	*Air Force Barrigada*
Carlia fusca	X	X	X	X	X
Emoia caeruleocauda	X	X	X	X	X
Hemidactylus frenatus	X	X	X	X	X
Lepidodactylus lugubrus	X	X	X	X	X
Gehyra mutilata	X		X	X	
Varanus indicus	X		X		
Boiga irregularis	X		X	X	
Bufo murinus	X		X	X	X

Botanical Surveys

See Table 3 for the tree density and mean size (diameter at breast height [DBH]) at each site. Because the floral communities between the eastern and western areas of the AAFB Finegayan parcel were markedly different they are presented separately.

Table 3. Tree density and mean size at survey sites

Site	*Number of trees per hectare (ha) and mean DBH (cm) (with 95% confidence interval)*
Dadi	5,632 trees/ha; DBH = 6.36 (4.96-7.76)
Tipalao	5,569 trees/ha; DBH = 7.16 (4.23-10>09)
Polaris Point	5,004 trees/ha; DBH = 6.12 (5.03-7.21)
Air Force Barrigada	6,309 trees/ha; DBH = 4.50 (3.85-5.15)
AAFB Finegayan West	3,695 trees/ha; DBH = 6.46 (4.85-11.31)
AAFB Finegayan East	3,183 trees/ha; DBH = 10.86 (9.11-12.61)

See Charts 1-6 for the tree species composition at each site.

Chart 1. Tree Species Composition at Tipalao Beach

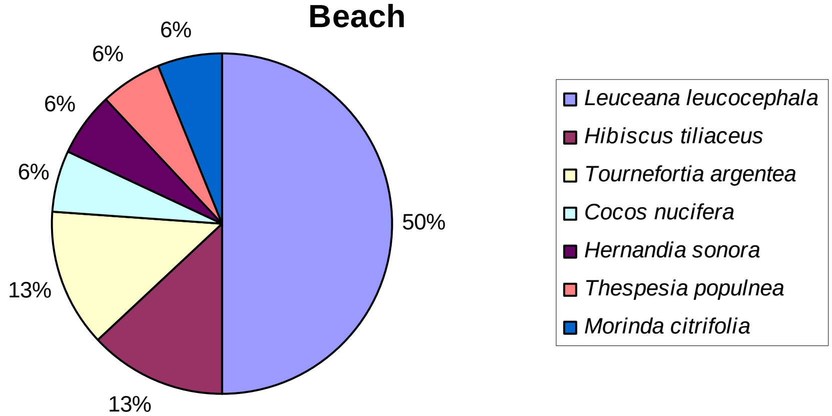


Chart 2. Tree Species Composition at Dadi Beach

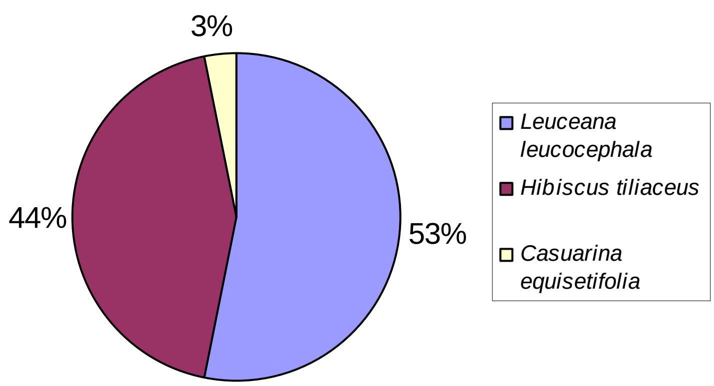


Chart 3. Tree Species Composition at Polaris Point

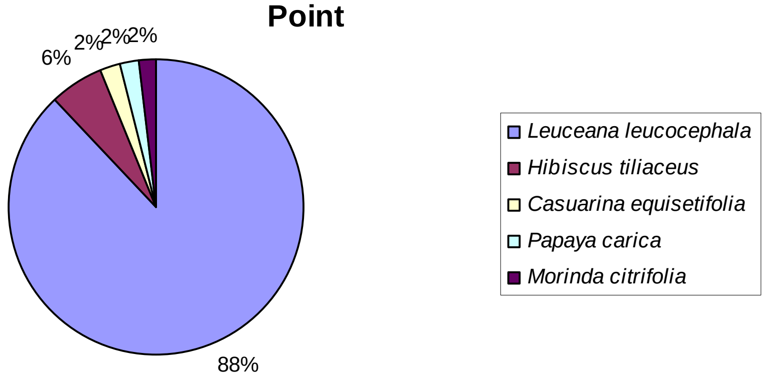


Chart 4. Tree Species Composition at Air Force Barrigada

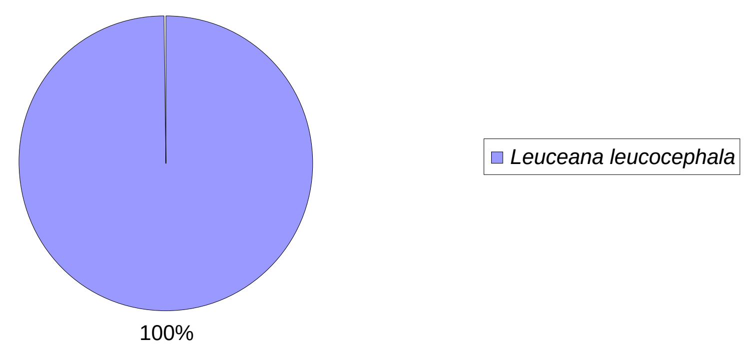


Chart 5. Tree Species Composition at AAFB Finegayan, East transect

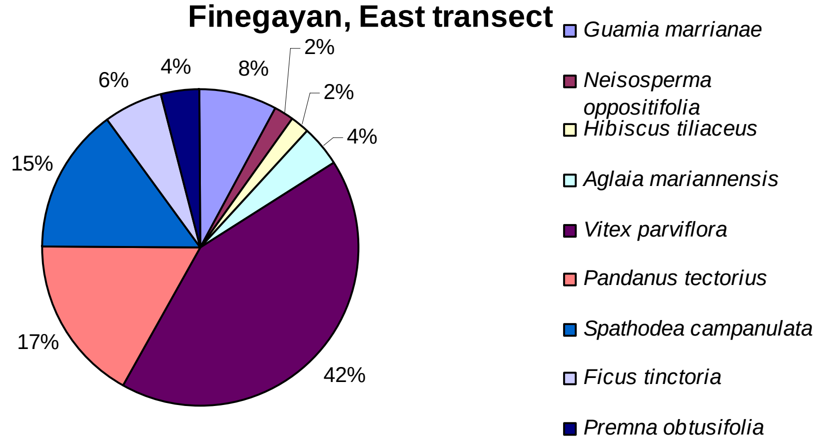
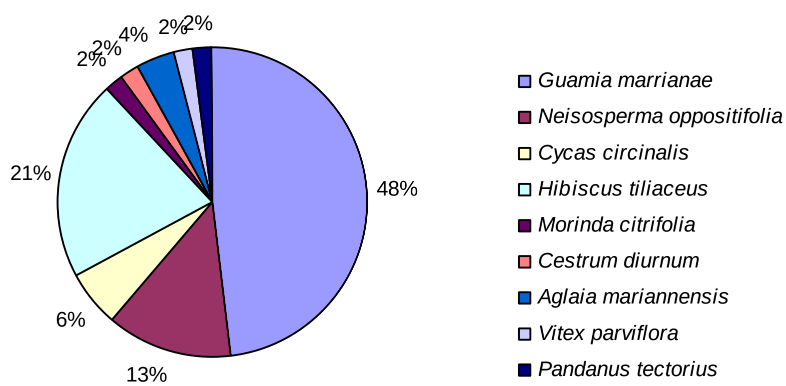


Chart 6. Tree Species Composition at AAFB Finegayan, West Transect



See Table 4 for non-woody plants documented at each site.

Table 4. Non-woody plants documented at survey sites

Site	*Non-woody species documented*
Dadi	Lilies
Tipalao	*Polypodium scolopendria*, Lilies
Polaris Point	*Sida sp., Polypodium scolopendria, Chromo odorata, Nephrolepis* sp.*, Euphorbia leterophella, Stachytarpheta urticifolia*
Air Force Barrigada	*Polypodium punctatum, Stachytarpheta urticifolia, Chromo odorata*
AAFB Finegayan West	*Piper guahamense, Polypodium punctatum , Chromo odorata, Stachytarpheta urticifolia, Chamaecrista nictitans*
AAFB Finegayan East	*Sida* sp.*, Piper guahamense, Polypodium punctatum , Chromo odorata, Chamaecrista nictitans*

Ungulate (deer or pig) sign was documented at Air Force Barrigada (deer and pig), Polaris point (pig), and both east and west AAFB Finegayan (deer and pig). AAFB Finegayan had very prominent and numerous ungulate signs.

DISCUSSION

Bird surveys

Due to the impacts of the introduced brown treesnake (*Boiga irregularis*) most of Guam's native forest birds are either extinct or extirpated. The few birds that are able to co-exist with the snake tend to be introduced or seabird/shorebirds with large size and nesting habits that preclude snake predation. The results of these surveys support this generalization.

Reptile and Amphibian Surveys

With the exception of sea turtles, the Marianas islands do not have any federally listed reptile or amphibian species. There are several locally listed species of concern and none of these were documented at the survey sites.

Botanical Surveys

No endangered plant species or species of concern were documented. Ungulate impacts were quite extensive at the AAFB site and appear to be causing fragmentation of the habitat. The western side of this parcel lacked canopy species trees and is becoming scrubby and open. The dominant tree species are native (*Guamia mariannae*, *Hibiscus tileaceus* and *Neisosperma oppisitifolia*) but are not canopy species. The eastern side of the parcel has an enclosed canopy and large trees but these are dominated by the introduced species *Vitex parviflora* and *Spathodea campanulata*. It is obvious that deer and pigs are having a pronounced effect on the habitat, preventing regeneration of many native tree species and reducing diversity.

LITERATURE CITED

Scott, J.M., S. Mountainspring, F.L. Ransey, and C.B. Kepler. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology, and conservation. Studies in Avian Biology 9.

APPENDIX D
Vegetation Surveys

Vegetation Survey of Various DoD and Non-DoD lands on Guam and M.I. Duenas, Camacho & Associates, Inc. March, 2010; and

Guam Vegetation Surveys in Support of the Military Buildup EIS at Various Locations on Guam. TEC Inc. April, 2010

VEGETATION SURVEY
OF VARIOUS DOD AND NON-DOD LANDS
GUAM, M.I.

Prepared for
AECOM and TEC Joint Venture

Prepared by
Duenas, Camacho& Associates, Inc.

June 2010

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1.0 INTRODUCTION

This vegetation survey is prepared for the U.S. Navy through a NAVFAC contract (Task Order 0016 and TO 0007 Mod 04 for Natural Resource (NR) Surveys on Guam) for AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives. The survey is intended to provide information on the terrestrial plant communities within certain Department of Defense (DOD) and non-DOD lands that are being considered in the Environmental Impact Statement (EIS) for the Marine Corps Relocation Initiative to Various Locations on Guam. The information collected will supplement the Final Natural Resources Survey and Assessment Report of Guam and Certain Islands of the Northern Mariana Islands (NAVFAC, 2007).

1.1 Study Area

Eight survey areas comprising DOD and non-DOD lands were included in the vegetation survey study area. Table 1.1-1 summarizes the acreage, total transect length, and number of transects at each site.

Table 1.1-1. Summary of Transect Lengths and Locations

Survey Area	Approximate Area (Acres)	Total Transect Length (Feet)	Number of Transects
North Finegayan	240	3,500	8
South Finegayan	418	500	2
Orote Peninsula	240	500	1
Navy Barrigada	400	1,000	2
Andersen South	2,024	4,000	6
Ordnance Annex	3,347	6,000	11
FAA Parcel	592	1,500	3
Route 15	395	4,265	3

The DOD parcels included six northern sites: North Finegayan, Navy Barrigada, South Finegayan housing area, and Andersen South housing area (Figure 1-1). Two DOD parcels were surveyed in southern Guam: Orote Peninsula and Ordnance Annex. The former Federal Aviation Administration (FAA) parcel and Route 15 parcels are non-DOD lands located in northern Guam.

2.0 MATERIALS AND METHODS

This section describes the procedures used in conducting a vegetation survey of selected terrestrial plant communities on DOD lands on Guam using Point-Center Quarter and Point Quadrat methodology (Mueller-Dombois, 1979). These procedures give descriptions of equipment and field procedures necessary to obtain qualitative and quantitative data on vegetation throughout the study area. All surveys were performed by Duenas, Camacho & Associates, Inc. and TEC, Inc. biologists.

2.1.1 Equipment and Supplies

The following equipment and resources were used in the field during the vegetation surveys:

1. Digital Camera
2. Field Notebook
3. Aerial Photographs and Maps covering the Survey Areas
4. Handheld Global Positioning System (GPS)
5. Vegetation Field Guides
6. Binoculars
7. Personal protective equipment (PPE)

2.1.2 Guidelines

Transect lines were previously identified and flagged at the initial and terminal points by others prior to the start of the field survey. Biologists walked the entire length of the transect lines and performed general and quantitative observations of the vegetation based on the methodology below. Plants were identified to species whenever possible. Vouchers of questionable specimens (e.g., non-flowering plants or seedlings) were collected when necessary.

2.1.2.1 General observations

Biologists walked each transect line observing the vegetation with the goal of locating any sensitive species, i.e., threatened or endangered plant species, or species of concern (Table 2.1-1). Upon identifying a sensitive species, the biologist would photograph the specimen and note its location relative to the nearest sampling station. The general health of the plant was noted, e.g., healthy, damaged, or infested.

2.1.2.2 Quantitative Observations

Concurrent with the general observations for sensitive species, a point-center quarter survey was performed at regular intervals along the same transect line (Mueller-Dombois and Ellenberg, 1979). The nearest tree in each quarter greater than 2 cm dbh was measured. The sampling interval was adjusted based on the size of the sampled area and transect length.

At the point-center quarter station, the presence or absence of ungulate sign (deer and pigs) was noted within a 5-meter radius around the station point. Within this same 5-meter radius, the tree seedlings smaller than 2 cm dbh were identified and tallied.

EcoSim (Acquired Intelligence, Inc.) was used to analyze the matrix of species presence × distance for each of the point-centered quarter sampling units along the different transects to generate rarefaction curves of species richness. Rarefaction curves are a useful method to compare the species richness between transects as well as to characterize overall species diversity at a site (Ludwig and Reynolds, 1988). This technique involves resampling the observed distribution of species presences from transect data and generating probabilistic species richness curves for a range of iterations. The number of iterations is equivalent to the abundance of individuals in a transect while species richness, an index of diversity, is equal to species number.

The point-center quarter station also served as a station for the point-quadrat survey. Ground cover was assessed with a 50 cm by 50 cm square quadrat frame, divided into a grid of 25 squares using string. Each 10 by 10 cm square provided 16 interior points where the grid lines intersect. At each station the frame was dropped in one of the cardinal directions approximately 1 meter from the station center. The types of ground cover that each intersecting gridline touched was recorded as follows: litter (dead vegetation), rock, bare soil, and live vegetation. The data for each station totaled 16 observations.

2.1.3 Documentation

Observations and data were recorded on data forms with the following information:

- Responsible person’s name
- Dates and times of activities
- Location description and GPS location
- General and quantitative observation data collected in the surveys
- Information (e.g., date, location) regarding each photograph
- Meteorological conditions

2.2 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat, such as ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. The conspicuous presence of ungulates is a factor in the health and status of the native vegetation. Feral pigs tread on native seedlings and tear up the understory growth, interrupting recruitment of new plants. Heavy browsing and rubbing by deer also affect the health of native plant communities. A high level of ungulate sign, is therefore, related to a more degraded and disturbed environment.

2.3 Threatened, Endangered and Sensitive Species

2.3.1.1 Sensitive Species

The *Guam Comprehensive Wildlife Conservation Strategy* was prepared by the Guam Department of Agriculture with the goal of promoting the recovery and sustainable use of Guam's native aquatic and terrestrial species, especially those of greatest conservation need. The Strategy listed 65 species recommended as Species of Greatest Conservation Need (SOGCN) for Guam. Five terrestrial plant species, all trees, were listed. These include *Heritiera longipetiolata*, *Merrilliodendron megacarpum*, *Serianthes nelsonii*, *Tabernaemontana rotensis*, and *Cycas micronesica*. The SOGCN were listed based on the following criteria:

- The status of the population of the species is not known, but the species is not extinct;
- The population of the species does not contain a self-sustained breeding population, there is no known breeding population, or is extirpated;
- The population size is considered threatened or endangered;
- A monitoring program is not in place;
- The range of the population is limited; or,
- A funded program is not in place for that species.

Guam Department of Agriculture also considers the native cycad tree, Fadang (*Cycas micronesica*) as a species of concern. Cycads are a component of native limestone and ravine forest.

2.3.1.2 Endangered Species

The U.S. Endangered Species Act (16 U.S.C. 1531-1544) of 1973, as amended, prohibits the taking of any listed species without prior approval of the Secretary of the Interior. The U.S. Fish and Wildlife Service (USFWS) lists 13 local species under the Act, including one plant, *Serianthes nelsonii*, which is listed as endangered for Guam (USFWS, 2005).

The Guam Department of Agriculture lists 31 species as endangered under the Endangered Species Act of Guam (5 GCA, Section 63205(c)). The list includes three plants: *Serianthes nelsonii* (fire tree or hayun lagu), *Cyathea lunulata* (tree fern or tsatsa), and *Heritiera longipetiolata* (looking-glass tree or ufa' halom-tano).

Table 2.1-1. Plant Species Listed as Threatened, Endangered or Species of Concern

Species	Chamorro/Common Name	Guam	Federal
Serianthes nelsonii	Hayun-lago, Fire tree	Endangered, SOGCN	Endangered
Cyathea lunulata	Tsatsa, Tree fern	Endangered	Not listed
Heritiera longipetiolata	Ufa-halomtano, Looking-glass tree	Endangered, SOGCN	Not listed
Coelogyne guamensis	Orchid	Not listed	SOC
Lycopodium phlegmaria	Disciplina	Not listed	SOC
Nervilia jacksoniae	Orchid	Not listed	SOC
Thelypteris warburgii	Fern	Not listed	SOC
Tinosperma homosepela		Not listed	SOC
Tabernaemontana rotensis		SOGCN	Not listed
Cycas micronesica	Fadang	SOGCN	Not listed
Merrilliodendron megacarpum	Faniok	SOGCN	Not listed

Key: SOC = Species of Concern; SOGCN = Species of Greatest Conservation Need

Only one plant, the fire tree (*S. nelsonii*), is protected under the U.S. Endangered Species Act. Other species listed include the five Species of Concern identified by the U.S. Fish and Wildlife Service. These and the other listed species above were noted if they were encountered during the field investigations (Table 2.1-1).

3.0 RESULTS AND DISCUSSION

This section presents the general and quantitative data collected during this survey. The following plant communities were documented in the project areas: primary limestone forest, scrub forest, ravine forest, savanna grassland, coconut grove, halophytic/xerophytic scrub, strand, and open field/weed community. Species names and distribution follow Raulerson (2006). Common and local names are taken from Stone (1970).

Primary limestone forest is considered the original forest type on the limestone plateau prior to man's habitation and disturbance. Little remains of this climax plant community on Guam because of the island's human and feral ungulate population growth and intensive urban development that has cleared much of the forest, especially in the last century. The best examples are typically in areas where extreme terrain or military controls prevent ready or easy access. The characteristic species include native breadfruit or dokdok (*Artocarpus mariannensis*), paipai (*Guamia mariannae*), mapunao (*Aglaia mariannensis*), yoga (*Eleocarpus joga*), *Pisonia* spp., *Pandanus* spp., and *Ficus* spp. Several plant associations that have been described as types or variations of limestone forest. These include the five types described by Fosberg (1960) based on the dominant species: *Artocarpus-Ficus* forest; *Mammea* forest; *Cordia* forest; *Merrioliodendon-Ficus* forest; and *Pandanus* forest.

Scrub forest is a derivative of and degraded form of primary limestone forest. It contains native and naturalized species in varying proportions and has been subjected to disturbance by feral ungulates, typhoons, and human activities. The forest is a scrubby, low-canopy community often with a tangled understory of vines (especially bejuco halomtano or *Flagellaria indica*) among the shrubs or small trees. The forest composition is variable, but *Vitex parviflora* is a particularly common, if not dominant, overstory and understory tree species.

Ravine forest is a distinct forest on volcanic soils with a shorter, shrubbier stature than limestone forest but with some overlapping species. Typical tree species include betelnut or pugua (*Areca catechu*) palms, screwpines (*Pandanus* spp.), and ilang-ilang (*Cananga odorata*).

Savanna grasslands are found over volcanic soils where forest has been cleared and replaced by homogeneous stands of swordgrass or neti (*Miscanthus floridulus*) and fields of foxtail (*Pennisetum polystachion*), *Dimeria chloridiformis*, and other low herbs and grasses. Trees such as ironwood or gagu (*Casuarina equisetifolia*) and shrubs such as nanaso (*Scaevola taccada*) are sparingly distributed in this community.

Coconut grove communities comprise nearly homogeneous monocultures of coconut (*Cocos nucifera*) palms and are found not far from sandy beaches. Other native tree species may be present, such as *Hernandia*, *Cordia subcordata*, and *Pandanus*.

The open field/weed community comprises low-stature herbaceous and shrubby vegetation of mostly introduced but naturalized species. The community arises from clearings by human or ungulates.

Halophytic/xerophytic scrub is located on limestone cliffs exposed to salt spray, and includes some components of limestone forest and strand communities. The vegetation is often stunted and gnarled from constant ocean spray and windy conditions.

Strand communities comprise the coastal vegetation on sandy beaches. The area closest to the shoreline, or forestrand, typically contains vines, such as *Ipomoea pes-caprae*, and grasses (e.g., *Thuarea involuta*) that bind the sand and may sprawl for long stretches. Other salt-tolerant plants often found in this zone are hunig (*Tournefortia argentea*), nigas (*Pemphis acidula*), and nanaso (*Scaevola taccada*). Further inland is the backstrand community, which often contains binalo (*Thespesia populnea*), kafu (*Pandanus tectorius*), gasoso (*Colubrina asiatica*), fadang (*Cycas micronesica*), coconut (*Cocos nucifera*) and nonag (*Hernandia nymphaeaefolia*).

3.1 North Finegayan

3.1.1 Location

North Finegayan comprises approximately 2,952 acres in northwestern Guam in the Municipality of Dededo. This U.S. Navy installation extends west from Route 3 to the Philippine Sea, and lies between Andersen Air Force Base and the former Federal Aviation Administration (FAA) parcel. Partial perimeter fencing encloses the base along the southern, eastern and western boundaries.

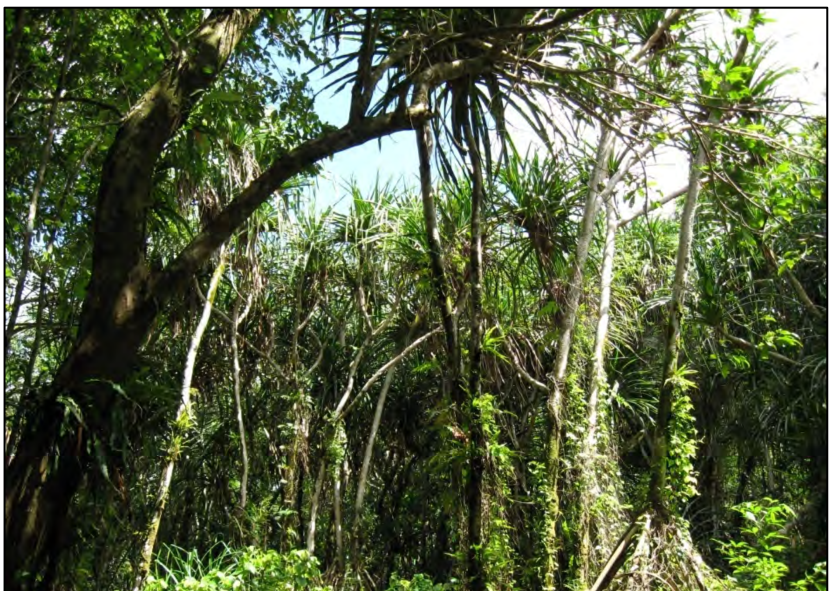


Figure 3.1-1. Limestone forest along Transect 4, upper NCTS North Finegayan.

3.1.2 Previous Studies

North Finegayan was formerly named Naval Communication Station (NCS) Finegayan, and also Naval Communications and Area Master Station (NAVCAMS) Finegayan. Previous studies of vegetation at the installation include a 1978 survey and letter report by Philip Moore (BioSystems Analysis, Inc. 1989); a plant survey conducted in conjunction with a reconnaissance of the Haputo Ecological Reserve Area (ERA) by U.S. Fish and Wildlife Service (1986); and a natural resources survey by BioSystems Analysis, Inc. (1989). The most comprehensive of these studies was performed by BioSystems Analysis, Inc. (1989), which examined 40% of the limestone forest and strand areas at Navy Finegayan and Navy Barrigada. The BioSystems survey identified four vegetation types at Navy Finegayan: limestone forest (171 acres); degraded limestone forest (1,175 acres); coastal strand (16 acres); and halophytic/xerophytic scrub (160 acres).

3.1.3 Quantitative Observations

The current quantitative survey areas at North Finegayan comprised three vegetation types: limestone forest, coconut grove, and disturbed/weed community. Limestone forest was present along six transects on the upper plateau (Transects 1 through 5, and Transect 8) (Figure 3.1-1) as well as below the cliffline along Transect 7 south of Double Reef (Figure 3.1-2). The coconut grove was sampled in Transect 6 in the Haputo ERA embayment. A disturbed/weed plant community occurred at forest edges and in patches within the forest.

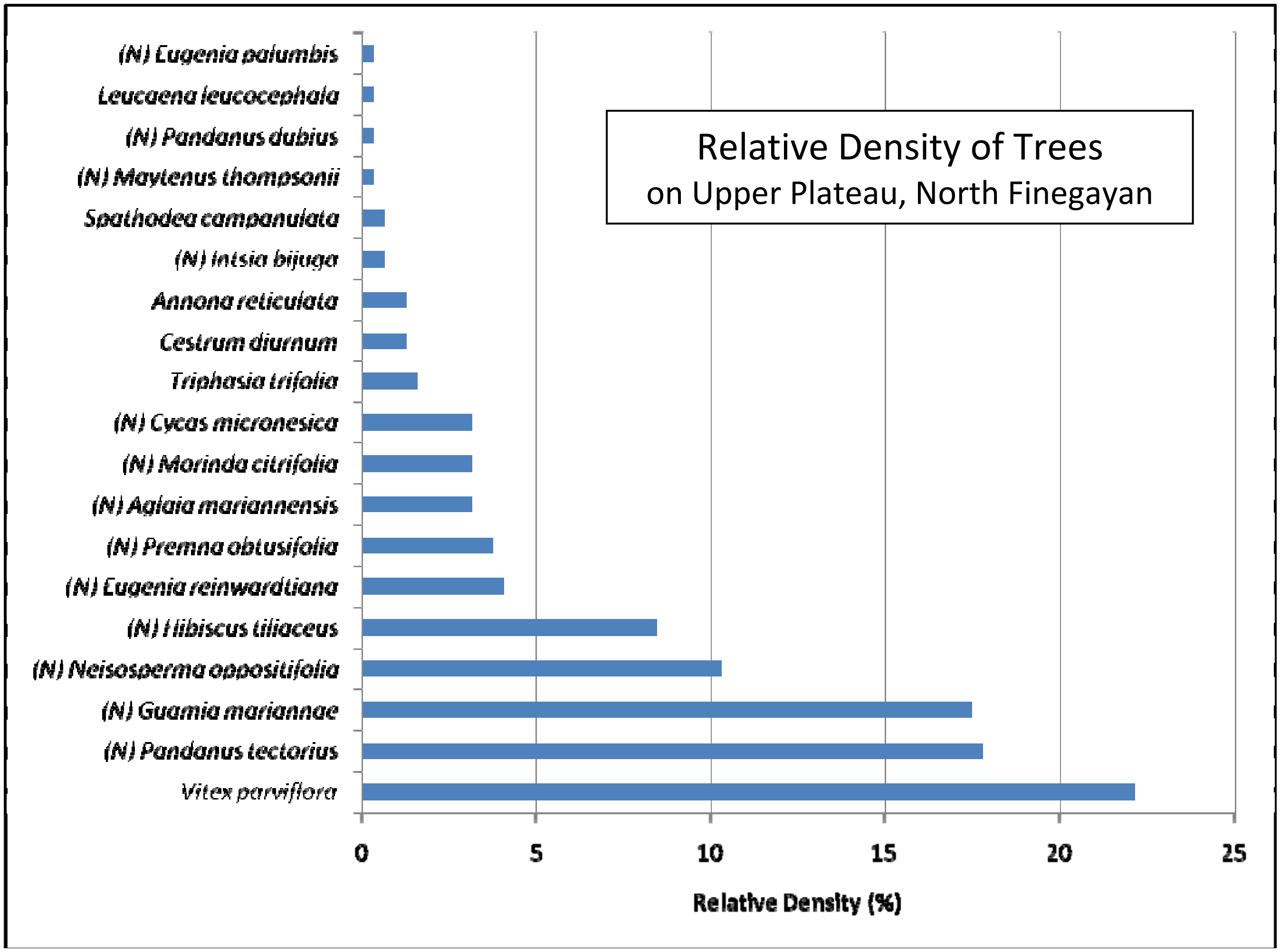
Point-center quarter surveys were performed along eight transects in the southern, northern and western sectors of North Finegayan (Figure 1 in Attachment A). Transects 1 through 5 and Transect 8 were in limestone forest. The results of these six surveys in the upper plateau of North Finegayan are summarized in Table 3.1-1. Thirteen or approximately 68% of the 19 species encountered on these transects were native trees. It is notable that *Vitex parviflora*, an introduced species, is a dominant component of these forests in terms of basal area, absolute dominance and frequency. The relative density of species among these six transects is presented in Figure 3.1-3. *Vitex* had the highest relative density (about 22%), followed by native kafu or screwpine (*Pandanus tectorius*) and endemic paipai (*Guamia mariannae*) trees with densities of about 17% each. *Vitex* is a Philippine species that was introduced to Guam prior to 1970 (Stone, 1970), and has since become a common component of its forests (Donnegan et al., 2004). *Guamia* is typically an understory tree.

Figure 3.1-2. Limestone forest with *Merrilliodendron megacarpum* and *Piper guahamense* along Transect 7, lower NCTS North Finegayan.

Table 3.1-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
NF-1, NF-2, NF-3, NF-4, NF-5, NF-8 NORTH FINEGAYAN, FEB. 2008

SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Neisosperma oppositifolia	N	33	1.92	41750.80	1265.18	2428.42	30
Pandanus tectorius	N	57	3.32	14921.03	261.77	867.88	46.25
Eugenia reinwardtiana	N	13	0.76	2798.18	215.24	162.76	12.5
Guamia mariannae	N	56	3.26	8120.10	145.00	472.30	40
Vitex parviflora	I	71	4.13	103353.93	1455.69	6011.53	47.5
Hibiscus tiliaceus	N	27	1.57	3947.59	146.21	229.61	20
Aglaia mariannensis	N	10	0.58	3428.86	342.89	199.44	11.25
Premna obtusifolia	N	12	0.70	9604.84	800.40	558.66	13.75
Triphasia trifolia	I	5	0.29	190.66	38.13	11.09	5
Morinda citrifolia	N	10	0.58	282.82	28.28	16.45	8.75
Cestrum diurnum	I	4	0.23	651.76	162.94	37.91	5
Leucaena leucocephala	I	1	0.06	41.83	41.83	2.43	1.25
Eugenia palumbis	N	1	0.06	5.72	5.72	0.33	1.25
Intsia bijuga	N	2	0.12	473.53	236.76	27.54	2.5
Maytenus thompsonii	N	1	0.06	29.21	29.21	1.70	1.25
Spathodea campanulata	I	2	0.12	326.76	163.38	19.01	2.5
Annona reticulata	I	4	0.23	153.43	38.36	8.92	2.5
Cycas micronesica	N	10	0.58	5590.11	559.01	325.15	6.25
Pandanus dubius	N	1	0.06	122.66	122.66	7.13	1.25



Note: (N) indicates native species; others are introduced.

Figure 3.1-3. Relative density of tree species in Transects 1 to 5 and Transect 8, North Finegayan.

The limestone forest along Transect 7 in lower North Finegayan is a distinctive community comprising a stand of faniok (*Merrilliodendron megacarpum*) trees that provide habitat for the Pacific tree snail (*Partula radiolata*). The forest is situated close to sea level along the base of an escarpment and overlies karst limestone substrate. From north to south, the site transitions from faniok-dominated forest to a more mixed community.

Native species comprised nearly three-quarters of the relative density of tree species among the six transects in the limestone forest at upper North Finegayan (Figure 3.1-4).

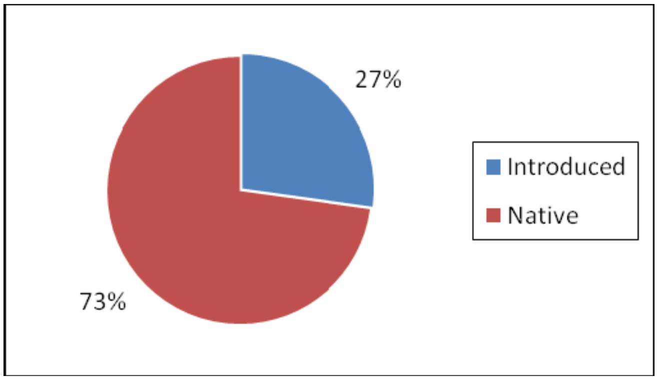
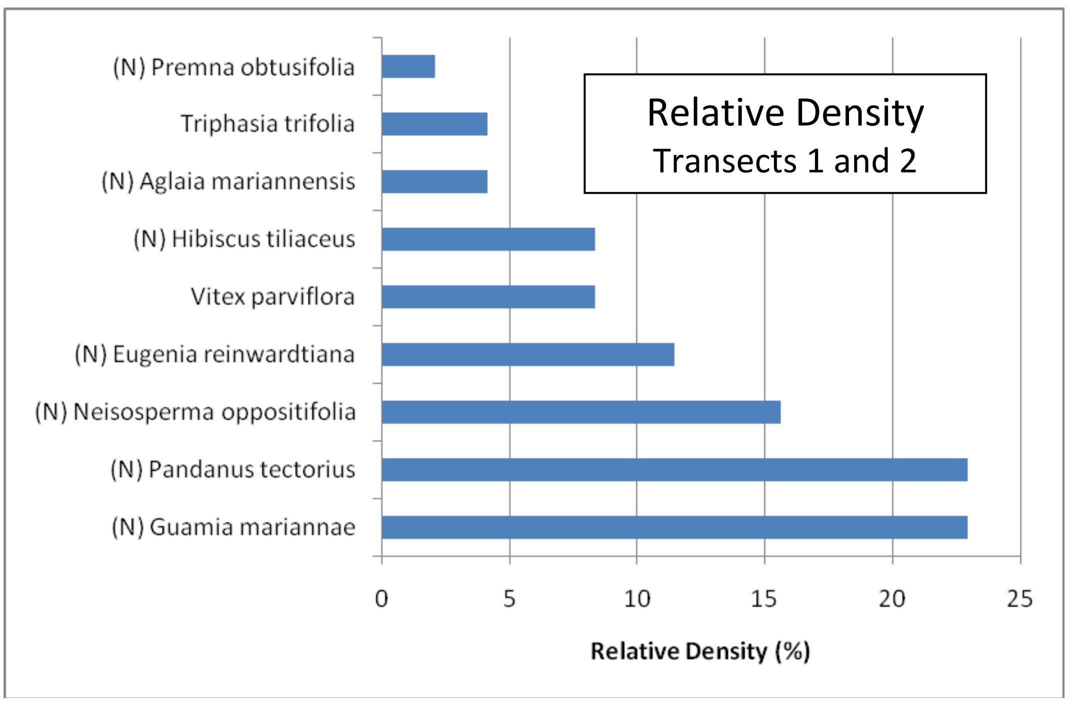


Figure 3.1-4. Relative density of native tree species in Transects 1 to 5 and Transect 8, North Finegayan.

In the forests of the southern sector (Transects 1 and 2), the three species with the highest relative densities were *Guamia mariannae*, *Pandanus tectorius*, and *Neisosperma oppositifolia*, which collectively accounted for 62% of the overall density (Figure 3.1-5). Native species had a combined density of 87%; two of these species, *Guamia* and *Aglaia*, are endemic to the Mariana Islands, and had a combined density of 27%. The non-native element comprised *Triphasia trifolia* and *Vitex parviflora* with a combined density of 13%.

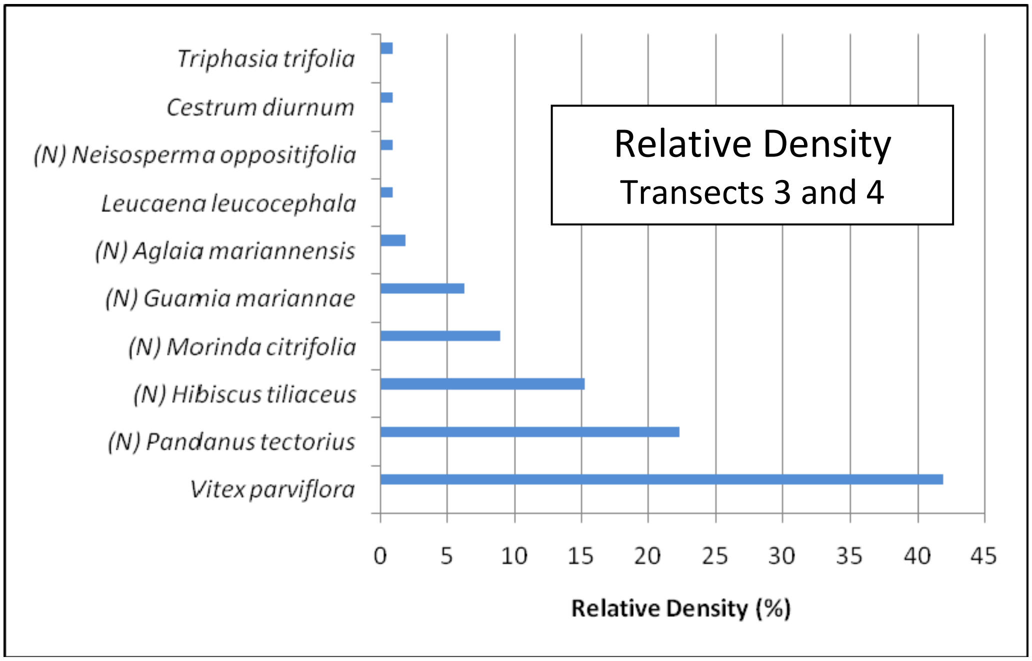


Note: (N) indicates native species; others are introduced.

Figure 3.1-5. Relative density (%) of trees in southern sector at North Finegayan.

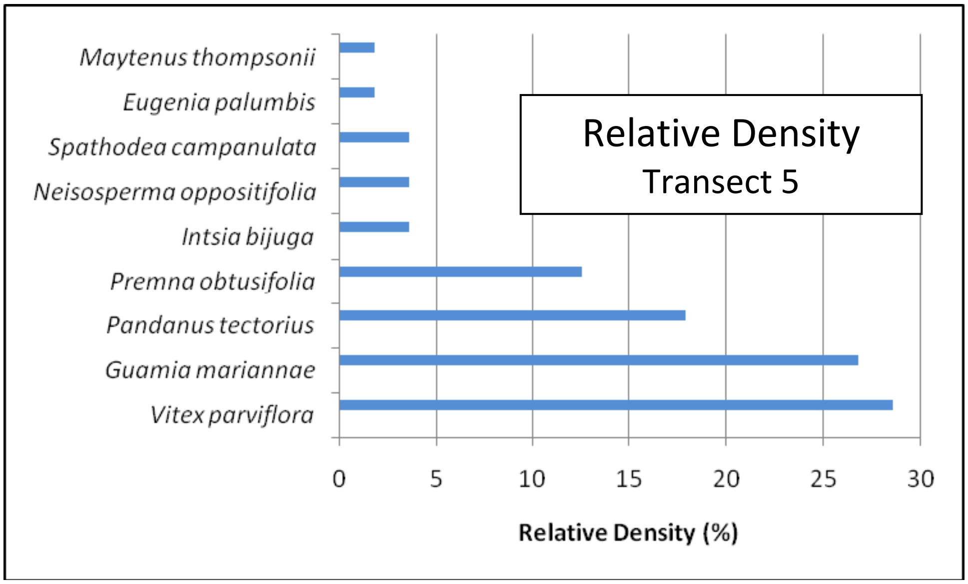
Non-native species (*Vitex*, *Cestrum*, and *Triphasia*) accounted for 45% of the relative density (Figure 3.1-6) in the limestone forest of the north-central sector of North Finegayan (Transects 3 and 4). Native species comprised slightly more than half of the overall density; however, endemic species (*Guamia* and *Aglaia*) accounted for only 8% of the relative density.

The limestone forest in the northeastern sector of North Finegayan (Transect 5) contained similar relative densities of the introduced *Vitex* and the endemic *Guamia* trees. *Vitex parviflora* and African tulip (*Spathodea campanulata*) trees comprised the non-native species, with a combined relative density of about 32% (Figure 3.1-7). The three endemic species (*Guamia*, *Eugenia palumbis*, and *Maytenus thompsonii*) comprise about 30% of the relative density.



Note: (N) indicates native species; others are introduced.

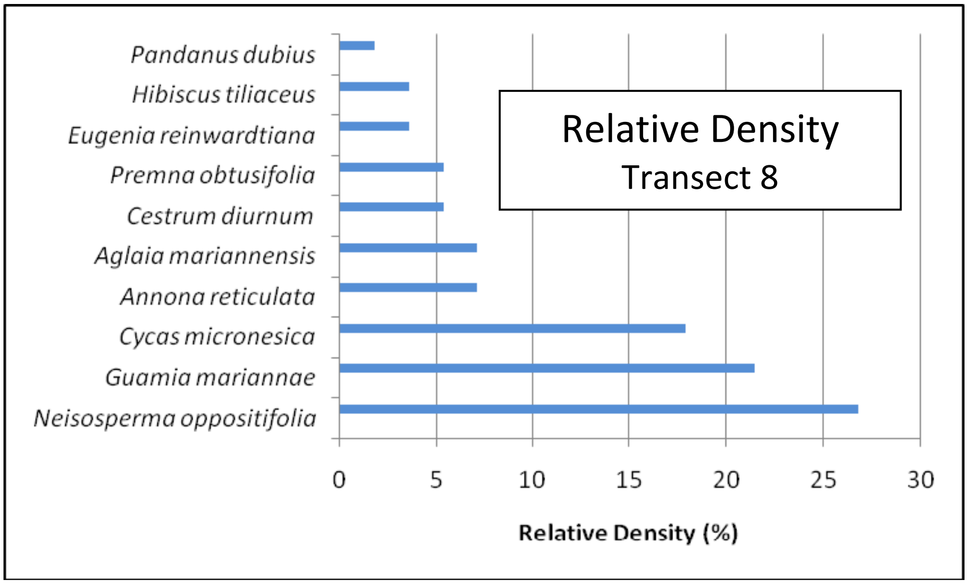
Figure 3.1-6. Relative density (%) of trees in north-central sector at North Finegayan.



Note: (N) indicates native species; others are introduced.

Figure 3.1-7. Relative density (%) of trees in northeastern sector at North Finegayan.

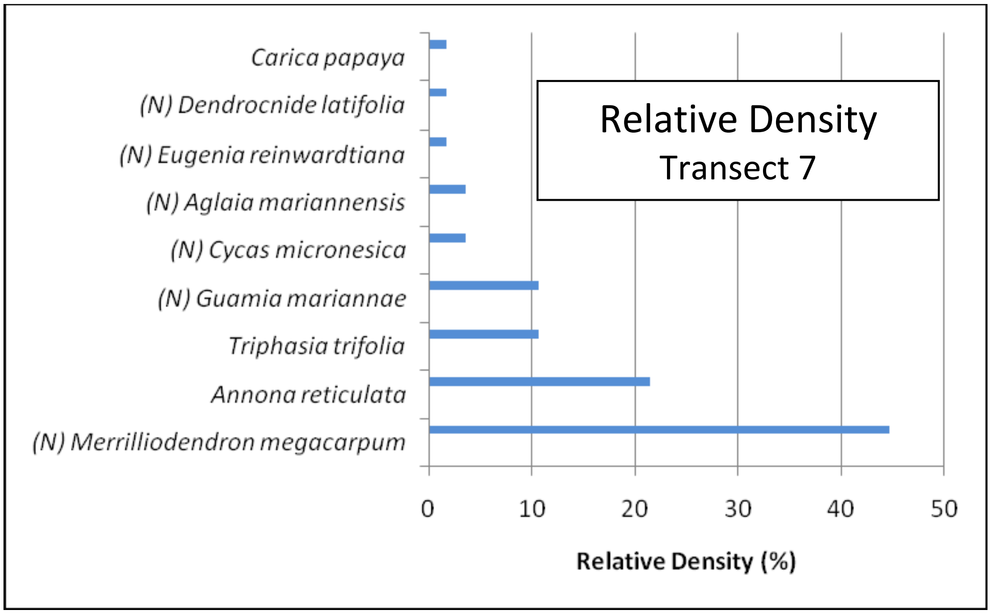
The northwestern sector of North Finegayan contains limestone forest along the western coast and upper plateau with the highest relative density (66%) of native tree species among the areas sampled (Figure 3.1-8). The two non-native species, *Annona squamosa* and *Cestrum diurnum*, comprised 12% of the relative density, while the endemic species, *Guamia* and *Aglaia*, comprised 28%. The forest in this area also had the highest relative density of native cycad trees (*Cycas micronesica*), with approximately 18%.



Note: (N) indicates native species; others are introduced.

Figure 3.1-8. Relative density (%) of trees in northwestern sector at North Finegayan.

The west-central sector of North Finegayan in the vicinity of Pugua Point (Transect 7) contains limestone forest with a native species density of 66% and a pronounced *Merrilliodendron megacarpum* component (Figure 3.1-9). *Merriolliodendron* is an indigenous species found in only a few localities on Guam because of its restricted habit. Non-native species comprised 34% of the relative density; *Annona*, *Triphasia*, and *Carica* are successful introductions that have long been naturalized in native forests. Endemic species (*Guamia* and *Aglaia*) accounted for 14% of the relative density. The native cycad, *Cycas micronesica*, had a low density of only 3%.



Note: (N) indicates native species; others are introduced.

Figure 3.1-9. Relative density (%) of trees in northwestern sector at North Finegayan.

The final area sampled in the North Finegayan annex was a coconut (*Cocos nucifera*) grove in the Haputo ERA embayment along the western coast (Figure 3.1-10). The area is located close to sea level below the limestone plateau of the main annex. Nonag (*Hernandia peltata*), an indigenous tree, had a relative density of about 22%; coconut palms comprised the remainder of the trees along this transect.

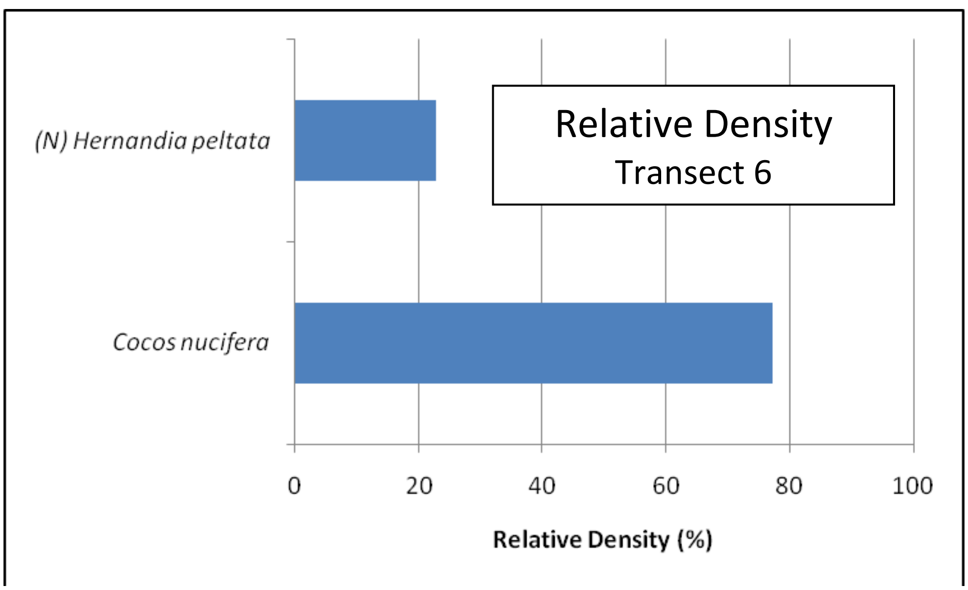


Figure 3.1-10. Relative density (%) of trees in southwestern sector at North Finegayan.

The percentage of native woody seedlings quantified along the transects exceeded 80% for Transects 4 and 8 in the northern and northwestern sectors on the upper plateau, and Transect 7 along the west-central coast (Figure 3.1-11). Elsewhere, the percentage was less than 60% native woody seedlings.

The mean woody seedling density for all transects at North Finegayan was slightly higher for native species (1.71 seedlings per SM) than for introduced species (1.12 seedlings per SM) (Figure 3.1-12).

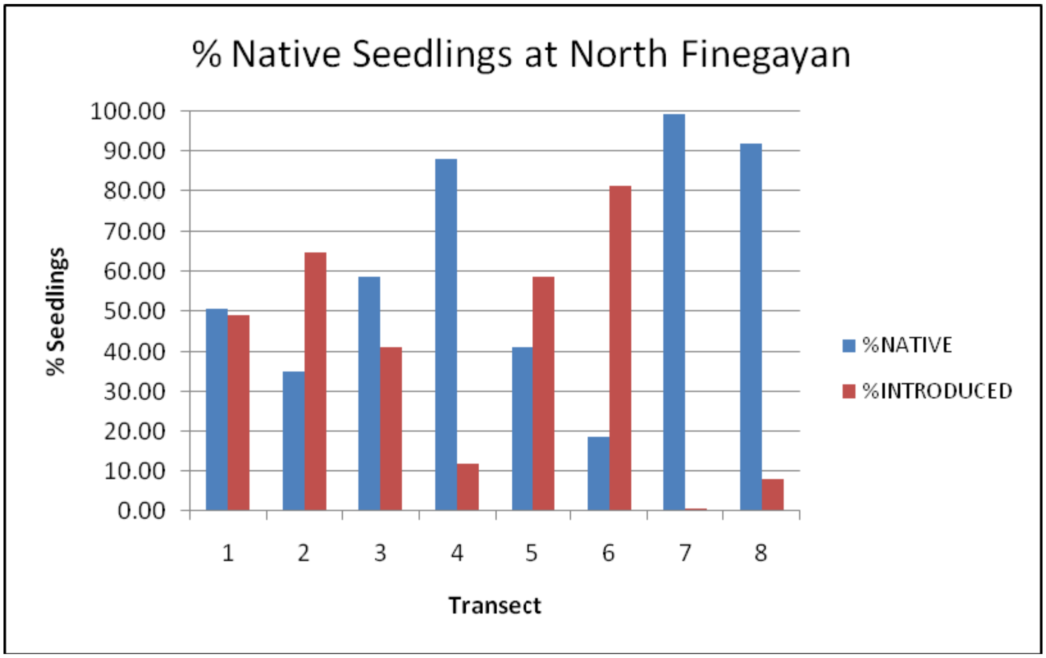


Figure 3.1-11. Native woody seedlings along all transects at North Finegayan.

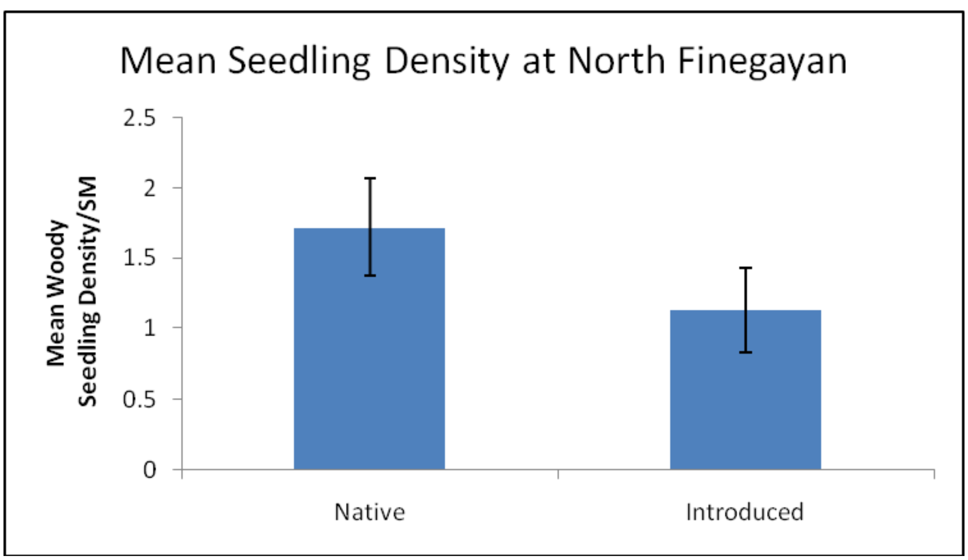


Figure 3.1-12. Mean density of woody seedlings along all transects at North Finegayan.

3.1.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at North Finegayan. These include the ungulate activity, presence of erosion, the percent of native plant species, and overall species richness.

The species richness for tree species across all transects was calculated with a 95% confidence interval and is presented in Figure 3.1-13. Species richness for all transects at North Finegayan was 24 species (Figure 3.1-13).

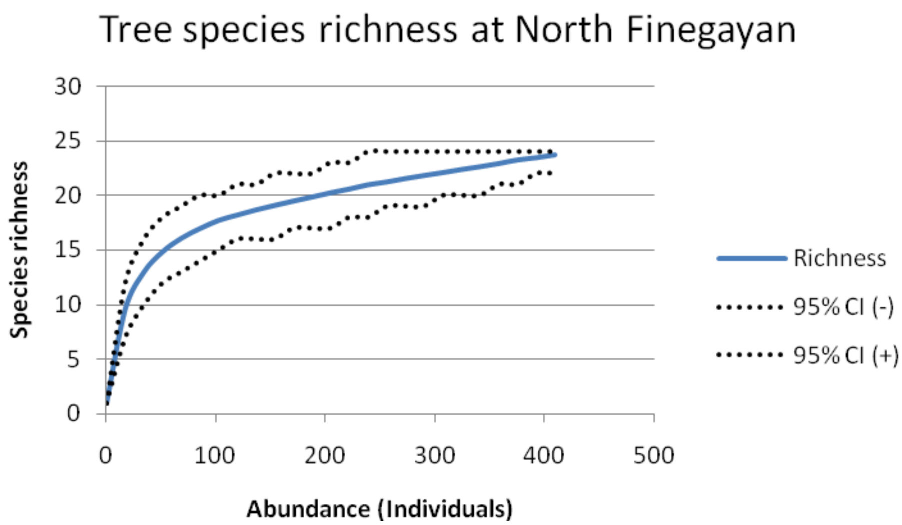


Figure 3.1-13. Species richness of trees along all transects at North Finegayan.

Analysis of individual transects revealed significantly lower species richness in the coconut grove of Transect 6 compared to all other sites (Figure 3.1-14; 95% confidence intervals not shown). This transect was in the lower plateau and lacked many of the woody species observed in the remaining seven transects. Similar species richness values were observed for Transect 5 in the northeastern sector, and Transect 8 in the northwestern sector, which are both on the upper plateau.

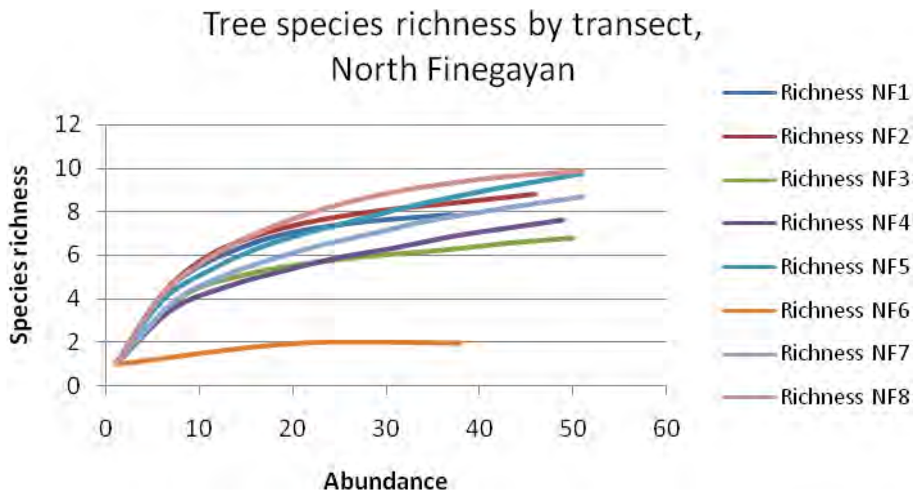


Figure 3.1-14. Species richness of trees along each transect at North Finegayan.

Ungulate activity was observed most frequently in the form of rubbings on tree trunks and browsing (Figure 3.1-15). Soil disturbance, such as wallows, was less frequently observed at North Finegayan.

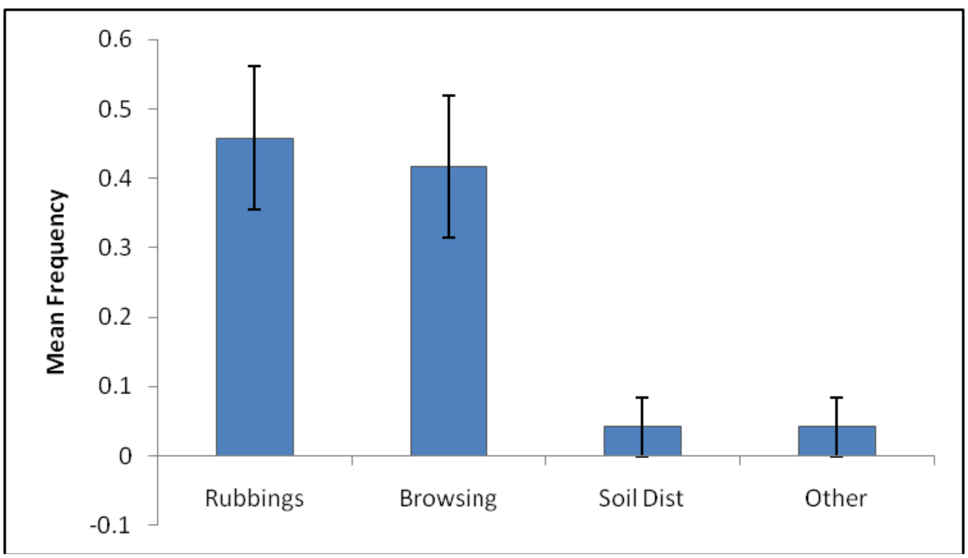


Figure 3.1-15. Mean frequency of ungulate activity along all transects at North Finegayan.

The ground cover along all transects at North Finegayan showed a high mean frequency of litter and relatively low mean frequencies of bare soil and rock (Figure 3.1-16).

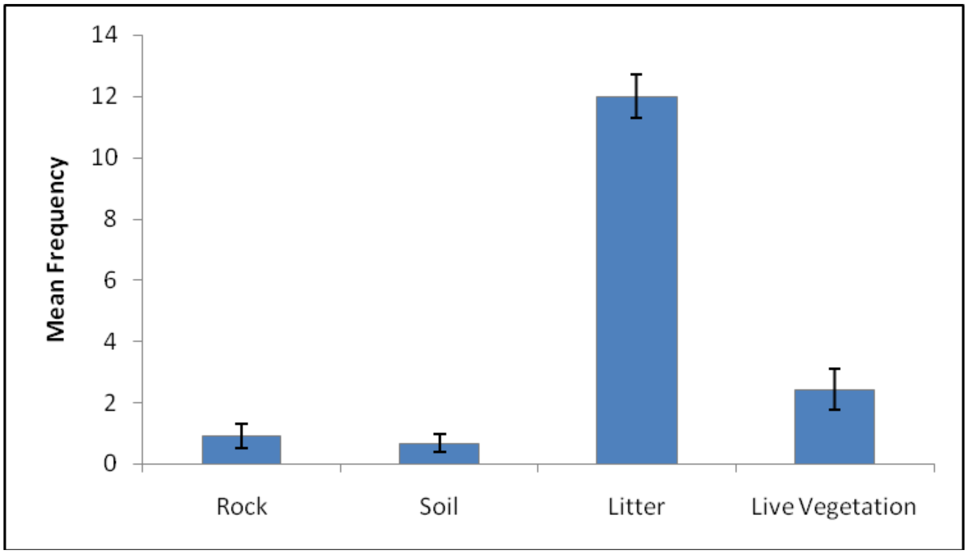


Figure 3.1-16. Mean frequency of ground cover along all transects at North Finegayan.

An example of the type of ungulate disturbance observed at North Finegayan is shown in Figure 3.1-17. Ungulates, most likely feral pigs, have toppled a fadang (*Cycas micronesica*) specimen, possibly to feed on the pith material in the trunk.

Figure 3.1-17. Ungulate damage to *Cycas micronesica*, Transect 8, North Finegayan.

3.1.5 Sensitive Species

3.1.5.1 Threatened and Endangered Species

None of the locally-listed or federally-listed endangered plants (see Table 2.2-1) were detected during the current survey in North Finegayan. BioSystems Analysis, Inc. (1989) did not detect *Heritiera longipetiolata* in their natural resources survey of Navy Finegayan, but noted that it is known to occur in the Haputo ERA.

The Haputo ERA provides habitat for the Pacific tree snail (*Partula radiolata*) and the last remaining colony of Mariana tree snails (*Partula gibba*) on Guam. These species are among the endemic tree snails locally-listed as threatened (*Partula radiolata*) or endangered (*Partula gibba*), and federally-listed as candidate species.

3.1.5.2 Species of Concern

Species of concern are those plants that have biological or cultural significance as determined by recognized authorities or regulatory agencies. The Guam Department of Agriculture/ Division of Aquatic and Wildlife Resources currently lists five plants among the Species of Greatest Conservation Need (SOGCN) for the island, based on certain criteria (see Table 2.2-1). Two SOGCN were observed at North Finegayan during the current survey: faniok (*Merrilliodendron megacarpum*) and fadang (*Cycas micronesica*). According to the *Guam Comprehensive Wildlife Conservation Strategy*, faniok is threatened by herbivory, typhoons, and development (Department of Agriculture, 2006). A faniok stand is present along Transect 7 close to sea level in the west-central sector of the installation. Fadang is typically distributed over limestone and volcanic substrates; however, populations islandwide are in decline from infestation by the Asian cycad scale (*Aulacaspis yasumatsui*) (Department of Agriculture, 2006). Fadang was quantified only on Transect 7 in the west-central sector, and Transect 8 in the northwestern sector of the upper plateau. These areas also had the most native tree species among those surveyed.

At North Finegayan, BioSystems Analysis, Inc. (1989) identified the following species of interest, which are rare or unusual but not subject to regulatory control or management at this time.

- *Balanophora indica* or chili-n-duendas is an endemic herb that is parasitic on the roots of autotrophic forest trees, such as *Cynometra* and *Guamia* (Stone, 1970).
- *Lycopodium phlegmaria*, or cordon de San Francisco, is an epiphytic club moss found in moist limestone forest sites at Finegayan.
- *Thelypteris truncata* is an indigenous fern of the Haputo ERA area.
- *Bulbophyllum longiflorum* is an indigenous orchid of the forest above Haputo ERA.
- *Geophila repens*, or tamanes-hating, is a native herb that has only been found at Haputo.
- *Merrilliodendron megacarpum*, or faniok, is an indigenous tree that occurs as a small stand south of Double Reef.

Of these, only *Merrilliodendron* was detected in the current survey.

The following species were identified within North Finegayan during the present survey.

- *Zeuxine fritzii* is an indigenous ground orchid found on the forest floor of Transects 3 and 5.
- *Nervilia aragoana* is an indigenous ground orchid found on the forest floor of Transects 3 and 5.

Although notable, these species are not subject to management controls or regulations on Guam.

3.2 South Finegayan

3.2.1 Location

South Finegyan is located adjacent and south of the Federal Aviation Administration (FAA) parcel, and east of the Guam Land Use Plan (GLUP) 77 parcel in northwestern Guam. The installation extends along Route 3 in Dededo. The land use is primarily residential.

3.2.2 Previous Studies

The previous vegetation studies at North Finegayan discussed under Section 3.1.2. did not encompass South Finegayan.

3.2.3 Quantitative Observations

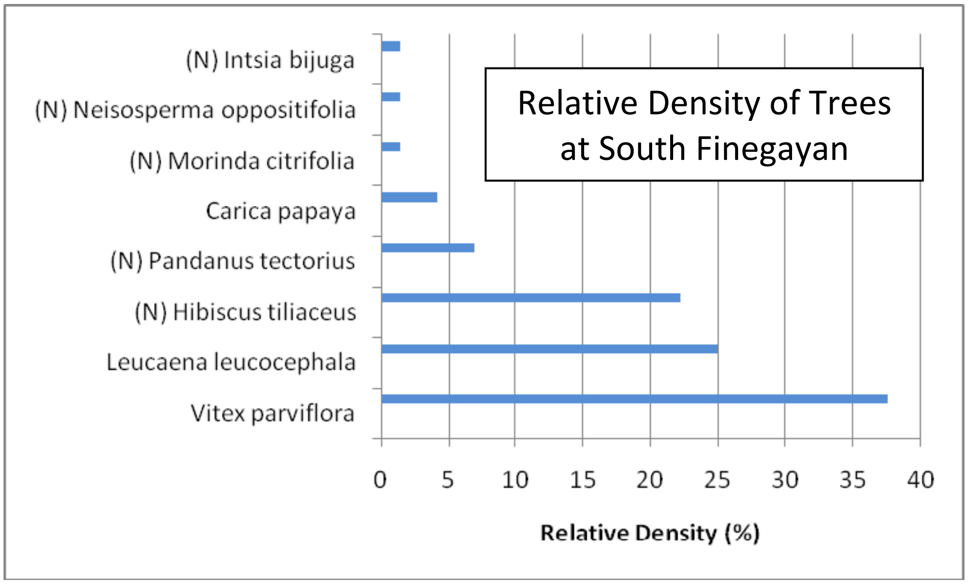
Surveys were performed along two transects in the central sector of South Finegayan (see Attachment A). The vegetation community is a disturbed limestone forest dominated by *Vitex parviflora*, tangantangan (*Leucaena leucocephala*) and pago (*Hibiscus tiliaceus*). The results of point-center quarter surveys are summarized in Table 3.2-1.

The relative density of tree species in South Finegyan (Figure 3.2-1) show the non-native *Vitex*, tangantangan (*Leucaena leucocephala*) and papaya (*Carica papaya*) comprised 67%. The remaining five native species comprised 33% of the density; none are endemic to the Marianas.

Table 3.2-1

SF-1 and SF-2, SOUTH FINEGAYAN, March 2008

SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Leucaena leucocephala	I	18	5.19	#VALUE!	44.50	230.93	50.00
Hibiscus tiliaceus	N	16	4.61	#VALUE!	77.39	356.97	38.89
Vitex parviflora	I	27	7.78	#VALUE!	361.34	2812.42	72.22
Pandanus tectorius	N	5	1.44	#VALUE!	52.54	75.73	22.22
Morinda citrifolia	N	1	0.29	#VALUE!	3.80	1.10	5.56
Neisosperma oppositifolia	N	1	0.29	#VALUE!	86.55	24.95	5.56
Carica papaya	I	3	0.86	#VALUE!	138.14	119.47	16.67
Intsia bijuga	N	1	0.29	#VALUE!	41.83	12.06	5.56



Note: (N) indicates native species; others are introduced.

Figure 3.2-1. Relative density (%) of trees at South Finegayan.

The density of trees in South Finegayan was approximately 21 trees per 100 SM, or 2,100 trees per hectare (Table 3.2-1). *Vitex parviflora* had the highest density (7.78 trees per 100 SM) and dominance among the trees surveyed. Five of the eight tree species (63%) surveyed are native to Guam. These include *Hibiscus tiliaceus*, *Pandanus tectorius*, *Morinda citrifolia*, *Neisosperma oppositifolia*, and *Intsia bijuga*.

The relative density of native trees was 33% for both transects at South Finegayan (Figure 3.2-2). The low native tree component may be attributed to past clearing activities at the site, which is adjacent to a fenced area enclosing what appears to be a hazardous waste remediation site.

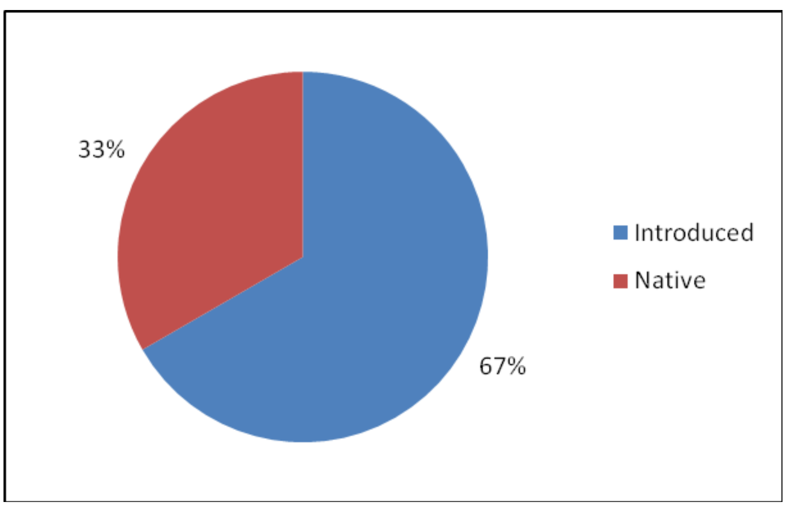


Figure 3.2-2. Relative density of native tree species at South Finegayan.

The mean woody seedling density at South Finegayan was lower for native species (1.46 seedlings per SM) than for introduced species (4.06 seedlings per SM) (Figure 3.2-3).

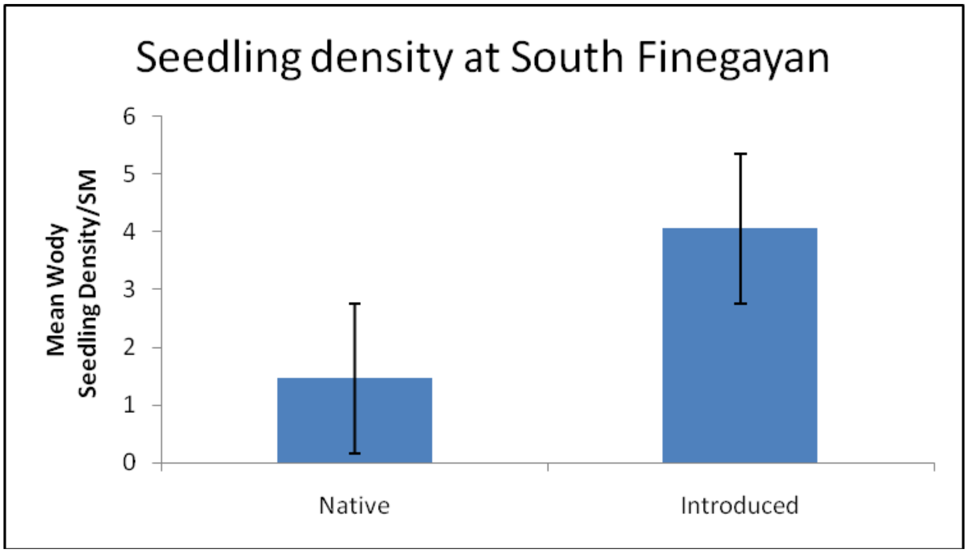


Figure 3.2-3. Seedling density of woody species at South Finegayan.

3.2.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at South Finegayan. These include the ungulate activity, presence of erosion, the percent of native plant species, and overall species richness. The species richness for tree species at South Finegayan is presented in Figure 3.2-4.

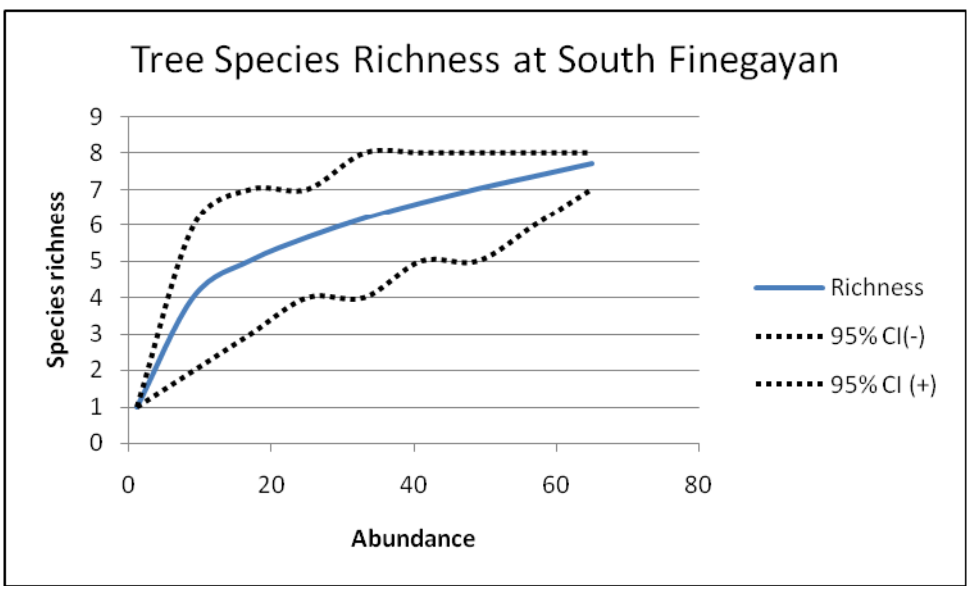


Figure 3.2-4. Species richness of trees at South Finegayan.

The ungulate activity at South Finegayan fell into two categories: rubbings and soil disturbance (Figure 3.2-5).

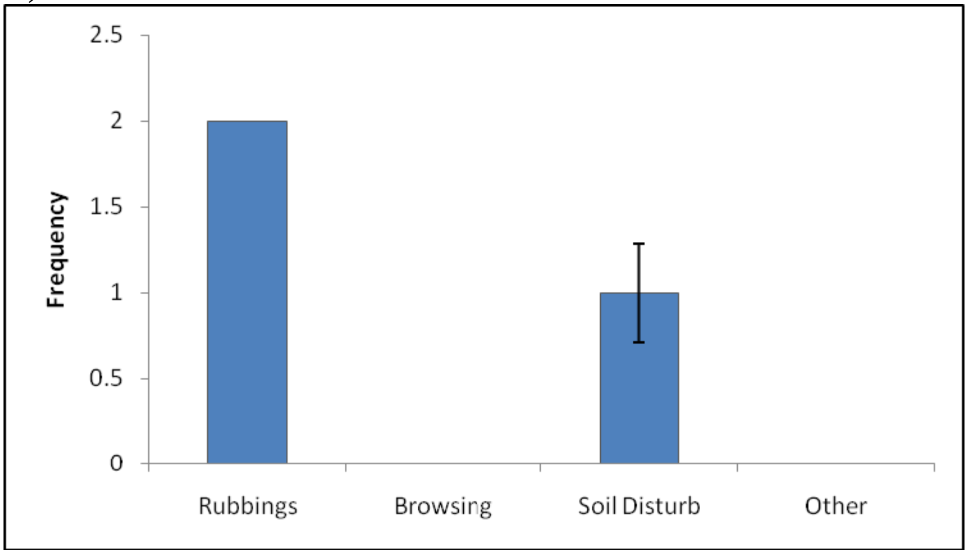


Figure 3.2-5. Mean frequency of ungulate activity at South Finegayan.

The ground cover at South Finegayan was primarily in the form of litter (Figure 3.2-6). Little live vegetation was detected.

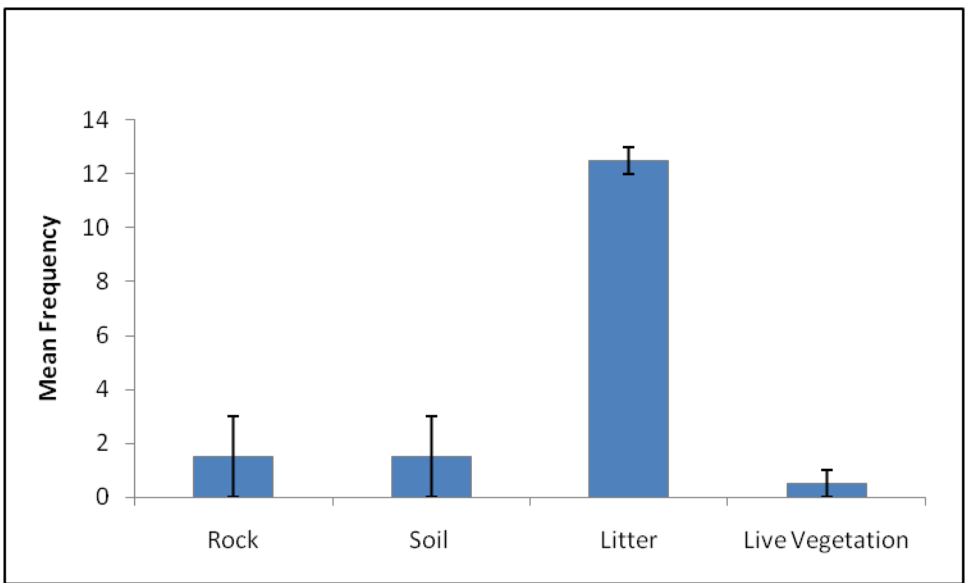


Figure 3.2-6. Mean frequency of ground cover at South Finegayan.

3.2.5 Threatened and Endangered Species and Species of Concern

No species listed as threatened or endangered, either by the Federal or local government, were observed along the transects at South Finegayan. Similarly, no species of concern were observed along the transects at South Finegayan.

3.3 Navy Barrigada

3.3.1 Location

Navy Barrigada is located in north-central Guam in the Municipality of Barrigada. The installation encompasses 1,848 acres with access from Route 15 on the west and Route 16 on the east. The primary land use is communication-related, with antenna fields and support facilities in the eastern and western sectors; a golf course is present in the southern sector of the installation.

Figure 3.3-1. *Cycas micronesica* in limestone forest along Transect 2, Navy Barrigada.

3.3.2 Previous Studies

The previous studies at Navy Barrigada include the BioSystems Analysis (1989) report that also documented the vegetation at Navy Finegayan. The report identified the following plant communities at Navy Barrigada: freshwater wetlands (4 acres), weeds with scattered shrubs (430 acres), cultivars (90 acres), tangantangan scrub forest (280 acres), limestone forest (350 acres), and degraded limestone forest (210 acres) (BioSystems Analysis, Inc., 1989).

3.3.3 Quantitative Observations

Much of Navy Barrigada comprises improved and unimproved roads, open fields and weedy vegetation, with the remaining forested areas mainly concentrated around Mt. Barrigada between two vast antenna fields. Surveys were performed along two transects in the north-central sector of Navy Barrigada (Attachment A): Transect 1 along an east-west axis near the toe of Mt. Barrigada, and Transect 2 along a north-south axis to the southwest of Transect 1 (Figure 3.3-1). Both transects were within limestone forest community mapped by BioSystems Analysis, Inc. (1989).

Tree density, dominance and frequency were quantified using the point-center quarter method and summarized for both transects (Table 3.3-1).

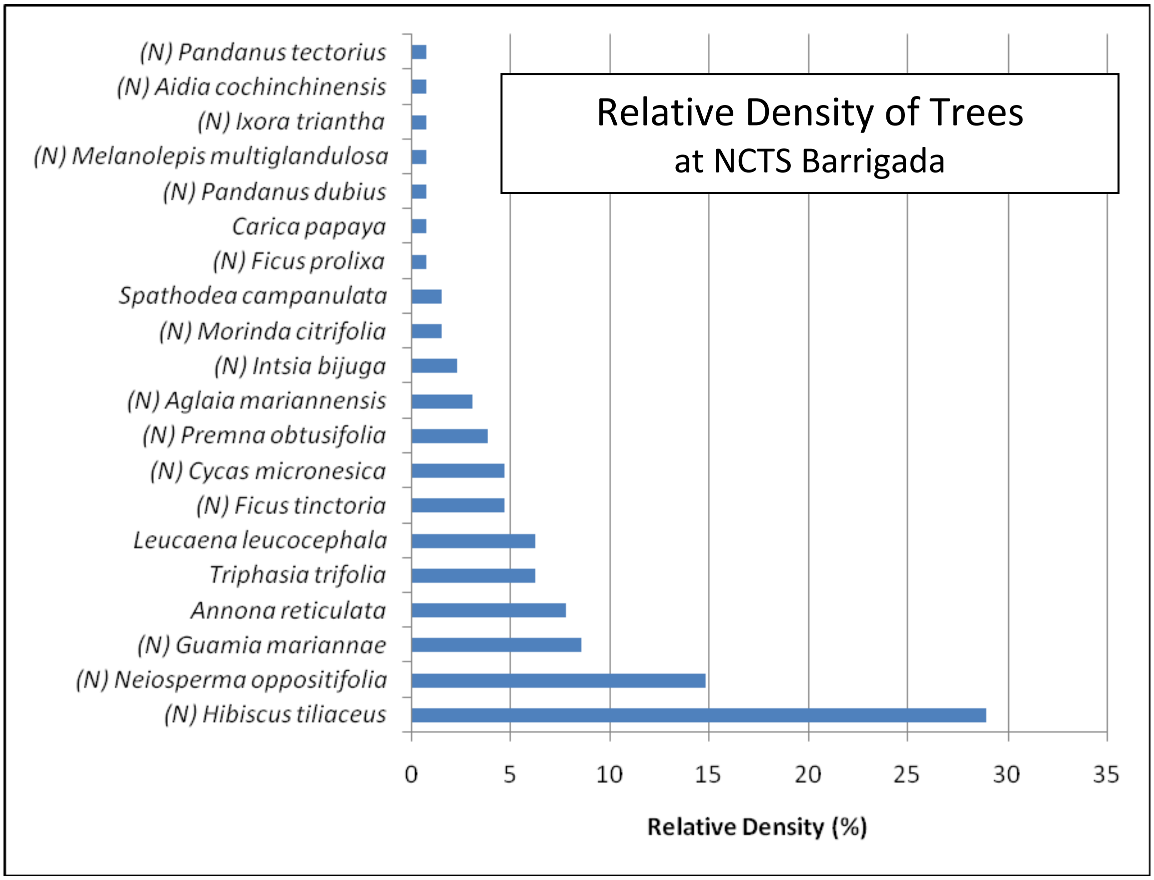
Table 3.3-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST NAVY BARRIGADA, FEBRUARY 2008							
SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Hibiscus tiliaceus	N	37	12.59	2316.62	62.61	788.21	59.38
Neiosperma oppositifolia	N	19	6.46	1917.15	100.90	652.29	37.50
Guamia mariannae	N	11	3.74	615.38	55.94	209.38	25.00
Annona reticulata	I	10	3.40	479.28	47.93	163.07	18.75
Triphasia trifolia	I	8	2.72	396.80	49.60	135.01	18.75
Aglaia mariannensis	N	4	1.36	270.89	67.72	92.17	12.50
Ficus tinctoria	N	6	2.04	1046.92	174.49	356.20	9.38
Morinda citrifolia	N	2	0.68	54.67	27.33	18.60	3.13
Spathodea campanulata	I	2	0.68	225.08	112.54	76.58	3.13
Leucaena leucocephala	I	8	2.72	438.57	54.82	149.22	15.63
Ficus prolixa	N	1	0.34	3726.56	3726.56	1267.93	3.13
Cycas micronesica	N	6	2.04	1796.87	299.48	611.37	15.63
Carica papaya	I	1	0.34	116.84	116.84	39.75	3.13
Pandanus dubius	N	1	0.34	41.83	41.83	14.23	3.13
Melanolepis multiglandulosa	N	1	0.34	22.89	22.89	7.79	3.13
Ixora triantha	N	1	0.34	4.91	4.91	1.67	3.13
Premna obtusifolia	N	5	1.70	1070.45	214.09	364.21	12.50
Intsia bijuga	N	3	1.02	151.49	50.50	51.54	9.38
Aidia cochinchinensis	N	1	0.34	8.04	8.04	2.73	3.13
Pandanus tectorius	N	1	0.34	10.75	10.75	3.66	3.13

Twenty species were quantified along the transects. The highest dominance observed was for the banyan tree (*Ficus prolixa*), an overstory species with numerous aerial roots that contribute to its large footprint. The species with the second and third highest dominance were pago (*Hibiscus tiliaceus*) and fago (*Neisosperma oppositifolia*), which typically occupy the overstory. All three species are native to Guam. It is interesting that the seeded breadfruit or dugdug (*Artocarpus mariannensis*) was not quantified on these transects, although this was cited as a dominant species of the Navy Barrigada limestone forest by BioSystems Analysis, Inc. (1989). Dugdug may be more common on the slopes of Mt. Barrigada where the forest is more intact.

The point-center quarter observations revealed the highest frequencies were for pago (*Hibiscus tiliaceus*), followed by fago (*Neisosperma oppositifolia*) and paipai (*Guamia mariannae*). Paipai is a native forest understory species. Two introduced species, custard apple (*Annona reticulata*) and lemonchina (*Triphasia trifolia*), had the next highest frequency values. Although they are not native components, these species have become naturalized in other limestone forests around the island.

The overall density of trees was calculated at 43.55 trees per 100 SM. The native species pago (*Hibiscus tiliaceus*), fago (*Neisosperma oppositifolia*) and paipai (*Guamia mariannae*) had the highest three relative densities of approximately 29%, 14% and 9%, respectively (Figure 3.3-2).



Note: (N) indicates native species; others are introduced.

Figure 3.3-2. Relative density (%) of tree species, Navy Barrigada.

Native species had a combined relative density of approximatley 77%, far exceeding the relative density of introduced species for both transects at Navy Barrigada (Figure 3.3-3).

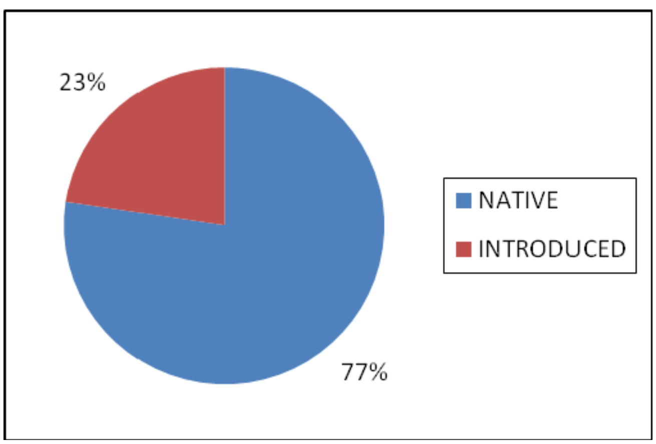


Figure 3.3-3. Relative density (%) of native and introduced tree species, Navy Barrigada.

A comparison of the woody seedling density revealed a higher density for Transect 2 (Figure 3.3-4). Both transects, however, showed markedly higher densities of native over introduced species.

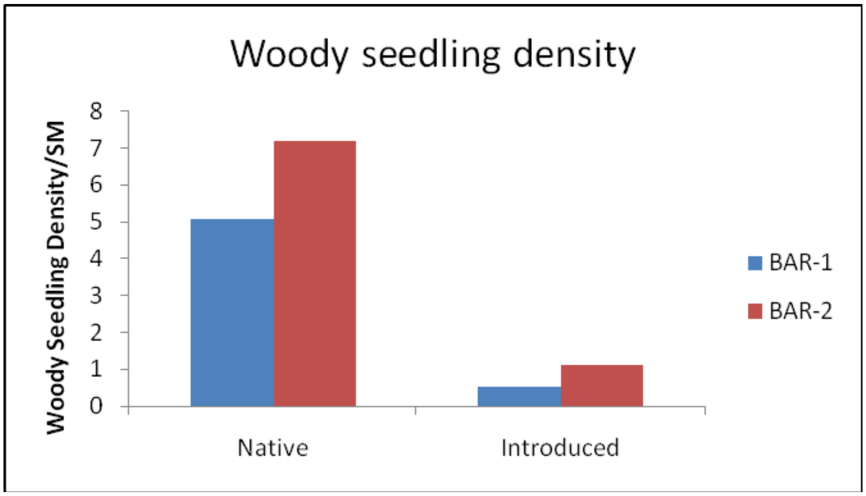


Figure 3.3-4. Density of woody seedlings along Transects 1 and 2, Navy Barrigada.

3.3.4 **Habitat Quality**

The habitat quality at Navy Barrigada may be described through the level of ungulate activity, percent of native species, and overall species richness.

Species richness calculated for the two transects was higher for Transect 2 (Figure 3.3-5). Nevertheless, the species richness × abundance curves for both transects had similar shapes and inflection points.

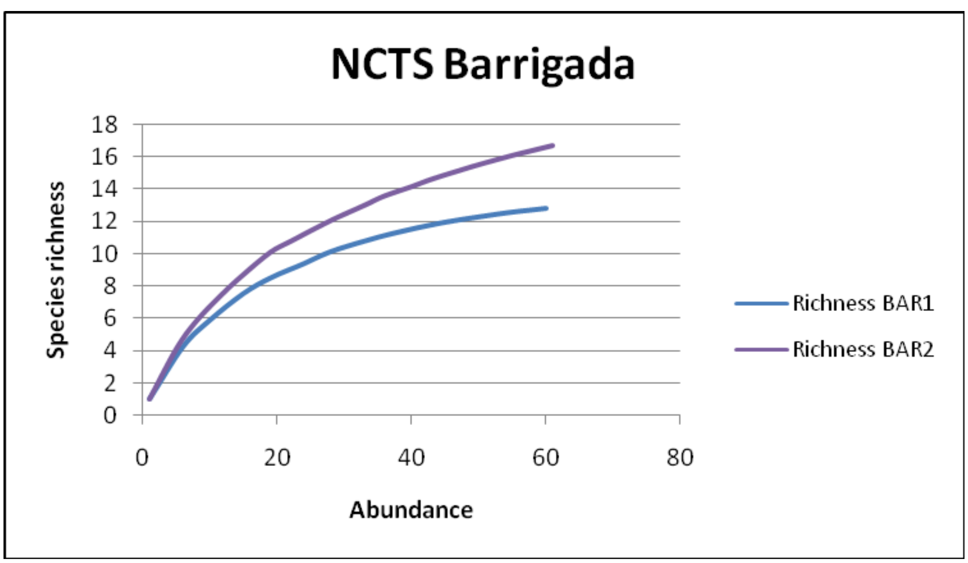


Figure 3.3-5. Species richness for Transects 1 and 2, Navy Barrigada.

There was no ungulate activity quantified at the transect stations during the survey. The ground cover observations revealed a high frequency of leaf litter (Figure 3.3-6). Bare soil, rock and live vegetation had relatively low mean frequencies.

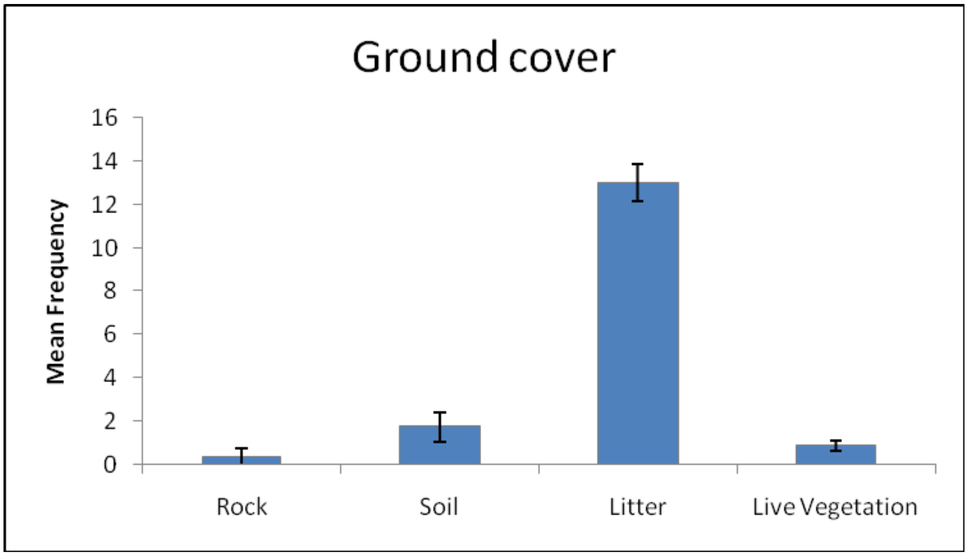


Figure 3.3-6. Mean frequency of ground cover along all transects, Navy Barrigada.

3.3.5 Threatened and Endangered Species and Species of Concern

3.3.5.1 Threatened and Endangered Species

Figure 3.3-7. *Partula radiolata* on *Neisosperma* leaf at Transect 2, Navy Barrigada.

BioSystems Analysis, Inc. (1989) identified no threatened or endangered species at Navy Barrigada. Likewise, no plant species listed as threatened or endangered were identified within Navy Barrigada during the current survey.

Live specimens of the Pacific tree snail (*Partula radiolata*) were found on fago (*Neisosperma oppositifolia*) along Transect 2 in the central sector (Figure 3.3-7). The Pacific tree snail is listed as threatened on the local endangered species list.

3.3.5.2 Species of Concern

BioSystems Analysis, Inc. (1989) reported that no species or habitats of concern were found at Navy Barrigada. The current survey found one species of concern, fadang (*Cycas micronesica*), which is considered a SOGCN by the local Department of Agriculture. Fadang was found along Transects 1 and 2, with densities of 3.81 and 0.61 trees per 100 SM, respectively. Specimens were not in good health and often topped by epiphytes, such as bird's nest fern (*Asplenium nidus*) (see Figure 3.3-1). BioSystems Analysis, Inc. (1989) cited fadang among the dominant species in the limestone forest at Navy Barrigada.

The presence of other uncommon species found in the current survey was also noted. These include *Nervilia aragoana* (Orchidaceae), an indigenous ground orchid, and *Eulophia graminea* (Orchidaceae), a possibly introduced ground orchid (Figure 3.3-8).

Figure 3.3-8. *Eulophia graminea* on Transect 1, Navy Barrigada.

3.4 Andersen South

3.4.1 Location

The Andersen South Housing Area, commonly known as Andy South, is an approximately 2,432-acre area located in the northeastern sector of Guam, inland and adjacent to Route No. 15. The official name is the Marianas Bonins Command (MARBO) Annex. Andy South comprises residential units in the southern sector, and scattered infrastructure facilities in the remaining areas; however, the majority of the Annex is undeveloped.

3.4.2 Quantitative Observations

Figure 3.4-1. *Averrhoa bilimbi* stand along Transect 3, Andersen South.

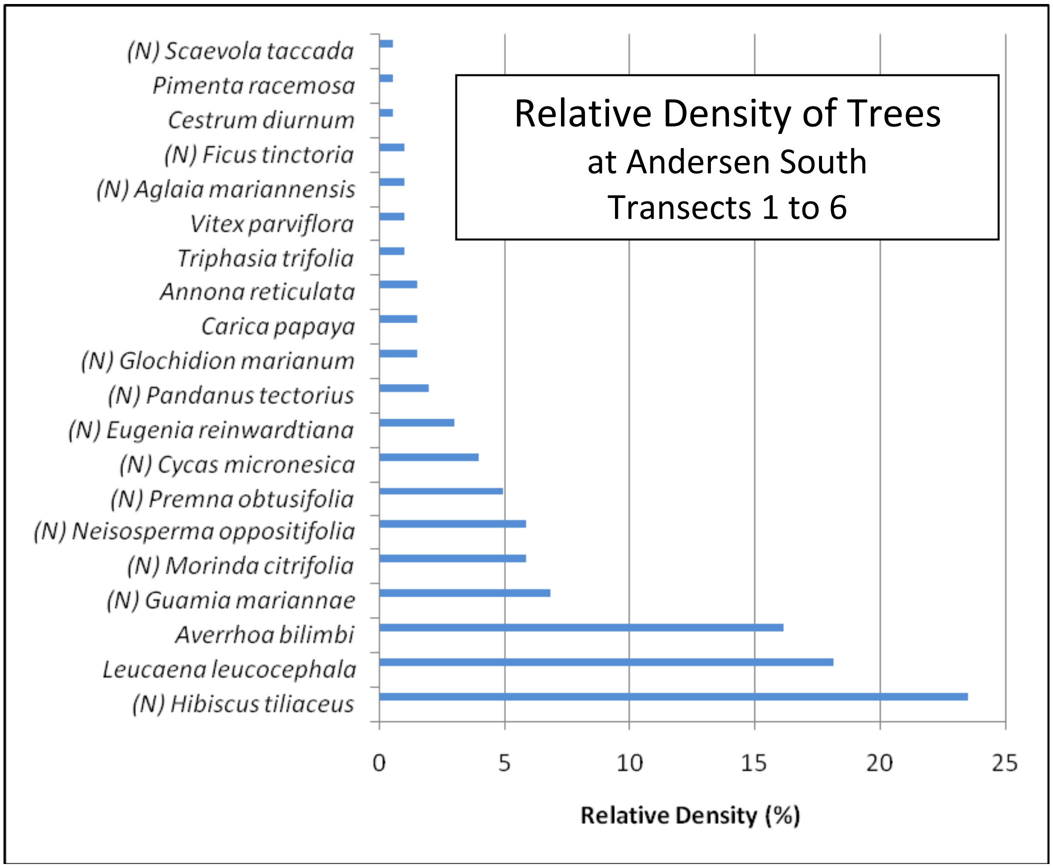
Quantitative surveys were performed along 6 transects in the forested sectors. Transects 1 through 3 were within the central area (Figure 3.4-1), Transect 4 was in the southwestern sector, and Transects 5 and 6 were in the northwestern sector (Attachment A).

The point-center quarter survey results are summarized in Table 3.4-1. The overall density for the six transects was calculated at 21.96 trees per 100 SM. The native pago (*Hibiscus tiliaceus*) is an important species in these forests. Pago had the highest relative density (approximately 24%) (Figure 3.4-2) and highest frequency among species, with specimens quantified on five of the six transects. Pago was also the third most dominant species at Andy South, following the introduced pickle tree (*Averrhoa bilimbi*) and endemic paipai (*Guamia mariannae*). *Averrhoa* and another introduced species, tangantangan (*Leucaena leucocephala*), followed pago with the next highest frequencies at approximately 33 each. *Averrhoa* was common along the transects in the central sector (see Figure 3.4-2); however, it was recorded on every transect at Andy South. Aside from pickle tree, other non-native species in the survey, such as papaya (*Carica papaya*) and custard apple (*Annona reticulata*), produce edible fruits that are likely dispersed by ungulate activity.

Table 3.4-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
AS-1 THROUGH AS-6, ANDERSEN SOUTH, MARCH 2008

SPECIES	STATUS	NO. TREES IN QTRS.	NO. SPECIES IN 100 SM	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Averrhoa bilimbi	I	33	3.55	5575.11	168.94	600.16	33.33
Guamia mariannae	N	14	1.51	4677.56	334.11	503.54	21.57
Hibiscus tiliaceus	N	48	5.17	4139.79	86.25	445.65	49.02
Leucaena leucocephala	I	37	3.98	3742.11	101.14	402.84	33.33
Morinda citrifolia	N	12	1.29	3551.99	296.00	382.37	19.61
Premna obtusifolia	N	10	1.08	3211.63	321.16	345.73	11.76
Pimenta racemosa	I	1	0.11	1734.07	1734.065	186.67	1.96
Neisosperma oppositifolia	I	12	1.29	1585.69	132.14	170.70	17.65
Carica papaya	I	3	0.32	1328.73	442.91	143.04	3.92
Cycas micronesica	N	8	0.86	1117.92	139.74	120.34	11.76
Pandanus tectorius	N	4	0.43	475.32	118.83	51.17	7.84
Vitex parviflora	I	2	0.22	415.12	207.56	44.69	3.92
Glochidion marianum	N	3	0.32	328.50	109.50	35.36	3.92
Annona reticulata	I	3	0.32	127.84	42.61	13.76	3.92
Eugenia reinwardtiana	N	6	0.65	103.11	17.18	11.10	5.88
Cestrum diurnum	I	1	0.11	91.56	91.56	9.86	1.96
Aglaia mariannensis	N	2	0.22	43.36	21.68	4.67	3.92
Triphasia trifolia	I	2	0.22	16.89	8.45	1.82	3.92
Ficus tinctoria	I	2	0.22	10.31	5.15	1.11	1.96
Scaevola taccada	N	1	0.11	4.91	4.91	0.53	1.96

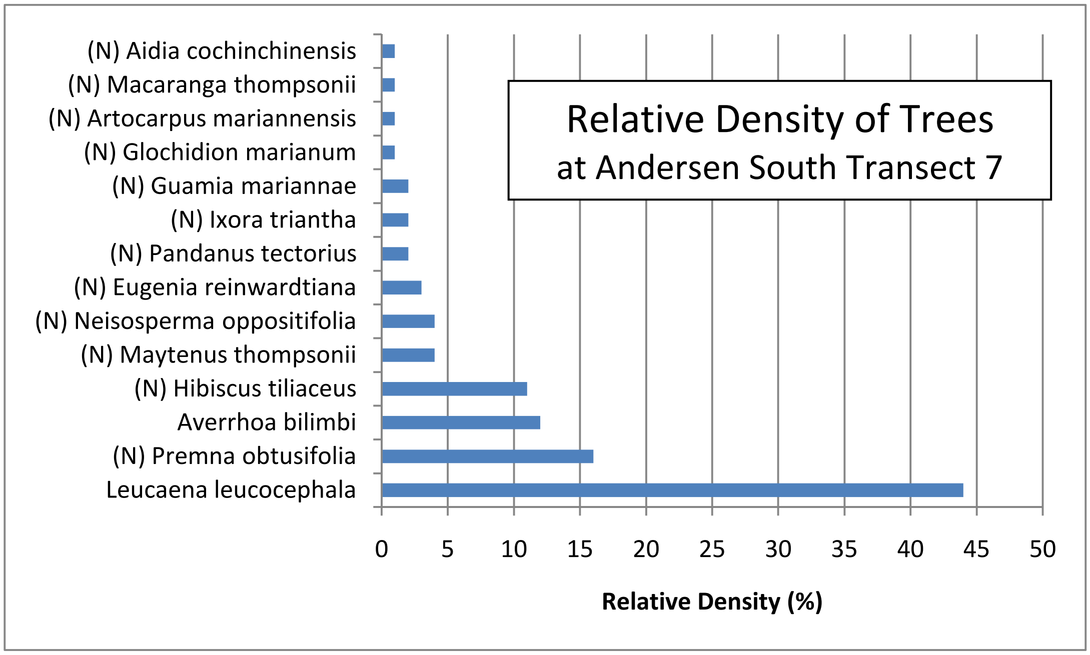


Note: (N) indicates native species; others are introduced.

Figure 3.4-2. Relative density (%) of tree species at Andersen South (Transects 1 to 6).

Of the 20 tree species quantified on the transects, 12 species are native to Guam (Figure 3.4-2). These native species had a collective relative density of 60% at Andy South (Figure 3.4-3). *Vitex parviflora* is a rapidly spreading introduction that is becoming dominant in many of Guam's forests (Department of Agriculture, 2006); however, *Vitex* accounted for less than 2% of the relative density at Andy South with only two specimens quantified on the transects. These specimens had mean basal area of 207 sq. cm, which places them among the larger trees in the forest. The introduced bay-rum tree (*Pimenta racemosa*), a relative of allspice (*P. dioica*), was encountered in the northwestern sector. Although only one specimen was quantified at Andy South (Transect 5), it was fairly large with a basal area of over 1,700 sq. cm. Bay-rum can be invasive, particularly in southern Guam.

One species that was noticeably absent or in low numbers at Andy South was dugdug or dokdok, the native seeded breadfruit (*Artocarpus mariannensis*). A few trees were seen but not surveyed on Transect 4. Dugdug is a characteristic species of native limestone forests in northern Guam (Fosberg, 1960). Specimens of native breadfruit were observed in other sectors of the Annex (i.e., east of Transect 1) that were not included in the sampled areas. The recruitment and distribution of seeded breadfruit at Andy South may be affected by typhoons and ungulate activity, as in other areas of the island.



Note: (N) indicates native species; others are introduced.

Figure 3.4-3. Relative density (%) of tree species at Andersen South Transect 7.

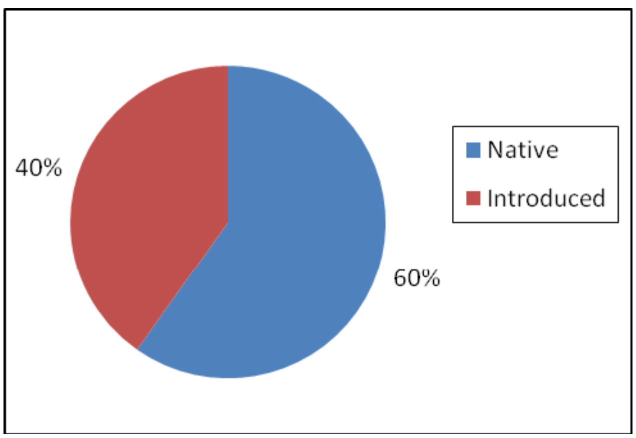


Figure 3.4-3. Relative density of native tree species at Andersen South, Transects 1 to 6.

Plots conducted at stations along the six transects quantified more native than introduced seedlings of woody species (Figure 3.4-4). Native species had a mean density of approximately 4 seedlings/SM; in comparison, introduced species had a mean density of less than 2 seedlings/SM.

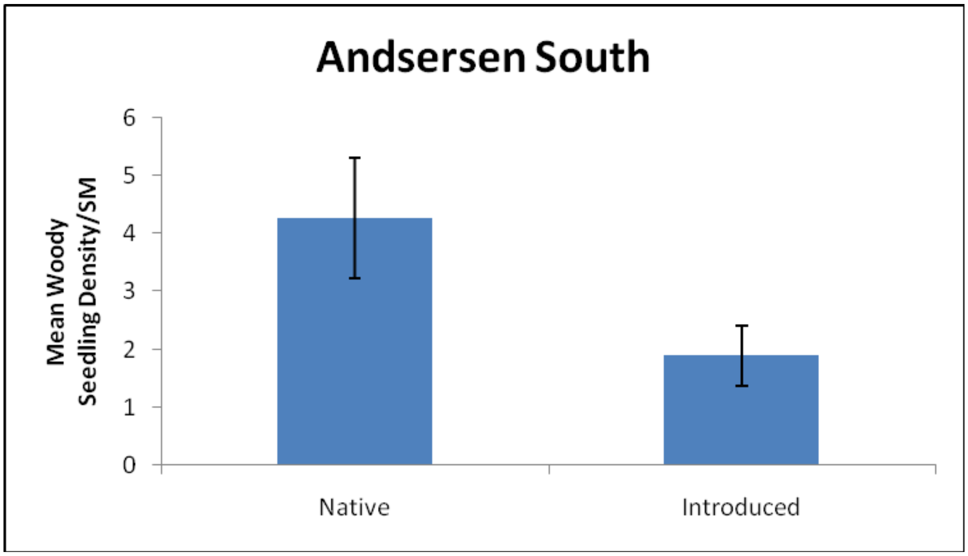


Figure 3.4-4. Mean density of woody seedlings along all transects at Andersen South.

3.4.3 Habitat Quality

The habitat quality at Andersen South may be described through the level of ungulate activity, percent of native species, and overall species richness.

Among the six transect, the calculated species richness was highest for Transect 4 (Figure 3.4-5). Although more points were sampled for Transect 4, rarefaction indicates that it does have a higher species richness than transects with fewer samples. The overall species richness curve for the combined transects is shown in Figure 3.4-6. The forest along Transect 4 is the most intact among the six areas sampled in terms of canopy. The native species ratio is also higher than other Andy South transects, with 10 of the 14 tree species either native or endemic to Guam or the Marianas.

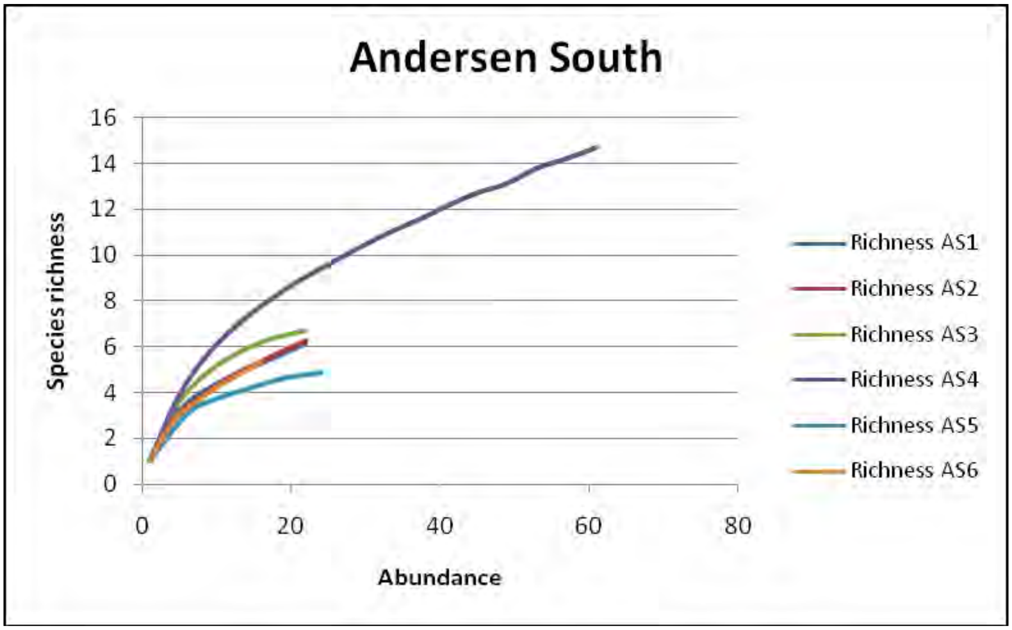


Figure 3.4-5. Species richness of trees along each transect at Andersen South.

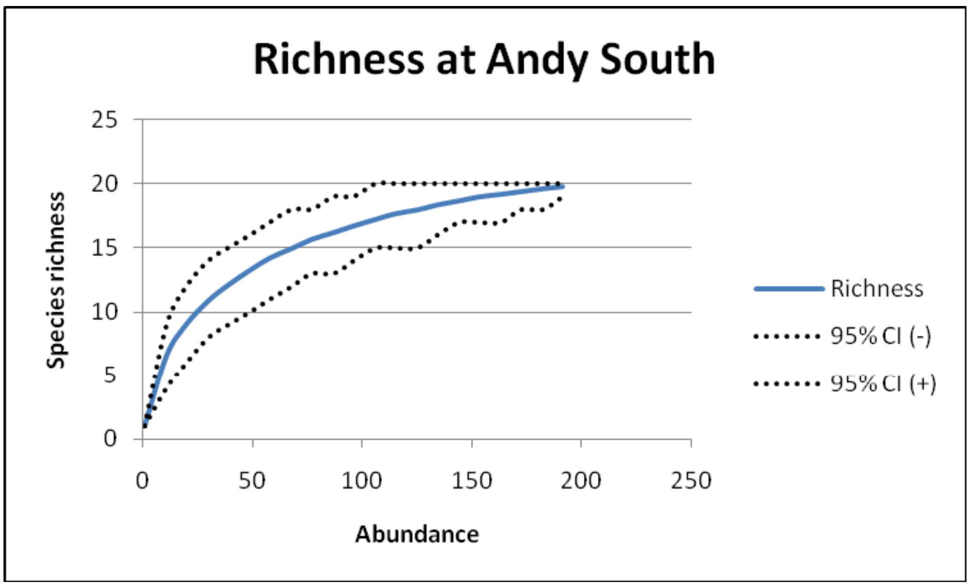


Figure 3.4-6. Species richness of trees along all transects at Andersen South.

The ground cover at Andersen South was quantified for all transects (Figure 3.4-7). Calculations showed leaf litter had the highest mean frequency (11.7) among the four categories of cover. Transects in the central sector of the Annex had high levels of leaf litter mostly beneath pickle tree (*Averrhoa bilimbi*) stands.

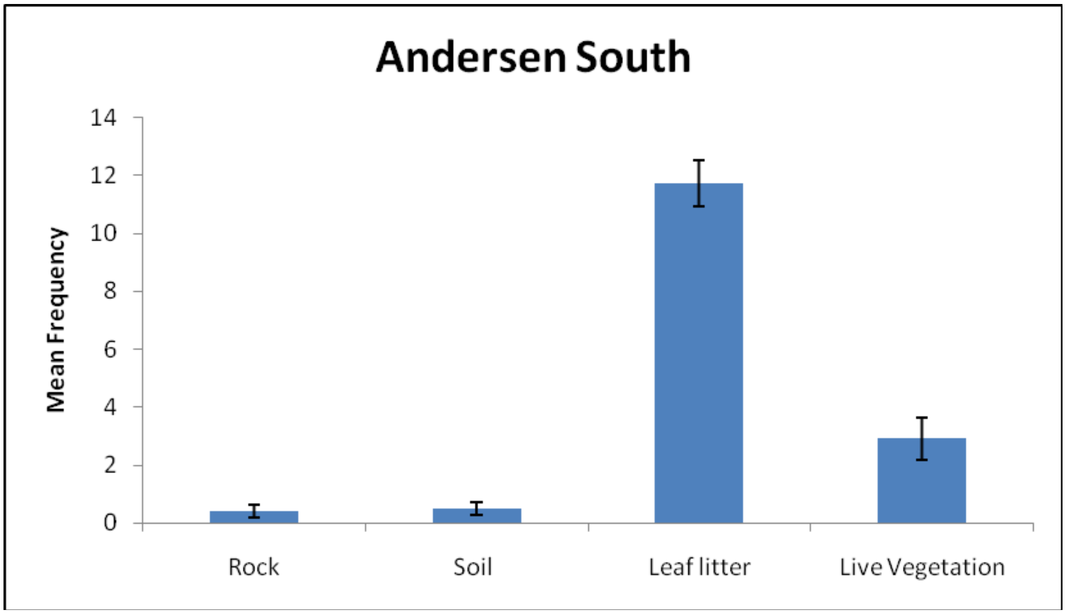


Figure 3.4-7. Mean frequency of ground cover along all transects at Andersen South.

The measure of ungulate activity for all transects revealed that rooting and rubbings were the most common observations, with mean frequencies of 0.59 and 0.50, respectively (Figure 3.4-8).

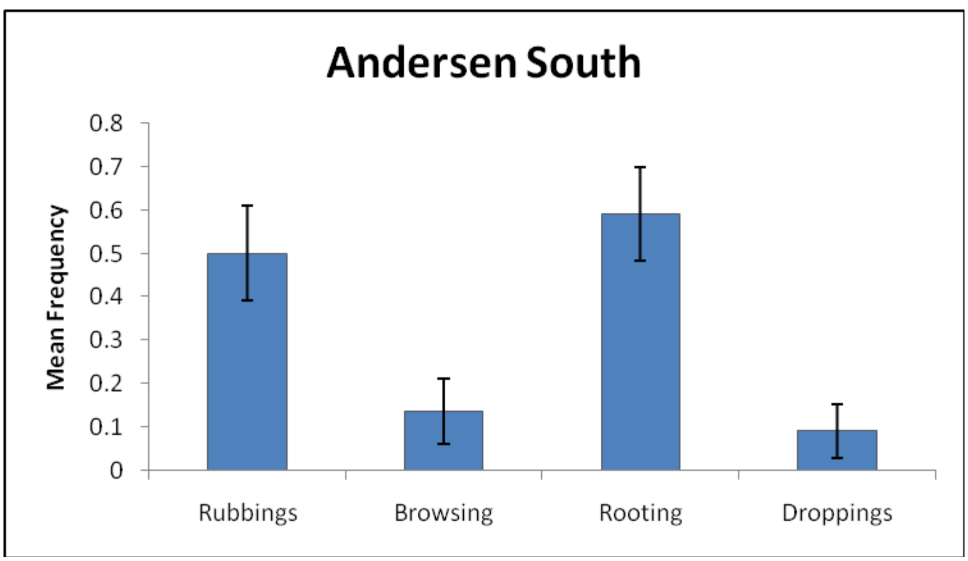


Figure 3.4-8. Mean frequency of ungulate activity along all transects at Andersen South.

3.4.4 Threatened and Endangered Species and Species of Concern

3.4.4.1 Threatened and Endangered Species

No species listed as threatened or endangered were identified within Andersen South during the current survey.

3.4.4.2 Species of Concern

The only species of concern identified within Andersen South during the current survey was the native cycad or fadang (*Cycas micronesica*). The Department of Agriculture's Division of Aquatic and Wildlife Resources lists fadang among the island's Species of Greatest Conservation Need (SOGCN) because of the threat from the introduced Asian cycad scale (Department of Agriculture, 2006). Both healthy and injured cycads were noted in the survey. Seven specimens were quantified, with the highest density of cycads observed on Transect 4 (3.61 trees per 100 SM) (Figure 3.4-9).

Figure 3.4-9. *Cycas micronesica* along Transect 4, Andersen South.

Figure 3.4-10. *Nervilia aragoana* in understory of Transect 4, Andersen South.

Incidental species that are not regulated or managed under local or federal law were also noted on the transects. These include water root orchid or saiyaihayon (*Nervilia aragoana*) (Figure 3.4-10), and (*Zeuxine fritzii*), an inconspicuous ground orchid (Figure 3.4-11).

Figure 3.4-11. *Zeuxine fritzii* in understory of Transect 5, Andersen South.

3.5 Naval Munitions Site

3.5.1 Location

The Naval Munitions Site (NMS) is located in southwestern Guam in the municipality of Agat. NMS is approximately 8,800 acres in size and was formerly known as Naval Magazine and as Ordnance Annex. The site encompasses ordnance storage and disposal, potable water supply infrastructure, and vast areas of watershed and natural communities.

Figure 3.5-1. *Pandanus*-dominated ravine forest along Transect 1, NMS.

3.5.2 Previous Studies

Several studies have been conducted in NMS that address the plant communities. BioSystems Analysis, Inc. (1989) performed vegetation studies at NMS that characterized the plant communities and identified species of concern. The following plant communities were identified at NMS: limestone forest (1,767 acres); degraded limestone forest (220 acres); ravine forest (3,091 acres); degraded ravine forest (927 acres); savanna (2,063 acres); and freshwater wetland (86 acres).

3.5.3 Quantitative Observations

Quantitative surveys were performed in 2008 and 2009 along transects in ravine forest, limestone forest, and a savanna grassland community (Transect 2). Ravine forest and limestone forest in the northeastern sector were sampled along Transects 4, 5 and 6, which traversed or were in the vicinity of stream channels. Transect 7 sampled ravine forest in the north-central sector near active and former operations areas. Ravine forest was also sampled in the western portion of NMS along Transects 1 and 3, which both cross stream channels. In the southern sector of NMS, Transects 8 and 11 sampled the ravine forest and coconut grove surrounding the Explosive Ordnance Disposal (EOD) Range. The faniok (*Merrilliodendron megacarpum*) forest around Mt. Almagosa was sampled in Transect 9. Transect 10 sampled ravine forest along the Sadog Gagu River, which drains into Fena Reservoir.

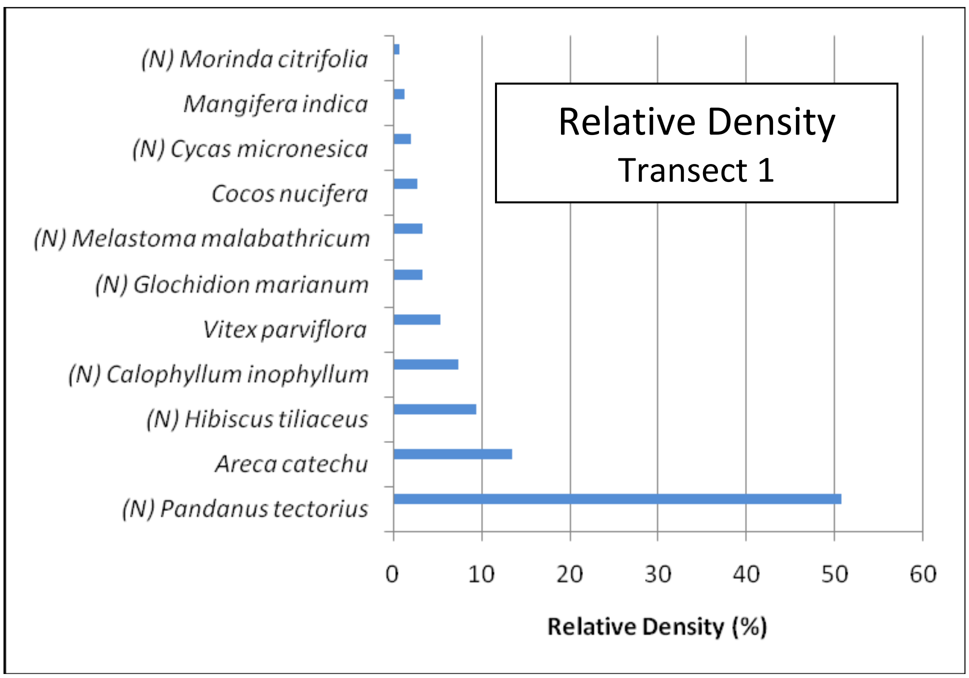
Transect 1 was the longest and traversed the most variable terrain of the seven transects conducted in northern NMS. The overall density for this transect was calculated at approximately 1,203 trees per hectare. The native kafu or screwpine (*Pandanus tectorius*) had the highest relative density (over 50%) and was the most dominant species among the 11 tree species encountered on the transect (Table 3.5-1 and Figure 3.5-1).

Table 3.5-1

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST
NMS-1, NAVAL MUNITIONS SITE, APRIL 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Pandanus tectorius	N	609.59	9929.16	132.39	8.07	83.78
Vitex parviflora	I	65.02	2181.61	272.70	1.77	10.81
Glochidion marianum	N	40.64	2139.01	427.80	1.74	13.51
Mangifera indica	I	16.26	1977.70	988.85	1.61	2.70
Cocos nucifera	I	32.51	1934.33	483.58	1.57	8.11
Areca catechu	I	162.56	1286.06	64.30	1.05	32.43
Cycas micronesica	N	24.38	979.81	326.60	0.80	8.11
Calophyllum inophyllum	N	89.41	425.19	38.65	0.35	18.92
Hibiscus tiliaceus	N	113.79	375.18	26.80	0.30	18.92
Morinda citrifolia	N	8.13	38.47	38.47	0.03	2.70
Melastoma malabathricum	N	40.64	34.76	6.95	0.03	8.11

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-2. Relative density (%) of trees along Transect 1, NMS

Native species accounted for approximately 70% of the relative density among the eleven tree species quantified along Transect 1 (Figure 3.5-3).

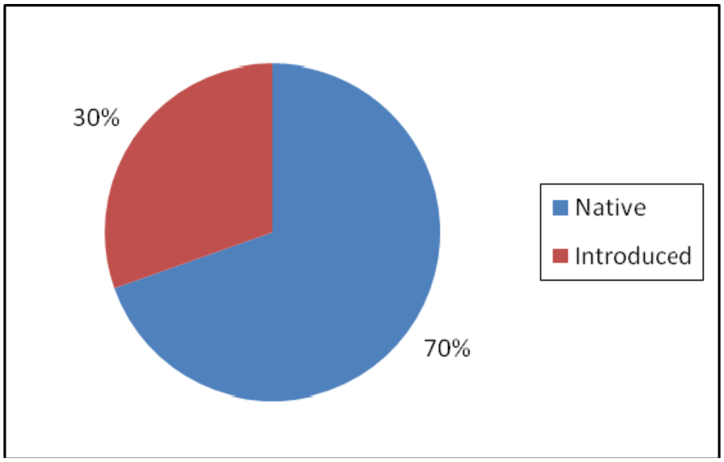
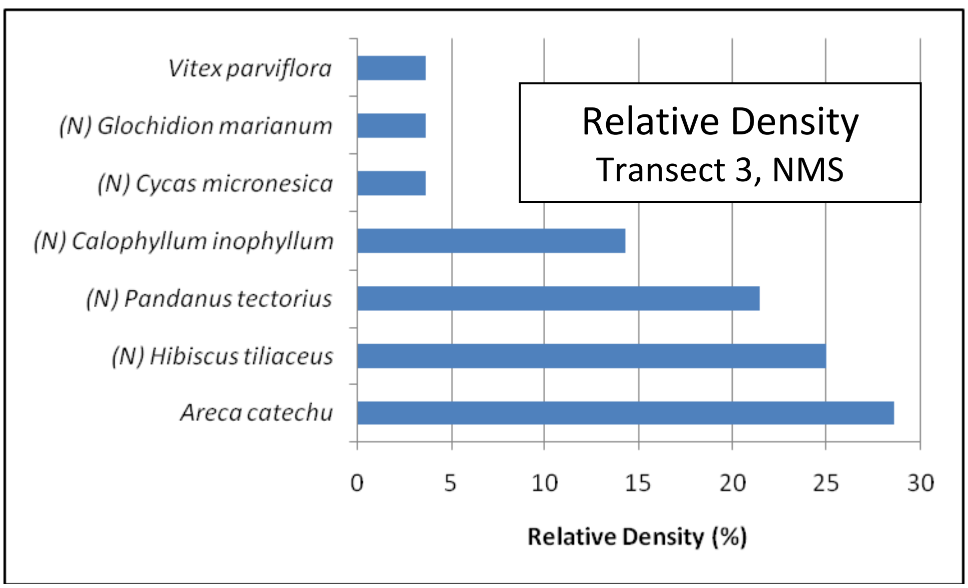


Figure 3.5-3. Relative density of native tree species in Transect 1.

The ravine forest sampled in Transect 3 had a density of approximately 1,700 trees per hectare. Betelnut palms (*Areca catechu*), which are thought to be an aboriginal introduction, had the highest relative density (29%) among the seven species on the transect. Aside from betelnut and *Vitex parviflora*, the transect comprised native species that accounted for approximately 67% of the relative density (Figure 3.5-4).



Note: (N) indicates native species; others are introduced.

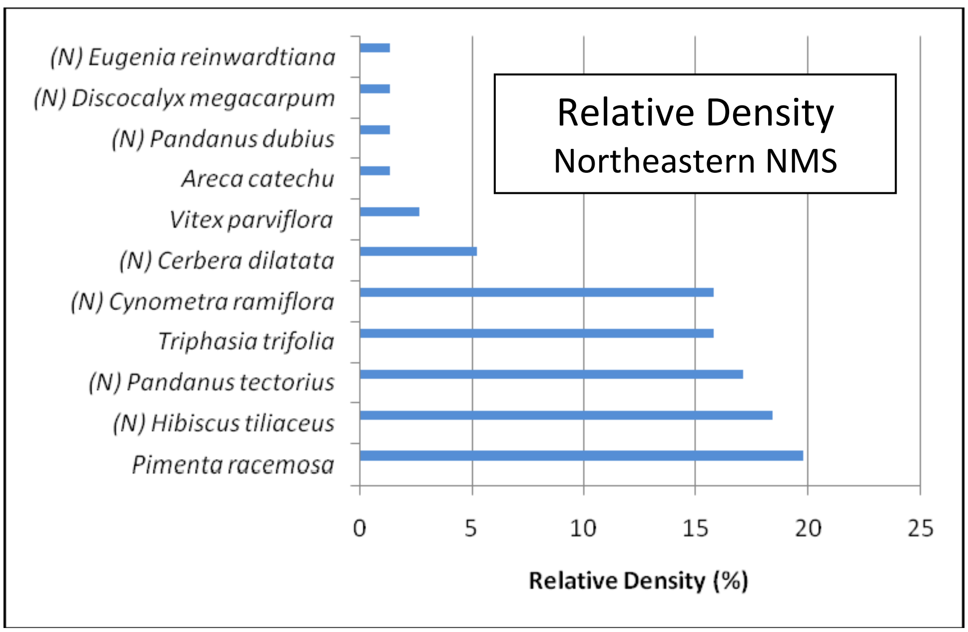
Figure 3.5-4. Relative density (%) of trees along Transect 3, NMS.

The transects in the northeastern sector (Transects 4 through 6) revealed a calculated density of approximately 5,261 trees per hectare (Table 3.5-2). The native kafu (*P. tectorius*) had the highest cover and third highest relative density (about 17%) among the 11 tree species in the transects (Table 3.5-2, Figure 3.5-5). The introduced and often invasive bay-rum (*Pimenta racemosa*) had the highest relative density (about 20%), followed closely by native pago (*H. tiliaceus*) with about 19%. Both native gulos (*Cynometra ramiflora*) and introduced lemonchina (*Triphasia trifolia*) had densities of about 16%. These five species each had relative densities exceeding 15%; in contrast, on Transect 1 the relative density of kafu was slightly more than 50% and the densities of the remaining species were less than 14%.

Table 3.5-2

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST NMS-4, NMS-5, NMS-6, NAVAL MUNITIONS SITE, MARCH 2008						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Pandanus tectorius	N	899.91	1381.09	106.24	9.56	31.58
Hibiscus tiliaceus	N	969.14	637.31	45.52	4.41	31.58
Cynometra ramiflora	N	830.69	467.45	38.95	3.24	31.58
Triphasia trifolia	I	830.69	408.91	34.08	2.83	21.05
Cerbera dilatata	N	276.90	212.49	53.12	1.47	5.26
Pimenta racemosa	I	1038.36	167.13	11.14	1.16	31.58
Vitex parviflora	I	138.45	63.78	31.89	0.44	10.53
Areca catechu	I	69.22	62.18	62.18	0.43	5.26
Pandanus dubius	N	69.22	38.47	38.47	0.27	5.26
Eugenia reinwardtiana	N	69.22	19.63	19.63	0.14	5.26

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-5. Relative density (%) of trees along Transects 4, 5 and 6, NMS.

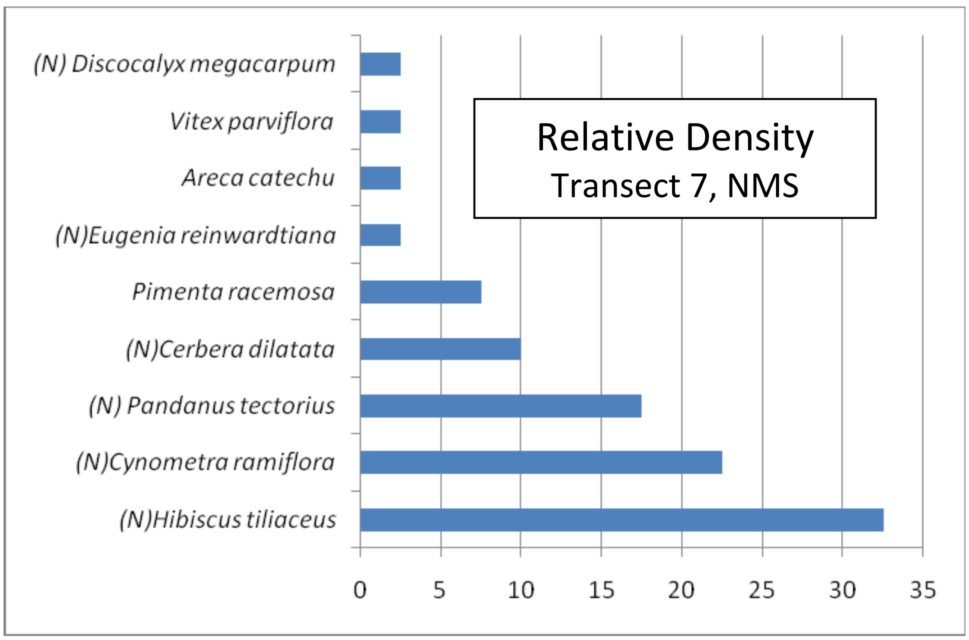
The ravine forest sampled along Transect 7 had a calculated density of approximately 1,791 trees per hectare (Table 3.5-3). The four highest relative densities were for species native to Guam (i.e., *Hibiscus tiliaceus*, *Cynometra ramiflora*, *Pandanus tectorius*, and *Cerbera dilatata*), which had relative densities ranging from about 33% to 10% (Figure 3.5-6). Introduced species accounted for less than 13% of the relative density among the nine species on the transect.

Table 3.5-3

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST
NMS-7, NAVAL MUNITIONS SITE, MARCH 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cerbera dilatata	N	179.09	0.00	842.76	15.09	20
Pandanus tectorius	N	313.41	0.00	79.83	2.50	50
Hibiscus tiliaceus	N	582.04	0.00	31.86	1.85	50
Cynometra ramiflora	N	402.95	0.00	23.51	0.95	40
Areca catechu	I	44.77	0.00	132.67	0.59	10
Pimenta racemosa	I	134.32	0.00	6.62	0.09	20
Vitex parviflora	I	44.77	0.00	12.56	0.06	10
Eugenia reinwardtiana	N	44.77	0.00	6.60	0.03	10
Discocalyx megacarpum	N	44.77	0.00	6.60	0.03	10

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-6. Relative density (%) of trees along Transect 7, NMS. Native species are indicated by (N).

The ravine forest in the southwestern sector of the annex was sampled along Transects 8 and 11, located south and west of the EOD Range, respectively. The survey revealed an overall density of about 1,500 trees per hectare. Coconut (*Cocos nucifera*) and betelnut palms were dominant with native kafu (*Pandanus tectorius*) in terms of density, dominance and frequency (Table 3.5-4). The remaining species had low relative densities (Figure 3.5-7). The native cycad or fadang

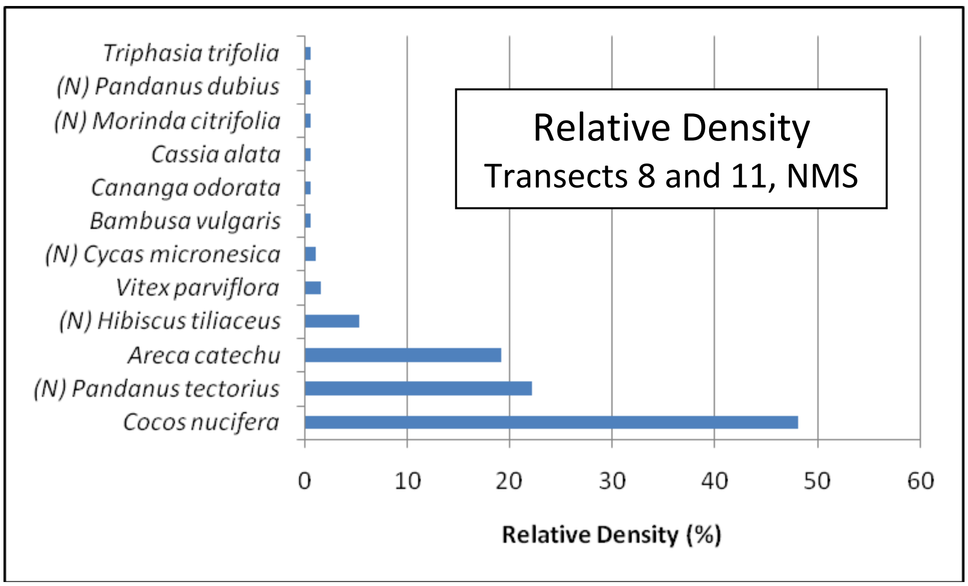
(*Cycas micronesica*) was represented by two specimens with a mean basal area of 630 cm²; both trees were sampled on Transect 8.

Table 3.5-4

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST NMS-8 AND NMS-11, NAVAL MUNITIONS SITE, DEC. 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	723.02	52974.40	529.74	38.30	69.23
Pandanus tectorius	N	332.59	4026.92	87.54	2.91	53.85
Areca catechu	I	289.21	2868.03	71.70	2.07	40.38
Vitex parviflora	I	21.69	1558.74	519.58	1.13	3.85
Cycas micronesica	N	14.46	1261.93	630.96	0.91	3.85
Hibiscus tiliaceus	N	79.53	359.91	32.72	0.26	11.54
Cananga odorata	I	7.23	289.38	289.38	0.21	1.92
Triphasia trifolia	I	7.23	66.44	66.44	0.05	1.92
Bambusa vulgaris	I	7.23	46.54	46.54	0.03	1.92
Cassia alata	I	7.23	36.30	36.30	0.03	1.92
Morinda citrifolia	N	7.23	35.24	35.24	0.03	1.92
Pandanus dubius	N	7.23	15.90	15.90	0.01	1.92

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-7. Relative density (%) of trees along Transects 8 and 11, NMS.

The limestone forest in the valley and slopes surrounding Mt. Almagosa was sampled on Transect 9 (Table 3.5-5). The overall density was calculated at approximately 2,637 trees per hectare. The forest is characterized by the dominant faniok (*Merrilliodendron megacarpum*) trees that comprised over 63% of the relative density (Figure 3.5-8). Faniok had an absolute cover of 21.31 m²/ha, well above any other species on the transect. Since faniok has a limited distribution on Guam, this is an uncommon forest type with few known stands, such as at the

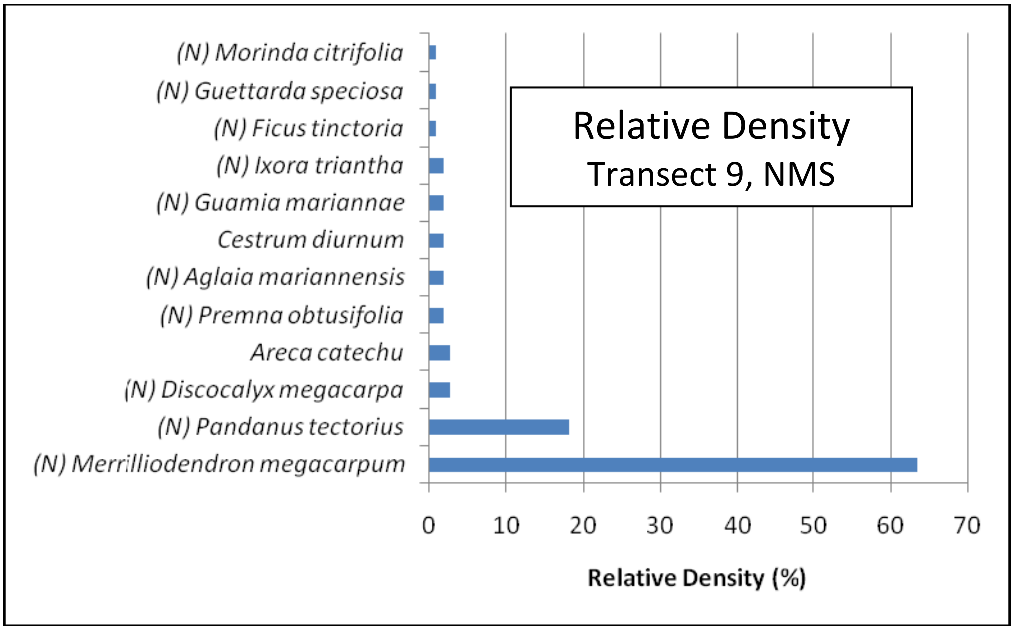
Haputo ERA in North Finegayan and near Mt. Jumullong-Manglo. Kafu (*Pandanus tectorius*) trees are an important component after faniok, forming dense, impenetrable patches where the canopy is open and fragmented. In areas where the canopy is more intact, the humid understory encourages the growth of lush ferns and mosses that blanket the dissected limestone karst. The uncommon terrestrial fern *Heterogonium pinatum*, and ground orchid *Calanthe triplicata*, are found in this area, with its unusual juxtaposition of high limestone ridges and freshwater springs.

Table 3.5-5

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
NMS-9, NAVAL MUNITIONS SITE, DEC 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Merrilliodendron megacarpum	N	1673.73	8402.10	127.30	21.31	76.92
Pandanus tectorius	N	481.83	1093.07	57.53	2.77	30.77
Areca catechu	I	76.08	255.79	85.26	0.65	11.54
Morinda citrifolia	N	25.36	254.34	254.34	0.64	3.85
Aglaia mariannensis	N	50.72	224.82	112.41	0.57	3.85
Ficus tinctoria	N	25.36	162.53	162.53	0.41	3.85
Premna obtusifolia	N	50.72	119.12	59.56	0.30	7.69
Guettarda speciosa	N	25.36	103.82	103.82	0.26	3.85
Guamia mariannae	N	50.72	80.61	40.31	0.20	3.85
Cestrum diurnum	I	50.72	78.37	39.18	0.20	7.69
Ixora triantha	N	50.72	33.17	16.58	0.08	7.69
Discocalyx megacarpa	N	76.08	15.05	5.02	0.04	11.54

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.5-8. Relative density (%) of trees along Transect 9, NMS.

Native species comprised 95% of the relative density of tree species along Transect 9 (Figure 3.5-9). The remaining 5% comprised two introduced but naturalized species, betelnut (*Areca catechu*) and tintanchina (*Cestrum diurnum*), which are long-established on Guam (Stone, 1970).

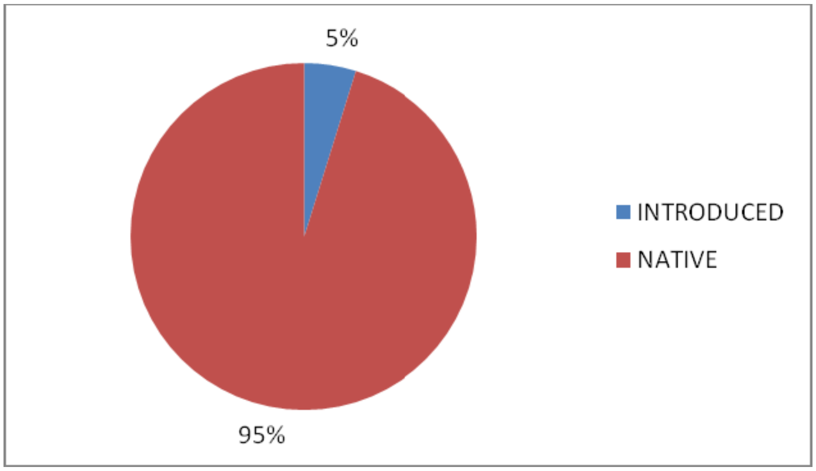


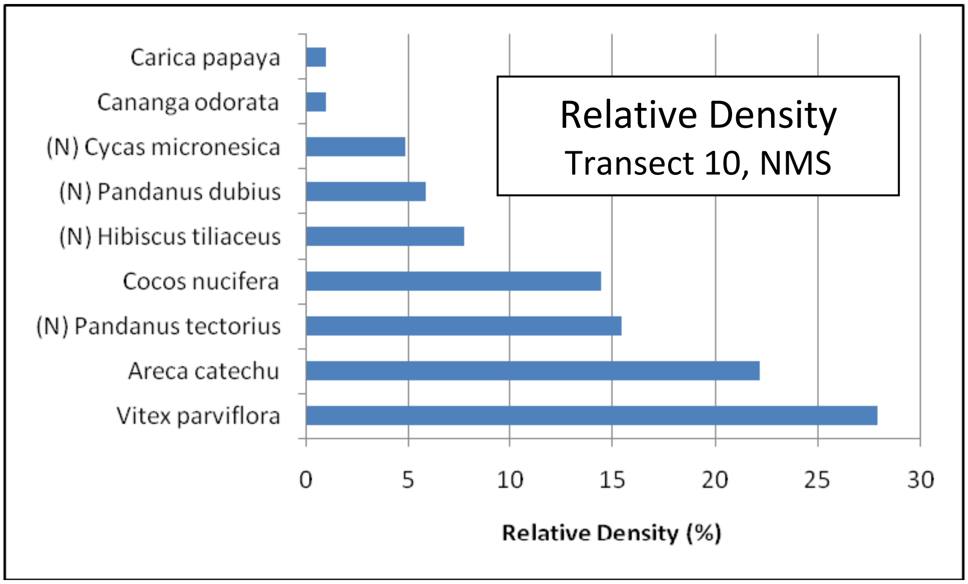
Figure 3.5-9. Relative density of native tree species along Transect 9, NMS.

Transect 10 sampled the ravine forest along theSadog Gagu River in the southern sector of the annex. Point-center quarter results revealed an overall tree density of approximately 1,474 trees per hectare. Two introduced and naturalized species, coconut (*Cocos nucifera*) and *Vitex parviflora*, outranked all other species with cover values of 13.46 m²/ha and 8.02 m²/ha, respectively (Table 3.5-6). *Vitex* also had the highest relative density (28%), followed by the betelnut palm or pugua (*Areca catechu*) (22%) (Figure 3.5-10). The overall relative density of native species was approximately 34% (Figure 3.5-11), which is lower than the densities observed in ravine forest transects in the northern sectors of the annex.

Table 3.5-6

POINT-CENTER QUARTER METHOD RESULTS FOR RAVINE FOREST
NMS-10, NAVAL MUNITIONS SITE, DEC 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	212.71	9488.12	632.54	13.46	42.31
Vitex parviflora	I	411.25	5657.10	195.07	8.02	50.00
Pandanus tectorius	N	226.89	1917.52	119.84	2.72	38.46
Cycas micronesica	N	70.90	1208.79	241.76	1.71	15.38
Areca catechu	I	326.16	1155.85	50.25	1.64	42.31
Pandanus dubius	N	85.09	537.38	89.56	0.76	11.54
Hibiscus tiliaceus	N	113.45	405.92	50.74	0.58	15.38
Cananga odorata	I	14.18	268.67	268.67	0.38	3.85
Carica papaya	I	14.18	122.66	122.66	0.17	3.85



Note: (N) indicates native species; others are introduced.

Figure 3.5-10. Relative density (%) of trees along Transect 10, NMS.

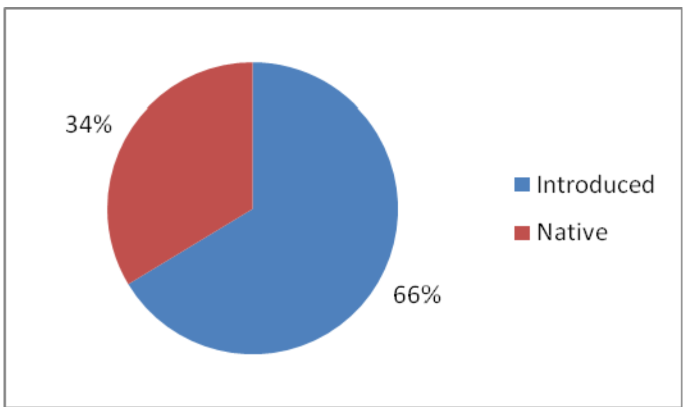


Figure 3.5-11. Relative density of native tree species in Transect 10.

Plots performed in the northern NMS revealed a lower native woody seedling desnity of approximately 1.83 seedlings per square meter compared with introduced seedlings, which had a denstiy of about 2.44 seedlings per square meter (Figure 3.5-12). Transect 4 in the northeastern sector had a particularly high desnity of bay-rum (*Pimenta racemosa*) seedlings, which contributed to the higher overall desnsity of introduced seedling species. Bay-rum appears to be thriving in the northeastern sector, possibly in part because of its prolific seed production.

The southern sector of NMS had a native woody seedling density of about 17.19 seedlings per square meter (Figure 3.5-13). This was higher than the density of introduced seedlings of approximately 1.06 seedlings per square meter. Native mapunao (*Aglaia mariannensis*) trees were prolific seedling producers on Transect 9, which contributed to the higher native seedling density in southern NMS.

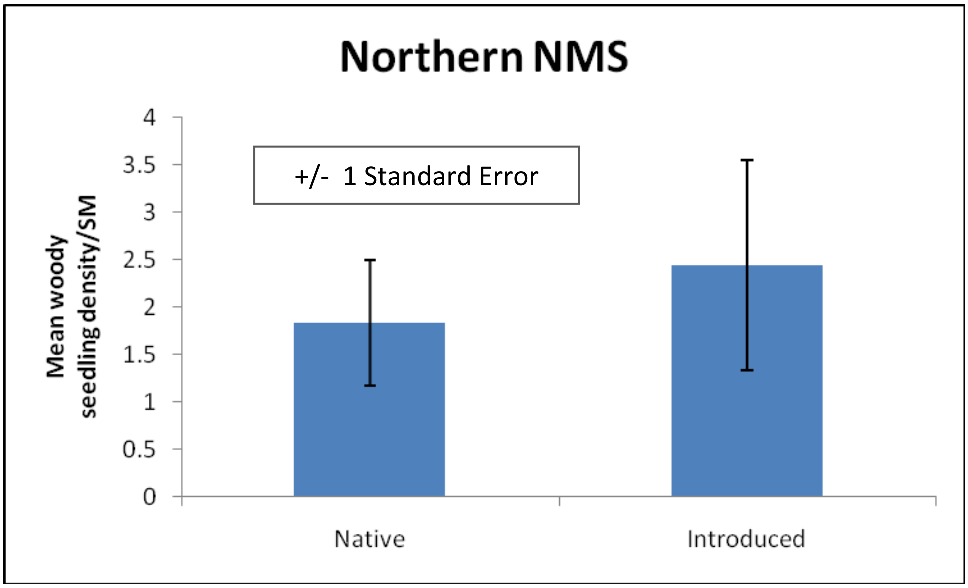


Figure 3.5-12. Mean density of woody seedlings along Transects 1 through 7, NMS.

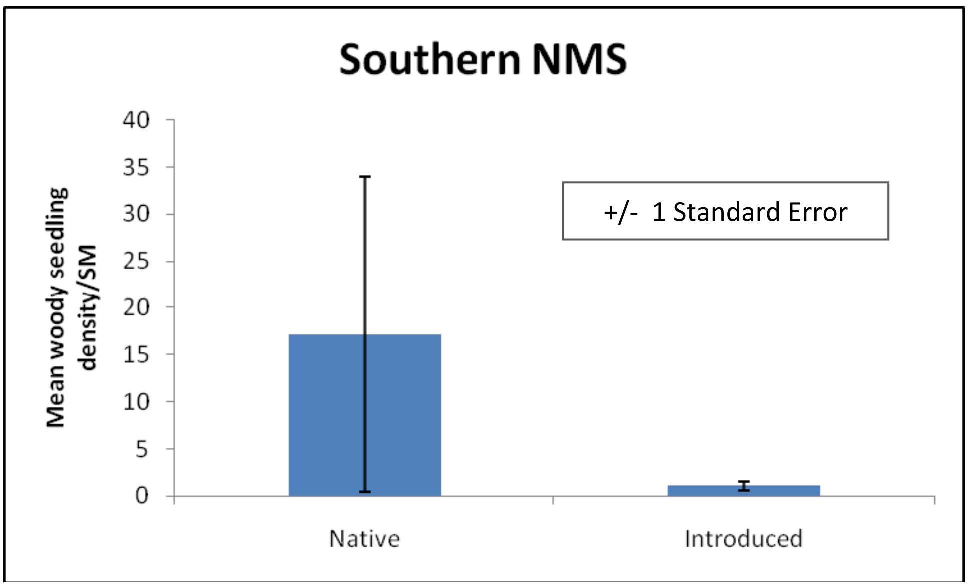


Figure 3.5-13. Mean density of woody seedlings along Transects 8 through 11, NMS.

3.5.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at Naval Munitions Site. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. Among the transects sampled in northern NMS, species richness was highest for Transect 5, followed by Transects, 7, 1, 6, 3 and 4, respectively (Figure 3.5-14). Transect 1 and Transect 7 appear to have similar points of inflection; rarefaction would indicate that richness is similar among these transects although fewer samples were obtained for Transect 7.

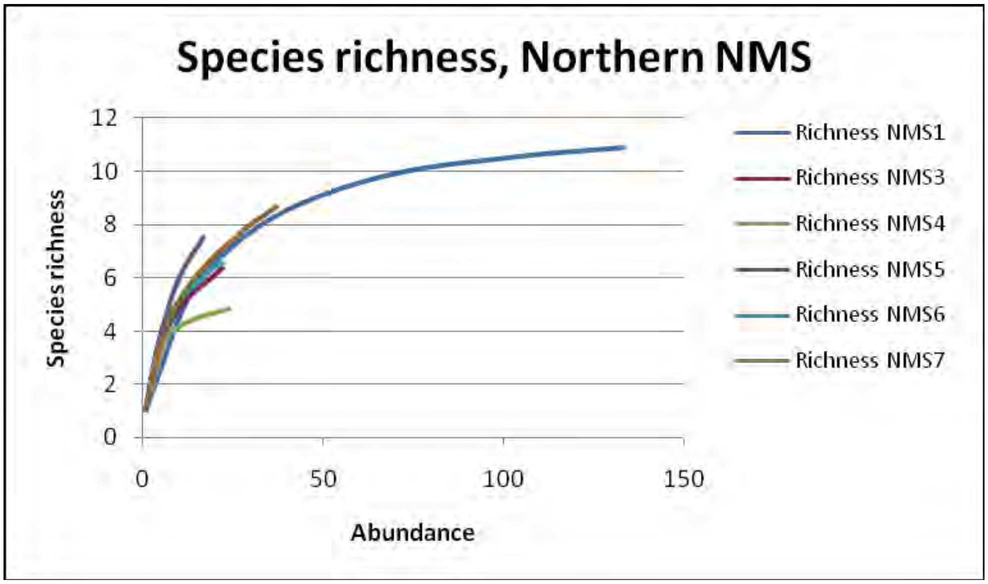


Figure 3.5-14. Species richness of trees along transects at northern NMS.

Species richness curves indicate a higher species richness for Transect 9 in the *Merrilliodendron* forest than for other transects in southern NMS (Transects 8, 10, and 11) (Figure 3.5-15). Transect 9 also had the highest relative density of native versus introduced species among all transect at NMS (Table 3.5-7).

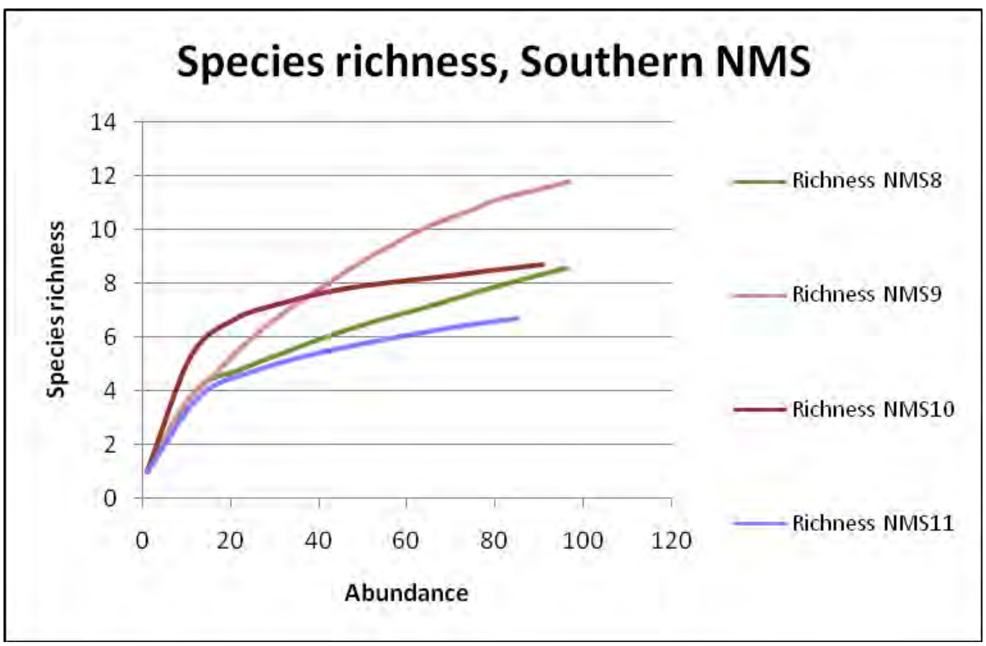


Figure 3.5-15. Species richness of trees along Transects 8 through 11, NMS.

Overall, the lowest species richness in the southern NMS was along Transect 11 in the ravine forest west of the EOD Range, which contained only 7 tree species. This forest contains a high proportion of coconut (*Cocos nucifera*) (approximately 55% of the relative density) among mostly kafu (*Pandanus tectorius*), betelnut (*Areca catechu*), and pago (*Hibiscus tiliaceus*) trees. In the northern NMS, the lowest species richness was observed along Transect 4 (see Figure 3.5-14); only 5 species were sampled on this transect, which contained similar relative densities of native and introduced species.

Table 3.5-7

SUMMARY OF RELATIVE DENSITY OF TREE SPECIES AT NMS

Transect	% Native	% Introduced	Total species
1	69.59	30.41	11
3	67.86	32.14	7
4	46.43	53.57	5
5	40.00	60.00	8
6	89.29	10.71	7
7	87.50	12.50	9
8	25.93	74.07	9
9	95.00	5.00	12
10	66.35	33.65	9
11	33.00	67.00	7

Ungulate activity was quantified at stations along Transects 1 through 11 (Figures 3.5-16 and 3.5-17). Soil disturbance, such as rooting, had the highest mean frequency, followed by browsing. Erosion, vegetation damage and other disturbance from wild pigs (*Sus scrofa*), deer (*Cervus unicolor*), and carabao (*Bubalis bubalis*) are considered major problems at the annex. The ungulate activity was especially conspicuous along Transect 11 in southern NMS, where active wallows, rooting and live feral pigs were observed.

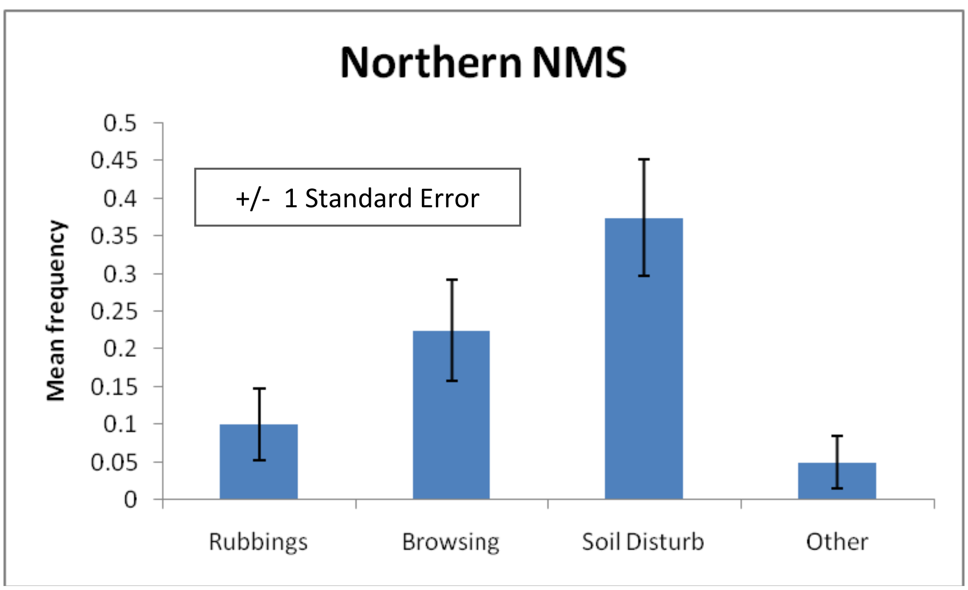


Figure 3.5-16. Mean frequency of ungulate activity along Transects 1 through 7.

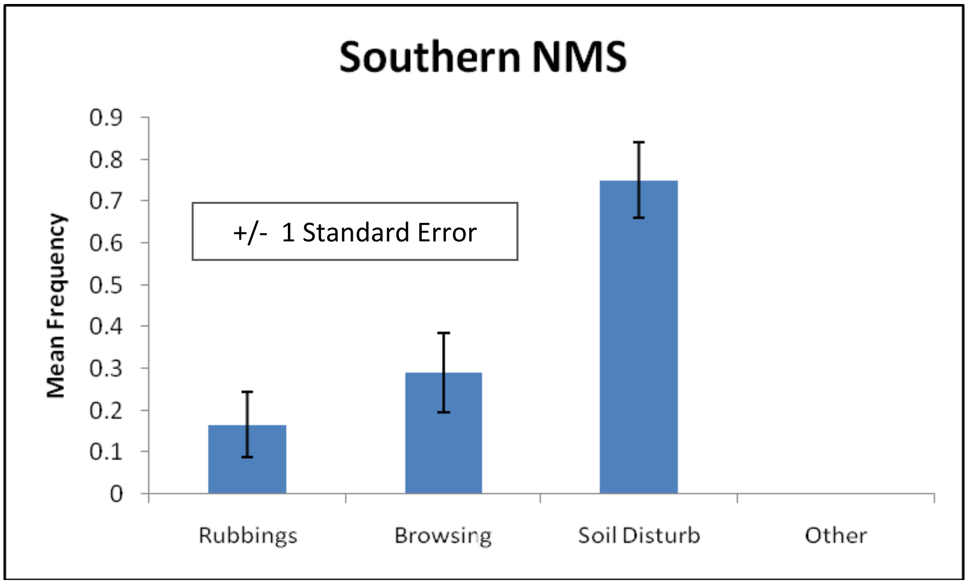


Figure 3.5-17. Mean frequency of ungulate activity along Transects 8 through 11.

The ground cover quantified along Transects 1 through 11 revealed that leaf litter had the highest mean frequency among the four cover classes in the northern and southern NMS (Figures 3.5-18 and 3.5-19). The lowest mean frequency in both areas of NMS was for bare rock, although this cover class had a slightly higher frequency in southern NMS.

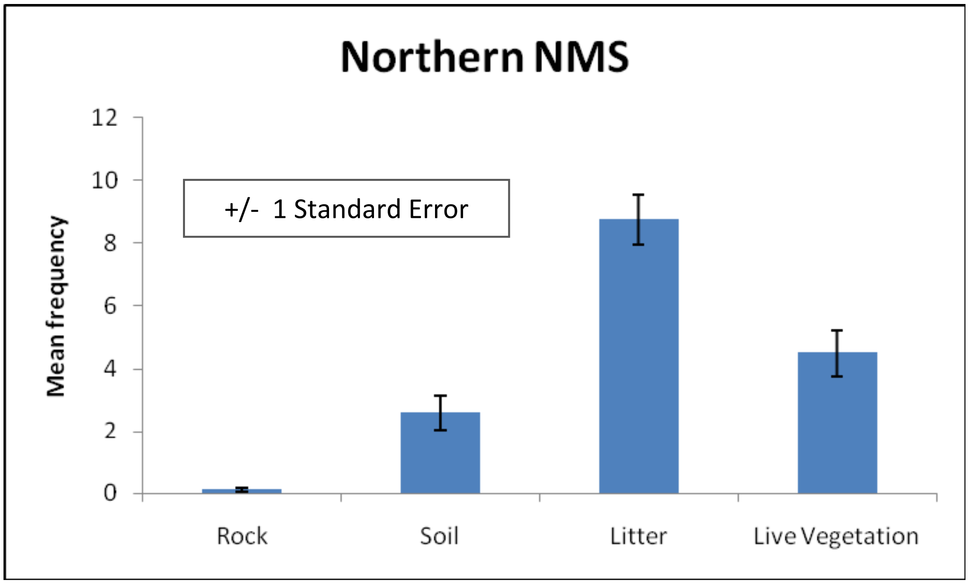


Figure 3.5-18. Mean frequency of ground cover along along Transects 1 through 7, NMS.

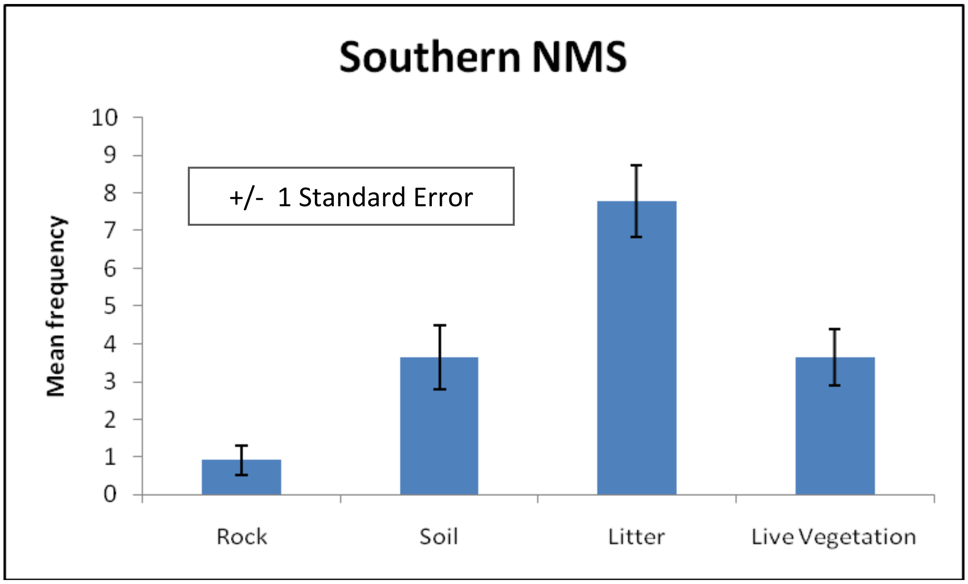


Figure 3.5-19. Mean frequency of ground cover along along Transects 8 through 11, NMS.

3.5.5 Threatened and Endangered Species and Species of Concern

3.5.5.1 Threatened and Endangered Species

The only federally or locally listed species identified at NMS by BioSystems Analysis, Inc. (1989) was the tree fern tsatsa (*Cyathea lunulata*), which is locally protected as an endangered species. No tree ferns or other listed species were observed at NMS during the current survey.

3.5.5.2 Species of Concern

BioSystems Analysis, Inc. (1989) cited the presence of several rare but unprotected species at NMS. These are listed below:

Figure 3.5-20. Faniok (*Merriolliodendron megacarpum*) forest along Transect 9, NMS.

- *Thelypteris warburgii*, a fern indigenous to Guam and Papua New Guinea that occurs only at NMS along the Bonya, Tolaeyuus and Maemong Rivers.
- *Eria rostiflora*, an epiphytic orchid found only at NMS.
- *Coelogyne guamensis*, an epiphytic orchid found locally only at NMS.
- *Nervilia platychila*, a ground orchid found locally only at NMS.
- *Maesa* sp., a tree found locally only at NMS.
- *Fagraea berteriana*, a native tree found locally only at NMS.

- *Merrilliodendron megacarpum*, a native tree with limited distribution on Guam (Figure 3.5-20).

The current survey found *Thelypteris warburgii* near Transects 5 and 6, with only one plant at each site (Figure 3.5-21). *T. warburgii* is also considered a species of concern by the U.S. Fish and Wildlife Service (USFWS, 2005). *Merrilliodendron megacarpum* was quantified in the forest stands along Transect 9 around Mt. Almagosa (see Figure 3.5-20). A few specimens of *Fagraea berteriana* were observed along Transects 1 and 9, some of which were flowering and fruiting.

Figure 3.5-21. *Thelypertis warburgii* along Bonya River, NMS.

Figure 3.5-22. *Tuberolabium guamensis* along Transect 5, NMS.

The following uncommon species were also noted along transects at NMS, although they are not regulated or managed by the federal or local authorities: *Heterogonium pinnatum*, a terrestrial fern; *Hedyotis laciniata*, an endemic herb of the savannas; *Tuberolabium* (*Trachoma*) *guamensis*, an endemic epiphytic orchid found on Guam and Rota (Figure 3.5-22; and *Luisia teretifolia*, an indigenous epiphytic orchid found on Guam and Rota (Figure 3.5-23).

The Guam Department of Agriculture lists fadang (*Cycas micronesica*) among the six plant species of greatest conservation need (SOGCN) (Department of Agriculture, 2006). This was the only SOGCN observed during the current survey. In the northern sector of NMS, fadang had a relative density of less than 4% on Transects 1 and 3; it was not sampled on other transects in northern NMS. On transects in the southern sector of NMS, fadang appeared only on Transects 8 and 10, where it had relative densities of approximately 2% and 4%, respectively.

Figure 3.5-23. *Luisia teretifolia* along Transect 7, NMS.

3.6 Orote Peninsula

3.6.1 Location

The Orote Peninsula extends into the Philippine Sea, forming the southern boundary of Outer Apra Harbor. The steep escarpments overlooking the ocean and strict security associated the Navy's ammunition wharf (Kilo Wharf) have kept the Peninsula relatively inaccessible to unauthorized persons and feral ungulates.

Figure 3.6-1. Limestone karst topography of Orote Peninsula. Native fadang (*Cycas micronesica*) and umumu (*Pisonia grandis*) trees are shown in the center and left of the photo, respectively.

3.6.2 Previous Studies

BioSystems Analysis Inc. (1988) described the limestone forest that lines the southern and western cliffs of Orote Peninsula as the largest in the Apra Harbor complex, with the best forest located in the western sector of the Peninsula. The study identified *Tristiropsis acutangula*, *Neisosperma oppositifolia*, *Ficus prolixa*, and *Heritiera longipetiolata*, among others, as the dominants in the limestone forest. The Peninsula has also undergone studies associated with the development of the ammunition wharf (VTN Pacific, 1983) and its extension (Department of the Navy, 2007) on the northern coast of the Peninsula. The vegetation survey for the extension of Kilo Wharf identified upland forests and strand vegetation; the upland forests were further categorized as native limestone forest, disturbed limestone forest, halophytic-xerophytic scrub, tangantangan (*Leucaena leucocephala*) secondary forest, and coconut (*Cocos nucifera*) forest (I Tano', 2006). The overall forest density in the vicinity of the wharf was calculated as 92 trees per 100 m², or approximately 9,200 trees per ha. Tangantangan (*Leucaena leucocephala*) had the highest density and frequency; the dominants based on biomass were *Pisonia grandis* and *Calophyllum inophyllum*.

3.6.3 Quantitative Observations

Surveys were performed along a transect in the upper plateau to the west of the old runway in the southern sector of Orote. The area has a rugged limestone karst topography (Figure 3.6-1). Based on the transect results, the overall density in this sector of Orote is approximately 5,030 trees per hectare (Table 3.6-1). The limestone forest was characterized by native fago (*Neisosperma oppositifolia*) trees, which comprised 28% of the relative density (Figure 3.6-2), or approximately 1,414 trees per ha. The next highest densities were for the well-established but non-native trees tangantangan (*Leucaena leucocephala*) and lemonchina (*Triphasia trifolia*), with densities of 16% and 14%, respectively. Collectively, these introduced species, including papaya (*Carica papaya*), comprised 33% of the relative density. The remaining 73% of the relative density comprised native species, including the Mariana Islands endemic species *Aglaia mariannensis* and *Tabernaemontana rotensis*.

Table 3.6-1

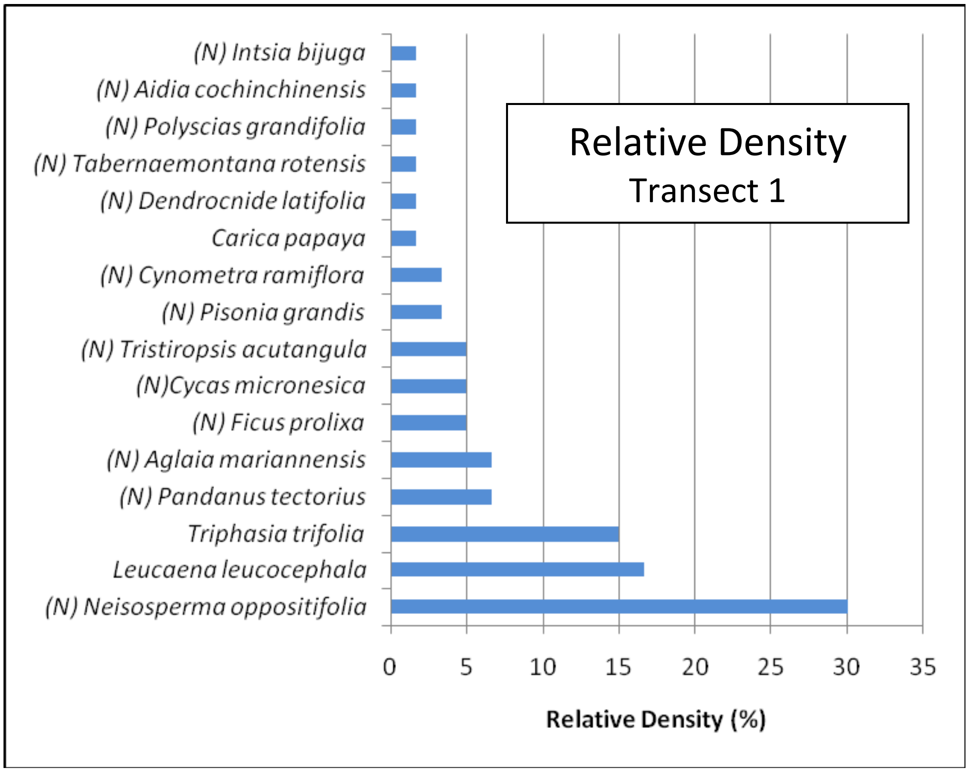
POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
OROTE PENINSULA, FEBRUARY 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Ficus prolixa	N	235.78	2651.70	883.90	20.84	12.50
Pisonia grandis	N	157.19	2060.95	1030.47	16.20	12.50
Tristiropsis acutangula	N	235.78	2027.03	675.68	15.93	18.75
Neisosperma oppositifolia	N	1414.67	717.11	39.84	5.64	56.25
Cycas micronesica	N	235.78	454.71	151.57	3.57	18.75
Aglaia mariannensis	N	314.37	364.22	91.06	2.86	18.75
Pandanus tectorius	N	314.37	362.43	90.61	2.85	25.00
Leucaena leucocephala	I	785.93	332.52	33.25	2.61	37.50
Triphasia trifolia	I	707.33	135.84	15.09	1.07	37.50
Carica papaya	I	78.59	66.44	66.44	0.52	6.25
Intsia bijuga	N	78.59	59.57	59.57	0.47	6.25
Polyscias grandifolia	N	78.59	41.46	41.46	0.33	6.25
Tabernaemontana rotensis	N	78.59	26.96	26.96	0.21	6.25
Cynometra ramiflora	N	157.19	19.82	9.91	0.16	12.50
Dendrocnide latifolia	N	78.59	18.09	18.09	0.14	6.25
Aidia cochinchinensis	N	78.59	10.17	10.17	0.08	6.25

Key to Status: N = native; I = introduced.

Absolute cover or dominance was highest for native *Ficus prolixa* (20.84 m²/ha), *Pisonia grandis* (16.20 m²/ha), and *Tristiropsis acutangula* (15.93 m²/ha); each had total basal areas exceeding 2,000 cm². These species occupy the uppermost canopy of the forest. In comparison, non-native *Leucaena leucocephala*, *Triphasia trifolia*, and *Carica papaya*, which occupy the forest understory, had relatively modest absolute cover values below 3 m²/ha.

Absolute frequency was led by native fago (*Neisosperma oppositifolia*), a mid to upper canopy tree, with a value of 56.25. The naturalized species, *Triphasia trifolia* and *Leucaena leucocephala*, had the next highest absolute frequencies at 37.50 each. *Leucaena* is well-distributed on Orote Peninsula, forming buffers between the periphery of the forest and cleared areas. *Leucaena* had a density of 59.23 trees per 100 m² (5,923 trees per ha) and an absolute frequency of 75 in forests sampled near the Kilo Wharf extension project on the northern coast of the Peninsula (I Tano', 2006).



Note: (N) indicates native species; others are introduced.

Figure 3.6-2. Relative density (%) of trees at Orote Peninsula.

The woody seedling composition in plots at Orote consisted of about 84% native seedlings, with a seedling density of 4.04 seedlings per m² (Figure 3.6-3). Introduced seedlings comprised approximately 15%, with a density of 0.76 seedlings per m².

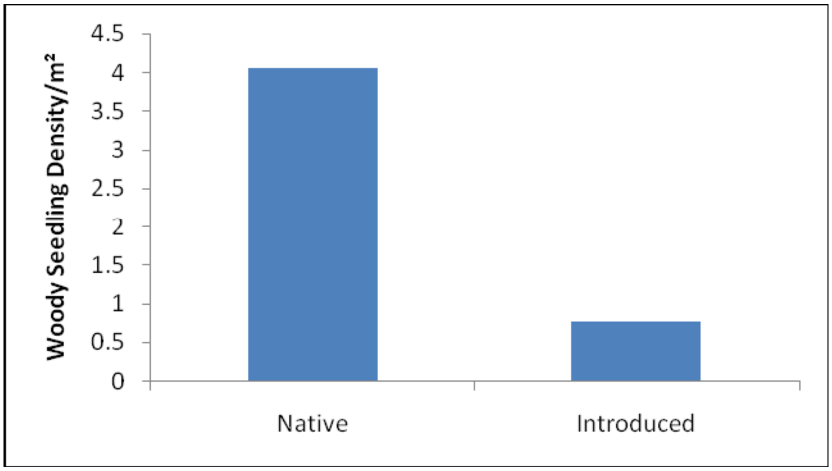


Figure 3.6-3. Density of native and introduced woody seedlings at Orote Peninsula.

The native woody seedling density seemed to reflect the higher relative density of native tree species quantified in the point-center quarter transect.

3.6.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at the Route 15 study area. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. The species richness curve does not show a definite asymptote to indicate that richness has leveled off (Figure 3.6-4).

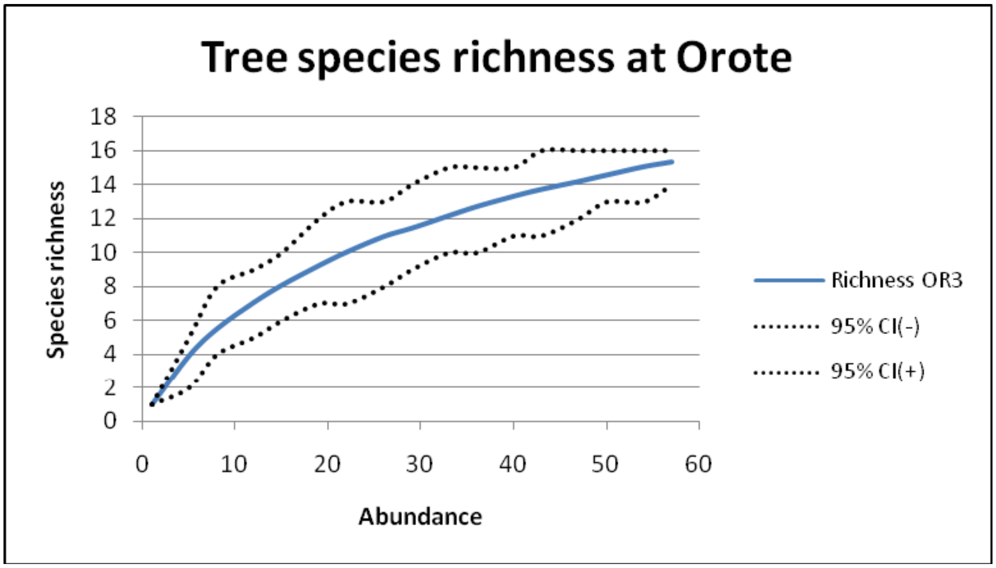


Figure 3.6-4. Species richness of trees at Orote Peninsula.

The mean frequency of ground cover in four categories was calculated based on quadrats (Figure 3.6-5). The categories of rock and vegetative litter had close mean frequencies; live vegetation was very low and no bare soil was observed in quadrats.

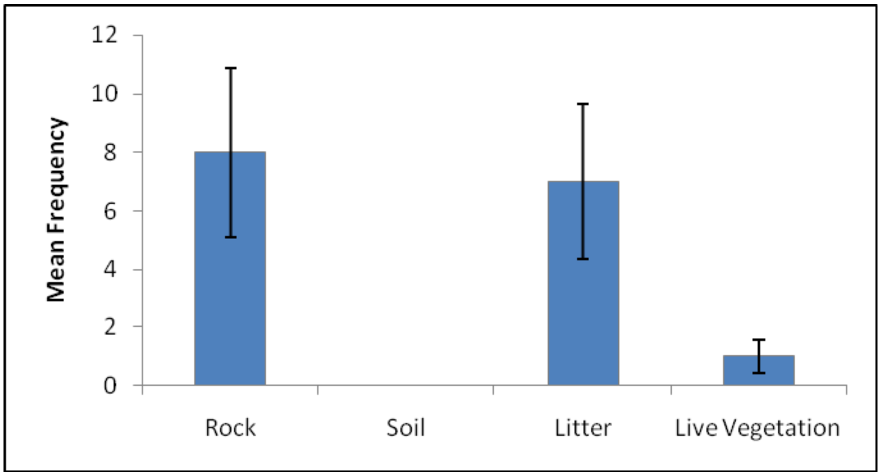


Figure 3.6-5. Mean frequency of ground cover at Orote Peninsula.

Orote Peninsula is considered free of ungulates because of its topography and relative isolation. Nonetheless, the area was surveyed for soil disturbance or other activity attributed to ungulates; however, no ungulate sign was recorded at Orote Peninsula along the vegetation transect.

3.6.5 Threatened and Endangered Species and Species of Concern

3.6.5.1 Threatened and Endangered Species

Guam's only federally-listed plant species, the fire tree or trongkon guafi (*Serianthes nelsonii*), is known to occur only at the northern tip of the island (USFWS, 1993). BioSystems Analysis, Inc. (1988) identified ufa halomtano (*Heritiera longipetiolata*) as the only listed species within Orote Peninsula. *Heritiera* is listed as an endangered species by the Government of Guam under the Endangered Species Act of Guam (5 GCA, Chapter 63), and is also considered a Species of Greatest Conservation Need (Department of Agriculture, 2006). The areas below the Spanish Steps and Orote cliffline contain significant numbers of ufa halomtano (BioSystems Analysis, Inc. 1988). The survey for the extension of Kilo Wharf documented seven live individuals (including one seedling) on the cliff south of the Wharf (I Tano', 2006). No specimens of *Heritiera* were found in the present survey, which sampled the forest on the southern region of the Peninsula opposite the ammunition wharf.

3.6.5.2 Notable Species and Species of Concern

The following species of concern were identified within Orote Peninsula during the current survey:

Figure 3.6-6. *Tabernaemontana rotensis* at Orote.

- *Tabernaemontana rotensis* (Apocynaceae) is an endemic tree with distribution limited to the islands of Guam and Rota. The species was proposed for federal listing under the U.S. Endangered Species Act; however, this candidacy status was removed in 2004. *Tabernaemontana* is considered a Species of Greatest Conservation Need by the Government of Guam (Department of Agriculture, 2006). Herbivory and insect infestations are thought to be the major threats to this species. *Tabernaemontana* was not detected by BioSystems Analysis (1988) or during the survey for the extension of Kilo Wharf (I Tano', 2006). One live specimen was encountered in the current vegetation survey (Figure 3.6-6), which appeared to be a healthy tree with a basal area of 26.96 cm². No flowers, fruits, or seedlings were observed.
- *Pisonia grandis* (Nyctaginaceae) is an indigenous tree considered important to the recovery of the Micronesian kingfisher (*Halcyon cinnamomina cinnamomina*) as nesting habitat. A density of 157 trees per ha was calculated for the survey at Orote.

- *Cycas micronesica* (Cycadaceae) is listed by the Guam Department of Agriculture as a Species of Greatest Conservation Need (SOGCN). This native cycad is under threat by an introduced insect, the Asian scale (*Aulacaspis yasumatsui*).

Although they are not regulated or managed by the local or federal governments, several notable species were observed at Orote and are discussed below.

- *Tristiropsis acutangula* (Balsalminaceae) is an indigenous tree of limited distribution on Guam. Orote had the highest density of *Tristiropsis* (approximately 236 trees per ha) among all DOD and non-DOD lands investigated in the current survey.
- *Zeuxine fritzii* (Orchidaceae) is an indigenous ground orchid found on forest floors. Feral pigs are known threats through their rooting activities.
- *Streblus pendulinus* (Moraceae) is a shrub or small tree indigenous to Guam (Figure 3.6-7). *Streblus* was not detected on any other transects on DOD or non-DOD lands in the current survey.

3.7

Figure 3.6-7. *Streblus pendulinus* at Orote.

Route 15

3.7.1 Location

The Route 15 study area encompasses three contiguous parcels: Lot 7161-R1 (252.54 acres) in the north; Andersen South MARBO Command "C", Andersen Administrative Annex (AJJW) (395.08 acres) located adjacent and south of this lot; and Lot 7164 (377.17 acres) located adjacent and east of both parcels along the northeastern coast of Guam. The study area is bound by the Pacific Ocean on the east and Route 15 on the west. The Andersen South Housing Area (also known as MARBO Base Command B-R5 or MARBO Annex) is located to the west of the site across Route 15. The northern parcel is actively quarried in support of on-going long-term construction of the Guam Raceway Park, a multi-sport venue with a completed drag racing strip and motocross track. Extensive sections of Lot 7161-R1 have been cleared and graded, and much of the intact forest is limited to the coastal plateau, and northern and southern peripheries. The southern parcel is mostly undeveloped with a network of overgrown jeep trails among the second growth forest. This parcel is administered by Guam Economic Development Authority (GEDCA) on behalf of the Guam Ancestral Lands Commission. The eastern parcel (Lot 7164) lies below the northern and southern parcels. Agricultural leaseholders actively farm assorted citrus and other fruit species on a portion of this lower limestone plateau.

Figure 3.7-1. View of lower plateau sampled in Transect 3, Route 15.

3.7.2 Previous Studies

The northern parcel was previously surveyed as part of the environmental impact assessment prepared by Duenas and Associates, Inc. (2000) for the existing Guam Raceway Park. The study identified 115 vascular plant species in three plant communities: primary/secondary limestone forest (158 acres), disturbed vegetation/grasslands (33 acres), and halophytic/xerophytic scrub on cliff faces. Sixteen of the species documented in Lot 7161-R1 are endemic to the Mariana Islands (Duenas and Associates, Inc., 2000). Quantitative data was collected in the study along three 200-meter transects using the point-center quarter method. The data revealed absolute densities of live trees of 50.3, 57.8 and 61.54 trees per 100 square meters, in the northern, central and southern sectors, respectively (Duenas and Associates, Inc., 2000). For comparison with the current survey, these values were converted to 5,030, 5,748, and 6,154 trees per hectare, respectively.

3.7.3 Quantitative Observations

Surveys were performed along three transects in the limestone forest communities of the Route 15 parcels. Transect 1 was located in the northeastern sector of Lot 7161-R1 along a north-south axis; Transect 2 was located on the GEDCA parcel to the south along a north-south axis; and Transect 3 was located along a north-south axis in Lot 7164 on the plateau below Transect 2 (Figure 3.7-1).

Figure 3.7-2. ***Eugenia reinwardtiana*****, or a'abang, in the limestone forest of the lower plateau, Lot 7164.**

The quantitative observations from the point-center quarter survey along Transect 1 revealed an absolute density of approximately 3,148 trees per hectare in Lot 7161-R1. Native fadang (*Cycas micronesica*) and ifil (*Intsia bijuga*), and introduced papaya (*Carica papaya*) were the most dominant species, with absolute cover values from 3.73 to 5.33 m² per hectare (Table 3.7-1). Pengua (*Macaranga thompsonii*), a species endemic to the Marianas, was the next most dominant species with an absolute cover of 3.08 m² per hectare. This tree is a broad-leaved canopy species ranging from 5 to 12 m tall (Raulerson and Rinehart, 1991). Pengua appeared on all three transects. Fadang had the highest total basal area (2,100 cm²); however, sizeable specimens of ifil, a native hardwood, were also present. Ifil had the highest mean basal area (293 cm²) based on five specimens sampled on the transect.

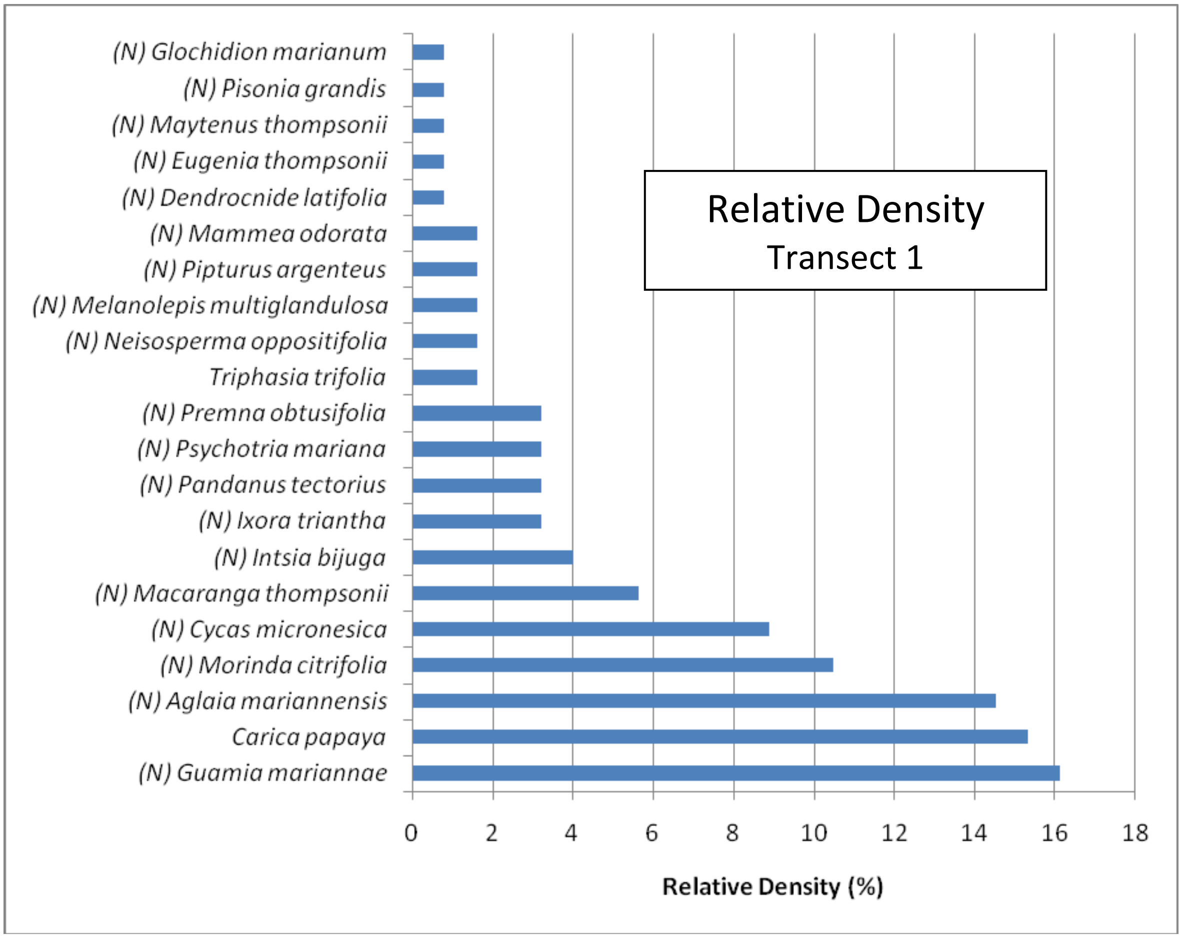
The relative density was highest for paipai (*Guamia mariannae*), papaya, and mapunao (*Aglaia mariannensis*), with relative densities of approximately 16%, 15% and 14.5%, respectively (Figure 3.7-3). These species also had the highest absolute frequencies, indicating that they are well-distributed along the transect.

Table 3.7-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 1, RT. 15, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Cycas micronesica	N	279.30	2100.84	190.99	5.33	29.03
Carica papaya	I	482.43	1599.16	84.17	4.06	35.48
Intsia bijuga	N	126.95	1468.32	293.66	3.73	16.13
Macaranga thompsonii	N	177.74	1211.87	173.12	3.08	19.35
Aglaia mariannensis	N	457.03	1178.10	65.45	2.99	38.71
Pandanus tectorius	N	101.56	629.89	157.47	1.60	9.68
Guamia mariannae	N	507.82	504.54	25.23	1.28	45.16
Mammea odorata	N	50.78	466.33	233.16	1.18	6.45
Morinda citrifolia	N	330.08	459.05	35.31	1.17	29.03
Premna obtusifolia	N	101.56	382.75	95.69	0.97	12.90
Psychotria mariana	N	101.56	329.43	82.36	0.84	12.90
Eugenia thompsonii	N	25.39	218.93	218.93	0.56	3.23
Pisonia grandis	N	25.39	172.46	172.46	0.44	3.23
Pipturus argenteus	N	50.78	125.46	62.73	0.32	6.45
Dendrocnide latifolia	N	25.39	63.59	63.59	0.16	3.23
Glochidion marianum	N	25.39	58.06	58.06	0.15	3.23
Ixora triantha	N	101.56	53.40	13.35	0.14	9.68
Neisosperma oppositifolia	N	50.78	44.41	22.20	0.11	6.45
Melanolepis multiglandulosa	N	50.78	28.36	14.18	0.07	3.23
Maytenus thompsonii	N	25.39	12.56	12.56	0.03	3.23
Triphasia trifolia	I	50.78	7.26	3.63	0.02	6.45

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.7-3. Relative density (%) of trees at Rt. 15 Parcel.

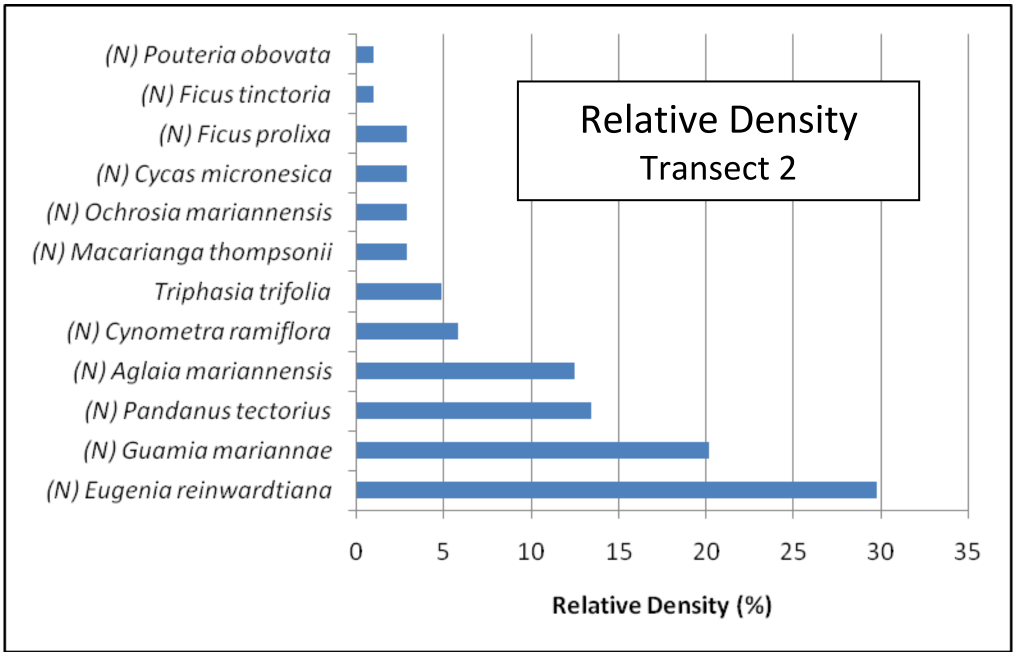
The forest in the southern GEDCA parcel had an absolute density of 4,566 trees per hectare. This was the highest overall density among the three transects in the Route 15 project area. On this transect, the native a'abang (*Eugenia reinwardtiana*) was dominant with an absolute cover of 8.19 m² per hectare and an absolute density of 1,321 trees per hectare (Table 3.7-2). A'abang was also well-dispersed, and had the highest frequency (57.69) among the 12 species on the transect. Pengua (*Macaranga thompsonii*) had an even higher absolute cover (5.13 m² per hectare) than in Transect 1, although absolute density was lower at 131.73 trees per hecatare. The relative density of trees was highest for a'abang at nearly 30%, followed by paipai (*Guamia mariannae*) and kafu (*Pandanus tectorius*) at 20% and 13%, respectively (Figure 3.7-4). Fadang (*Cycas micronesica*) had a lower absolute density (131.73 trees per hectare), absolute cover (218.61 cm²), and absolute frequency (7.69) than in Transect 1 (see Table 3.7-1, Figure 3.7-3).

Table 3.7-2

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 2, RT. 15, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Eugenia reinwardtiana	N	1361.19	1865.37	60.17	8.19	57.69
Pandanus tectorius	N	614.73	1551.13	110.79	6.81	30.77
Macarianga thompsonii	N	131.73	1169.42	389.81	5.13	11.54
Guamia mariannae	N	922.09	779.91	37.14	3.42	53.85
Cycas micronesica	N	131.73	655.83	218.61	2.88	7.69
Aglaia mariannensis	N	570.82	646.02	49.69	2.84	30.77
Ficus prolixa	N	131.73	201.22	67.07	0.88	7.69
Cynometra ramiflora	N	263.46	189.81	31.64	0.83	19.23
Ochrosia mariannensis	N	131.73	86.95	28.98	0.38	11.54
Ficus tinctoria	N	43.91	56.72	56.72	0.25	3.85
Triphasia trifolia	I	219.55	36.76	7.35	0.16	15.38
Pouteria obovata	N	43.91	12.56	12.56	0.06	3.85

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.7-4. Relative density (%) of trees along Transect 2, Route 15.

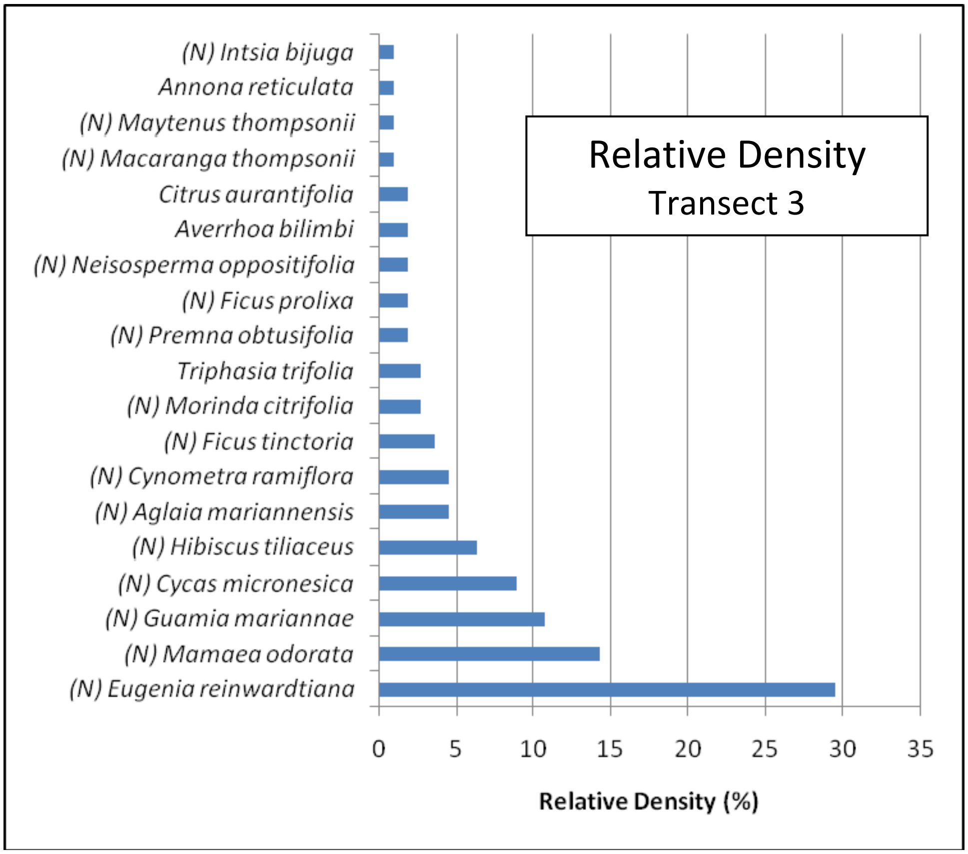
Transect 3, on the lower plateau of Lot 7164, was closest to sea level among the three transects in the project area, but was further inland from the halophytic/xerophytic plant community along the coast. The absolute density was approximately 3,183 trees per hectare. As with Transect 2, a'abang (*Eugenia reinwardtiana*) was a dominant component, with the highest absolute density (937.92 trees per hectare), absolute cover (6.84 m² per hectare), and absolute frequency (67.86) (Table 3.7-3).

Table 3.7-3

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 3, RT. 15, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Eugenia reinwardtiana	N	937.92	2407.77	72.96	6.84	67.86
Cycas micronesica	N	284.22	1973.40	197.34	5.61	32.14
Neisosperma oppositifolia	N	56.84	1676.52	838.26	4.76	7.14
Ficus tinctoria	N	113.69	1638.75	409.69	4.66	3.57
Premna obtusifolia	N	56.84	1210.86	605.43	3.44	7.14
Mamaea odorata	N	454.75	1103.45	68.97	3.14	39.29
Intsia bijuga	N	28.42	961.63	961.63	2.73	3.57
Macaranga thompsonii	N	28.42	720.70	720.70	2.05	3.57
Aglaia mariannensis	N	142.11	486.38	97.28	1.38	17.86
Hibiscus tiliaceus	N	198.95	400.85	57.26	1.14	14.29
Morinda citrifolia	N	85.27	275.64	91.88	0.78	10.71
Averrhoa bilimbi	I	56.84	268.04	134.02	0.76	3.57
Guamia mariannae	N	341.06	243.99	20.33	0.69	35.71
Cynometra ramiflora	N	142.11	228.23	45.65	0.65	14.29
Ficus prolixa	N	56.84	96.94	48.47	0.28	3.57
Citrus aurantifolia	I	56.84	66.33	33.17	0.19	3.57
Triphasia trifolia	I	85.27	50.91	16.97	0.14	3.57
Maytenus thompsonii	N	28.42	9.62	9.62	0.03	3.57
Annona reticulata	I	28.42	7.54	7.54	0.02	3.57

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.7-5. Relative density (%) of trees along Transect 3, Route 15.

The mean woody seedling density was calculated for the three transects at Route 15 (Figure 3.7-6). Native seedlings exceeded mean density of 6 seedlings per m², compared with a mean density of approximately 1 seedling per m² for non-native species.

Native seedlings outranked introduced seedlings in every transect (Figure 3.7-7), especially in Transect 1. Non-native seedlings were nearly equivalent with native seedlings along Transect 3, which can be attributed to the presence of naturalized introductions, such as *Triphasia trifolia*, pickle tree (*Averrhoa bilimbi*), and custard apple (*Annona reticulata*), and some cultivated species, such as sweetsop (*Annona squamosa*) and citrus trees.

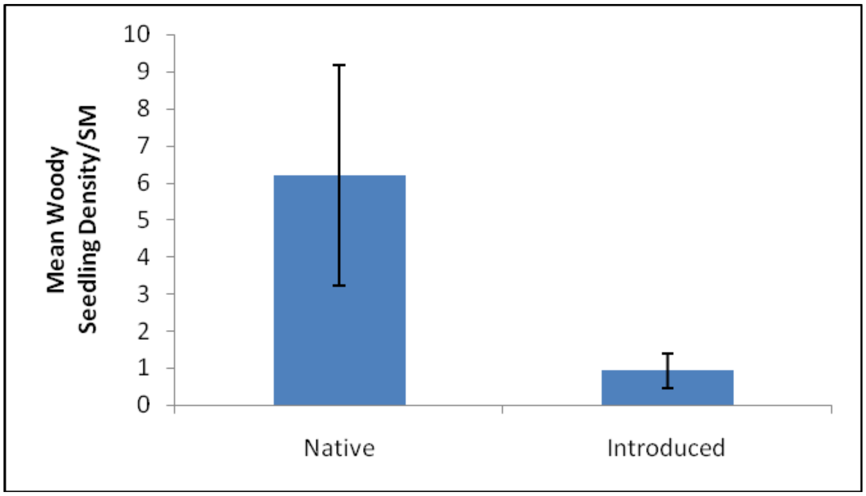


Figure 3.7-6. Mean woody seedling density for all transects, Route 15 (± 1 S.E.).

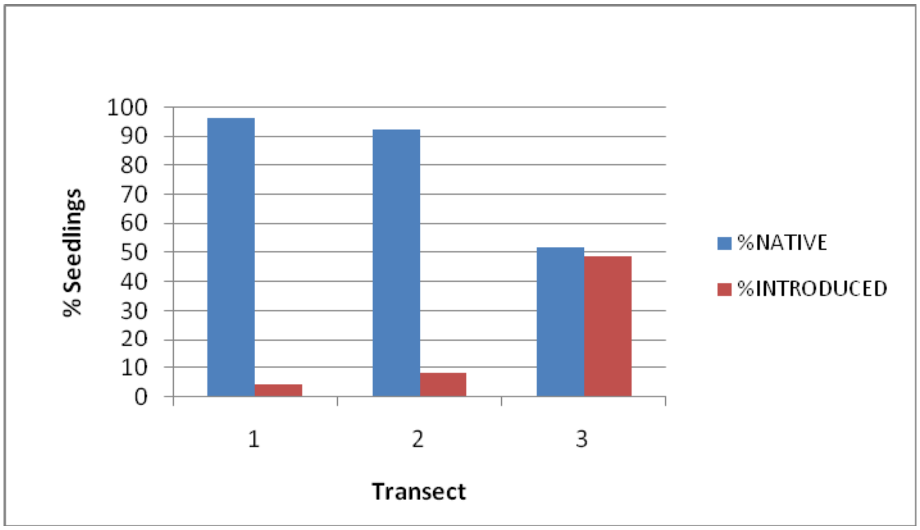


Figure 3.7-7. Percentage of native seedlings for each transect, Route 15.

3.7.4 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat at the Route 15 study area. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. Species richness curves for Transects 1 and 3 indicate higher richness for these areas than Transect 2 in the GEDCA parcel south of Lot 7161-R1 (Figure 3.7-8).

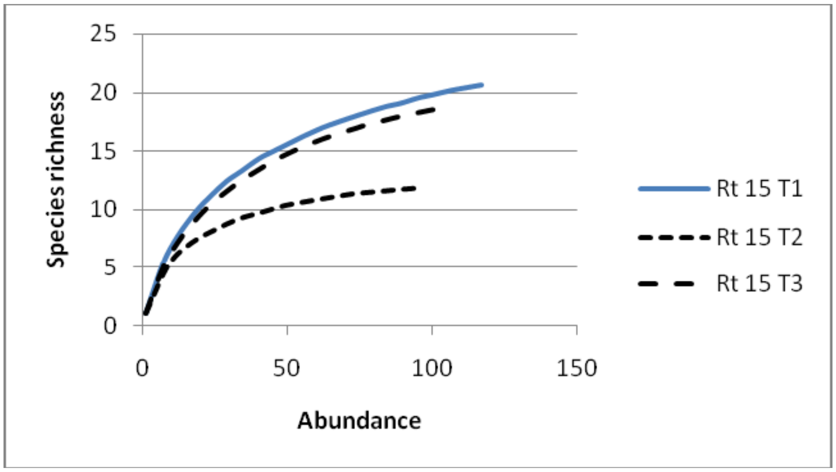


Figure 3.7-8. Species richness of trees along all transects at Route 15.

Leaf and vegetative litter had the highest frequency (8.7) among the four categories of ground cover quantified on the three transects (Figure 3.7-9). Live vegetation (3.9), rock (2.3), and soil (1.0) had significantly lower frequencies. Limestone rock outcrops were prevalent along all three transects as a natural feature of the terrain.

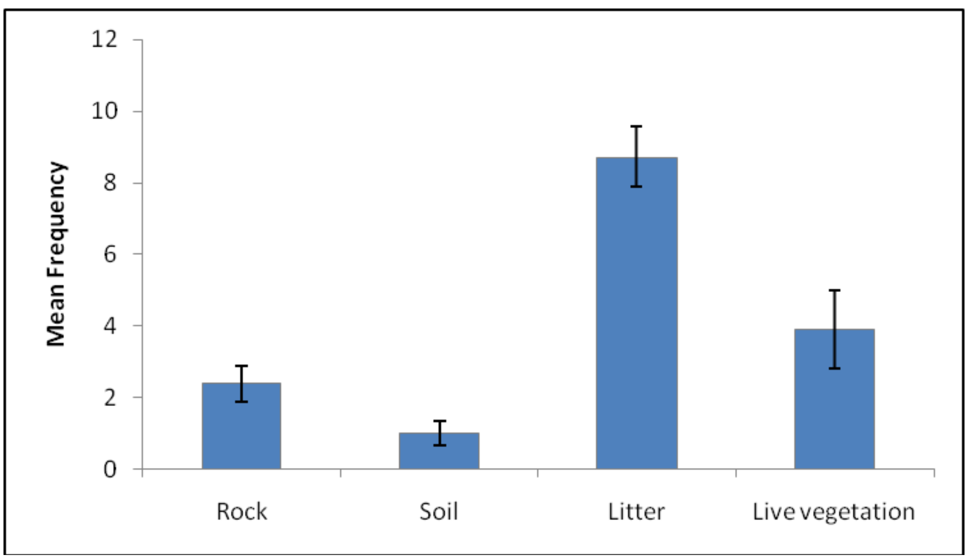


Figure 3.7-9. Mean frequency of ground cover along all transects at Route 15 (± 1 S.E.).

Ungulate activity along all three transects was highest in the form of soil disturbance (0.4), such as rooting or wallows (3.7-10). Rubbing and signs of browsing had similar frequencies approaching 0.2, while other signs, such as scat, were least observed with a frequency of around 0.1.

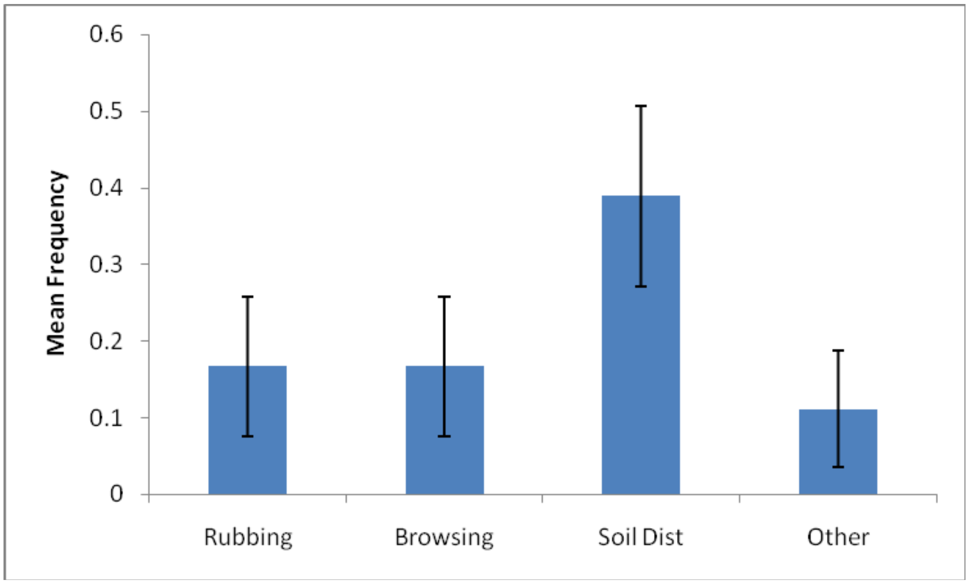


Figure 3.7-10. Mean frequency of ungulate activity along all transects at Route 15 (± 1 S.E.).

3.7.5 Threatened and Endangered Species and Species of Concern

3.7.5.1 Threatened and Endangered Species

The previous survey in Lot 7161-R1 identified 22 ufa halomtano (*Heritiera longipetiolata*) trees, with 184 associated seedlings (Duenas and Associates, Inc., 2000). This species is endemic to the Marianas and is listed as endangered by the Government of Guam, which considers ungulate damage, typhoons, and infrequent flowering as major threats to the viability of the population (Department of Agriculture, 2006). Other threats appear to be present, since several of the trees in Lot 7161-R1 were infested with termites or ants, or were parasitized by other plants, such as strangling fig (*Ficus* spp.) (Duenas and Associates, Inc., 2000). Several trees were left intact within a designated conservation area at the Guam Raceway Park as a required condition of the Department of Agriculture.

Figure 3.7-11. *Cycas micronesica* with *Nephrolephis acutifolia* epiphytes, Transect 1, Route 15.

No ufa halomtano trees were observed on the present transects in Lot 7161-R1 and Lot 7164; a single specimen was found near Transect 2 in the adjacent GEDCA parcel. The tree was mostly dead except for a 7 cm diameter branch near the base. The main trunk had a diameter at breast height (dbh) of 37 cm.

3.7.5.2 Species of Concern and Notable Species

The following species of concern were identified within the Route 15 parcels.

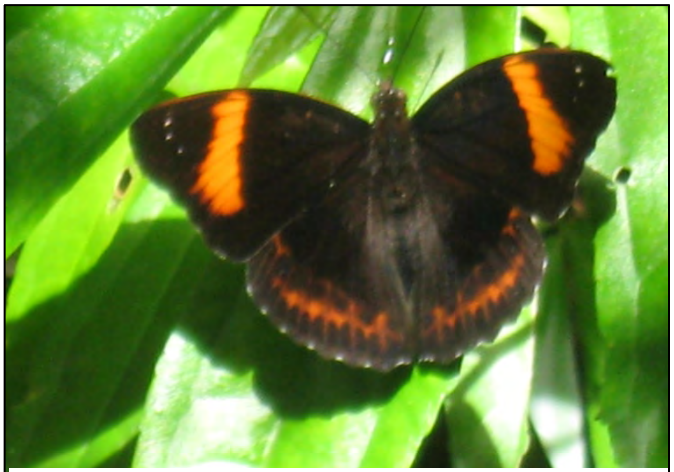


Figure 3.7-12. *Hypolimnas octocula* on Transect 2, Route 15.

Cycas micronesica (Figure 3.7-11) is considered a Species of Greatest Conservation Need (SOGCN) by the Government of Guam (Department of Agriculture, 2006). The islandwide populations are threatened by an introduced scale insect, *Aulocapsis yasumatsui*.

Elatostema calcareum (Urticaceae) and *Procris pedunculata* (Urticaceae) are indigenous succulent herbs that grow in limited habitats over limestone rock outcrops in moist limestone forest. These plants serve as host species for the Mariana eight-spot butterfly (*Hypolimnas octocula*), which is listed as a species of concern by the U.S. Fish and Wildlife Service (USFWS). One butterfly was found along Transect 2 in the GEDCA parcel (Figure 3.7-12).

Other species were noted, although they are not managed or protected by the local or federal governments.

Zehneria (*Melothria*) *guamensis* (Cucurbitaceae) is a rare endemic vine. The species was found in one small area of Lot No. 7161-R1 (Figure 3.7-13).

Figure 3.7-13. *Zehneria* (*Melothria*) *guamensis* with distinctive orange fruits, Transect 1, Route 15.

3.8 Former FAA Parcel

3.8.1 Location

The former FAA parcel (Lot Radio Station (R) Finegayan-1) is located adjacent and north of the Navy South Finegayan housing area in the Municipality of Dededo, Guam. The 678-acre property was the former site of the Federal Aviation Authority (FAA) Headquarters, but has since been returned to the Government of Guam (Guam Ancestral Lands Commission), and is currently administered by the Guam Economic Development and Commerce Authority (GEDCA). The parcel extends northwest from Route 3 to the western coastline encompassing Ague Point.

3.8.2 Quantitative Observations

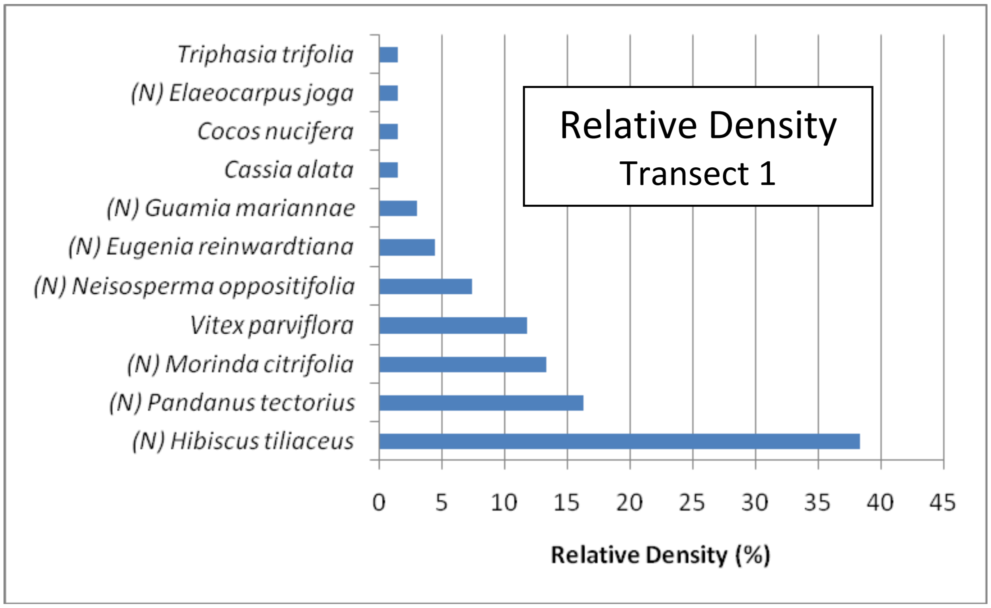
Quantitative surveys were performed using the point-center quarter method along three transects in the FAA parcel. Transect 1 was located along a north-south axis in the eastern sector and Transects 2 and 3 were located along a northwest-southeast axis in the central-southern sector.
Overall tree density among the three transects was lowest in the eastern sector with approximately 1,798 trees/ha and a total absolute cover of 25.85 m²/ha (Table 3.8-1). *Hibiscus tiliaceus*, or pago, was dominant with the highest density (687.44 trees/ha) and absolute frequency (58.82); however, this native species had a modest absolute cover of 2.03 m²/ha. Pago occurred as a mid-canopy species and comprised approximately 38% of the relative density among the 11 tree species encountered on the transect (Figure 3.8-1). Native species had a higher relative density (approximately 84%) than introduced species (approximately 16%). Aside from pago, kafu (*Pandanus tectorius*), lada (*Morinda citrifolia*) and *Vitex parviflora* had relative densities greater than 10%. Kafu and lada are native mid-canopy species; non-native *Vitex* occupied the upper canopy. Yoga (*Eleocarpus joga*), a native emergent canopy species, had the highest total basal area (4,126 cm²) and absolute cover (10.91 m²/ha), although only one specimen was encountered. *Eleocarpus* was not encountered along the other transects.

Table 3.8-1

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 1, FAA PARCEL, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Elaeocarpus joga	N	26.44	4126.16	4126.16	10.91	5.88
Vitex parviflora	I	211.52	2337.49	292.19	6.18	41.18
Morinda citrifolia	N	237.96	785.25	87.25	2.08	41.18
Hibiscus tiliaceus	N	687.44	766.06	29.46	2.03	58.82
Cocos nucifera	I	26.44	637.62	637.62	1.69	5.88
Pandanus tectorius	N	290.84	498.48	45.32	1.32	35.29
Neisosperma oppositifolia	N	132.20	304.42	60.88	0.80	17.65
Eugenia reinwardtiana	N	79.32	227.14	75.71	0.60	11.76
Guamia mariannae	N	52.88	51.94	25.97	0.14	11.76
Cassia alata	I	26.44	35.24	35.24	0.09	5.88
Triphasia trifolia	I	26.44	5.72	5.72	0.02	5.88

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.8-1. Relative density (%) of trees along Transect 1, FAA parcel.

Transect 2 in the central-southern sector had the highest density among the transects, with 2,856.98 trees/ha and a total absolute cover of 24.86 m²/ha (Table 3.8-2). Both pago (*Hibiscus tiliaceus*) and kafu prevailed over other species with densities of 546.19 trees/ha and absolute frequencies of 47.06. These species, and paipai (*Guamia mariannae*) and fago (*Neisosperma oppositifolia*), had relative densities exceeding 10% (Figure 3.8-2). Overall, native species had a higher relative density (about 82%) than introduced species (about 18%), which was similar to the proportion observed in the eastern sector along Transect 1. Two species, paipai and mapunao (*Aglaia mariannensis*), are endemic to the Mariana Islands.

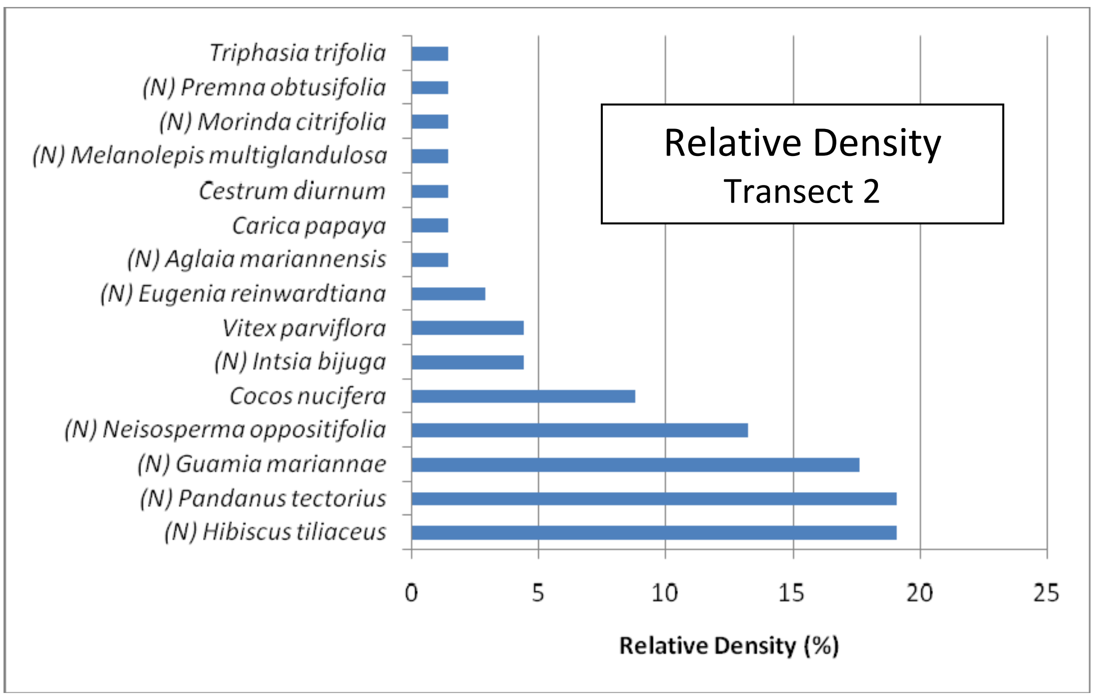
Coconut (*Cocos nucifera*) was dominant overall in absolute cover (12.75 m²/ha), followed by kafu, fago and ifil (*Intsia bijuga*). *Vitex parviflora* was less dominant than in Transect 1 in density (126 trees/ha) and absolute cover (0.93 m²/ha). The mean basal area of *Vitex* (73.91cm²) was also the lowest observed among the transects.

Table 3.8-2

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST
TRANSECT 2, FAA PARCEL, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	252.09	3034.26	505.71	12.75	17.65
Pandanus tectorius	N	546.19	802.61	61.74	3.37	47.06
Neisosperma oppositifolia	N	378.13	786.81	87.42	3.31	35.29
Intsia bijuga	N	126.04	406.21	135.40	1.71	11.76
Vitex parviflora	I	126.04	221.72	73.91	0.93	17.65
Hibiscus tiliaceus	N	546.19	194.10	14.93	0.82	47.06
Guamia mariannae	N	504.17	151.66	12.64	0.64	35.29
Premna obtusifolia	N	42.01	118.76	118.76	0.50	5.88
Carica papaya	I	42.01	88.20	88.20	0.37	5.88
Morinda citrifolia	N	42.01	52.78	52.78	0.22	5.88
Eugenia reinwardtiana	N	84.03	20.07	10.04	0.08	5.88
Triphasia trifolia	I	42.01	13.85	13.85	0.06	5.88
Aglaia mariannensis	N	42.01	11.34	11.34	0.05	5.88
Cestrum diurnum	I	42.01	10.17	10.17	0.04	5.88
Melanolepis multiglandulosa	N	42.01	4.52	4.52	0.02	5.88

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.8-2. Relative density (%) of trees along Transect 2, FAA parcel.

Transect 3 had an overall tree density of 1,868.79 trees/ha and a total absolute cover of 41.24 m^2/ha (Table 3.8-3). The overall absolute cover was the highest among the three transects. Pago was consistently dominant among the transects, with the highest individual density (632.09 trees/ha) on Transect 3, and a relative density of about 33% (Figure 3.8-3). Pago (*Hibiscus tiliaceus*) also had the highest frequency among the seven species on Transect 3. Collectively, native species had a relative density of about 62%, which was the lowest proportion of native species among the three transects.

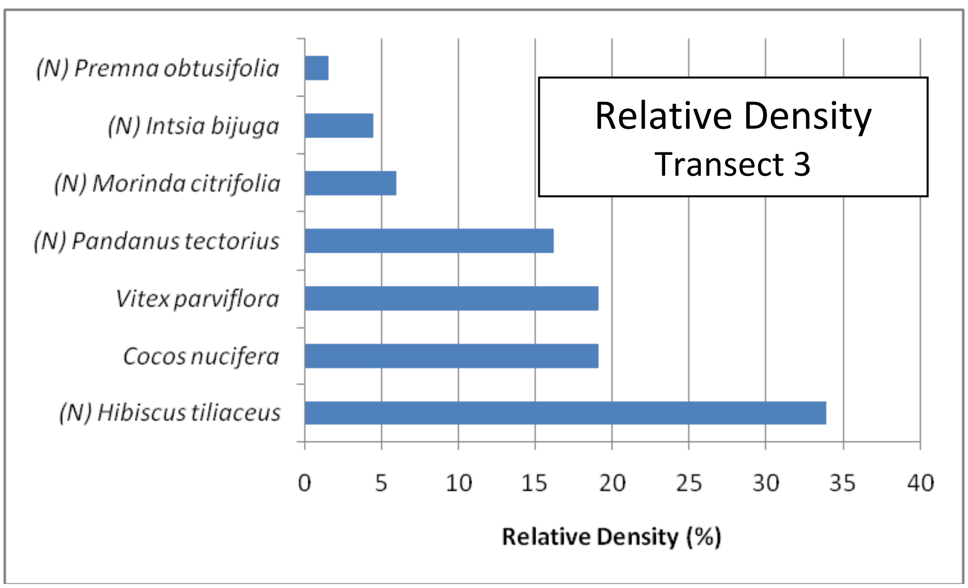
Coconut comprised the bulk of absolute cover (20.52 m/ha) on Transect 3; both density (357 trees/ha) and absolute cover were higher than in Transect 2. *Vitex parviflora* had the next highest absolute cover, and was as equally well-distributed along the transect as coconut with an absolute frequency of 41.18.

Table 3.8-3

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST TRANSECT 3, FAA PARCEL, DECEMBER 2008

SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Cocos nucifera	I	357.27	7470.79	574.68	20.53	41.18
Vitex parviflora	I	357.27	5764.55	443.43	15.84	41.18
Intsia bijuga	N	82.45	525.32	175.11	1.44	17.65
Pandanus tectorius	N	302.30	507.47	46.13	1.39	35.29
Hibiscus tiliaceus	N	632.09	375.67	16.33	1.03	64.71
Premna obtusifolia	N	27.48	319.72	319.72	0.88	5.88
Morinda citrifolia	N	109.93	41.62	10.41	0.11	17.65

Key to Status: N = native; I = introduced.



Note: (N) indicates native species; others are introduced.

Figure 3.8-3. Relative density (%) of trees along Transect 3, FAA parcel.

The mean woody seedling density was significantly higher for native species (2.7 seedlings/m²) than for non-native species (0.3 seedlings/m²) (Figure 3.8-4). The proportion of native to introduced seedlings was similar for Transects 1 and 2, and slightly lower for Transect 3 (Figure 3.8-5). The seedling density reflects the higher native component observed in the relative tree densities along the transects.

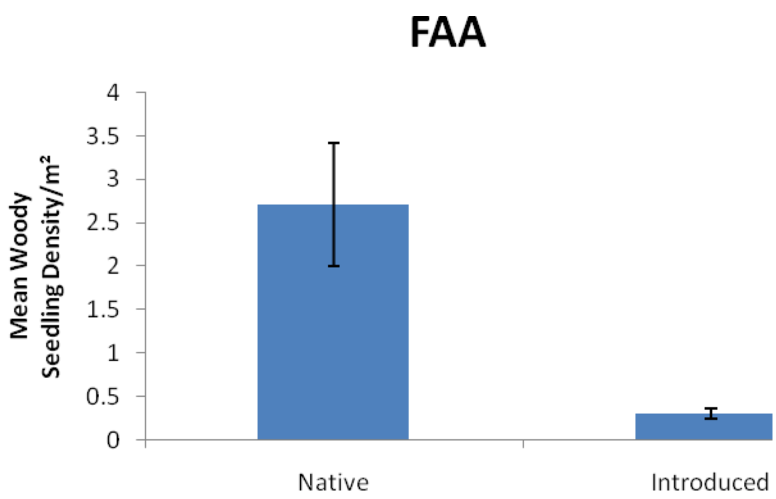


Figure 3.8-4. Mean woody seedling density for all transects, FAA parcel (± 1 S.E.).

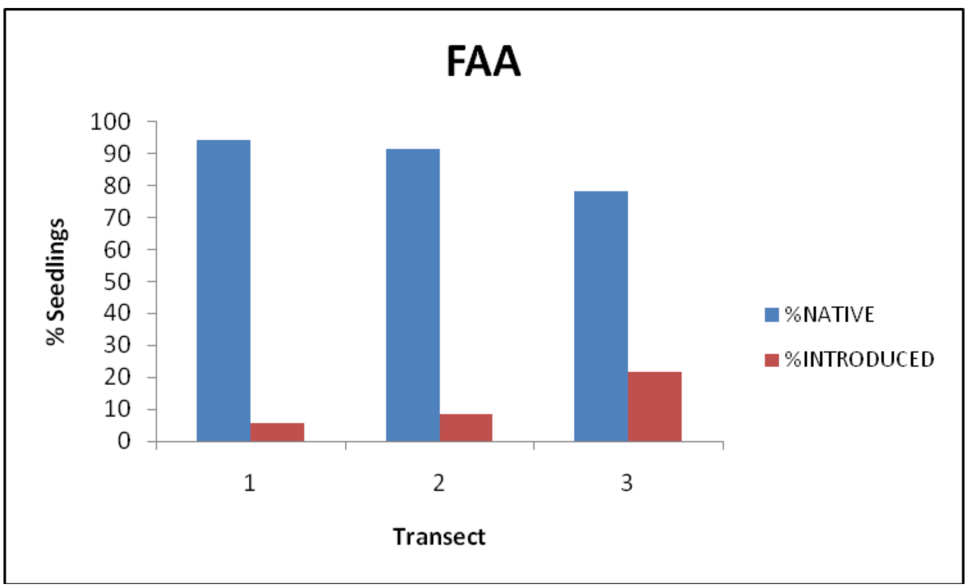


Figure 3.8-5. Percentage of native seedlings for each transect, FAA parcel.

3.8.3 Habitat Quality

Certain aspects of the plant communities may provide a general indication of the quality of the habitat in the former FAA parcel. These include ungulate activity, the presence of erosion, percent of native plant species, and overall species richness. Species richness curves indicate the highest tree species richness among the transects was along Transect 2, while Transect 3 had the lowest richness (Figure 3.8-6).

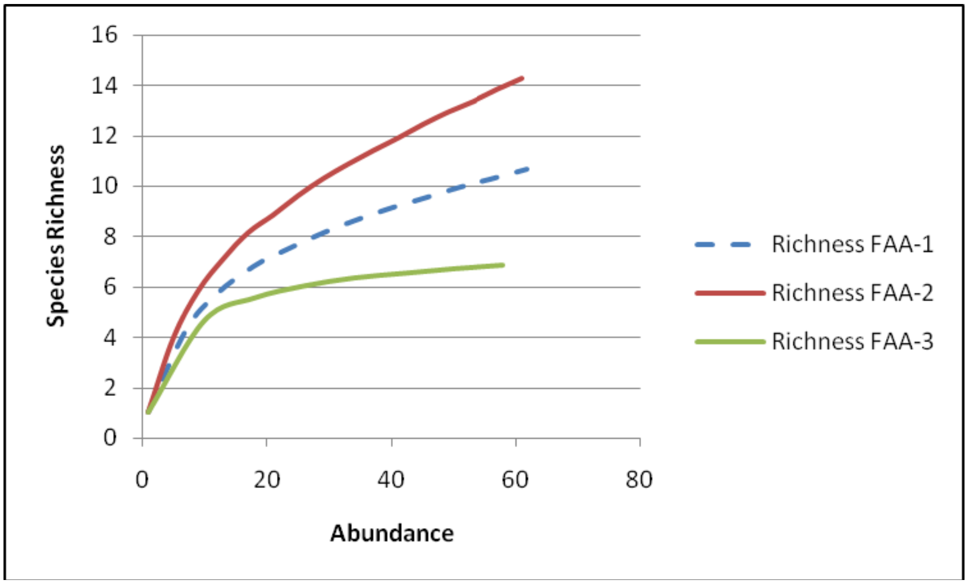


Figure 3.8-6. Species richness of trees along all transects at FAA parcel.

Leaf and vegetative litter comprised the highest mean frequency (5.6) among the four ground cover categories in the survey (Figure 3.8-7). Live vegetation had a similar frequency (5), while the limestone substrate and rocky terrain was reflected in the moderate frequency for rock (3.75). The lowest mean frequency was for bare soil (1.6).

Ungulate activity was encountered most frequently as soil disturbance, such as pig wallows and rooting (Figure 3.8-8). The mean frequency for soil disturbance appeared to be significantly higher than for rubbing and browsing on vegetation. Other signs of ungulate activity, such as scat, were not observed on the transects.

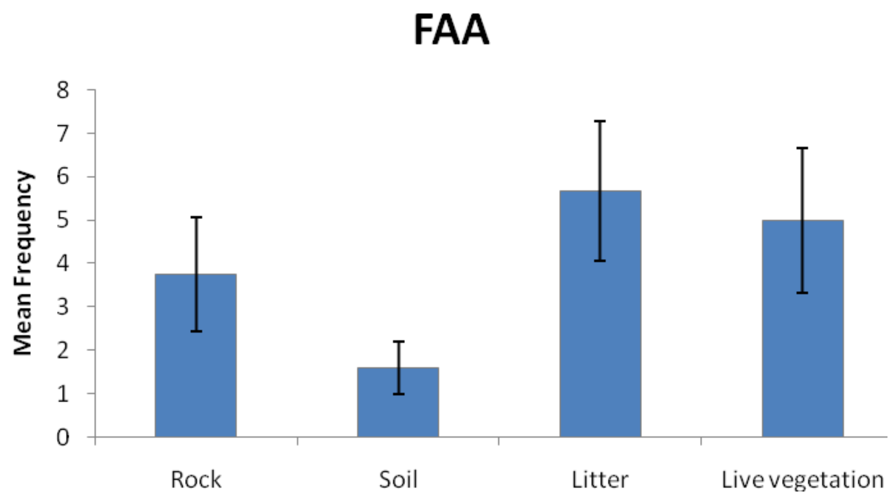


Figure 3.8-7. Mean frequency of ground cover along all transects at FAA (± 1 S.E.).

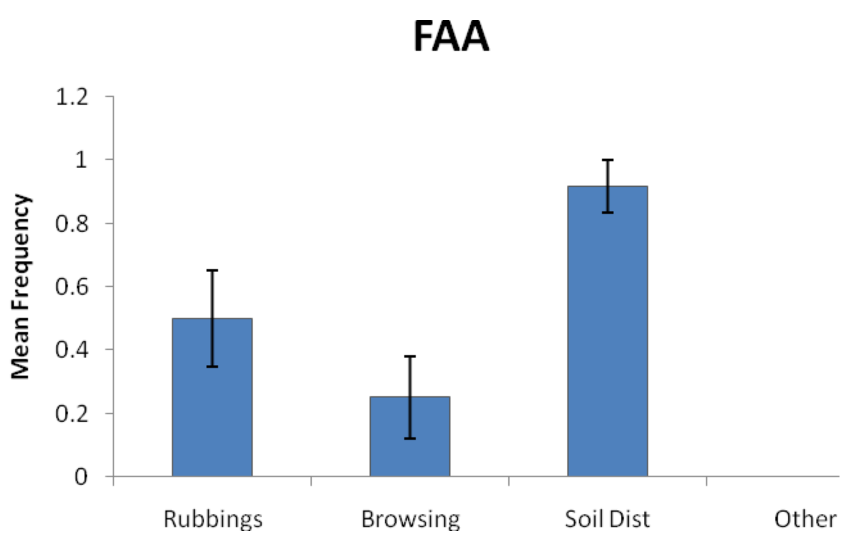


Figure 3.8-8. Mean frequency of ungulate activity along all transects at FAA (± 1 S.E.).

3.8.4 Threatened and Endangered Species and Species of Concern

No locally or federally listed threatened or endangered species were identified within former FAA parcel in the current survey. Likewise, no species of concern were identified within the study site.

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ATTACHMENT A

MAPS OF TRANSECTS

Figure 2. NCTS South Finegayan

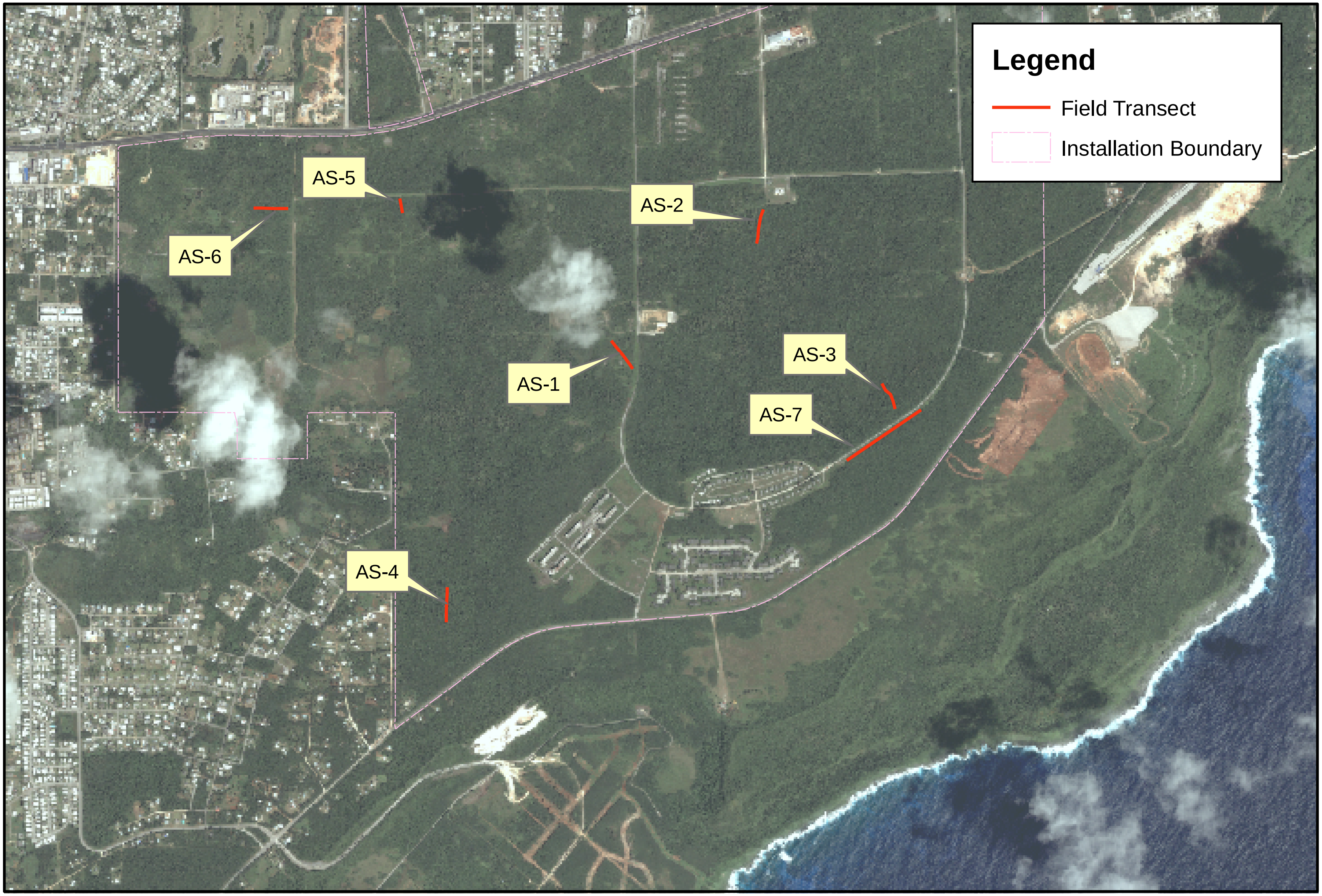

Figure 4. Andersen South

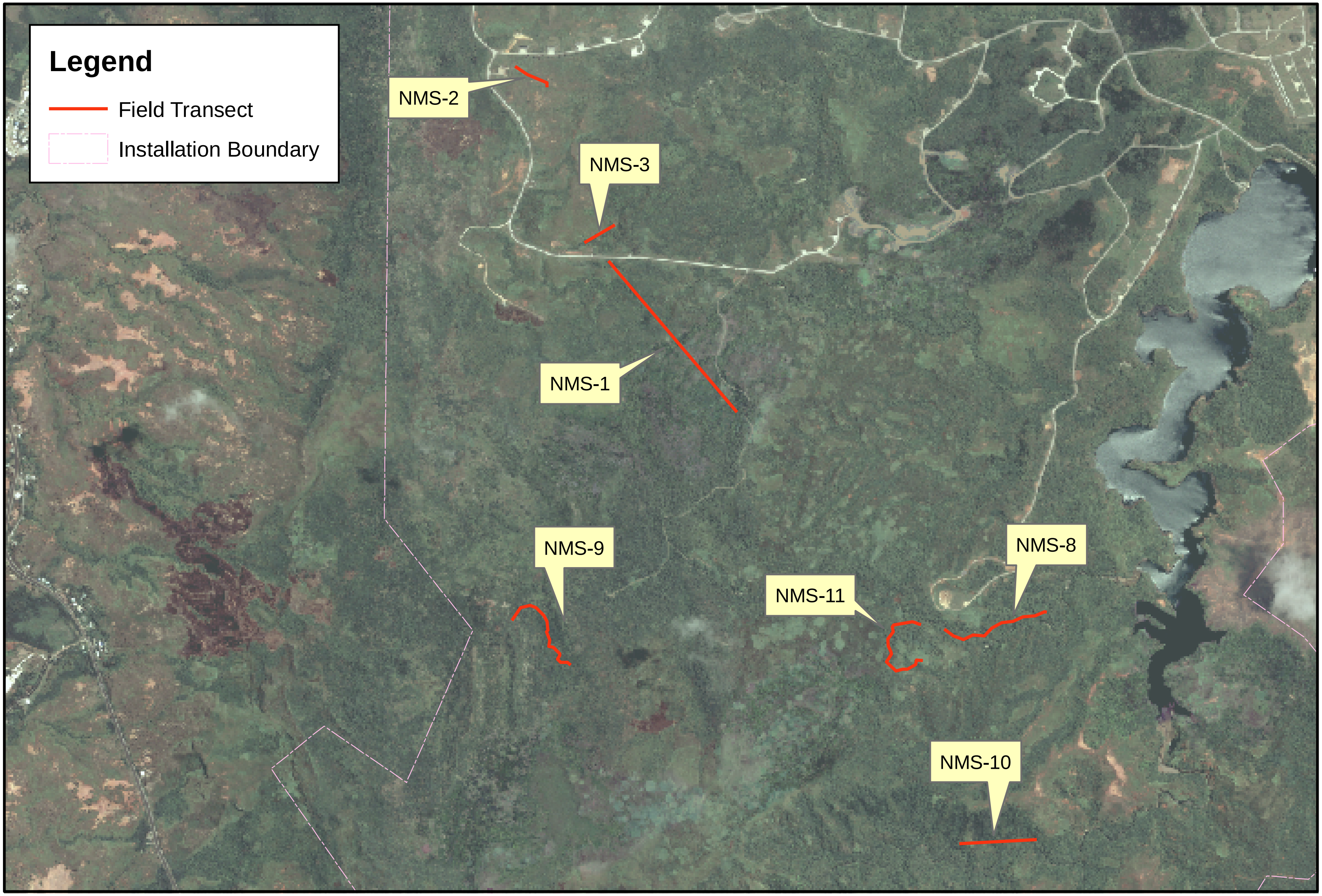

Figure 5b. Naval Munitions Site -South & West

0 495 990 1,980 Feet

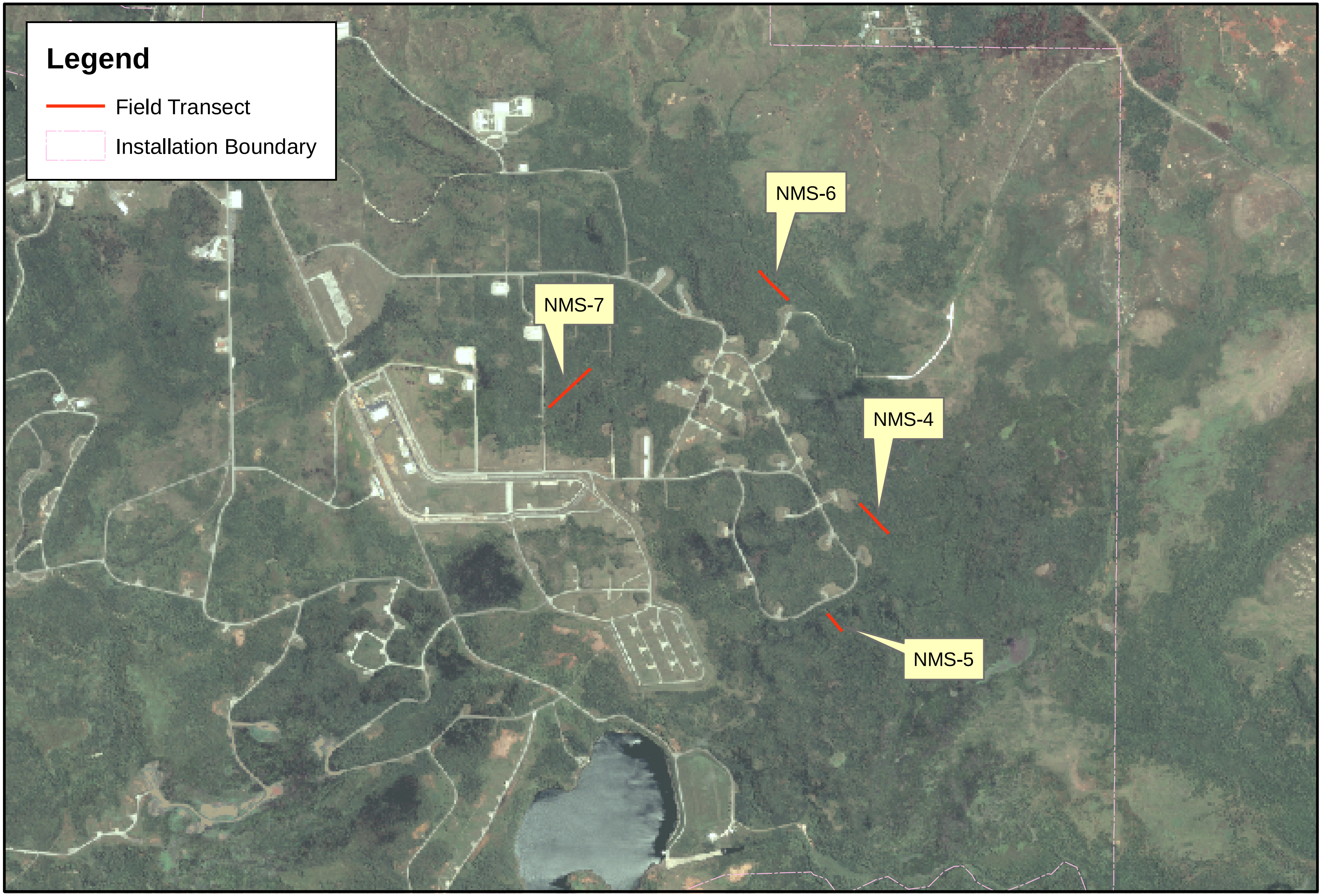

Figure 5a. Naval Munitions Site - East

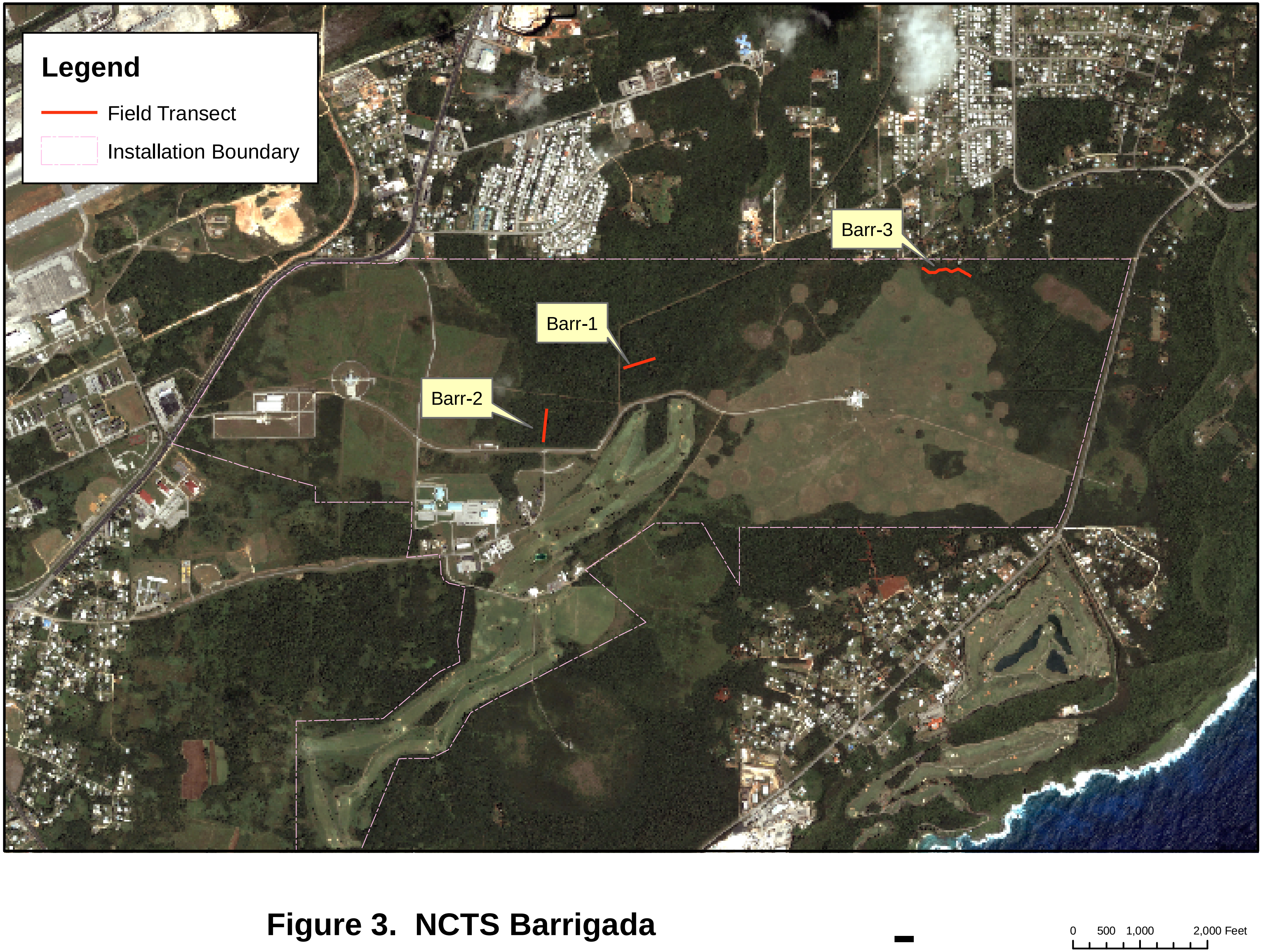

Figure 3. NCTS Barrigada

Figure 6. Orote

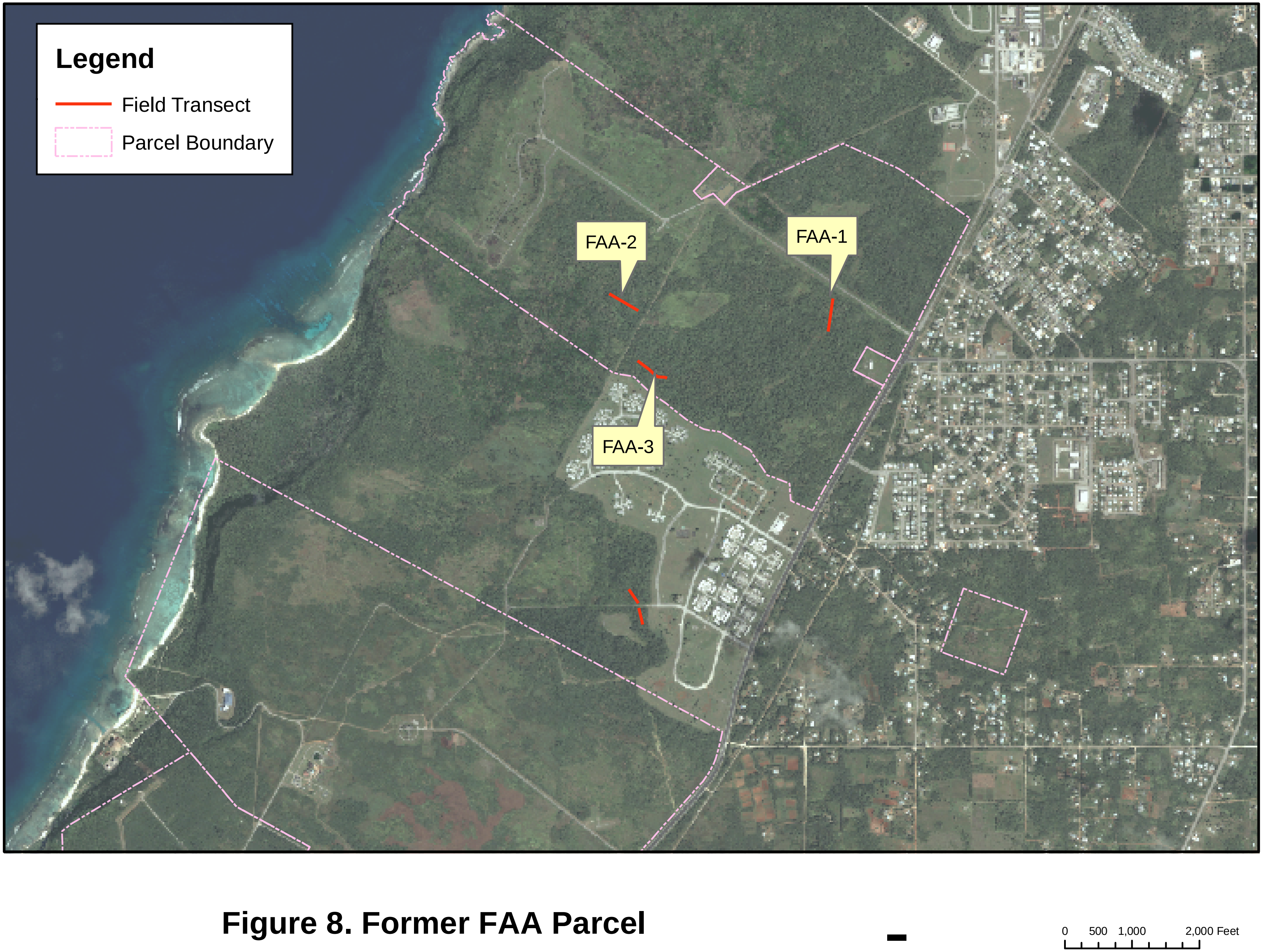

Figure 8. Former FAA Parcel

Guam Vegetation Surveys in Support of the Military Buildup EIS at Various Locations on Guam

Proposed Access Route to the Naval Magazine Site

Prepared for:

TEC Joint Venture

Prepared by:

TEC Inc.

Honolulu, Hawaii

Contract N62742-06-D-1870, TO 016 with Modifications 1,2, and 5

April 2010

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Table of Contents

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1.0 Introduction

Vegetation field surveys have been conducted in support of the Guam Military Buildup EIS. This report documents qualitative surveys conducted and additional survey transects that were completed as followup to cover several additional areas after the initial set of transects that are described in another report. Qualitative surveys were conducted primarily to confirm or refine mapping of vegetation communities, targeting primary (relatively undisturbed) limestone forest and forest dominated by *Merrilliodendron mega-carpum*, a relatively uncommon forest type on Guam that is typically dominated by the species and is a known host plant for endangered tree snails. The surveys were also intended to document any Federal- or Guam-listed or rare plant species. Surveys were conducted at NCTS Finegayan, NMS Almagosa Basin, Access Road to NMS, and the Route 15 upper plateau lands (Firing Range Option A lands being considered in the EIS). At Andersen AFB the specific task was to document the presence of host plants for butterfly species that are candidates for listing under the Endangered Species Act (ESA). The primary host plant species targeted were two species that are hosts for the Marianas eight-spot butterfly (*Hypolimnas octocula mariannensis*) with limited distribution: *Procris pedunculata* and *Elatostema calcareum*. The Marianas wandering butterfly (*Vagrans egistina*) is the second candidate species and its known host plant is *Maytenus thompsonii*, a plant that is relatively common in primary and disturbed limestone forests.

The rare plant species that are not listed species are those identified in the Guam Comprehensive Wildlife Conservation Strategy as species of conservation concern (CWCS; Guam DAWR 2006). The native cycad identified in the CWCS (*Cycas circinalis* [*C. micronesica*]) was not evaluated in detail because it is relatively common but threatened by disease. The rare species evaluated and the listed species are as follows:

- *Cyathia lunulata* – Listed in the CWCS.
- *Cycas circinalis (C. micronesica*) – Listed in the CWCS.
- *Heritiera longipetiolata* – Guam-endangered.
- *Merrilliodendron mega-carpum* – Listed in the CWCS.
- *Serianthes nelsonii* – Federal- and Guam-endangered.
- *Tabernaemontana rotensis* – Listed in the CWCS (this species was determined by USFWS to be the same as *T. pandacaqui* [69 Federal Register 18499-18500]).

In addition to these species, other species that are thought to be uncommon based on the field experience of the botanists conducting the surveys are noted in the description of each site.

2.0 Methods

Qualitative general pedestrian surveys were conducted over several periods by three biologists (Glenn Metzler and Malia Kipapa of TEC Inc. and Claudine Camacho of Duenas, Camacho & Associates, Inc.). Surveys were conducted at NCTS Finegayan, NMS Almagosa Basin, Access Road to NMS, the Route 15 upper plateau lands (Firing Range Option A lands being considered in the EIS), and Andersen AFB. The survey periods for each site are listed under each site. Surveys consisted of walking transect lines in areas where specific vegetation communities were uncertain or where edges of certain mapped community types were uncertain, or in areas where specific activities are proposed (NMS Access Road where a new road is proposed and Andersen AFB were new utility lines are proposed). Transect lines, although depicted on maps as straight lines for clear visual depiction, were typically not straight lines but did follow generally the transect lines shown on the accompanying figures. Observation points are identified on figures and represent a general area for which vegetation is described in the text.

Quantitative surveys along 3 separate transects, one each at NCTS Finegayan, Anderson South, and Navy Barrigada. Methods included a point-quarter survey and plots. Methods are further described in the vegetation report in Appendix C and transect locations are shown in the Natural Resources Report to which this document is appended to.

Plants specifically searched for during all surveys are listed species or noted as species of conservation concern. Also searched for were the ERA candidate butterfly species host plants, with less emphasis on *Maytenus thompsonii* since it is a relatively common plant in most primary and disturbed limestone habitats. Plant names referred to in the text are the names listed by Raulerson (2006).

3.0 Results

3.1 Key Findings

One plant species listed as endangered by the Government of Guam, the tree *Heritierata longipetiolata*, was observed at the Route 15 site. These trees have been previously reported by Duenas and Associates (2000). They identified a total of 22 mature trees and 184 seedlings. No attempt was made to relocate all the individuals but some of them were observed in the present study. One species noted as a species of conservation concern in the Guam Wildlife Conservation Strategy (Guam DAWR 2006), the tree *Tabernaemontana rotensis*, was noted along one transect at Andersen AFB. *Merrilliodendron mega-carpum,* designated a species of conservation concern, is typically present in stands or patches and a total of 10 acres (4 hectares) were mapped at NMS. Another species noted as a species of conservation concern, the cycad *Cycas circinalis* (*C. micronesica*), was observed in numerous limestone forest locations.

Note: All figures showing sites and survey locations for the qualitative studies are provided at the end of this report. Transect locations for the quantitative vegetation descriptions along transects are shown in the Natural Resources Report to which this document is appended to.

Table 1. Presence of Plant Species in Survey Areas

Site Transects	*Cyathea lunulata*	*Cycas circinalis (C. micro-nesica*	*Heritiera longipet-iolata*	*Merrill-iodendron meg-carpum*	*Serian-thes nelsonii*	*Tabernae-montana rotensis*	*Maytenus thompsonii*	*Procris pedunculata or Elatostema calcareum*
Andersen AFB	-	X	-	-	-	X	X	-
NCTS Finegayan*	-	X	-	-	-	-	X	-
Route 15 Plateau	-	X	X	-	-	X	X	X
NMS	-	X	-	X	-	-	-	-
NMS Access Rd.	-	X	-	X	-	-	-	-
Potts Jct	-	-	-	-	-	-	-	-
NCTS Fin T-9	-	-	-	-	-	-	-	-
Andy South T-7	-	-	-	-	-	-	x	-
Navy Barr T-3	-	-	-	-	-	-	-	-

*excluding Haputo ERA

3.2 Route 15

Surveyors: Glenn Metzler (all dates) and Malia Kipapa (2008 only) for transects A-M; G. Metzler and Claudine Camacho (transects N-Q only).

Dates of Survey: December 5-10, 2008; January 19, 2010.

Summary – Several *Heritiera longipetiolata* trees and samplings were observed in one area and a single *Tabernaemontana rotensis* was observed. Primary limestone forest is prevalent in the cliffline area and this survey established a line separating primary limestone forest from secondary (disturbed) limestone forest. Near the cliffline rocky ground and outcrops become more common and the habitat is less disturbed and invaded by non-indigenous species. In the southern portions, the forest floor and limestone outcrops are moss-covered and have succulent herbs and ground orchids such as *Nervilia aragoana* and *Zeuxine fritzii*. Current quarry operations (as of January 2010) were removing primary limestone forest in the northern part of the survey area.

Reference Figure 1. Route 15 North.

Rt15-A, cleared area with scattered patches of trees and shrubs.

Rt15-A. Disturbed primarily open land with *Morinda citrifolia*, *Carica papaya*, *Pennisetum polystachion*, and *Nephrolepis hirsutula*. There are scattered patches of natives including a few *Cycas circinalis*.

Rt15-B. Native forest of *Neisosperma oppositifolia*, *Eugenia thompsonii*, *Aglaia mariannensis*, *Macarganga thompsonii*, *Pisonia grandis*, *Intsia bijuga*, *Casuarina equisetifolia*, and *Elaeocarpus joga*. At the cliffline is *Ficus prolixa*, *Hedyotis foetida*, *Bikkia tetandra*, *Allophyllus timoriensis*, *Thuarea involuta*, and *Cycas circinalis*. A few non-indigenous species including *Bidens alba* and *Passiflora suberosa*.

Rt15-C. The entire transect is cleared with small patches of native vegetation with indigenous native trees and shrubs of *Morinda citrifolia*, *Neisosperma oppositifolia*, and *Macaranga thompsonii* that are now being invaded by non-indigenous species such as *Bidens alba* and woody species such as *Carica papaya* and *Triphasia triflora* and the indigenous *Hibiscus tiliaceous*. Open areas are dominated by non-indigenous grasses and *Bidens alba*, *Stachytarpheta* spp, *Mikania scandens*, and *Cardiospermum halicacabum*.

Rt15-B, cliffline area with predominately indigenous woody plants, native cycad and non-indigenous herbs.

Rt15-B, quarry operations in January 2010 up to the cliffline.

Rt15-D. Similar to transect C.

Rt15E. This location is native forest up to the cliffline with dominants including *Macaranga thomsonii*, *Aglaia mariannensis*, *Eugenia reinwardiana*, and *Pisonia grandis* (ranging to 12 inch diameter).

Rt15-F. This is an area of predominately native vegetation with some cleared patches and lanes, with edges of native forest being invaded by *Carica papaya*, various non-indigenous herbs and vines, and indigenous *Hibiscus tiliaceus*. Vegetation outside of the cleared lanes is a diverse primary limestone forest including *Pandanus tectorius*, *Neisosperma oppositifolia*, *Macaranga thompsonii*, *Ficus tinctoria*, *Intsia bijuga*, *Aglaia mariannensis*, *Guamia mariannae*, *Eugenia reinwardtiana and E. thompsonii*, *Cycas circinalis* (to 15-20 feet tall), *Dendrocnide latifolia*, and abundant native ferns. A single *Tabernaemontana rotensis* tree was observed. The shrub *Maytenus thompsonii*, host for the Mariana wandering butterfly (*Vagrans egestina*), was observed but was not abundant. The substrate is estimated as 75% limestone rocks or rock outcrops.

Rt15-F, primary limestone forest with high diversity.

Rt15-G. Native vegetation is dominant including *Aglaia mariannensis*, *Guamia marianae*, *Macaranga thompsonii*, *Eugenia reinwardtiana*.

Rt15-H. This area is disturbed to the cliffline and dominated by the non-indigenous species *Bidens alba* and *Triphasia triflora*, and the indigenous *Hibiscus tiliaceous*.

Rt15-C, cleared areas with patches of native vegetation being taken over by invasives.

Reference Figure 2. Route 15 Central.

Rt15-I, transect disturbed up to cliffline; vegetation at cliffline is primarily native with stunted trees.

Rt15-I. This area consists of larger remnant forest patches with roads and clearings intermixed. Cleared area dominated by the herbaceous *Bidens alba* with some scattered native trees such as *Ficus tinctoria* and *Hibiscus tiliaceous* in edge areas. At the northwestern corner of the transect is a population of *Heritiera longipetiolata* with at least several remaining large trees and several saplings observed. This population was previously documented in an EIS prepared for the raceway in 2000 (Duenas and Associates 2000). Other species in this diverse forest are *Ficus tinctoria*, *Mammea odorata*, *Pandanus tectorius*, *Guamia mariannae*, *Aglaia mariannensis*, *Pisonia grandis*, and *Eugenia reinwardtiana*. Near the cliff is a stunted *Ficus prolixa* forest festooned with the non-indigenous vine

Cuscuta campestris. Entire area is mapped as primary limestone forest because that is the predominant vegetation.

Rt15-K, *Pisonia grandis* with fern epiphytes.

Rt15-J. Edge of forest at open field that is dominated by grasses, *Triphasia triflora*, and the native pioneer species, *Hibiscus tiliaceous*, *Psychotria mariana*, and *Flagellaria indica*. The vegetation transitions quickly into relatively undisturbed primary limestone forest.

Rt15-K. Primary limestone forest dominated by *Neisosperma oppositifolia*, *Eugenia reinwardtiana*, *Aglaia mariannensis*, *Guamia mariannensis* with a few large *Pisonia grandis* trees.

<u>Reference Figure 3. Route 15 South.</u>

Rt15-L. Scrub forest at field edge with non-indigenous *Triphasia trifolia* and *Leucaena leucocephala* and in more open areas *Lantana camara* and *Bidens alba*; native pioneers or edge species present including *Hibiscus tiliaceous*, *Wikstromia elliptica*, and *Ochrosia mariannensis*.

Rt15-M. Primary limestone forest of *Macaranga thompsonii*, *Ficus* spp, *Neisosperma oppositifolia*, *Eugenia reinwardtiana*, *Cynometra ramiflora*, *Ochrosia mariannensis*, *Intsia bijuga* and a few *Barringtonia asiatica*. *Maytenus thompsonii* was also observed.

Rt15-L, edge of primary limestone forest with mix of native and non-native species.

Rt15-N. Field-grass edge with *Pennisetum polystachion* and a few scattered *Psychotria mariana* and *Morinda citrifolia*.

Rt15-O. Primary limestone forest near cliff edge including *Mammea odorata*, *Ficus prolix*, *Premna obtusifolia*, *Pandanus tectorius*, and small *Cycas circinalis*, but becomes progressively more invaded towards the open field. Cliffline species *Bikkia tetrandra*, *Allophyllus timoriensis*, and *Xylosma nelsonii.*

Rt15-N, forest field edge.

Rt15-O, native limestone forest with mix of native species including *Mammea odorata*.

Rt15-P. Native species dominate similar to Rt15-O but with larger *Cycas circinalis*, *Mammea odorata* and some large *Pisonia grandis*. Also in this forest are *Eugenia reinwardtiana* and *Intsia bijuga*, Fern species are present such as as *Asplenium polyodon* and *Polypodium scolopendria*, and vines such as *Jasminum marianum*) and *Flagellaria indica*. There is heavy pig damage in some areas of the forest in less rocky areas away from the cliffline. Most *Cycas circinalis* are dying.

Rt15-Q. This is a mixed shrub community of woody species with indigenous and invasive, non-indigenous species. There is much *Hibiscus tiliaceous* and non-indigenous species including *Triphasia trifolia*, *Lantana camara*, and the herbaceous *Eupatorium odoratum* (*Chromolaena odorata*) and large area with heavy *Coccinea grandis* vine infestation. Pig damage is very heavy in places.

Rt15-P, pig damage.

3.3 NCTS Finegayan

Surveyors: Glenn Metzler (all dates) and Malia Kipapa (2008 only).

Dates of Surveys: December 9, 2008; January 15, 2010 (Fin Central only).

Summary – No listed or rare species were observed. A small patch of the host plant for the Mariana eight-spot butterfly (*Hypolimnas octocula mariannensis*), *Procris pedunculata* was observed scattered in one area of cockscomb limestone in a few patches. The cockscomb limestone area also has some large *Cycas circinalis* to nearly 20 feet in height.

<u>Reference Figure 4. NCTS Finegayan North.</u>

Fin-A. Transect traverses a disturbed limestone forest of mixed native and invasive species with a heavily browsed understory and openings. A few large *Ficus tinctoria* and *Artocarpus mariannensis* are scattered at various locations. Species in the forest include *Vitex parviflora*, *Neisosperma oppositifolia*, *Hibiscus tiliaceus*, *Morinda citrifolia*, *Pandanus tectorius*, and *Cycas circinalis*.

Fin-A, disturbed limestone forest with scattered emergent trees and open areas.

Reference Figure 5. NCTS Finegayan Central.

Fin-B, large *Cycas circinalis* on limestone.

Fin-B. An area of cockscomb limestone, very uneven. Abundant *Cycas circinalis* present, some large to nearly 20 feet in height. Mixed diverse canopy and understory, primarily indigenous species such as *Neisosperma oppositifolia*, *Macaranga thompsonii*, *Guamia mariannae*, *Aglaia mariannensis*, *Pandanus dubius*, *Eugenia reinwardtiana*, and a few *Dendrocnide latifolia.* Scattered non-indigenous species are also present. Herbaceous species on the rocky substrate includes scattered patches of *Procris pedunculata*.

Fin-C. Approximate boundary between primary limestone forest and secondary (disturbed) limestone forest with the disturbed vegetation primarily *Annona reticulata*, *Triphasia triflora*, *Cestrum diurnum*, and *Stachytarpheta* spp and the primary limestone forest dominated by a mix of indigenous species as noted above .

Fin-D. There is a large sinkhole depression just to the north, approximately 100 or more feet in diameter with a large *Artocarpus mariannensis* down in the bottom. The boundary between primary and secondary limestone forest includes similar species to those described above with the addition of *Leucaena leucocephala* along the edge of the access road.

Reference Figure 6. NCTS Finegayan South.

Fin-E. The overstory is dominated by *Vitex parviflora* with scattered *Premna obtusifolia*, *Neisosperma oppositifolia*, and *Intsia bijuga*. An occasional specimen of indigenous *Elaeocarpus joga* or *Artocarpus mariannensis* trees. The understory is of mixed species, predominantly native including *Neisosperma oppositifolia*, *Guamia marianae*, and *Pandanus tectorius* or *Pandanus dubious*. *Maytenus thompsonii* was also noted. Occasional clearings dominated by herbaceous invasive species including *Eupatorium odoratum* (*Chromolaena odorata*), *Mikania scandens* and other invasive vines, and the native swordfern *Nephrolepis hirsutula*.

Fin-E, opening in disturbed forest with non-native herbaceous vegetation and a large *Eleaocarpus joga*.

Fin-F. The vegetation is similar to Fin-E but with a more rocky substrate.

Photo 13. Fin-G, *Vitex parviflora* dominanted canopy with substrate of mixed moss-covered rock and soil.

Fin-G. The forest is primarily a *Vitex parviflora* canopy with an understory of *Neisosperma oppositifolia*, *Aglaia mariannensis*, *Guamia marianae*, and *Eugenia reinwardtiana*. The substrate is mixed areas of soil and rock.

Fin-H. The area is heavily disturbed with much bare ground, including a very large pig wallow approximately 20 feet x 8 feet. The area is dominated by *Cestrum diurnum*, *Hibiscus tiliaceous* (the primary indigenous species), *Triphasia trifolia*, *Annona reticulata*, and *Mikania scandens*. There is scattered *Neisosperma oppositifolia*.

<u>Reference Figure 7. NCTS Finegayan East.</u>

Fin-H, large pig wallow in open area of the forest.

Fin-I. Vegetation in this area near a borrow pit is similar to many other areas on NCTS Finegayan. The forest canopy is generally closed and dominated by *Vitex parviflora* with some large individual trees. There are scattered large *Artocarpus mariannensis* (to approximately 18 inch diameter with prominent buttresses) and an occasional *Elaeocarpus joga*. One large *Barringtonia asiatica* was also observed. Other species in the canopy or subcanopy are *Morinda citrifolia*, *Hibiscus tiliaceous*, *Pandanus dubious*, *Pandanus tectorius*, *Ficus tinctoria*, and *Neisosperma oppositifolia*. Understory woody species that are prevalent include the indigenous species *Guamia mariannae*, *Hibiscus tiliaceous*, and *Eugenia reinwardtiana* and *Eugenia palumbis* (in patches) and the invasive *Triphasia trifolia*. *Piper guahamense* was common in the understory as were ferns, both terrestrial and ephytic, including *Polypodium* spp., *Pteris tripartita*, and *Pteris vittata*. Some areas had abundant moss-covered rock. Vines included *Jasminum marianum* and *Flagellaria indica* and a single specimen of *Dischidia puberula*, an uncommon species, was also observed. Along the utility line right-of-way in this area were numerous *Maytenus thompsonii*, many of which were noted in flower and fruit. Some *M. thompsonii* were also observed in the forest.

Fin I, an emergent *Artocarpus mariannensis* in a surrounding disturbed limestone forest.

3.4 Naval Munitions Site

Surveyors: Glenn Metzler (December 08 and January 2010) and Malia Kipapa (December 08 only).

Dates of Surveys: December 19, 2008 and January 20, 2010.

Summary – Three separate *Merrilliodendron mega-carpum* stands were mapped totaling 10 acres (4 hectares). In addition numerous other smaller scattered patches of *Merrilliodenron* were noted in the area. Several uncommon species were observed including *Dishidia puberula* and *Coelogyne guamense*, the latter an orchid species found primarily in the branches of large trees on high limestone ridges and found on Guam, Rota, and Palau (Raulerson and Rinehart 1992).

Reference Figure 8. Naval Munitions Site Almagosa.

NMS-A. Edge of *Merrilliodendron* forest in rocky outcrop understory including ferns and *Freycinetia reineckei*.

Merrilliodendron forest is a relatively uncommon forest type on Guam with known stands in the Haputo ERA, Hiilan Point, Mt. Lamlam, Mt. Tenjo (Guam DAWR 2006), within the Almagosa basin and surrounding areas of NMS, and a small patch located along the proposed western access road to NMS (see Access Road description in Section 3.5 of this report). Other stands may be present in other areas on Guam, particularly on private lands where there have been few studies. The *Merrilliodendron* trees at Haputo ERA and the Lost Pond area are known hosts of tree snails that are Guam-listed species and are candidate species for listing under the Endangered Species Act. *Merrilliodendron* forest patches appear to be scattered throughout the Alamagosa basin area but there are only a few known larger *Merrilliodendron* areas that are hereafter described as stands (see Figure 7). No tree snails were observed in a cursory visual examination in these forests but a thorough search was not conducted.

NMS-B , northern end of Merrilliodendron Stand A and open areas between trees.

NMS-B. This location is near the northern limit of the largest *Merrilliodendron* stand where there are more openings in the canopy and species such as *Pandanus* spp. and *Hibiscus tiliaceus* become more prevalent. Elevation is generally increasing.

NMS-C. The terrain becomes more varied in this area with areas of dissected limestone with crevasses 6 feet or more deep. Based on observations to the south, some water may drain from the large wetland into this area. The

NMS-C, near edge of *Merrilliodendron* stand, an area with highly dissected limestone.

vegetation is also more varied with *Pandanus* spp., *Discocalyx megacarpa*, *Guettarda speciosa*, *Cycas circinalis,* and *Ficus* spp. and ferns such as *Microlepia speluncae*. A specimen of an uncommon vine, *Dischidia puberula*, was observed in the area.

NMS-D. This location is quite open and beyond the edge of the *Merrilliodenron* stand. A specimen of the somewhat uncommon shrub *Drypetes dolichocarpa* was noted in this area. *Fagrea berteriana*, an uncommon tree, was also noted at scattered locations in the general area.

NMS-E. This location is near the eastern edge of a smaller *Merrilliodendron* stand. This edge is on the west-facing slope of a north-south ridge with slopes estimated at 25-40 degrees. This west-facing slope is lush with ground cover of fern species and rock outcrops covered in thick moss. On the side of this ridge near the southern edge of the *Merrilliodendron* stand in one area is a large group of *Coelogyne guamense*, an epiphytic orchid species typically found primarily in the branches of large trees on high limestone ridges (Raulerson and Rinehart 1992), so not often observed. The western edge of this smaller stand is not as clearly defined as the sloped eastern edge because there are more openings and less dominance by *Merrilliodendron*.

NMS-E, the epiphytic orchid *Coleogyne guamense*.

NMS-E, West facing slope at the edge of the *Merrilliodendron* stand with diverse vegetation.

NMS-E, from the ridgetop looking southwest. towards cliffs, probably limestone and with heavy vegetation.

NMS-E, from the ridgetop looking southeast with savanna vegetation and a large wetland in the basin.

NMS-F, edge of *Merrilliodendron* forest with some openings and dead cycad.

NMS-F. This location is near the western edge of this smaller *Merrilliodendron* stand. There are numerous openings in the canopy. The pattern of vegetation and some dead cycads indicates a possibility that fires occurred which created the openings.

NMS-G. This area has another small *Merrilliodendron* stand as well as other small scattered patches of this species not within the stand to the north and south. Scattered in this area are a few large *Artocarpus mariannensis*, standing out well above any of the surrounding vegetation, which is fairly low in stature at about 15-25 feet.

NMS-H. This area is somewhat open and weedy with numerous invasives such a s*Eupatorium odoratum* (*Chromolaena odorata*), grasses, *Mikania scandens*, and other vines. The native vine *Stictocardia tiliaefolia* is common and the dominant trees include the palms *Cocos nucifera* and *Areca catechu* and *Pandanus* spp.

NMS-H, View looking southwest over ravine forest with open canopy dominated by *Cocos nucifera* and a mix of other species.

NMS-I. Patches of *Merrilliodendron* were noted in this area on the east-facing slope above where Almagosa spring emerges.

NMS-J. A brief visual survey along the trail to Mt. Lamlam noted several scattered patches of forest dominated by *Merrilliodendron* in this area. These areas were not investigated in detail but may cover up to several acres.

Reference Figure 9. Naval Munitions Site EOD.

NMS-EOD-1. Canopy on slopes dominated by *Vitex parviflora* with patches of *Cocos nucifera*.

EOD-1. This area is off to the left of the road going into the EOD site. It had a canopy nearly completely dominated by *Vitex parviflora* with much young *Cocos nucifera* in the understory and some of the canopy dominated by *Cocos nucifera*. Other areas of the understory were sparse.

EOD-2, 3. This area consists of ravine forest. The trees on the upper slopes in this entire area are almost entirely the invasive tree *Vitex parviflora* and they tend to occur in small groves interspersed by openings. These trees, particularly the numerous larger specimens (up to 2 feet in diameter), often host the ephiphytic orchid *Dendrobium guamense* and common epiphytic ferns, typically the common species such as the small *Pyrrosia lanceolata and Polypodium punctatum*. Even within the forested areas the canopy is thin with much sunlight and an understory of mixed indigenous and non-indigenous woody and herbaceous species.

EOD-2. Looking southwest over a ravine forest dominated by *Vitex parviflora* on slopes (entire view) and *Cocos nucifera* and *Pandanus* spp. near valley bottoms.

EOD-3. *Vitex parviflora* dominates the canopy with some trees attaining large size.

3.5 NMS Access Road

Surveyors: Glenn Metzler and Claudine Camacho.

Date: July 2, 2009.

Summary – The proposed access road would follow an existing foot trail that traverses savanna vegetation with a few stands of forest in minor valleys. The area surveyed was within approximately 75 feet of either side of the trail. *Merrilliodendron mega-carpum* forest was present and dominated a portion of the small forest on either side of the trail at the highest forest stand encountered along the trail. As discussed in Section 3.3, this forest type is not common on Guam. On both sides of the trail the *Merrilliodendron* forest did not appear to extend much, if any, beyond the survey corridor. No threatened or endangered or rare species were observed.

Reference Figure 10. NMS Access Road.

AccessRd-A. This is a forested patch with openings and dominated by tangantangan and *Hibiscus tiliaceous* with scattered *Cocos nucifera*. *Panicum maximum* and *Saccharum officianarum* dominate in openings and the surrounding area and herbaceous weeds such as *Bidens alba*, *Elephantopus mollis*, and *Mikania scandens* are in the understory along with indigenous *Piper guahamense* and *Flagellaria indica*.

AccessRd-A, view of typical terrain and vegetation along the trail; the initial forested patch is dominated by *Leucaena leucocephala*.

AccessRd-B. Forest stand of mixed indigenous and non-indigenous trees and shrubs.

AccessRd-B. This area is a strip of ravine forest oriented north-south with a diverse mix of indigenous and non-indigenous species. Indigenous trees and shrubs include *Premna obtusifolia*, *Guettarda speciosa*, *Ficus tinctoria*, *Pandanus dubious*, *Morinda citrifolia*, *Glochidion marianum*, *Aglaia mariannensis*, and *Phyllanthus marianus*. *Leucaena leucocephala* and *Triphasia triflora* are the dominant invasive woody species. Epiphytes are common including various common ferns and some specimens of the endemic orchid *Dendrobium guamense*. The understory contains indigenous ferns including *Thelypteris guamensis*, *Antrophyum plantagineum*, and *Nephrolepis biserrata*, and the indigenous vines *Freycinetia reineckei*, *Jasminum marianum*, and *Entada pursaetha*. Grasses and sedges present included the indigenous *Miscanthus floridus*, *Centotheca lappacea*, *Isachne miliacea*, *Scleria polycarpa*, and various non-indigenous grasses.

AccessRd-C. West end of highest elevation forest stand.

AccessRd-C. This is the western portion of a north-south oriented strip of ravine forest. This western portion is somewhat open and includes a mix of indigenous and non-indigenous species but dominated by *Leucaena leucocephala*. Indigenous species present are primarily those that do well in disturbed conditions such as *Morinda citrifolia* and *Flagellaria indica*.

AccessRd-D. This is the eastern portion of a north-south oriented strip of ravine forest. This is the location with a statue of the Virgin Mary placed on a ledge of a limestone outcrop. On either side of the existing trail in the eastern portion of the forested strip the vegetation is dominated by *Merrilliodendron mega-carpum*. The cleared width of the trail through this area ranges from approximately 15-20 feet. The area containing the *Merrilliodendron* forest is estimated at less than 1 acre. The dominant tree/shrub in much of this forest near the trail is *Leucaena leucocephala*. *Areca catechu* and *Triphasia triflora* are other common invasive trees or shrubs. Indigenous trees and shrubs include *Premna obtusifolia*, *Pandanus dubious* and *P. tectorius*, *Glochidion marianum*, *Hibiscus tiliaceous*, and a few *Cycas circinalis*. Low shrubs include *Discocalyx megacarpa* (in fruit) and *Medinilla medinilliana*. Epiphytes are common including various common ferns and some specimens of the endemic orchid *Dendrobium guamense*. Ferns on the ground or on rock walls include *Thelypteris gretheri*, *Thelypteris torresiana*, *Tectaria crenata*, and *Nephrolepis biserrata*. The indigenous vines *Freycinetia reineckei*, and *Flagellaria indica* are common. There are few grasses and sedges. Edges of the forest patch are dominated by *Leucaena leucocephala*. Soil disturbance from pigs in this forest is light.

AccessRd-D. *Merrilliodendron* forest with limestone rock outcrops.

AccessRd-E. This is savanna dominated by *Miscanthus floridulus*, *Saccharum officinarum*, and *Pennisetum polystachion*. *Elephantopis mollis* is a common invasive species along trails. Mixed in with grasses in places are non-indigenous *Pueraria phaseoloides*, *Buchnera floridana*, and the indigenous fern *Blechnum orientale*.

AccessRd-E. Top of ridges are primarily savanna.

3.6 Andersen AFB Utility Lines

Surveyors: Glenn Metzler and Claudine Camacho.

Date: January 14, 2010.

Summary – A primary purpose of this survey was to determine if there were any host plants for the two Federal candidate butterfly species *Hypolimnas octocula mariannensis* and *Vagrans egistina*. These host plants, *Elatostema calcareum, Procris pedunculata*, and *Maytenus thompsonii*, were not observed on any of these transects. Transects were in disturbed limestone forests ranging from highly degraded to somewhat degraded with a primarily indigenous understory. Two *Tabernaemontana rotensis* trees were observed on Transect B in flower and fruit. Several trees of the uncommon *Geniostoma micranthum*, and endemic species, were observed on transect C. On January 28, during surveys by others, a fruit bat was observed during the daytime roosting in a Guamia tree.

AAFB-A, degraded limestone forest with *Vitex parviflora* that has been blown over with resprouts.

Reference Figure 11. Andersen AFB Utility Line Transect A.

AAFB-Transect A. The forest on this transect is highly degraded. Substrate is primarily soil with less than 10 percent mossy rock. The primary invasive species are *Vitex parviflora* (some to 2 feet diameter), many of which have been blown over to horizontal with vertical resprouts, and *Averrhoa bilimbi*. Epiphytic ferns on these trees are all common species. Native (or early introduced) trees present in some abundance are *Pandanus tectorius* and *Cocos nucifera*. The *Pandanus* was generally heavily browsed and the understory in general was very open in this forest.

Reference Figure 12. Andersen AFB Utility Line Transects B and C.

AAFB-B, typical vegetation on the transect.

AAFB-B. Transect B traverses a low-stature (generally less than 20 feet) disturbed limestone forest with a few old downed or partially dead large *Intsia bijuga* trees, dominated primarily by indigenous species. The very southwestern end, after crossing the cleared lane, is a taller forest dominated by *Vitex parviflora* with *Pandanus tectorius* in the understory and a highly disturbed soil from pig damage and almost no herbs. The low-stature forest contained small openings typically dominated by *Eupatorium odoratum* (*Chromolaena odorata*). The forest was dominated by *Premna obtusifolia*, *Pandanus tectorius*, *Guamia mariannae*, *Aglaia mariannensis*, and *Neisosperma oppositifolia,* with an abundance of the indigenous herbaceous vine *Stictocardia tiliaefolia*, the woody vine *Jasminum marianum,* and common epiphytic ferns and the less common *Vittaria incurvata* present. *Intsia bijuga* was also quite common as was *Discocalyx megacarpa*, some of which were in fruit. Heavily browsed *Pandanus* leaves were noted and there were areas of high soil disturbance from pig rooting. Two *Tabernaemontana rotensis* trees were noted and both were either in flower or fruit. One of these trees had numerous (15-20) small saplings underneath that were heavily browsed. On January 28 during other surveys a fruit bat was observed roosting in a *Guamia* tree near the northeast end of the transect. Numerous butterflies were noted on this transect and included 3 common species: *Papilio polytes*, *Euploea eunice*, and *Eurema blanda*.

AAFB-Transect B, *Tabernaemontana rotensis* flowers.

AAFB-Transect B, *Tabernaemontana rotensis* sapling that is heavily browsed.

AAFB-C, *Geniostoma micranthum* in flower and fruit.

AAFB-C. The transect is located adjacent to the road. The forest consisted of a *Vitex parviflora* dominated canopy with a somewhat dense understory or sometimes canopy of *Hibiscus tiliaceous*, *Guamia mariannae*, *Aglaia mariannensis*, *Pandanus tectorius*, *Premna obtusifolia*, *Ficus tinctoria*, and *Neisospema oppositifolia*. Other species noted included *Pyschotria mariana*, *Guettarda speciosa*, and the somewhat uncommon *Geniostoma micranthum* in flower and fruit. Herbaceous species included *Piper guahamense*, several common fern species, the ground orchids *Nervillia aragoana* and *Zeuxine fritzii*, and the vine *Stictocardia tiliaefolia*.

3.7 Potts Junction

Surveyors: Glenn Metzler and Claudine Camacho.

Date: July 8, 2009.

Summary – The Potts Junction site is dominated by a highly disturbed shrub/grassland vegetation community with few native species. Much of the site is low vegetation including *Bidens alba*, *Passiflora suberosa*, and *Fimbristylis cymosa* with patches of grass including *Pennisetum purpureum*, *Pennisetum polystachion*, and *Saccharum spontaneum*. There are patches of trees or shrubs including *Buddleja asiatica*, *Spathodea campanulata*, *Hibiscus tiliaceus*, and *Leucaena leucocephala* and some patches of the fern *Pteris vittata*. There are some *Cocos nucifera* trees near the boundary with the Starts Golf Course.

3.8 NCTS Finegayan Transect 9

Surveyors: Glenn Metzler and Claudine Camacho.

Date: July 7, 2009.

Summary - The point-center quarter survey results for Transect NF-9 are summarized in Table 2. The overall density for this transect was calculated at 1,435 trees per hectare. Only four species of tree were encountered throughout the survey. The introduced *Vitex parviflora* was the most dominant species encountered along this transect, and the only introduced species observed. *Vitex parviflora* had a relative density of 55% (Figures 1and 2) and a relative dominance of 93%. *Hibiscus tiliaceus* and *Pandanus tectorius*, together, had a

North Finegayan Transect 9.

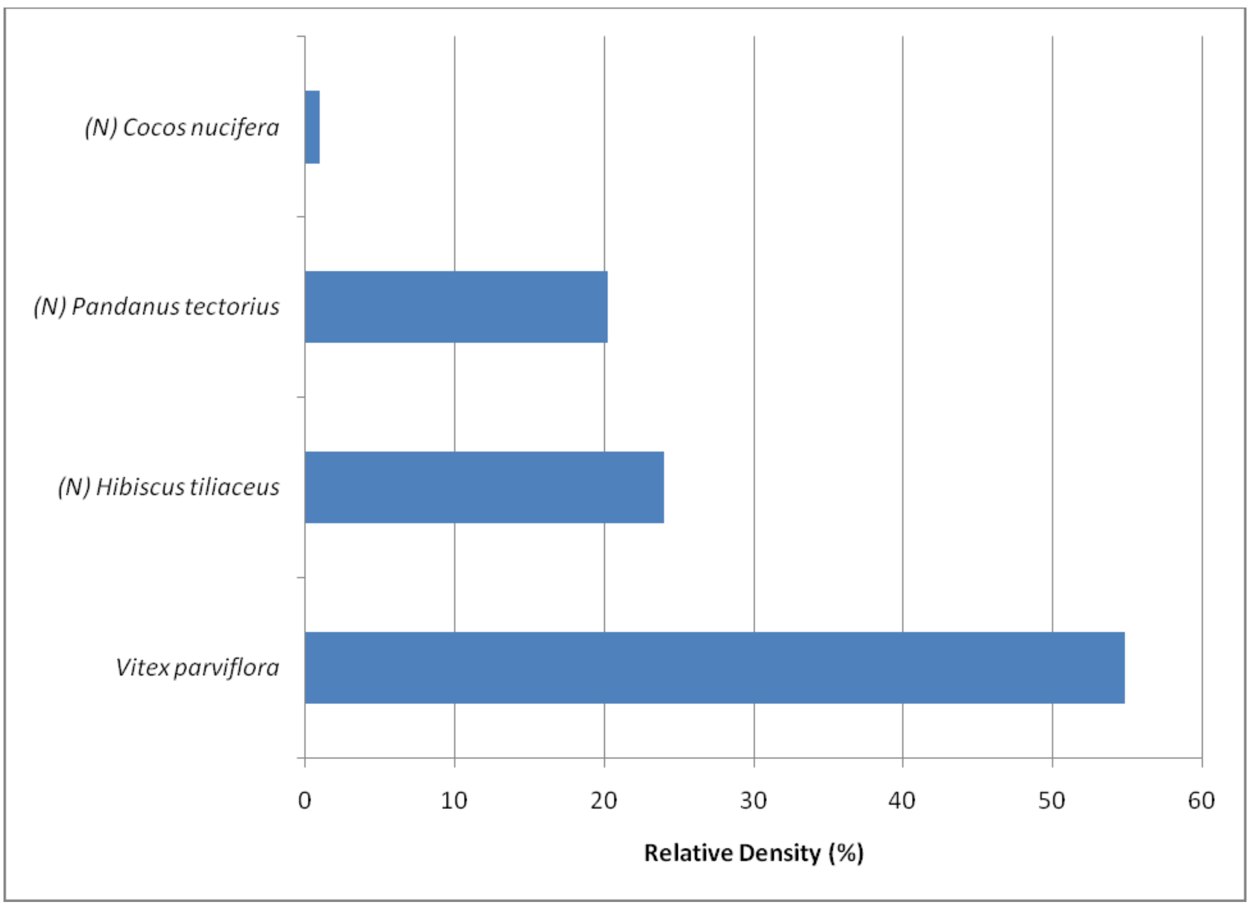
relative density of 44%, yet only accounted for approximately 6% of the relative dominance within the transect. One individual of *Cocos nucifera* was encountered. The tree species richness for Transect NF-9 is presented in Figure 3.

Table 2. Summary of forest at NF-9, Finegayan.

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST NF-9 NCTS Finegayan, JULY 2009						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm^2)	MEAN BASAL AREA (cm^2)	ABSOLUTE COVER (m^2/ha)	ABSOLUTE FREQUENCY
Vitex parviflora	I	786	19101.11	335.11	26.34	219.23
Hibiscus tiliaceus	N	345	709.44	28.38	0.98	96.15
Pandanus tectorius	N	290	596.03	28.38	0.82	80.77
Cocos nucifera	N	14	206.02	206.02	0.29	3.85

Key to Status: N = native; I = introduced

Figure 1. Relative Density (%) of Trees at NF-9, Finegayan



Note: (N) indicates native species; others are introduced.

Figure 2. Relative density of native tree species along NF-9, Finegayan

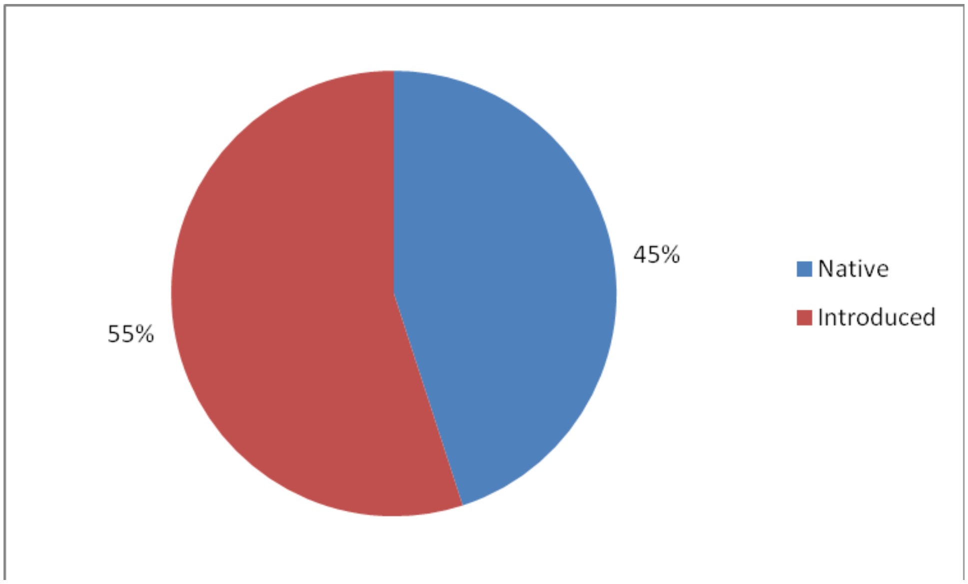


Figure 3. Species Richness of Trees at NF-9, Finegayan

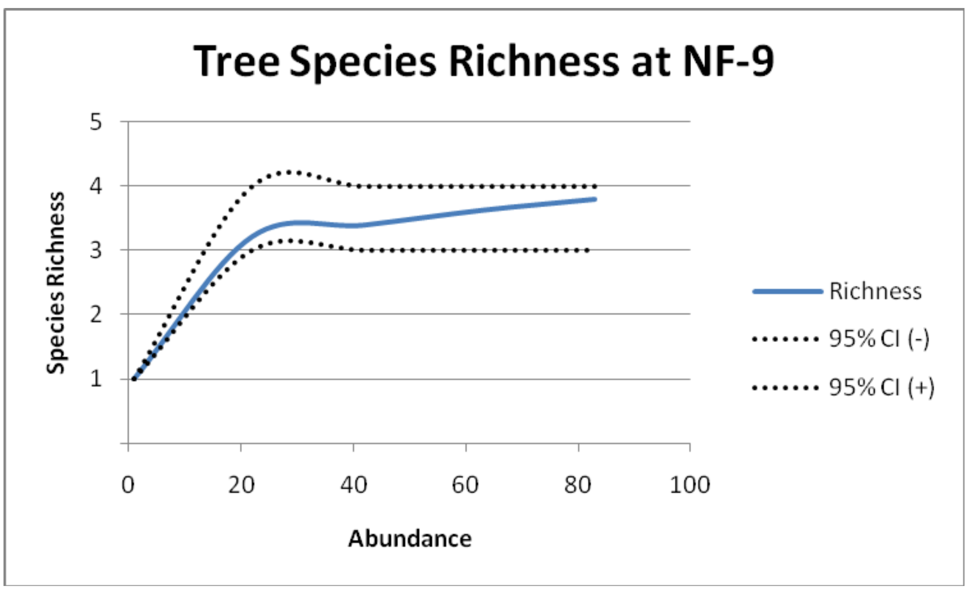


Table 3. Woody Seedling Species Encountered in Plots at NF-9, Finegayan

Woody Seedling Species (<2cm dbh)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Cocos nucifera			9	2		
Flagellaria indica					1	1
Glochidion marianum				1		
Hibiscus tiliaceus	3			3	9	
Leucaena leucocephala				2		
Morinda citrifolia	2	13		21	8	21
Pandanus tectorius	3	1			9	5
Triphasia trifolia				3	1	
Vitex parviflora	2	1	6	23	4	3
Totals	10	15	15	55	32	30

Table 4. Non-Woody Seedling Species Presence in Plots at NF-9, Finegayan

Non-Woody Seedling Species (Presence/Absence)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Belvisia	1	1	1	1	1	1
Davalia			1			1
Nephrolepis acutifolia				1		
Nephrolepis hirsutula	1	1	1	1	1	1
Polypodium punctatum		1		1		1
Polypodium scolopendria				1	1	1
Pteris tripartita					1	1
Pyrrosia	1	1	1	1		1
Achyranthes aspera					1	
Axonopus compressus		1	1			1
Cassia leschenaultiana	1	1	1			
Centosteca lappacea	1					
Chromolaena odorata		1	1	1	1	1
Cyperus kyllingia			1			
Cyperus ligularis			1			
Desmodium triflorum			1			
Hyptis capitata		1				
Hyptis pectinata			1	1		
Mikania	1	1	1	1	1	1
Momordica charantia				1	1	1
Nervillia aragoana		1			1	
Oplismenus			1	1	1	1
Passiflora suberosa	1	1	1	1	1	
Piper guahamense					1	1
Sida rhombifolia			1			
Spermacoce						1
Stachytarpheta jamaicensis			1			
Stichtocardia tiliaefolia				1	1	
Taeniophyllum		1	1			
Urena lobata			1			
Zeuxine fritzii	1					
Total Seedlings	8	12	18	13	13	14

Note: "1" indicates presence within plots

Table 5. Ground Cover at NF-9, Finegayan.

Meters from start	Rock	Soil	Leaf litter	Live vegetation	Total
0		1	15		16
100			14	2	16
200			10	6	16
300			11	5	16
400			15	1	16
500			13	3	16
Frequency	0	1	78	17	

3.9 Andersen South Transect 7

Surveyors: Glenn Metzler and Claudine Camacho.

Date: January 12, 2010.

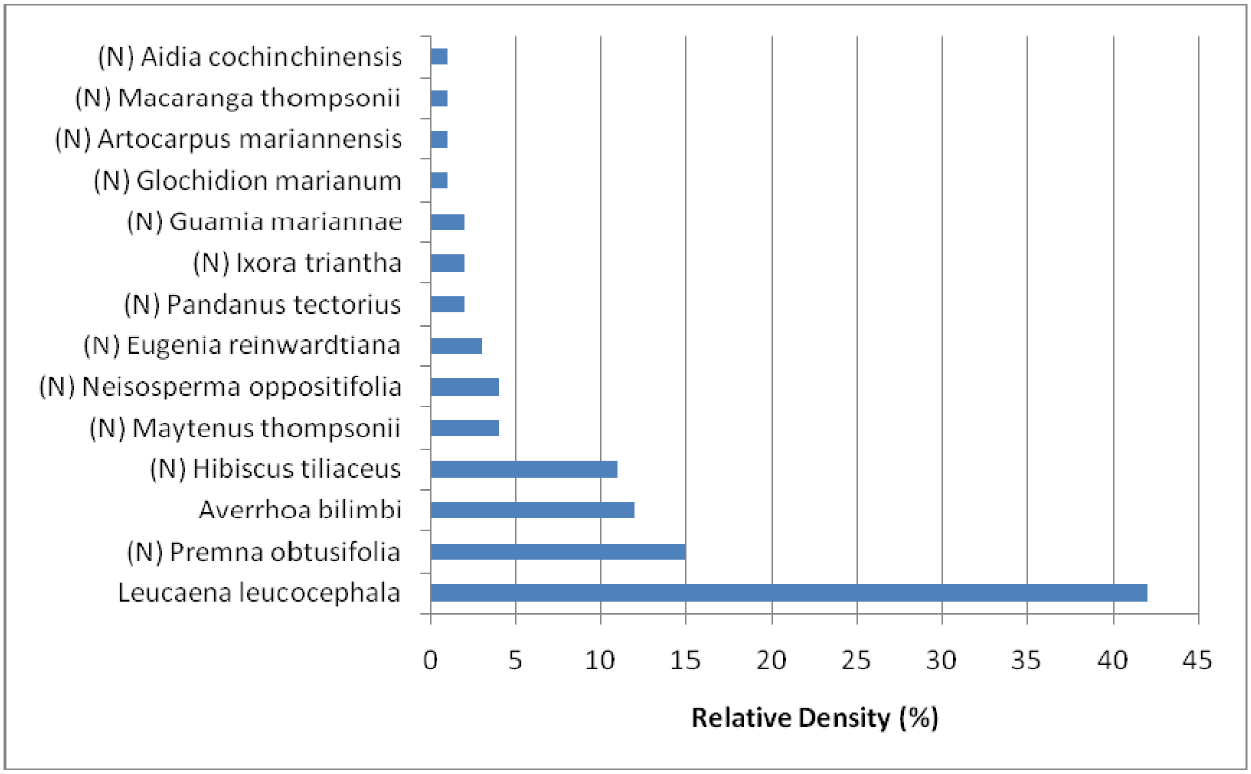
Summary - The point-center quarter survey results for Transect AS-7 are summarized in Table 6. The overall density for this transect was calculated at 3,300 trees per hectare. Fourteen species of tree were encountered throughout the survey. The introduced *Leucaena leucocephala* had the highest relative density (approximately 42%) of all species (Figure 4). Tangantangan and *Averrhoa bilimbi* were the only introduced tree species encountered in this survey, yet accounted for approximately 54% of the relative density (Figure 5) and 41% of the relative dominance of all species combined. *Premna obtusifolia* was the most encountered native tree species and had the highest relative density (approximately 15%) of all native species. The tree species richness for AS-7, Anderson South is presented in Figure 6.

Table 6. Summary of forest at Transect AS-7, Anderson South.

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST AS-7, ANDERSEN SOUTH, JAN. 2010						
SPECIES	STATUS	NO. TREES/ HECTARE	TOTAL BASAL AREA (sq. cm)	MEAN BASAL AREA (sq. cm)	ABSOLUTE DOMINANCE	ABSOLUTE FREQUENCY
Leucaena leucocephala	I	1434	4548.01	103.36	1482.33	84.62
Premna obtusifolia	N	521	3873.21	242.08	1262.39	42.31
Averrhoa bilimbi	I	391	634.61	52.88	206.84	19.23
Hibiscus tiliaceus	N	359	254.19	23.11	82.85	23.08
Maytenus thompsonii	N	130	46.83	11.71	15.26	15.38
Neisosperma oppositifolia	N	130	353.27	88.32	115.14	11.54
Eugenia reinwardtiana	N	98	105.43	35.14	34.36	7.69
Pandanus tectorius	N	65	51.03	25.51	16.63	7.69
Ixora triantha	N	65	41.33	20.67	13.47	7.69
Guamia mariannae	N	65	54.65	27.33	17.81	7.69
Glochidion marianum	N	33	16.61	16.61	5.41	3.85
Artocarpus mariannensis	N	33	2418.00	2418.00	788.10	3.85
Macaranga thompsonii	N	33	280.41	280.41	91.39	3.85
Aidia cochinchinensis	N	33	78.29	78.29	25.52	3.85

Key to Status: N = native; I = introduced

Figure 4. Relative Density (%) of Trees at AS-7, Anderson South.



Note: (N) indicates native species; others are introduced.

Figure 5. Relative density of native tree species at AS-7, Anderson South.

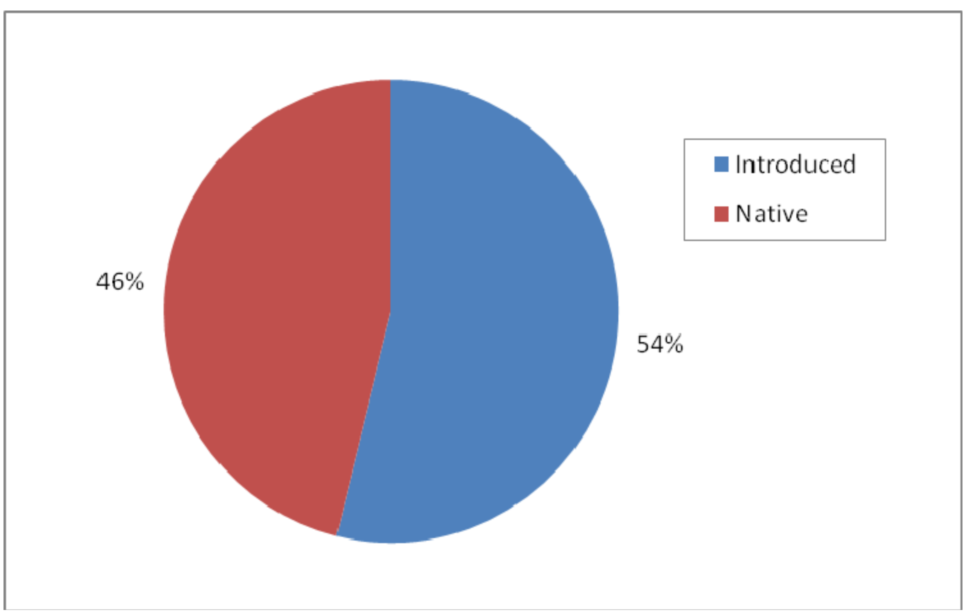


Figure 6. Species Richness of Trees at AS-7, Anderson South.

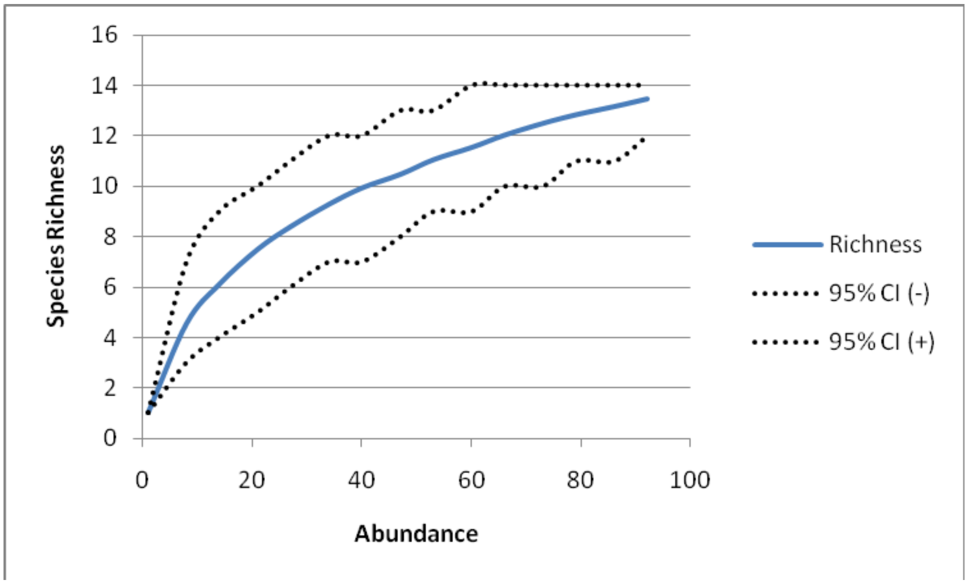


Table 7. Woody Seedling Species Encountered in Plots at AS-7, Anderson South.

Woody Seedling Species (<2cm dbh)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Aglaia mariannensis						*2*
Averrhoa bilimbi	*4*	*6*			*1*	*2*
Carica papaya						*1*
Colubrina asiatica	*4*					
Discocalyx megacarpa						*1*
Eugenia reinwardtiana				*1*		*1*
*Flagellaria indica (climbing)**	*80*	*61*	*100*	*100*	*100*	*100*
Guamia mariannae				6	2	15
*Ixora triantha***	6	3	1		15	4
Jasminum marianum	2		1	1		
Leucaena leucocephala	6	4	2			
Morinda citrifolia	11	16			1	2
Neisosperma oppositifolia		1	14	2	3	
Pandanus tectorius			3			8
Pouteria obovata	2			1		
Premna obtusifolia	2					
Triphasia trifolia	3	4	6	2	4	4
Ximenia americana	3					
Total Seedlings	123	95	127	113	126	140

*Notes: * Counts of 100 were terminated at 100 but exceeded that number.*

*** Some or all of this species may be Aidia cochinchinenis - definitive determination could not be made for the seedlings.*

Table 8. Non-Woody Seedling Species Presence in Plots at AS-7, Anderson South.

Non-Woody Seedling Species (Presence/Absence)						
	0m	*100m*	*200m*	*300m*	*400m*	*500m*
Asplenium nidus						1
Davalia		1				
Nephrolepis biserrata	1	1	1		1	1
Polypodium punctatum	1	1		1	1	1
Polypodium scolopendria	1	1			1	1
Pyrrosia	1	1				
Achyranthes aspera	1					
Caesalpinia			1			1
Chromolaena odorata		1				1
Mikania		1				1
Passiflora suberosa	1	1				1
Zeuxine fritzii	1	1	1			6
Total Seedlings	7	9	3	1	3	14

Note: "1" indicates presence within plots

Table 9. Ground Cover at AS-7, Anderson South

Meters from start	**Rock**	**Soil**	**Leaf litter**	**Live vegetation**	**Total**
0		2	10	4	16
100		4	8	4	16
200	1	11	4		16
300		12	3	1	16
400		6	7	3	16
500	3	2	8	3	16
Frequency	4	37	40	15	

3.10 Navy Barrigada Transect 3

Surveyors: Glenn Metzler and Claudine Camacho.

Date: January 13, 2010.

Barrigada Transect 3.

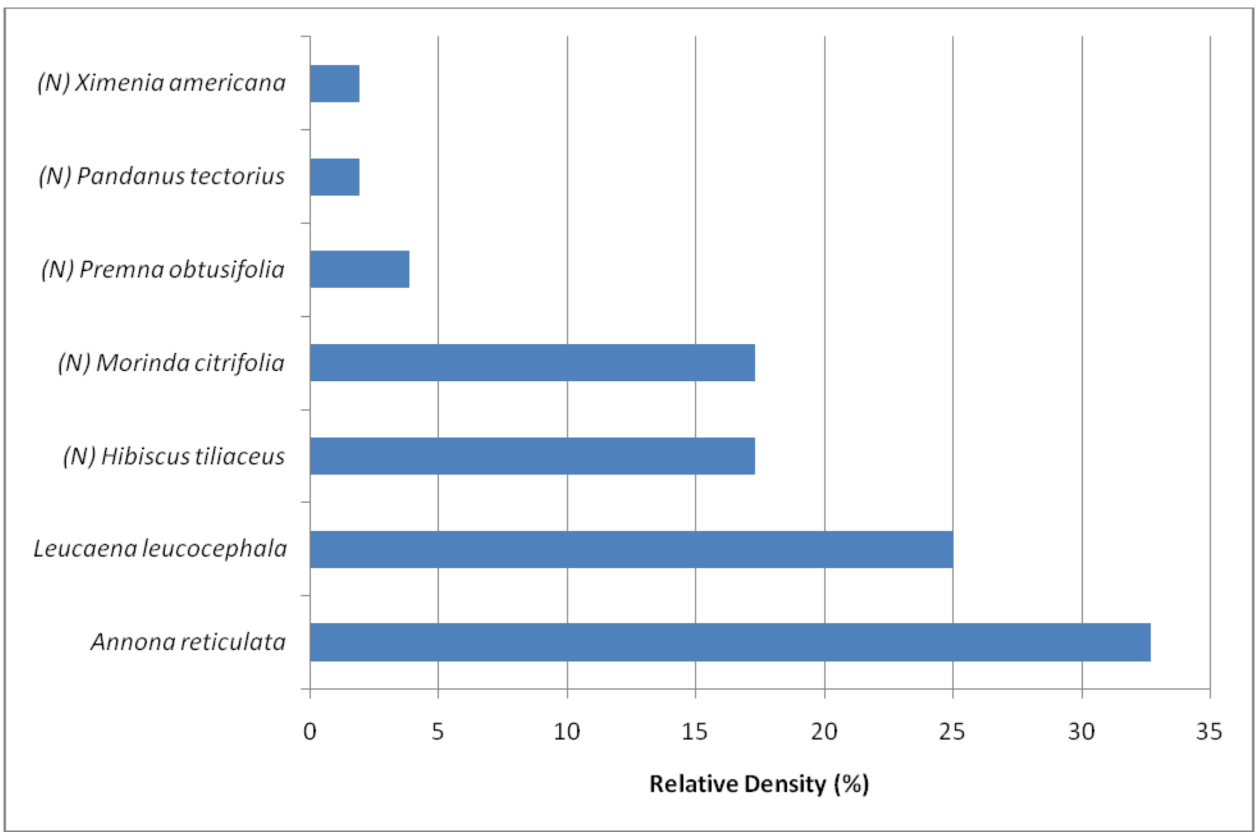
Summary - The point-center quarter survey results for Transect T-3 are summarized in Table 10. The overall density for this transect was calculated at 4,632 trees per hectare. Seven species of tree were encountered throughout the survey. The introduced *Annona reticulata* and *Leucaena leucocephala* had the two highest relative densities of all species observed (Figure 7), and were the only introduced species encountered throughout the survey. Together, these two species accounted for approximately 58% of the relative density (Figure 8) and 47% of the relative dominance. *Hibiscus tiliaceus* was the most encountered native tree species and had the highest relative density (approximately 17%) and relative dominance (approximately 31%) of all native species. The tree species richness for Transect T-3 is presented in Figure 9.

Table 10. Summary of Forest at Transect 3, NCTS Barrigada

POINT-CENTER QUARTER METHOD RESULTS FOR LIMESTONE FOREST T-3 Barrigada, January 2010						
SPECIES	STATUS	NO. OF TREES/ha	TOTAL BASAL AREA (cm²)	MEAN BASAL AREA (cm²)	ABSOLUTE COVER (m²/ha)	ABSOLUTE FREQUENCY
Annona reticulata	I	1514	645.47	37.97	5.75	130.77
Leucaena leucocephala	I	1158	264.98	20.38	2.36	100.00
Hibiscus tiliaceus	N	802	597.74	66.42	5.33	69.23
Morinda citrifolia	N	802	254.96	28.33	2.27	69.23
Premna obtusifolia	N	178	106.54	53.27	0.95	15.38
Pandanus tectorius	N	89	23.75	23.75	0.21	7.69
Ximenia americana	N	89	26.41	26.41	0.24	7.69

Key to Status: N = native; I = introduced

Figure 7. Relative Density (%) of Trees at Transect 3, NCTS Barrigada



Note: (N) indicates native species; others are introduced.

Figure 8. Relative density of native tree species along Transect 3, NCTS Barrigada.

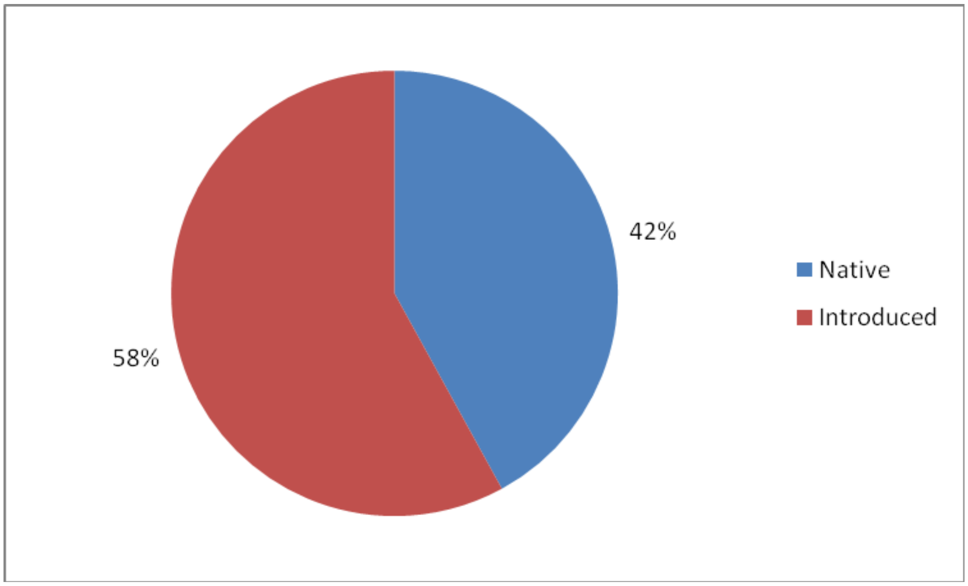


Figure 9. Species Richness of Trees at Transect 3, NCTS Barrigada

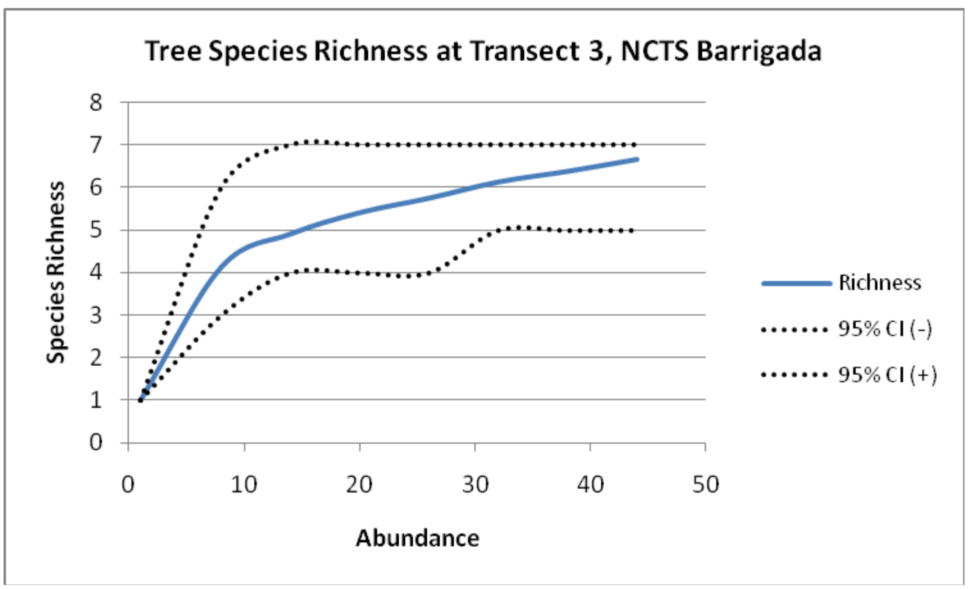


Table 11. Woody Seedling Species Encountered in Plots at Transect 3, NCTS Barrigada

Woody Seedling Species (<2cm dbh)			
	40m	*140m*	*240m*
Annona reticulata			3
Averrhoa bilimbia			1
Carica papaya	1		
Colubrina asiatica		60	
Flagellaria indica	20		39
Guamia mariannae			1
Ixora triantha	1		
Jasminum marianum	2		50
Lantana camara		5	
Leucaena leucocephala	67	73	11
Morinda citrifolia	16	12	9
Pandanus tectorius		1	
Psidium guajava		3	
Triphasia trifolia	3		
Ximenia americana		14	2
Unknown Tiliaceae sp.		6	
Totals	110	174	116

Table 12. Non-Woody Seedling Species Presence in Plots at Transect 3, NCTS Barrigada.

Non-Woody Seedling Species (Presence/Absence)			
	40m	*140m*	*240m*
Achyranthes aspera		*1*	*1*
Mikania scandens	1	1	1
Nephrolepis acutifolia	1		
Nephrolepis biserrata			1
Nephrolepis hirsutula		1	
Passiflora suberosa	1	1	1
Polypodium punctatum	1	1	1
Polypodium scolopendria	1	1	1
Pyrrosia lanceolata		1	1
Chromolaena odorata		1	1
Momordica charantia	1		
Stichtocardia tiliaefolia	1	1	
Total Seedlings	7	8	7

Note: "1" indicates presence within plots

Table 13. Ground Cover at Transect 3, NCTS Barrigada.

Meters from start	Rock	Soil	Leaf litter	Live vegetation	TOTAL
40	2	4	6	4	16
140		10	6		16
240		2	10	4	16
Frequency	2	16	22	8	

4.0 References

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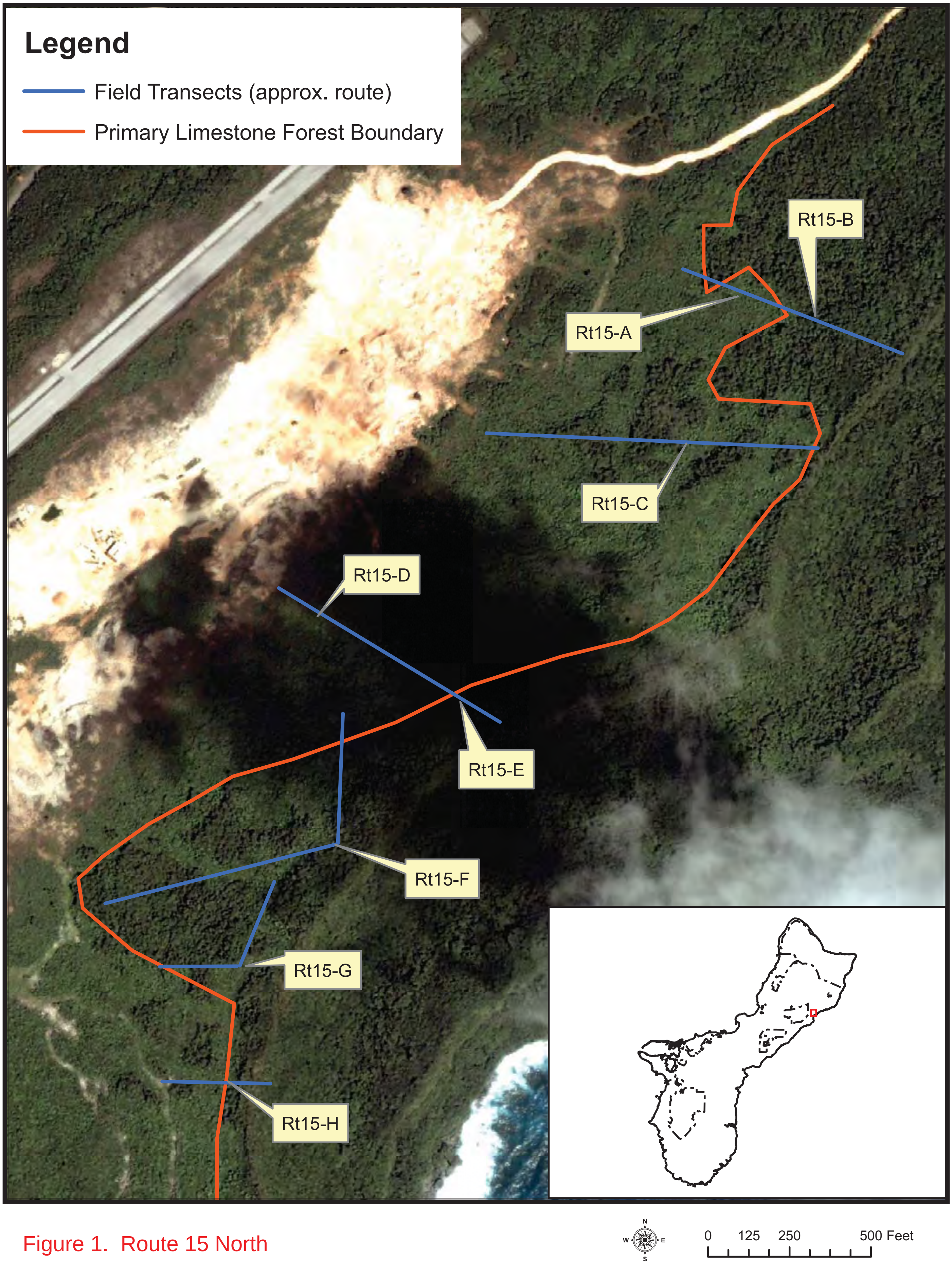

Figure 1. Route 15 North

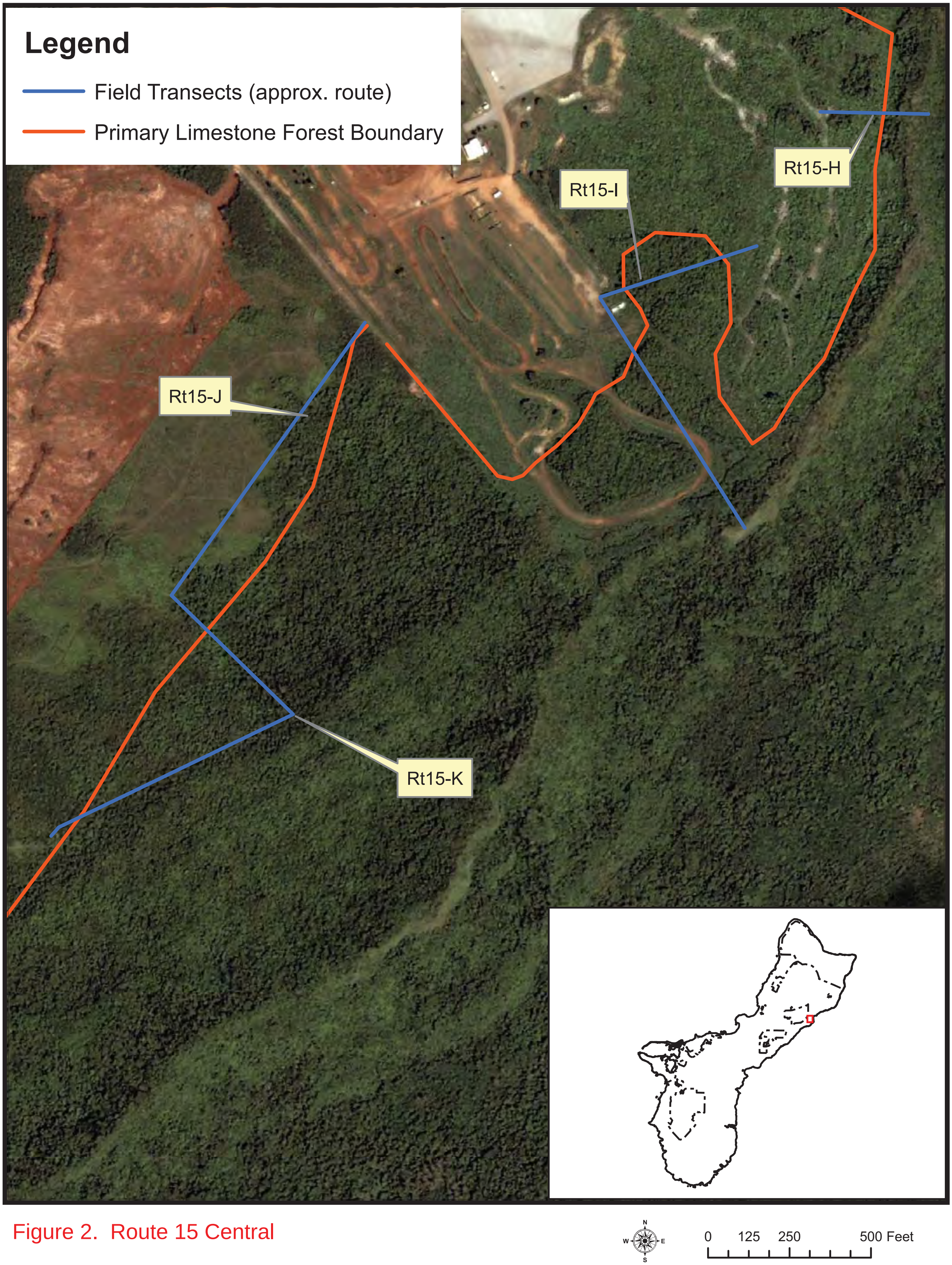

Figure 2. Route 15 Central

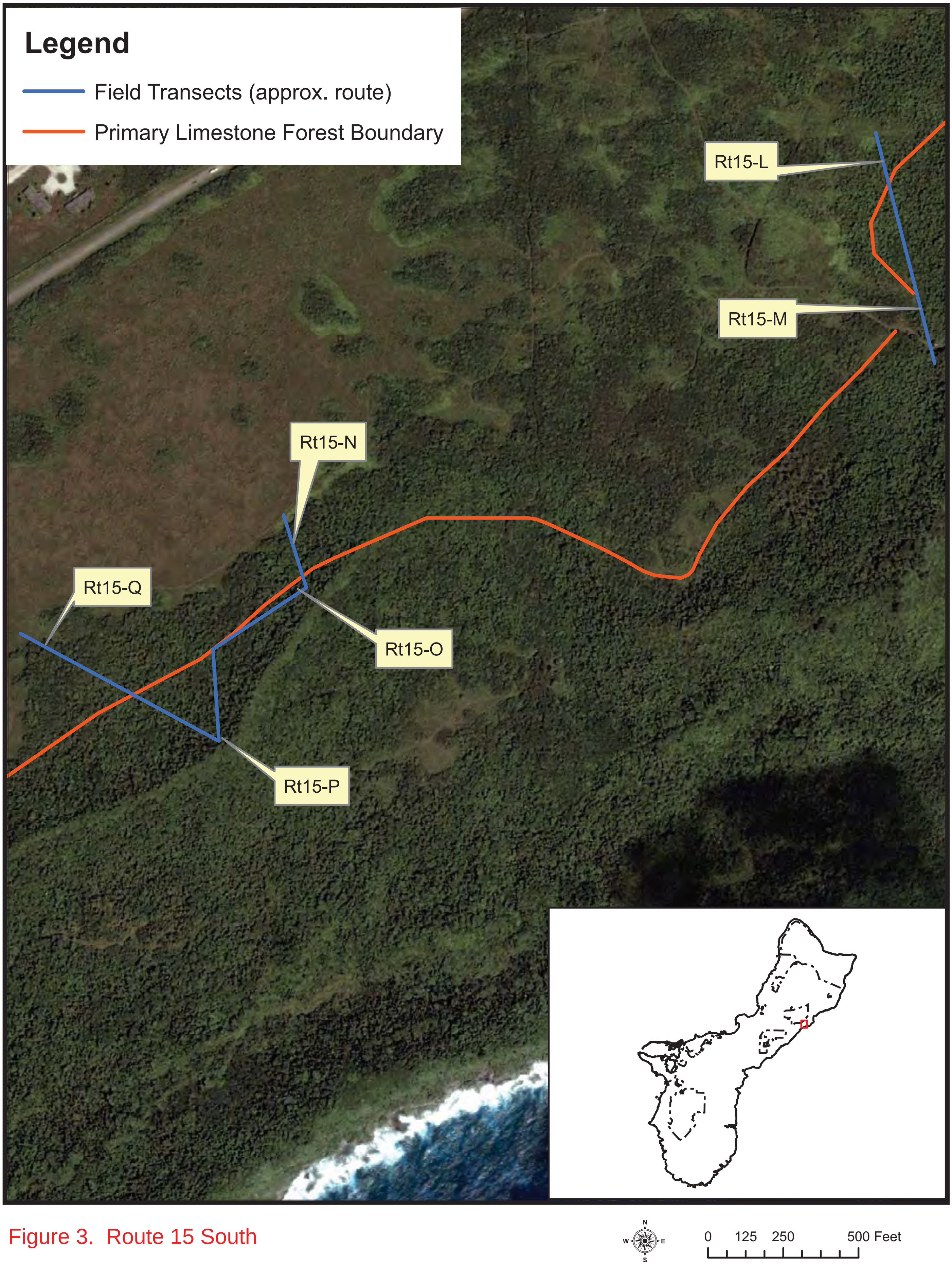

Figure 3. Route 15 South

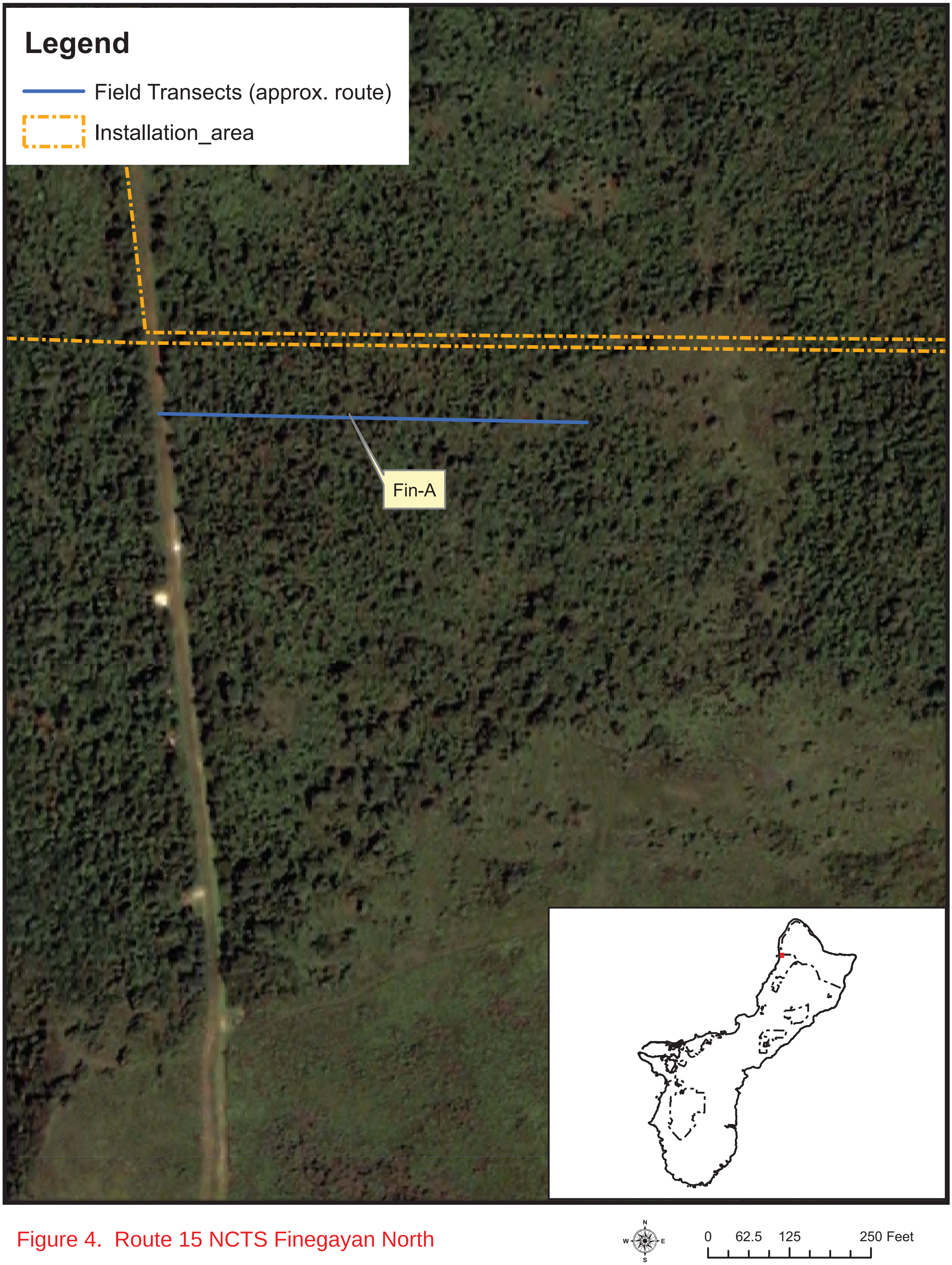

Figure 4. Route 15 NCTS Finegayan North

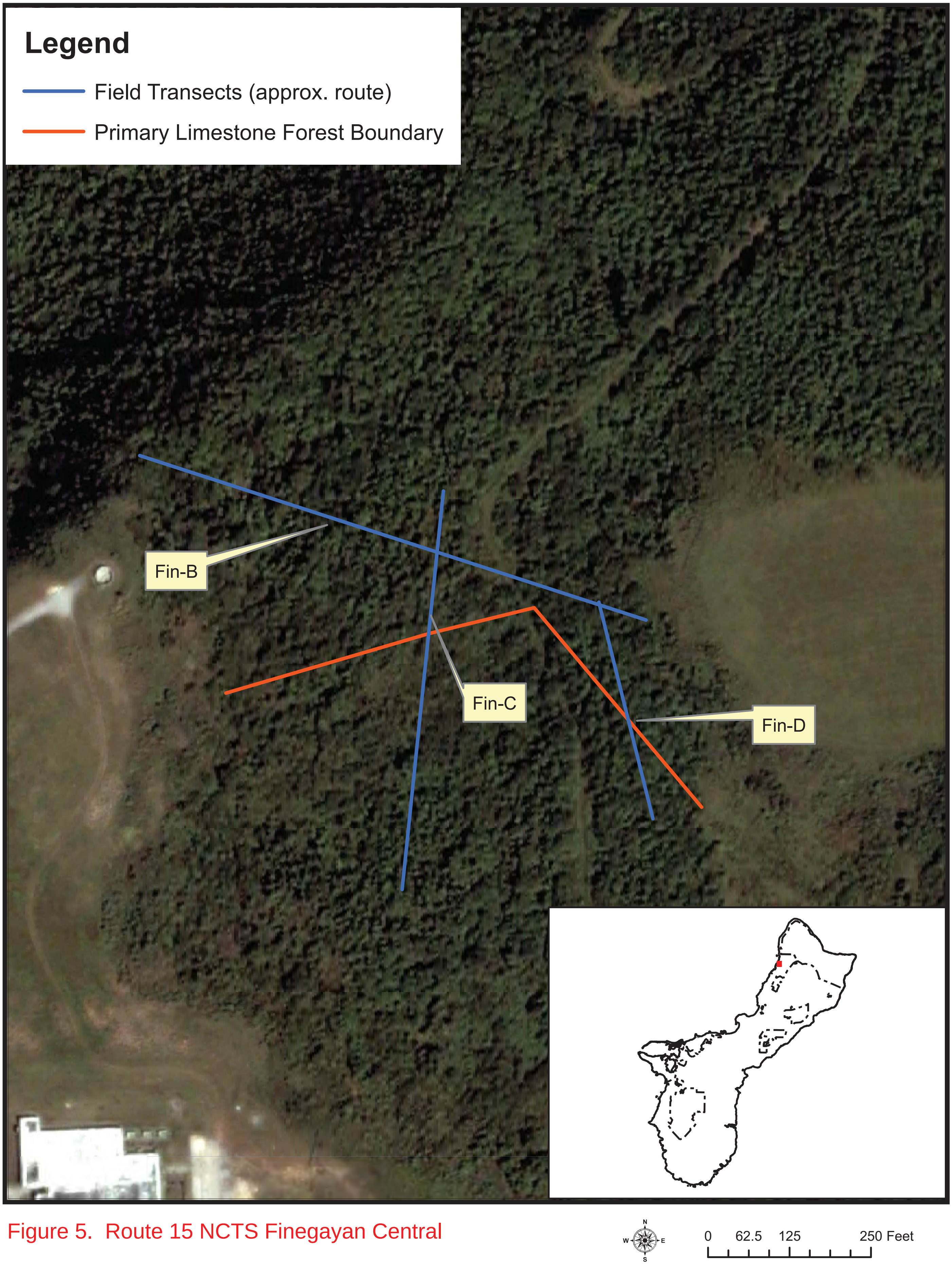

Figure 5. Route 15 NCTS Finegayan Central

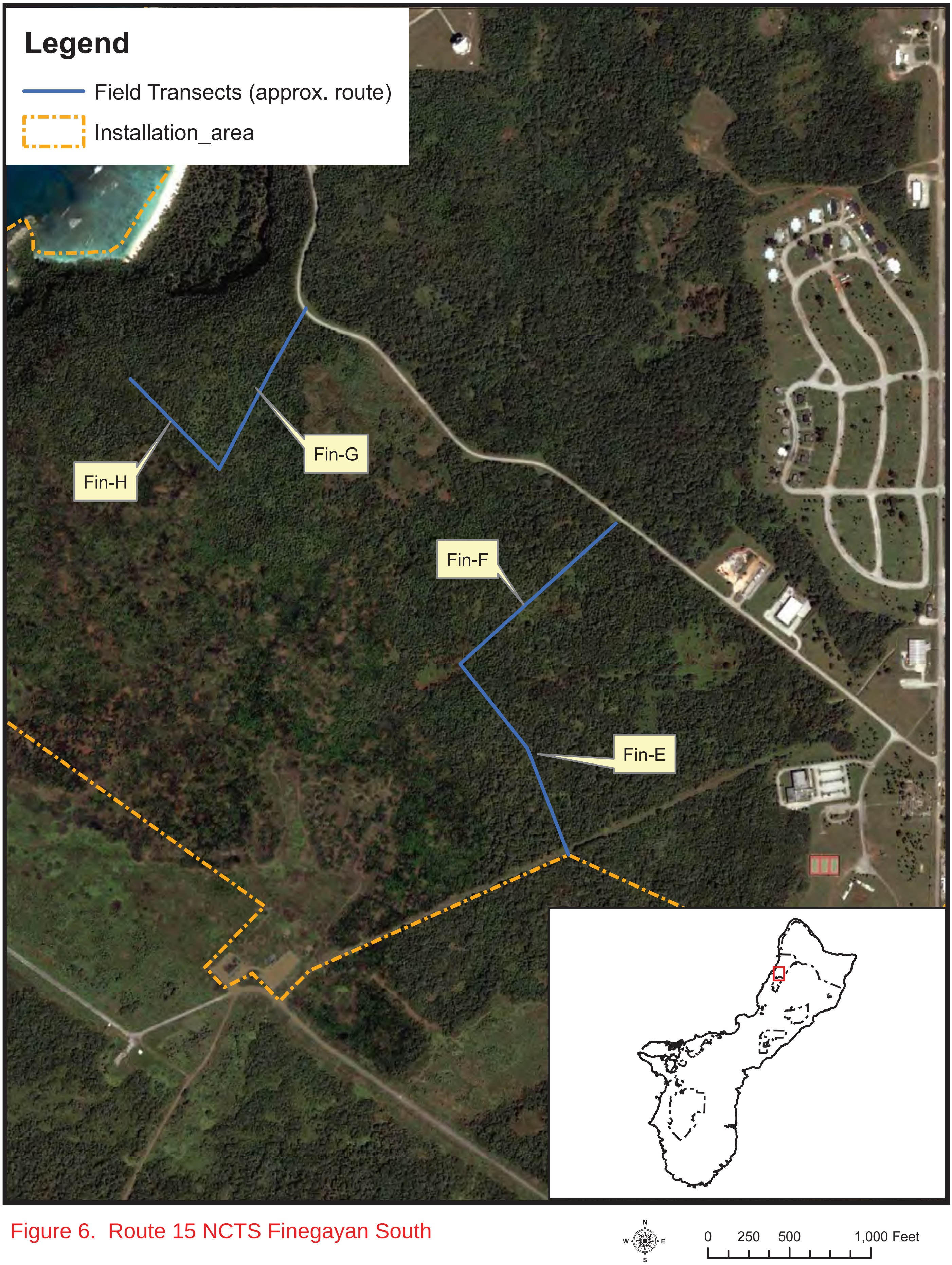

Figure 6. Route 15 NCTS Finegayan South

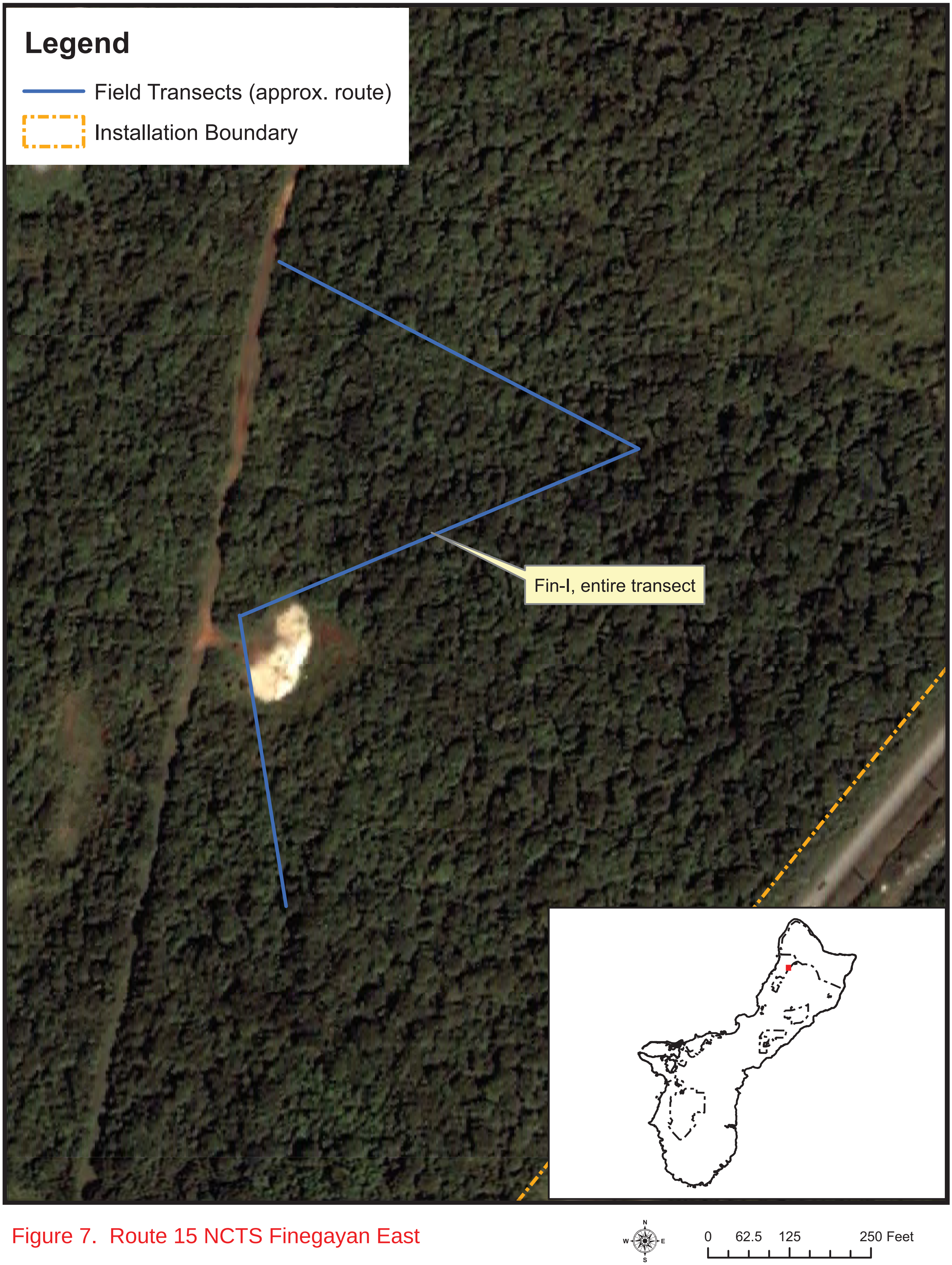

Figure 7. Route 15 NCTS Finegayan East

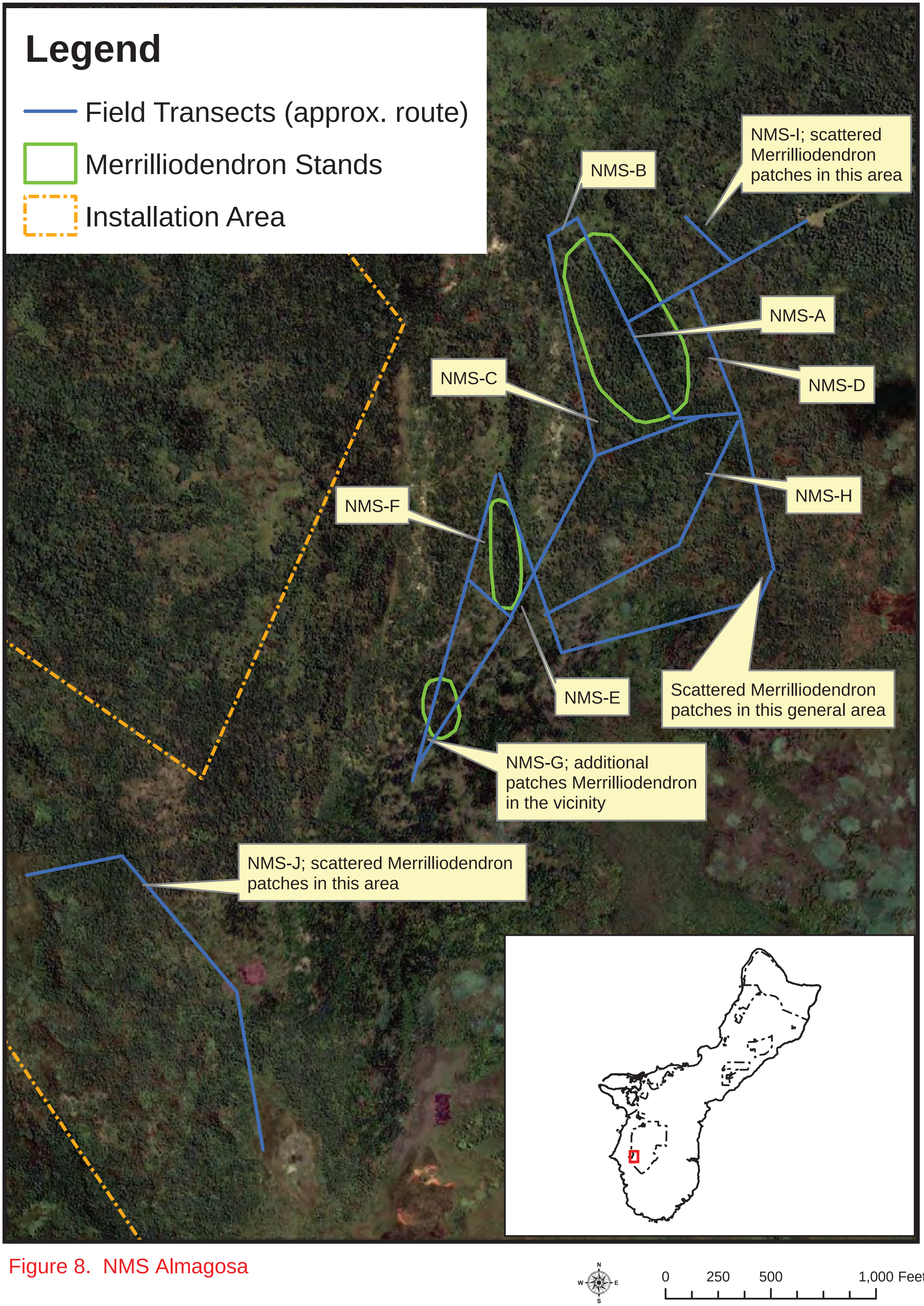

Figure 8. NMS Almagosa

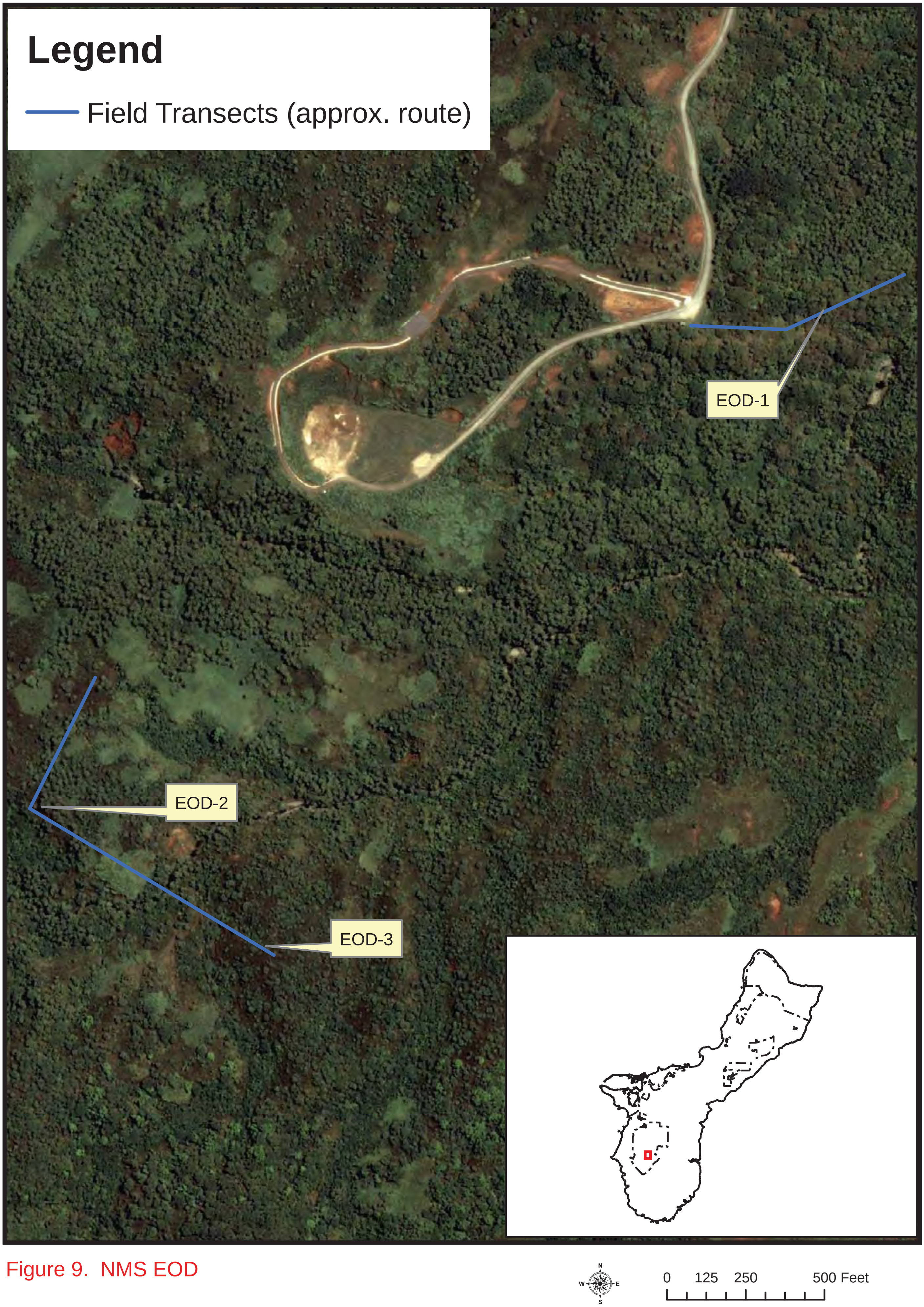

Figure 9. NMS EOD

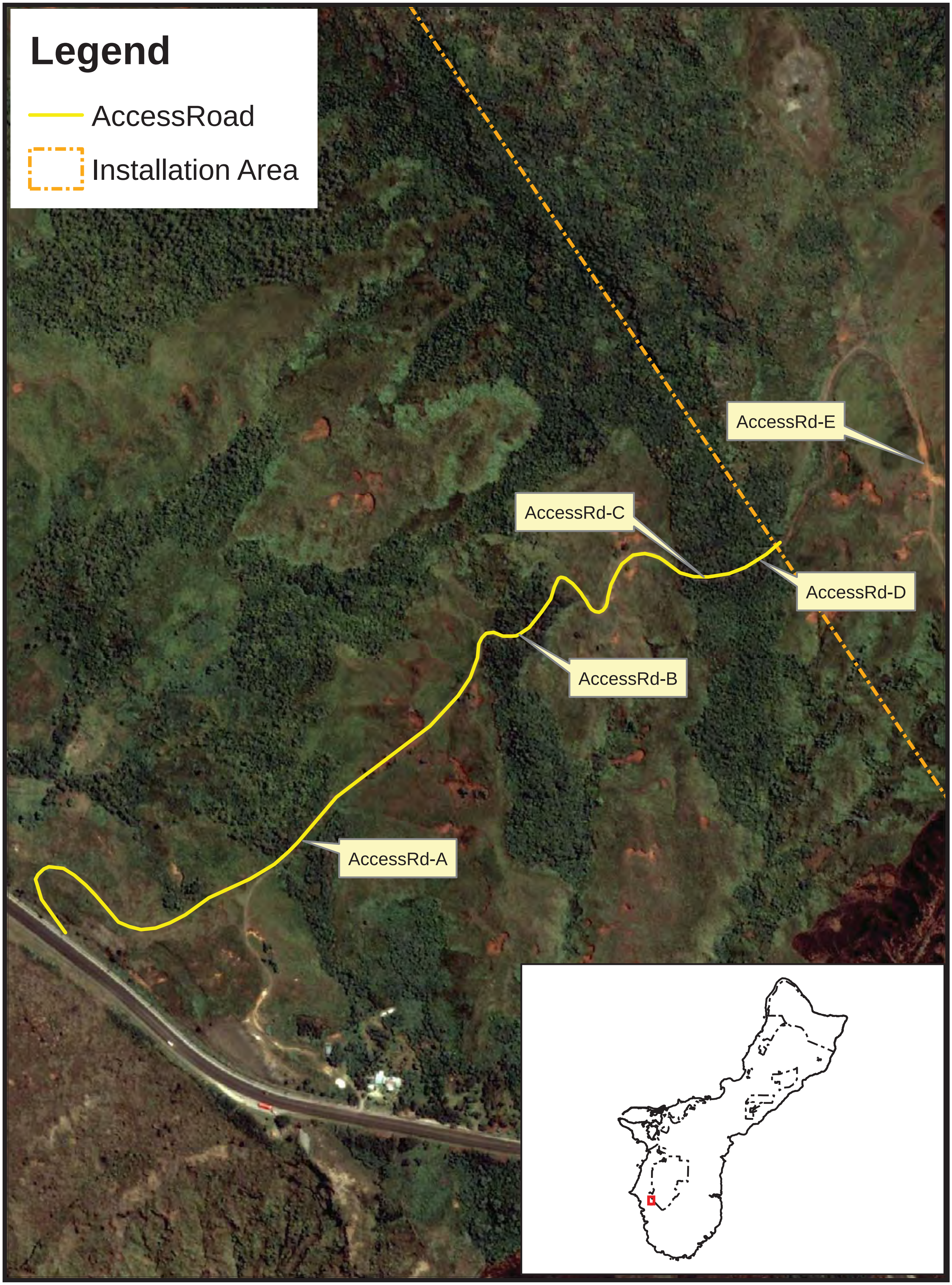

Figure 10. NMS Access Road

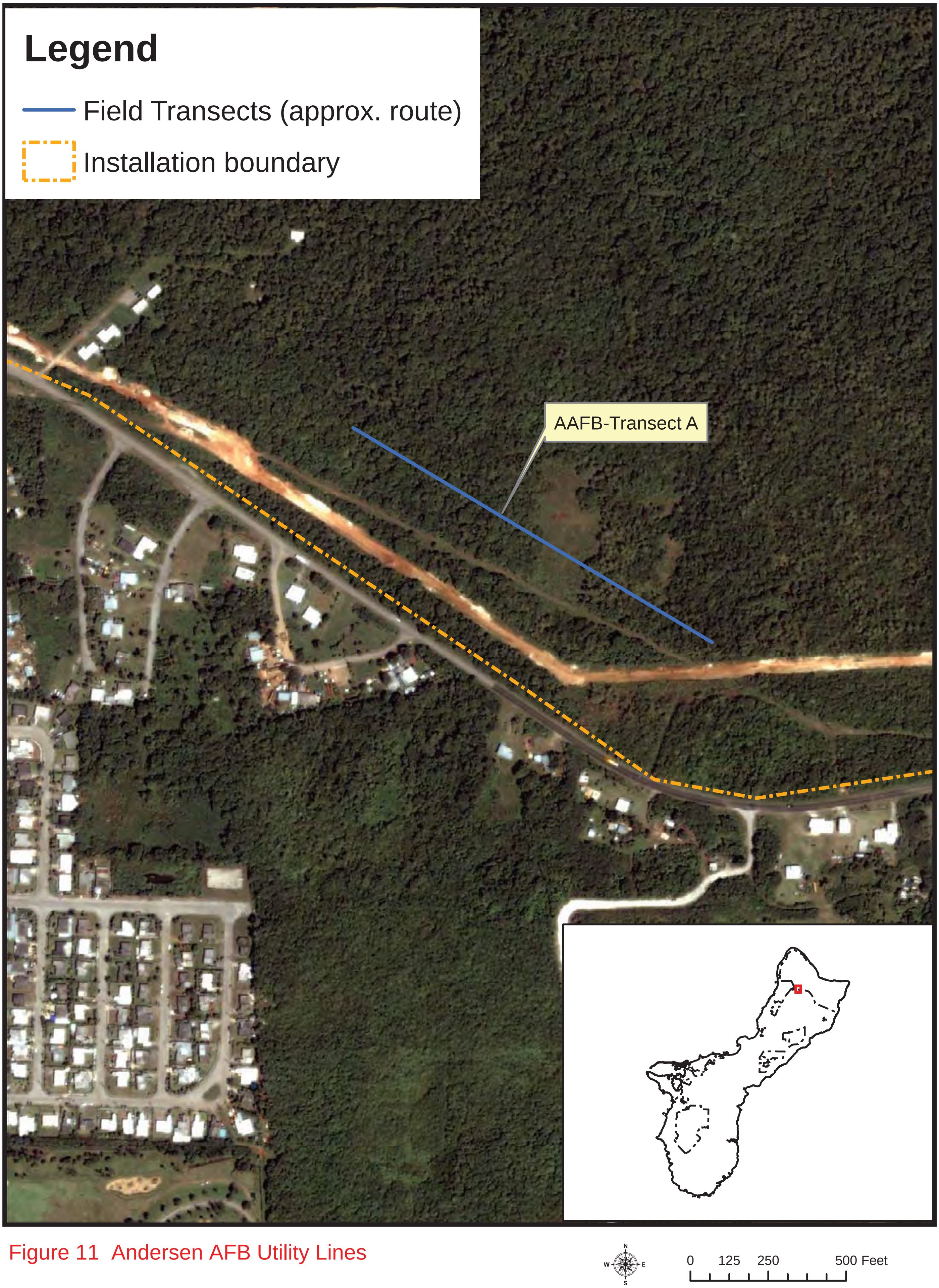

Figure 11 Andersen AFB Utility Lines

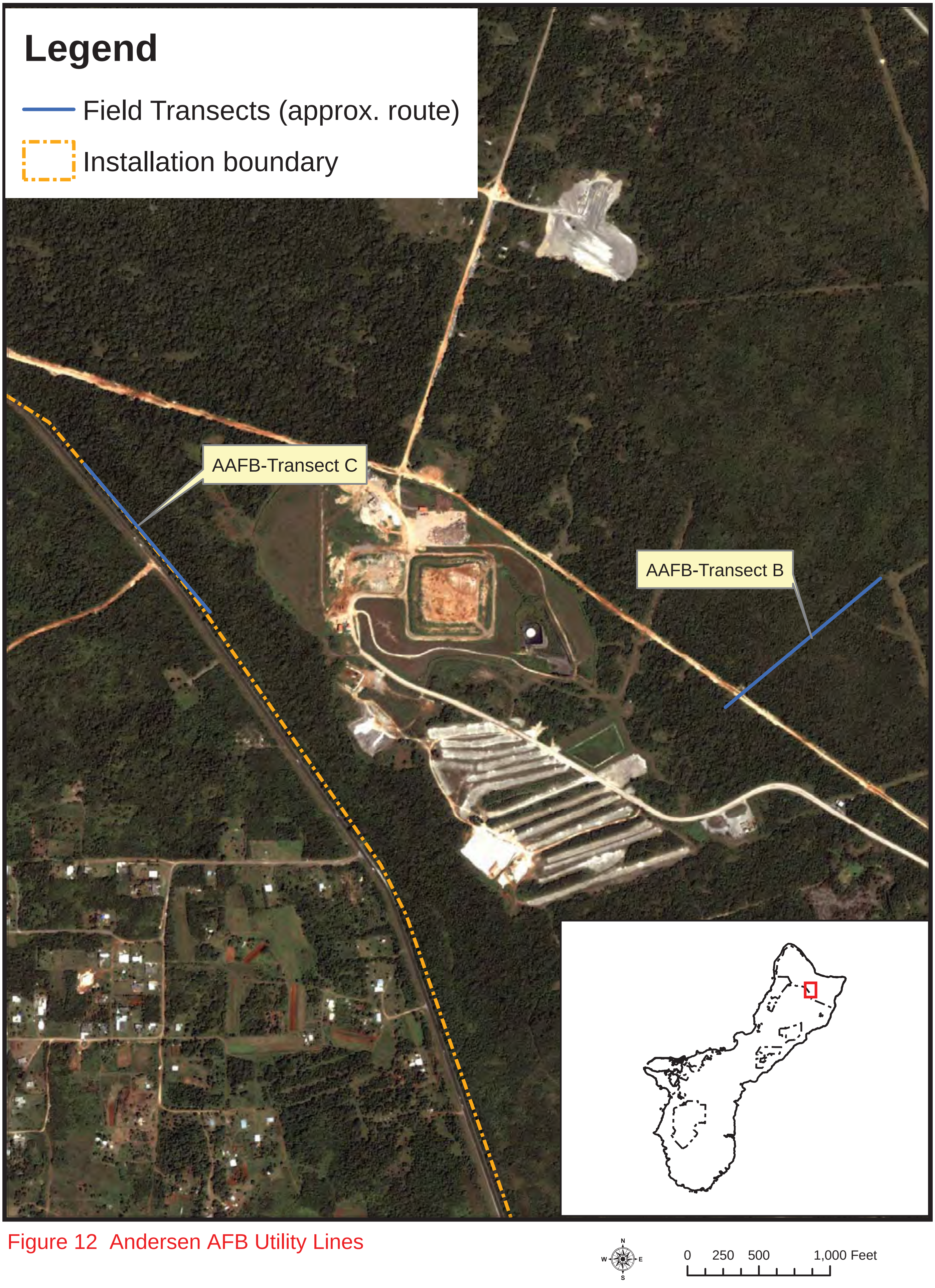

Figure 12 Andersen AFB Utility Lines

APPENDIX E
Butterfly Surveys

Butterfly Survey Report. Andersen Air Force Base, Andersen South, and Navy Barrigada. AECOM. June 28, 2010; and

Survey for the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* (Lepidoptera: Nymphalidae), in the Pagat Route 15 area of Yigo Village, Guam. NAVFAC Pacific, Pearl Harbor, HI August 2009.

BUTTERFLY SURVEY REPORT

Andersen Air Force Base

Andersen South

Navy Barrigada

June 28, 2010

Department of the Navy
Naval Facilities Engineering Command,
258 Makalapa Drive, Suite 100
Pacific Pearl Harbor, HI 96860-3134

AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives
Contract Number N62742-06-D-1870, TO 0016

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List of Photos Page

1 Introduction

Under a NAVFAC contract for AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives and in support of the "Marine Corps Relocation Initiative to Various Locations on Guam", the TEC JV received Task Order 0016 with subsequent modifications 1 & 2 and TO 0007 Mod 04 for Natural Resource (NR) Surveys on Guam. The basis for this assignment is to provide the necessary data to support the Environmental Impact Statement (EIS) for the Joint Guam Program Office actions relating to the relocation of the Marines by filling existing data gaps identified in the Final Natural Resources Survey and Assessment Report of Guam and Certain Islands of the Northern Mariana Islands (NAVFAC 2007).

As part of the natural resource surveys, investigations for the presence of the Mariana Eight-Spot Butterfly (*Hypolimnas octucula mariannensis*) and the Mariana wandering butterfly (*Vagrans egistina*) were conducted on three DoD parcels on Guam: Andersen Air Force Base (AAFB), Andersen South and Navy Barrigada. Both species are candidate species for listing by the United States Fish and Wildlife Service (USFWS) under the Endangered Species Act of 1973 (USFWS, 2010). The Mariana Wandering Butterfly is also considered a Species of Greatest Conservation Need (GDAWR, 2005).

1.1 Mariana Eight-Spot Butterfly

The Mariana Eight-Spot Butterfly (Photo 1) is a nymphalid butterfly, feeds upon two host plants, *Procris pedunculata* and *Elatostema calcareum,* which are indigenous succulent herbs that grow in limited habitats over limestone rock outcrops in moist limestone forest. The buttefly is endemic to the islands of Guam and Saipan, and the species is now known from ten populations on Guam. This species is currently threatened by predation and parasitism. The Mariana Eight-Spot Butterfly has extremely high mortality of eggs and larvae due to predation by alien ants and wasps. Because the threat of parasitism and predation by nonnative insects occurs range-wide and can cause significant population declines to this species, they are high in magnitude. The threats are imminent because they are ongoing (USFWS, 2010).

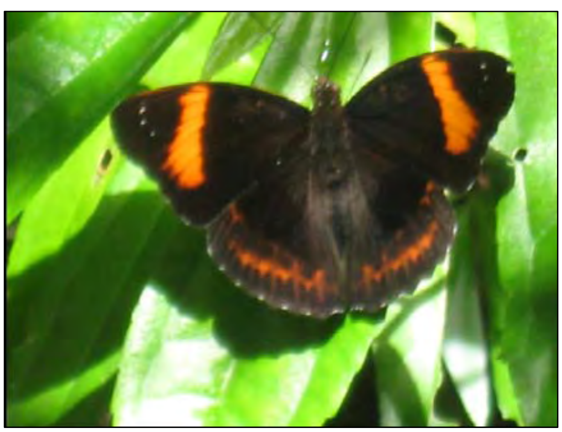

Photo 1 Mariana Eight-Spot Butterfly (*Hypolimnas octucula mariannensis*)

Surveys on the Rt 15 properties (Figure 1) identified the host plants: *Elatostema calcareum* (Urticaceae) and *Procris pedunculata* (Urticaceae) and observed Mariana Eight-Spot Butterfly along Transect 2. Also, evidence of eggs was found in other locations throughout the investigated areas (Figure 1).

1.2 Mariana Wandering Butterfly

A very rare butterfly, endemic to the islands of Guam and Rota. Although, historically found on Guam and CNMI (Rota), the species now occurs with any certainty only on Rota (USFWS, 2010a).

Body color is primarily orange and black, with black bordering the wings. A large orange irregular shape extends from the forewings to the hindwings. Females and males are similar in body color and size. Larvae feed on a plant species (*Maytenus thompsonii*) that is endemic to the Mariana Islands. Adults are good fliers and can move considerable distances (USFWS, 2008).

2 Methods

During September 28– October 2, 2009 and January 25-31, 2010 a butterfly survey was conducted on three transects at Andersen AFB, one transect on Andersen South, and one transect on Navy Barrigada. The butterfly survey consisted of two methods: timed counts and baited traps. Descriptions of these methods are provided in the sections below.

2.1 Timed Counts

Timed counts were conducted along linear transects within each of the three parcels. At every 30-m, two scientists would stand back-to-back and enumerate the observations of all butterfly species within a 5-minute period. The areas investigated along the transect consisted of 20-m diameter circle plots. The biologists communicated with each other frequently throughout the survey period so as not to count the same individual butterfly twice. A total of five transects were studied. Three transects were located on AAFB (Figure 2) and one transect was located on Andersen South (Figure 3) and Navy Barrigada (Figure 4).

2.1.1 Andersen AFB

On AAFB, the butterfly survey occurred on Transects 5, 6, and 7 (Figure 2), which are all located in the southern portion of AAFB. Each transect was 400 m in length. The transects were located in forested areas with a canopy of 6-12 m in height with moderate to dense undergrowth. On Transect 5, between 130 m and 190 m, an open area dominated by herbaceous vegetation, grasses, and a few small isolated trees results in a break in the forest canopy.

2.1.2 Andersen South

On Andersen South, the butterfly survey was conducted on Transect 7 (Figure 3), which is 500-m long and located in a forested area. The forest canopy is approximately 10 m in height, with moderate to heavy undergrowth. The undergrowth often occurred in the form of smaller saplings and numerous vines.

2.1.3 Navy Barrigada

On Navy Barrigada, the butterfly survey was conducted on Transect 3, which measured 250-m in length (Figure 4). The transect is located in a forested area with a canopy of approximately 6-8 m in height with several small clearings on and/or near the transect. The forested area is located adjacent to a large, maintained grass field associated with communication towers. The survey began approximately 15 m from the forest's edge.

2.2 Baited Traps

Two baited traps were placed on each transect during daylight hours. The bait consisted of a mixture of mashed ripe bananas, apple cider, sugar, and yeast (Photo 2). At the end of the trapping period, which lasted approximately 6 hours, the traps were checked, and captured butterflies were noted and then released.

Photo 2 Butterfly Trap. The bait is placed in the white dish. Butterflies land on the edge of the dish and consume the bait. When the butterflies initiate their next flight they instinctively fly upwards and become trapped in the mesh cylinder.

2.2.1 Andersen AFB

Two baited traps were placed on each transect (Transects 5, 6, and 7) in the morning and retrieved in the late afternoon. On Transect 5, the traps were placed within a forested area in the beginning of the transect (September and January) and a second trap was placed within a clearing in the September survey and near the end of the transect in the January survey. On Transect 6 and Transect 7, the traps were placed in forested areas at the beginning and the end of each transect in both the September and January surveys.

2.2.2 Andersen South

Butterfly traps were set at the 0 and 470 meter mark on Transect 7. The baited traps were placed on each transect during daylight hours.

2.2.3 Navy Barrigada

Two baited traps were placed on Transect 3 during daylight hours. The trap was placed at the start of the transect, and at approximately the 60 meter mark near a clearing.

3 Results

3.1 Description of Species Observed

A total of six butterfly species were identified during the surveys. The descriptions of the species are based on Schreiner and Haus, 1997.

- Lemon Emigrant, *Catopsilia pomona.* The species is found in the Marianas and Palau. The larvae feed on various species of *Cassia* sp. The species is often found in moist open areas and engages in migratory flights.

- Monarch, *Danaus plexippus.* This species' range includes the America, Australia and numerous pacific Islands – including the Marianas. In Micronesia, the species feeds on *Asclepias curassavica* and crown flower, *Caltopis gigantean.* The species is a known migrant capable of flying thousands of miles.

- Blue-branded King Crow, *Euploea Eunice.* This species' range extends from India to Micronesia. The larvae feed on *Ficus* sp., edible figs, and oleander. They are often sighted hanging on aerial roots of fig trees, other vegetation, or structures.

- Blue Moon, *Hypolimnas bolina.* This species ranges from Madagascar to New Zealand; moreover, the species is considered the most widely distributed butterfly in the world. The species is recorded as taking migratory flights from Australia to New Zealand.

- Common Evening Brown, *Melanitis leda.* In the Pacific, the Common Evening Brown butterfly occurs within the Marianas and Caroline Island Chains. On Guam, the species has been found on corn, Guinea grass, and Napier grasses. The larvae also feed on grasses.

- Common Mormon, *Papilio polytes.* This species is found throughout southeast Asia, Philippines, Palau, Yap, and the Marianas Islands; although, the species is thought to be a recent arrival to the Marianas. The butterflies are attracted to salt and frequently found at puddles. Food plants include citrus and other Rutaceae plants.

The Mariana Eight-Spot Butterfly and the Mariana Wandering Butterfly were not observed on any transect.

3.2 Timed Counts

Tables 1, 2, and 3 identify the number of individuals and species observed within the various sampling plots on AAFB, Andersen South, and Navy Barrigada, respectively.

3.2.1 Andersen AFB

In September 2009, the Common Mormon and Blue-banded King Crow were the two most common butterflies sighted and comprised 46 and 43.6 percent of the total sightings at AAFB, respectively (Table 1). Approximately 62 percent (57 of 92 sightings) of the total sightings of the Blue-banded King Crow occurred within two plots along Transect 5 associated with a road cut.

In January 2010, the Blue-banded King Crow and the Common Mormon were the two most common butterflies sighted, comprising 64.5 and 24.5 percent of the total sightings, respectively. Similar to the September findings, a majority of the total sightings on the Blue-banded King Crow (152 of 160 [95 percent]) occurred within the first 120 m of Transect 5.

The January sightings total of 282 individuals is approximately one-third higher than the September total of 211. Although there were two additional species sighted in September (Blue Moon and Monarch), the total number of individuals of these two species was only three. All of the species sighted are widely distributed in the Mariana Islands.

3.2.2 Andersen South

Table 2 identifies the numbers of individuals and species observed within the various sampling plots on Andersen South in September 2009 and February, 2010. None of the species that werte observed on Andersen South are considered endangered or threatened and all are widely distributed in the Mariana Islands.

On Andersen South the Common Mormon was the most numerous sighted butterfly in both September 2009 and January 2010, comprising 88.8 and 56.3 percent of the total sightings, respectively. The numbers of butterflies sighted, on average, also decreased between September and January. This reduction in abundance may be the result may be the result of natural cycles in butterfly population, the relatively short observation periods involved, or other factors.

3.2.3 Navy Barrigada

On Navy Barrigada, the Common Mormon was the most frequently observed butterfly in September and January, comprising 73.2 and 52.5 percent of the total sightings, respectively (table 3). The numbers of individuals and species showed little variation between September and January.

Table 1

Butterfly Sightings on AAFB

Transect	September 2009						January 2010			
	Meter Dist. On Transect	Species					Meter Dist. On Transect	Species		
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant
5	10		1				0		40	
	40						30	1	9	
	70	1	4				60		28	
	100	2	6				90	1	24	
	130	2	29	2	2		120		51	
	160	3	28	4		1	180	2		
	190						220	1	1	
	230						250	1		
	260						280	3		
	290	1					310	3	1	
	320	1					340	2	2	
	350						370	2		
	380	2					400	2	4	
	TOTAL SIGHTINGS	12	68	6	2	1	TOTAL SIGHTINGS	18	160	
	Percent of Sightings	13.48	76.40	6.74	2.25	1.12	Percent of Sightings	10.1	89.8	0
6	0									
	30						20	1		
	60	2					50	2		1
	90	8	2	3			80	2		
	120	8		1			110	2	1	
	150	3		2			140	1		
	180	5		1			170	3		6
	210		3	1			200	3		3

Table 1										
Butterfly Sightings on AAFB										
Transect	September 2009						January 2010			
	Meter Dist. On Transect	Species					Meter Dist. On Transect	Species		
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant
	240	1		3			230	2		7
	270	2					260		1	
	300	3		1			290	2		1
	330	2					320	2		4
	360	6					350	2		6
	390	5	17				380	3	1	1
	TOTAL SIGHTINGS	45	22	12	0	0	TOTAL SIGHTINGS	25	3	29
	Percent of Sightings	56.96	27.85	15.19	0.00	0.00	Percent of Sightings	43.9	5.3	50.9
7	0	2		1			0	3		
	30						30	2	1	
	60	1					60	2	2	
	90	1					90	5		
	120	3					120	1		
	150	2					150	2	4	
	180	3	2				180	1	6	
	210	4					210	4	1	
	240	4					240	1	1	
	270						270	4		1
	300	8					300	2		
	330	6					340		1	
	360	4					370			
	390	2					400		3	
	TOTAL SIGHTINGS	40	2	1	0	0	TOTAL SIGHTINGS	27	19	1

Table 1											
Butterfly Sightings on AAFB											
Transect	September 2009						January 2010				
	Meter Dist. On Transect	Species					Meter Dist. On Transect	Species			
		Common Mormon	Blue-banded King Crow	Lemon Emigrant	Blue Moon	Monarch		Common Mormon	Blue-banded King Crow	Lemon Emigrant	
	Percent of Sightings	93	5	2	0	0	Percent of Sightings	61.36	36.36	2.27	

Table 2							
Butterfly Sightings Andersen South							
September 2009				January 2010			
Meter Dist. On Transect	Species			Meter Dist. On Transect	Species		
	Common Mormon	Blue-banded King Crow	Lemon Emigrant		Common Mormon	Blue-banded King Crow	Lemon Emigrant
0	3			0	3	3	
20	4			30		1	
40	2			60			
60	4			90	3		1
80	4	1	2	120	3	1	
100			1	150	1		
120	6			180			
140	16			210	2		
160	10	1		240	1	1	1
180	2			270		2	
200	4			300			
220	4			330		1	
240	4			360	1		
260	1			390	2		
280	3			420	1	2	
300	3	2		450	1		
320	3		1	480		1	
340	4						
360	3						
380	3	2	1				
400	2						
420	1		1				
440	3						
460	1						
480	3						
500	2						
TOTAL SIGHTINGS	95	6	6	TOTAL SIGHTINGS	18	12	2
Percent of Sightings	88.79	5.61	5.61	Percent of Sightings	56.3	37.5	6.3

Table 3
Butterfly Sightings at Navy Barrigada – September 2009 and January 2010

Survey Plot - Meter Distance on Transect	Species			Survey Plot - Meter Distance on Transect	Species			
	Common Mormon	Blue-banded King Crow	Blue Moon		Common Mormon	Blue-banded King Crow	Blue Moon	Common Evening Brown
0	2	6		0	2	6		1
30	2	2		30	3			
60	7			60	2	1		
90	7	2	1	90	7		1	
120	3			120	1	2		
150	2			150	4	3		
180	2			180		4		
210	1			210				
240	4			240	2	1		
TOTAL SIGHTINGS	30	10	1	TOTAL SIGHTINGS	21	17	1	1
Percent of Sightings	73.2	24.4	2.4	Percent of Sightings	52.5	42.5	2.5	2.5

3.3 Baited Traps

3.3.1 Andersen AFB

No butterflies were captured in the baited traps on AAFB in September 2009. In January 2010, one Blue-banded King Crow was captured in a trap on Transect 6.

3.3.2 Andersen South

Butterfly traps were set at the 0 and 470 meter mark on the transect. The baited traps were placed on each transect during daylight hours. No butterflies were captured on Andersen South during the butterfly surveys.

3.3.3 Navy Barrigada

Two individuals of Common Evening Brown butterfly were captured in September 2009. In January 2010, one Common Evening Brown was captured.

4 Summary

Six butterfly species were observed or trapped as part of this study. Table 4 identifies species observed within the various transects on AAFB, Andersen South, and Navy Barrigada. None of the six species are considered endangered or threatened and are fairly well-distributed throughout Guam and portions of the Mariana Islands (Schreiner and Nafus, 1997). The number of sightings of butterflies within forested areas was generally low. Sightings typically increased dramatically in areas dominated by grasses or wooded areas with less understory vegetation.

Table 4
Butterfly Species Identified at AAFB, Andersen South, and Navy Barrigada

Species	AAFB Transects			Andersen South	Navy Barrigada
	5	6	7		
Blue-branded king crow	x	x	x	x	x
Blue Moon*	x				x
Common Mormon	x	x	x	x	x
Common Evening Brown**					x
Lemon Emigrant	x	x	x	x	
Monarch	x				

Notes: *Observed several times along the road on Andersen South.
**Although not observed on the transects or during the survey, the species was observed on AAFB and Andersen South.

The Mariana Eight-Spot Butterfly and Mariana Wandering Butterfly were not observed on any transect. Moreover, the host plants for the Mariana Eight-Spot Butterfly were also not observed on AAFB, Andersen South, or Navy Barrigada. The plant (*Maytenus thompso*nii) for the Marianas Wandering Butterfly was observed on Andersen South.

5 References:

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Survey for the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* (Lepidoptera: Nymphalidae), in the Pagat Route 15 area of Yigo Village, Guam

August 2009

Prepared by Cory Campora and Stephan Lee
NAVFAC Pacific

Summary

Surveys were performed for all life stages of the Mariana eight spot butterfly, *Hypolimnas octocula marianensis* Fruhstorfer, and its two documented host plant species along three transects (Rt 15 North, Rt 15 South, and Pagat Cave) in the Pagat area south of Route 15, in the southern corner of Yigo Village, Guam during the time period from July 15 to July 24, 2009. Host plants of *H. octocula marianensis* were sparse except for two areas, one on the Rt 15 North transect and one on the Rt 15 South transect, which contained large groups of both plant species. One adult *H. octocula marianensis* was seen in the large host plant area on the Rt 15 North transect. Other life stages (e.g. egg, larvae, pupae) were found on host plants in all three transects, however, without rearing these stages to the adult form they cannot be identified with complete certainty as *H. octocula marianensis*. Geographic locations are provided for all locations of *H. octocula marianensis* and host plants.

Introduction

Hypolimnas octocula marianensis Fruhstorfer, also known as the Mariana eight spot butterfly or forest flicker, is one of eight subspecies in the *Hypolimnas octocula* complex (Tennent 2006) and is currently classified as a candidate species for listing as endangered by United States Fish and Wildlife Service (FWS). It is reported to occur on the islands of Guam and Saipan (Tennent 2006); however, it may have been extirpated from Saipan (Hawley and Castro 2008, Schreiner and Nafus 1997). The status of *H. octocula marianensis* on Guam is also unclear. It was described as scarce during a 1936 Lepidoptera survey, with only one specimen collected from the Piti area (Swezey 1942). According to the Guam Agricultural Experiment Station collection, three specimens were collected at Hilaan Point in 1975, one specimen was collected from Anderson Air Force Base in 1982, and two more specimens were collected from Hilaan Point in 2001 (GDAWR 2005). Results from surveys conducted in 1996 for the FWS by Schreiner and Nafus indicated that there were 10 populations of the butterfly on Guam (Hawley and Castro 2008). The locations of these populations were as follows: Fadian Cove (1), Hilaan (2), Mangilao golf course (2), Orote (1), Pagat (2), and Tweeds Cove (2). No quantitative estimates of population sizes were provided, but it was noted that the highest number of individuals seen in one day was six (USFWS 2008). The two known host plants of *H. octocula marianensis* are *Elatostema calcareum* and *Procris pedunculata*

(Schreiner and Nafus 1997). Both host plants are from the family Urticaceae and occur in wet, native forest areas with exposed limestone karst.

The current survey was conducted in the Pagat area south of Route 15, near the Guam International Raceway in the southern corner of Yigo Village. One adult *H. octocula marianensis* was observed in this area during recent biological surveys for the Guam and Common Wealth of the Northern Mariana Islands (CNMI) Military Relocation Environmental Impact Statement (EIS) (M. Moese, personal communication, 5 Jan. 2009). The purpose of this survey was to gather more information on *H. octocula marinensis* in this area.

Methods

Two primary transects used were used to survey the butterfly and host plants. These were established by biologists from TEC Inc. and SWCA Environmental Consultants and are referred to as Route 15 North and Route 15 South. A third transect, the trail leading to Pagat Cave, was surveyed only once. Personnel participating in the surveys consisted of two entomologists from NAVFAC Pacific and one biologist from NAVFAC Marianas. All transects were surveyed during the period from 15 to 24 July, 2009. Surveys were generally conducted from late morning (~ 9:00-10:00 am) to late afternoon (~ 2:00-4:00 pm); however on 17 July the survey was conducted one hour before and after sunrise (~ 5:30 am to 7:30 am) and one hour before and after sunset (~ 7:00 pm to 9:00 pm) to determine if larvae were active during these time periods. A handheld GPS (Garmin GPSMap60Csx) was used to track all movement and record geographical locations of host plants and all observed life stages of *H. octocula marianensis*.

Transects were first surveyed over their entire length for host plants. Once the most probable areas of butterfly habitat (i.e. areas with a high density of host plants) were identified, efforts were then focused on those sites. This consisted of searching host plants for eggs, larvae, and pupae, monitoring the understory and upper forest canopy for adults, and monitoring bait pans. A digital camera (Canon 30D) was used to capture images of host plants and all butterfly life stages. Field binoculars were used to identify adult butterflies from long distances. Bait pans consisted of aluminum pie tins and were suspended approximately five to six feet from the ground. Banana and pieces of fish were used as bait. Bananas were prepared one day in advance by mashing and mixing with cane sugar and water and leaving at room temperature in a sealed bag for 24 hours. Fish pieces were obtained from a local market and placed in bait stations on the same day of purchase. Three bait pans were used in each area of butterfly habitat for a period of two days.

Results

Two areas were identified which contained numerous plants of both host plant species. These areas were near the beginning of the Route 15 North and Route

15 South transects and are shown respectively (sites N01 and S03) in Figures 1 and 2. A description of the search effort in these areas is provided in Table 1. Other host plants sighted on occurred in small isolated groups and were represented as discrete points in Figures 1, 2, and 3. All host plant locations are listed in Table 1, and images of host plants are included as appendix A.

Sightings of *H. octocula marianensis* are listed in Table 2, and displayed in Figures 1, 2, and 3. No butterflies of any species were observed at the bait pans. With the exception of the site on the Pagat Cave trail where three larvae were found, all sightings occurred within sites N01 and S03. One adult male *H. octocula marianensis* was seen and photographed within N01. The following day, an identical butterfly was seen at the same location and was presumed to be the same individual. There was a possible sighting of an adult female *H. octocula marianenis* within S03, but it passed quickly out of sight and could not be positively identified. A total of 7 *Hypolimnas* larva were found at 5 different locations on both *E. calcareum* and *P. pecunculata*. *Hypolimnas* eggs were found only on *E. calcareum*, with a total of 19 eggs at 5 different locations. One viable *Hypolimnas* chrysalis was found on *E. calcareum* within site N01, and three empty *Hypolimnas* chrysalides were found on *P. pedunculata* within site S03.

Discussion

Results from this survey and others conducted in the Pagat area of Route 15 indicate that there are at least two areas of habitat that are supporting *H. octocula marianenis*. The sighting of the adult butterfly within N01 during the current survey and the sighting of the adult butterfly in the vicinity of S03 by TEC Inc. (M. Moese, personal communication, 5 Jan 2009) are evidence that the species is present in these two areas. The site on the lower shelf down by Pagat Cave may represent a third area with *H. octocula marianensis*, but it cannot be confirmed without the presence of adults. These findings support the results from surveys conducted in 1996 by Schreiner and Nafus who reported 2 populations of *H. octocula marianensis* in the Pagat area (USFWS 2008). Whether or not the two confirmed areas support a single population or two separate populations is unclear. The habitat sites on the north and south transects are separated by approximately 1.5 kilometers. The Pagat Cave Trail site is approximately 1.5 kilometers from the south transect site and 3 kilometers from the north transect site, but it was at a much lower elevation than the other two sites. The cave trail site was on the lower island shelf at about 82 meters above sea level compared to approximately 166 m and 185 m above sea level for the north and south transect sites. If it is assumed that the larva found near Pagat cave were *H. octocula marianenis*, it would seem more likely that they would represent a separate population from the butterflies seen at the other two sites.

Unfortunately there is some uncertainty regarding the identification of immature life stages of *H. octocula marianensis*. These stages are not easily distinguishable from other *Hypolimnas* species unless they are successfully reared to the adult form. While the larva found on *E. calcareum* and *P. pedunculata* fit Schreiner and Nafus' (1997) description (black with reddish orange spines and a black head), there are two other *Hypolimnas* species*, H. anomala* and *H. bolina*, which look similar during their immature stages. Schreiner and Nafus (1997) describe *H. anomala* larva as black with black spines and greasy in appearance when they are younger, and black with orange spines when they are older. *Hypolimans bolina* is described as similar to *H. anomla* but with a "diffuse brownish orange stripe down each side". The younger larvae also differ from *H. anomala* in that they have orange spines rather than black and they do not have a greasy appearance (Schreiner and Nafus 1997). All larva seen during the current survey were black or blackish gray with black heads and orange spines. Differentiating these from *H. anomala* is not easy since the amount of red in the orange spines is listed as the primary distinguishing factor (Schreiner and Nafus 1997) and is difficult to characterize. Based on Schreiner and Nafus' (1997) descriptions, it would seem unlikely that these larva were *H. bolina* since there was no evidence of a lateral stripe. However, they cannot be completely discounted as *H. bolina* because images of larva were also sent to Chris Samson, a lepidopterist who has worked with *H. octocula* complex (Sampson 1986), and his opinion was that some of them could be *H. bolina* or *H. anomala*, while others could be *H. octocula marianensis* (C. Samson and J. Tennent, personal communication, 21 July 2009).

Images of larvae were also sent to Ilse Schreiner, a former entomologist at the University of Guam and coauthor of <u>Butterflies of Micronesia</u> (Schreiner and Nafus 1997). Her comment was that while it is difficult to identify the immature stages, if they were on either of the known host plants, then they were probably *H. octocula marianensis* (I. H. Schreiner, personal communication, 17 July 2009). The only host plant listed for *H. anomala* is *Pipturus argenteus* (Wright et al. 1977, Schreiner and Nafus 1997). *Hypolimnas bolina* has also not been documented to feed on *E. calcareum* or *P. pedunculata*, but, unlike *H. anomala*, it has an extensive list of foodplants, including other species of *Elatostema* (Wright et al. 1977, Parsons 1991). It is consequently not implausible that *H. bolina* could be found on *E. calcareum*. Adult butterflies of both *H. anomala* and *H. bolina* were seen flying within the large host plant areas on the north and south transects; however, they were not common. The most common butterfly species seen flying in these areas were *Euploea eunice* (Danaidae) and *Papilio polytes* (Papilionidae).

Eggs of *H. bolina*, *H. anomala*, and *H.octocula marianensis* are also very similar in appearance and very difficult, if not impossible, to differentiate in the field (C. Samson and J. Tennent, personal communication, 21 July 2009). It is interesting to note, however, that out of 19 *Hypolimnas* eggs found during this survey, all of them were black (Appendix B, Images 7, 10, 11, and 13) except for two, which were green (Appendix B, image 12). Healthy, viable eggs should be green in color, and eggs which have been parasitized are black (I. H. Schreiner, personal communication, 17 July 2009). Egg parasitism of *H. bolina* and *H. anomala*. on Guam was reported by Donald Nafus in 1993 (Nafus 1993); however, it was found that *H. bolina* was parasitized more frequently during the egg stage than *H. anomala* . The majority of egg parasitism on both butterfly species was carried out by three parasitoids: 1) *Telenomus* sp. 2) *Oencyrtus* sp. and 3) *Trichogramma chilonus*. This study did not include Guam's endemic nymphalid species (*Vagrans egista* (Latreille and Godart)) and subspecies (*H. octocula marianensis*), however, given that the three parasitoids listed above show a lack of host specificity, it is highly probably that the native nymphalids are also attacked.

The adult *H. octocula marianensis* that were observed on July 22 and 23 were probably the same individual. The butterflies were identical in appearance and were seen roosting in the same location on the same tree at approximately the same time. On both occasions the butterfly remained in the upper, sunlit canopy and spent the majority of its time perched. This is consistent with behavior documented for *H. octocula elsina* on New Caledonia: "*Octocula* favors well-developed rainforest, emerging from the undergrowth to sun itself on leaves, especially in the morning. It is very much commoner on the wetter, eastern side of New Caledonia (Holloway and Peters 1976)." The pattern and coloration of this butterfly alone do not provide enough information to assess the gender of the butterfly - male and female *H. octocula marianensis* are very similar in appearance, unlike other subspecies show strong sexual dimorphism (Wright et al. 1977, Schreiner and Nafus 1997). However, judging from the behavior it displayed, it was probably a male. Males are generally less active and fly about with no obvious sense of purpose while females are much more businesslike, flying from hostplant to hostplant in their quest to oviposit (I. H. Schreiner, personal communication, 17 July 2009). It also appeared to exhibit some territorialism, never flying far from its roost and chasing other butterflies which entered its air space.

In summary, there is at least one population of the Mariana eight spot butterfly in the Pagat area. There are two areas that contain relatively high numbers of both host plants for the butterfly, and which appear to be sustaining the butterfly population. Any negative impact on these areas would have a direct effect on the butterfly population. The population in these areas already appears to be under stress from parasitization, and any further pressures from habitat degradation could potentially be very damaging. Other areas of habitat for *H. octocula marianensis*, similar to the Pagat Cave trail site, may exist on the lower limestone shelf; however, these would probably support separate populations from the Route 15 area. Additional surveys would be required to identify these habitat areas at lower elevations.

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Table 1. *Hypolimnas octocula marianensis* host plant sites and search effort.

Site	Transect & Coordinates	Elev (ft)	Species	Date & Time Searching for *H. octocula*	Date & No. People[1] Searching for *H. octocula*	Total Search Time (m)	Notes
N01	Rt 15 North N/A[2]	545	*Elatostema calcareum* and *Procris pedunculata*	15JUL09 0948-1033 20JUL09 0900-1015 22JUL09 1030-1220 23JUL09 1000-1100	15JUL09 2 (CC, SL) 20JUL09 3 (CC, SL, MS) 22JUL09 2 (CC, MS) 23JUL09 2 (CC, SL)	290	Mostly *P. pedunculata*, some *E. calcareum*. (Appendix A, images 1-3, 5, 7-10)
N02	Rt 15 North N13 30.759 E144 53.660	563	*Procris pedunculata*	15JUL09 1100-1105	15JUL09 2 (CC, SL)	5	Small group of plants in a patch of limestone forest just after a cleared area.
N03	Rt 15 North N13 30.763 E144 53.661	570	*Procris pedunculata*	15JUL09 1130-1135	15JUL09 2 (CC, SL)	5	Small group of plants in a patch of limestone forest just after a cleared area.
N04	Rt 15 North N13 30.794 E144 53.640	576	*Procris pedunculata*	15JUL09 1150-1153	15JUL09 1 (CC)	3	Small group of plants
N05	Rt 15 North N13 30.809 E144 53.633	565	*Procris pedunculata*	15JUL09 1200-1203	15JUL09 1 (CC)	3	Small group of plants
S01	Rt15 South N13 30.144 E144 53.202	593	*Elatostema calcareum*	16JUL09 0950-0955	16JUL09 2 (CC, SL)	5	Small group of plants
S02	Rt15 South N13 30.143 E144 53.199	603	*Procris pedunculata*	16JUL09 0955-1000	16JUL09 2 (CC, SL)	5	Small group of plants
S03	Rt 15 South N/A[2]	N/A[3]	*Elatostema calcareum* and *Procris pedunculata*	16JUL09 1002-1138 17JUL09 0538-0745 17JUL09 1900-2034 20JUL09 1430-1545 21JUL09 1000-1200 22JUL09 1245-1315 23JUL09 1120-1220 23JUL09 1430-1600 24JUL09 1000-1115	16JUL09 2 (CC, SL) 17JUL09 2 (CC, SL) 17JUL09 2 (CC, SL) 20JUL09 2 (CC, MS) 21JUL09 2 (CC, MS) 22JUL09 2 (CC, MS) 23JUL09 2 (CC, SL) 23JUL09 2 (CC, SL) 24JUL09 2 (CC, SL)	767	Very large stands of *E. calcareum* and *P. pedunculata*. (Appendix A, images 4, 6, and 11)

Site	Transect & Coordinates	Elev (ft)	Species	Date & Time Searching for *H. octocula*	Date & No. People[1] Searching for *H. octocula*	Total Search Time (m)	Notes
S04	Rt 15 South N13 30.123 E144 53.147	615	*Elatostema calcareum*	16JUL09 1207-1220	16JUL09 2 (CC, SL)	13	Small group of *E. calcareum.*
S05	Rt 15 South N13 30.115 E144 53.110	600	*Procris pedunculata*	16JUL09 1220-1227	16JUL09 2 (CC, SL)	7	Small group of *P. pedunculata*.
S06	Rt 15 South N13 30.095 E144 53.092	600	*Elatostema calcareum*	16JUL09 1240-1245	16JUL09 2 (CC, SL)	5	Small group of *E. calcareum.*
S07	Rt 15 South N13 30.100 E144 53.079	600	*Elatostema calcareum*	16JUL09 1247-1252	16JUL09 2 (CC, SL)	5	Small group of *E. calcareum.*
S08	Rt 15 South N13 30.106 E144 53.091	589	*Elatostema calcareum*	16JUL09 1342-1400	16JUL09 2 (CC, SL)	8	Small group of *E. calcareum*.
S09	Rt 15 South N13 30.164 E144 53.183	-	N/A[4]	24 JUL09 1100-1130	24 JUL09 1 (CC)	30	Used binoculars to search top of canopy covering site S03.
P01	Pagat Cave Trail N13 29.524 E144 52.643	268	*Elatostema calcareum*	22JUL09 1550-1610	22JUL09 1 (CC)	20	Medium sized group of *E. calcareum*. (Appendix A, image 12)

[1]CC = Cory Campora, SL = Stephan Lee, MS = Maria Santos
[2]This site consists of a large area and cannot be defined accurately by a single point.
[3]Elevation was variable within this area.
[4]This site was an observation point for looking at upper canopy.

Table 2. Observed life stages of *Hypolimnas octocula marianensis*.

Date & Time	Site	Transect & Coordinates	Elev (ft)	Life Stage (quantity)	Host Plant	Weather - Cloud Cover (%):Wind (1-3):Rain (Y/N)	Notes
15JUL09 1050	N01	Rt 15 North N13 30.819 E 144 53.651	545	Chrysalis (1)	*Elatostema calcareum*	20:1:N	Signs of feeding on leaves *E. calcareum* near the chrysalis. (Appendix B, image 1.)
16JUL09 1030	S03	Rt 15 South N13 30.157 E144 53.164	615	Larvae (1)	*Procris pedunculata*	70:2:N	Late instar, actively feeding during part of the time it was observed, large green frass pellets seen nearby. (Appendix B, images 2-4.)
16JUL09 1138	S03	Rt 15 South N13 30.132 E144 53.164	621	Larvae (1)	*Elatostema calcareum*	70:2:N	Late instar. (Appendix B, images 5 and 6.)
16JUL09 1135	S03	Rt 15 South N13 30.132 E144 53.164	621	Egg (3)	*Elatostema calcareum*	70:2:N	Located in same location as larvae, but on a separate plant. All three eggs were black. (Appendix B, image 7.)
17JUL09 1915	S03	Rt 15 South N13 30.141 E144 53.167	580	Chrysalis (2)	*Procris pedunculata*	80:0:Y	Both chrysalides were empty.
17JUL09 0630	S03	Rt 15 South N13 30.141 E144 53.167	580	Egg (4)	*Elatostema calcareum*	80:0:Y	All four eggs were black.
17JUL09 0550	S03	Rt15 South N13 30.134 E144 53.160	609	Larvae (1)	*Procris pedunculata*	80:0:Y	Very late instar, actively feeding. (Appendix B, image 8.)
17JUL09 1955	S03	Rt15 South N13 30.138 E144 53.165	589	Larvae (1)	*Elatostema calcareum*	10:0:N	Very late instar, actively feeding, large green frass pellets seen nearby. (Appendix B, image 9.)
20JUL09 0915	N01	Rt 15 North N13 30.819 E144 53.651	545	Egg (5)	*Elatostema calcareum*	80:1:N	Near the same plant we found the chrysalis 15 July. (Appendix B, images 10 and 11.)
21JUL09 1130	S03	Rt 15 South N13 30.140 E144 53.167	607	Egg (6)	*Elatostema calcareum*	70:1:N	Two eggs green, 4 eggs black. (Appendix B, images 12 and 13.)

Date & Time	Site	Transect & Coordinates	Elev (ft)	Life Stage (quantity)	Host Plant	Weather - Cloud Cover (%):Wind (1-3):Rain (Y/N)	Notes
21JUL09 1027	S03	Rt 15 South N13 30.143 E144 53.163	624	Chrysalis (1)	*Procris pedunculata*	70:1:N	Empty. (Appendix B, image 14.)
22JUL09 1130	N01	Rt 15 North N13 30.818 E144 53.653	567	Adult (1)	N/A (*Macaranga thompsonii*)	80:0:N	Was flying up in a small clearing within the canopy, but seemed to prefer resting on the leaves of the *M. thompsonii*. (Appendix B, images 15 and 16.)
22JUL09 1600	P01	Pagat Cave Trail N13 29.524 E144 52.643	268	Larvae (3)	*Elatostema calcareum*	50:1:N	One late instar, two earlier instars.
23JUL09 1145	S03	Rt 15 South N13 30.156 E144 53.174	620	Chrysalis (1)	*Procris pedunculata*	20:2:N	Empty.
23JUL09 1045	N01	Rt 15 North N13 30.818 E144 53.653	567	Adult (1)	N/A (*Macaranga thompsonii*)	30:2:N	Was in the same location as the adult butterfly seen on 22 July – appeared to be the same individual. (Appendix B, image 17.)
24JUL09 1050	S03	Rt 15 South N13 30.129 E144 53.159	606	Egg (1)	*Elatostema calcareum*	20:2:N	Egg was black.

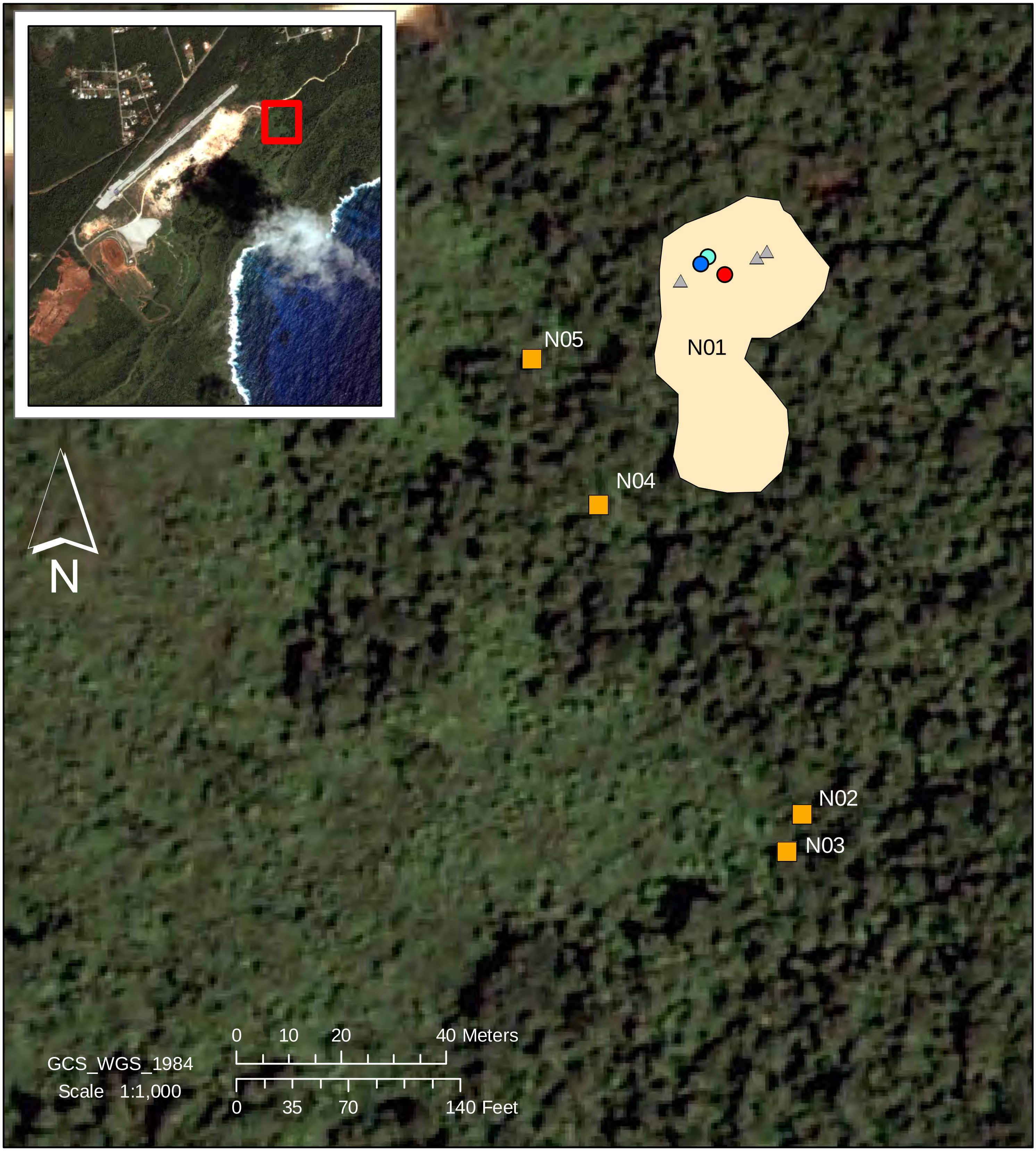

Figure 1
Hypolimnas octocula
and host plant sites
RT 15 North Transect
15 -24 July, Guam

Hypolimnas_octocula

Type

- Butterfly
- Chrysalis
- Caterpillar
- Egg

Bait_pans

Mixed host plant area

Host plant individual

Species

- Elatostema calcareum
- Procris pedunculata

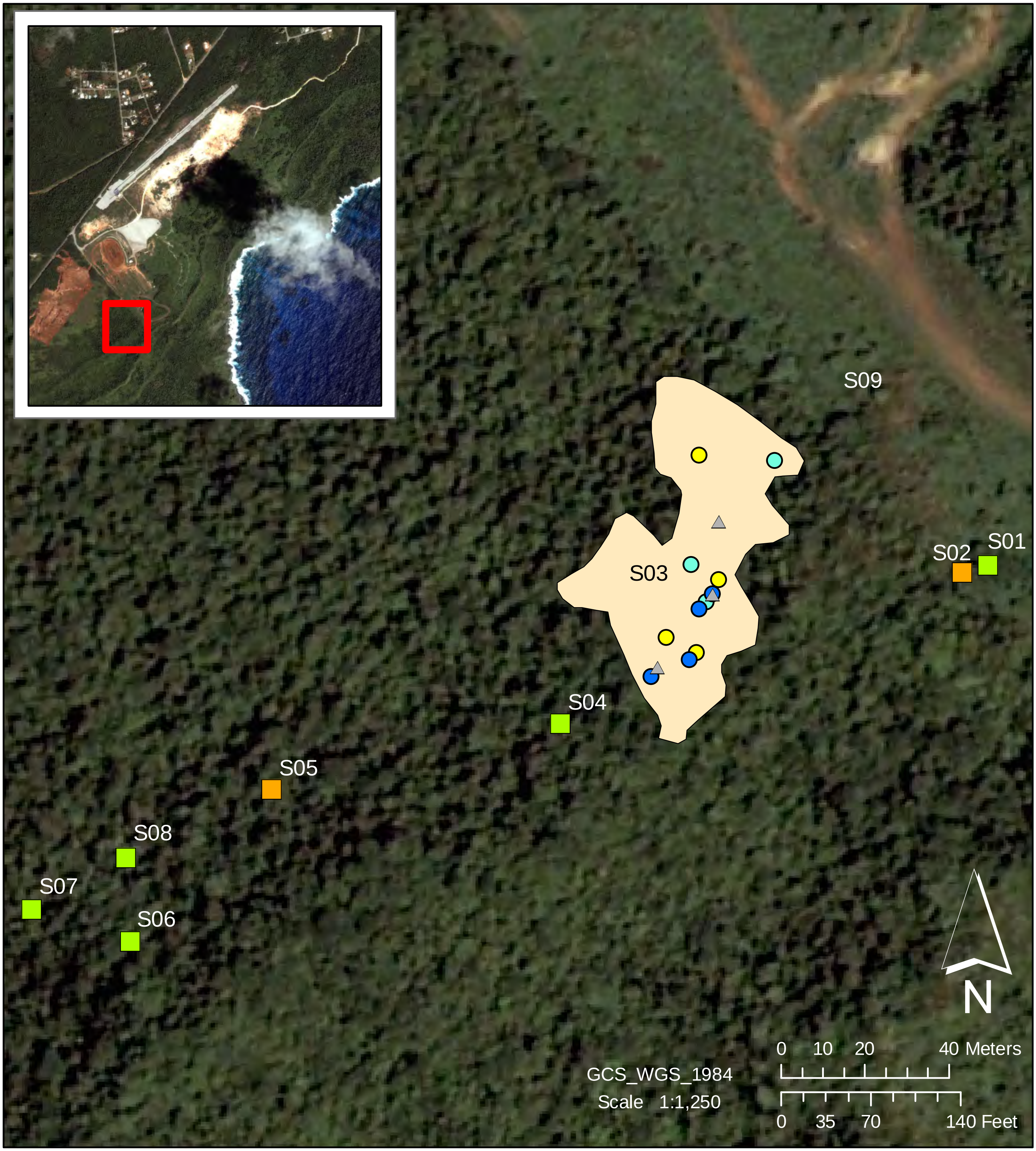

Figure 2
Hypolimnas octocula
and host plant sites
RT 15 South Transect
15 -24 July, Guam

Hypolimnas_octocula

Type

Butterfly

Chrysalis

Caterpillar

Egg

Bait_pans

Mixed host plant area

Host plant individual

Species

Elatostema calcareum

Procris pedunculata

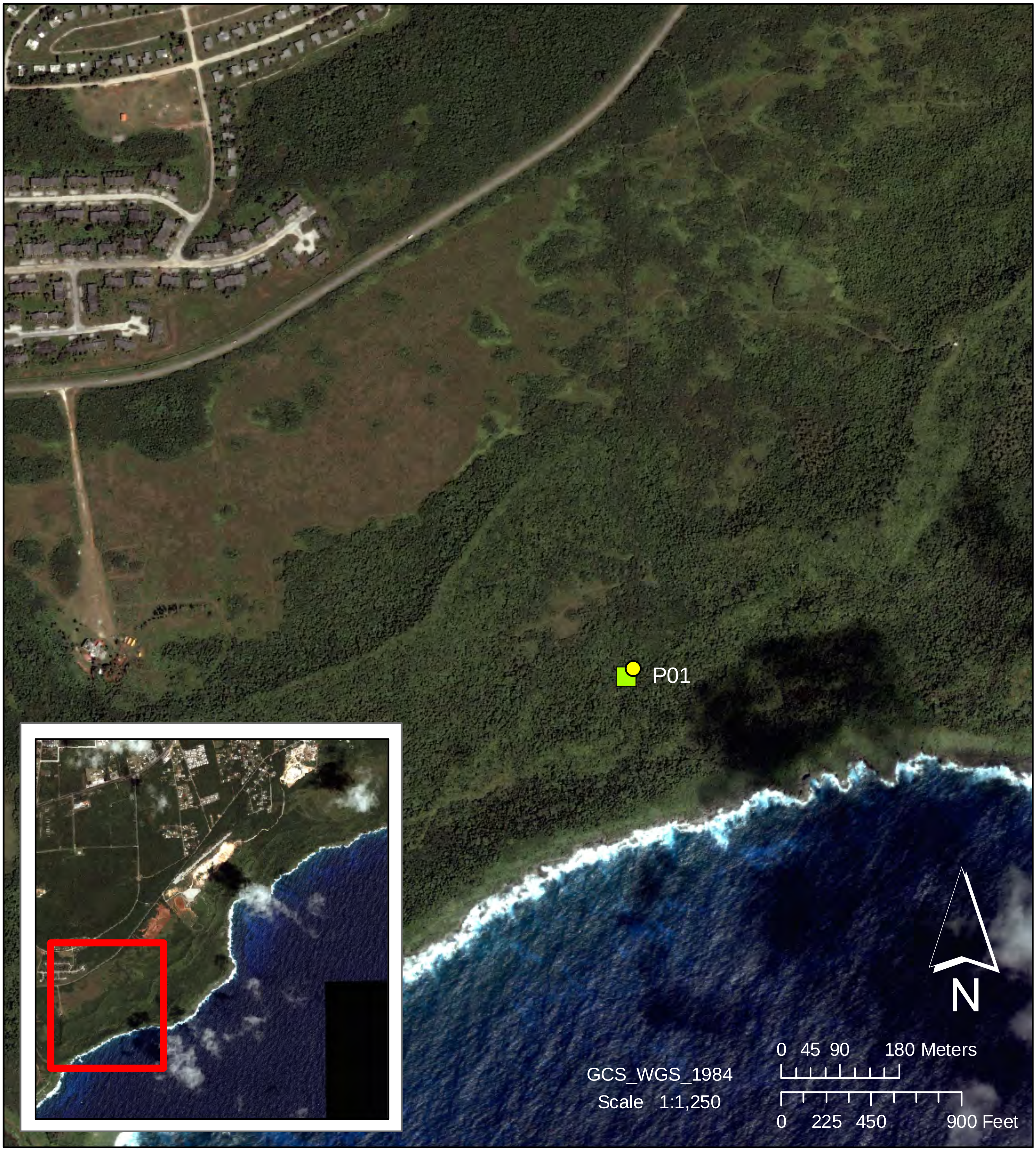

Figure 3
Hypolimnas octocula
and host plant sites
RT 15 Pagat Cave Trail
15 -24 July, Guam

Hypolimnas_octocula

Type

- Butterfly
- Chrysalis
- Caterpillar
- Egg

Host plant individual

Species

- Elatostema calcareum
- Procris pedunculata

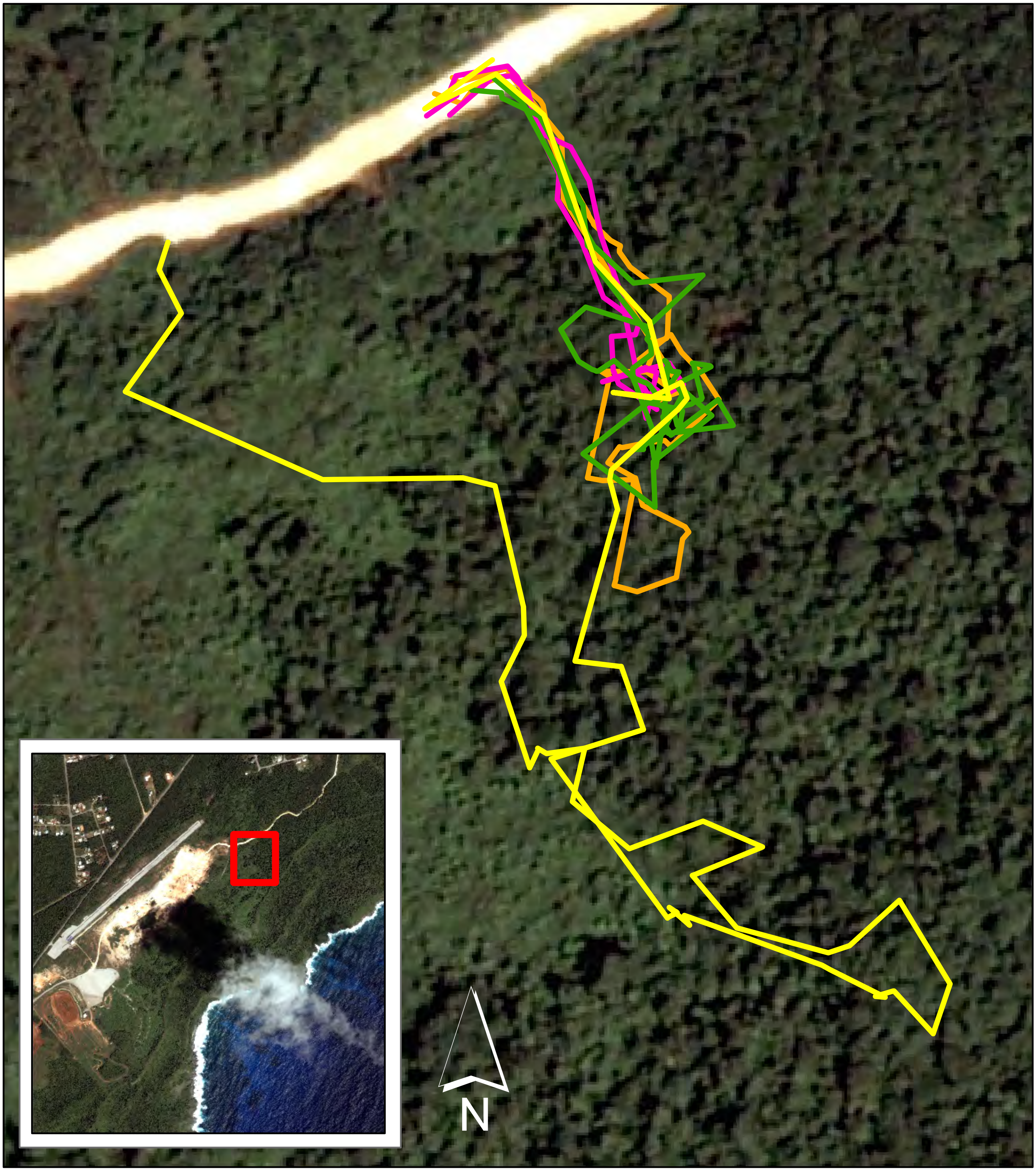

Figure 4
RT 15 North Transect
Survey Routes
15 -24 July, Guam

15 July 2009
20 July 2009
22 July 2009
23 July 2009

GCS_WGS_1984
Scale 1:1,133

0 12.5 25 50 Meters
0 40 80 160 Feet

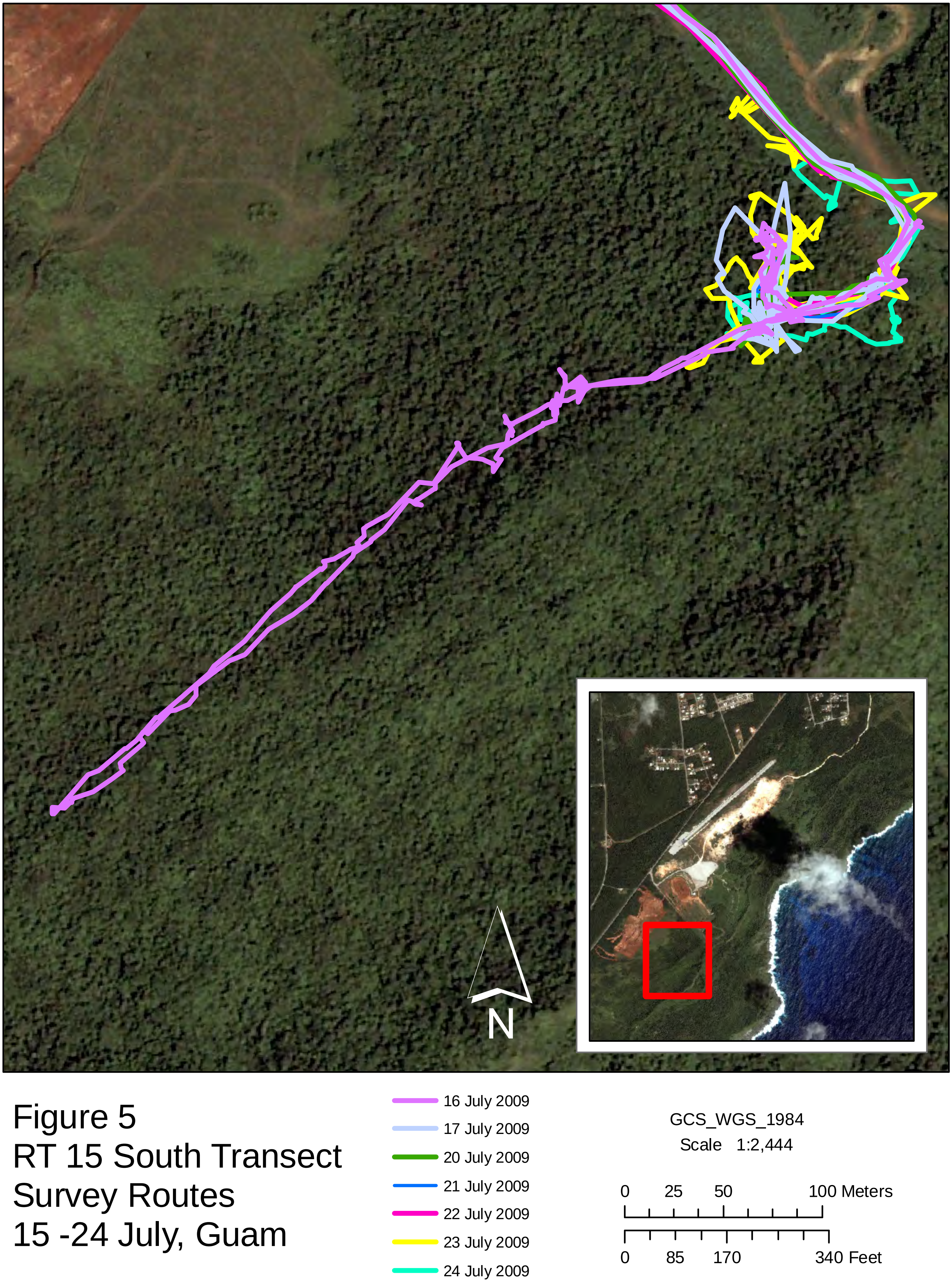

Figure 5
RT 15 South Transect
Survey Routes
15 -24 July, Guam

Figure 6
RT 15 Pagat Cave Trail
Survey Route
15 -24 July, Guam

22 July 2009

GCS_WGS_1984
Scale 1:6,200

0 62.5 125 250 Meters

0 210 420 840 Feet

Appendix A
Host Plant Images

1. Leaves of *Elatostema calcareum*. (Rt 15 North transect, site N01, 15 July 2009)

2. Leaves of *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

3. *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

4. *Elatostema calcareum*. (Rt 15 South transect, site S03, 16 July 2009)

5. Flowers of *Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)

6. Flowers of *Elatostema calcareum*. (Rt 15 South transect, site S03, 16 July 2009)

7. ***Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)**

8. ***Procris pedunculata*. (Rt 15 North transect, site N01, 15 July 2009)**

9. ***Elatostema calcareum*****. (Rt 15 North transect, site N01, 15 July 2009)**

10. ***Procris pedunculata*****. (Rt 15 North transect, site N01, 15 July 2009)**

11. ***Elatostema calcareum*** **with bait pan. (Rt 15 South transect, site S03, 20 July 2009)**

12. ***Elatostema calcareum*****. (Pagat Cave Trail, site P01, 22 July 2009)**

Appendix B
Hypolimnas octocula marianensis Images

1. *Hypolimnas* sp. chrysalis on *Elatostema calcareum* . (Rt 15 North transect, site N01, 15 July 2009)

2. *Hypolimnas* sp. larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 16 July 2009)

3. ***Hypolimnas*** **sp. larvae on** ***Procris pedunculata*** **. (Rt 15 South transect, site S03, 16 July 2009)**

4. *Hypolimnas* sp. frass and larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 16 July 2009)

5. *Hypolimnas* sp. larvae on *Elatostema calcareum* . (Rt 15 South transect, site S03, 16 July 2009)

Appendix B

6. ***Hypolimnas* sp. larvae on *Elatostema calcareum* . (Rt 15 South transect, site S03, 16 July 2009)**

7. ***Hypolimnas* sp. eggs on *Elatostema calcareum* . (Rt 15 South transect, site S03, 16 July 2009)**

Appendix B

8. *Hypolimnas* sp. larvae on *Procris pedunculata* . (Rt 15 South transect, site S03, 17 July 2009)

9. *Hypolimnas* sp. larvae on *Elatostema calcareum*. (Rt 15 South transect, site S03, 17 July 2009)

Appendix B

10. ***Hypolimnas*** **sp. egg on** ***Elatostema calcareum*****. (Rt 15 North transect, site N01, 20 July 2009)**

11. ***Hypolimnas*** **sp. eggs on** ***Elatostema calcareum*****. (Rt 15 North transect, site N01, 20 July 2009)**

Appendix B

12. ***Hypolimnas*** **sp. eggs on** ***Elatostema calcareum*****. (Rt 15 South transect, site S03, 21 July 2009)**

13. ***Hypolimnas*** **sp. eggs on** ***Elatostema calcareum*****. (Rt 15 South transect, site S03, 21 July 2009)**

14. *Hypolimnas* sp. chrysalis on *Procris pedunculata*. (Rt 15 South transect, site S03, 21 July 2009)

15. *Hypolimnas octocula marianensis* adult. (Rt 15 North transect, site N01, 22 July 2009)

Appendix B

16. ***Hypolimnas octocula marianensis*** **adult. (Rt 15 North transect, site N01, 22 July 2009)**

17. ***Hypolimnas octocula marianensis*** **adult. (Rt 15 North transect, site N01, 23 July 2009)**

APPENDIX F
Marine Biological Surveys

Marine Biological Survey of Inner Apra Harbor. Guam. Marine Laboratory, University of Guam, UOG Station, Mangilao; and

Marine Biological Survey of Oscar and Papa Wharves, Inner Apra Harbor, Guam. Marine Laboratory, Laboratory, University of Guam, UOG Station, Mangilao.

MARINE BIOLOGICAL SURVEY OF INNER APRA HARBOR, GUAM

by

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Aja Reyes, Kathryn Chop, and Katrina Dugger

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Review Draft

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ACKNOWLEDGMENTS

We are most grateful for the support and assistance provided by several organizations and individuals. We extend our thanks to Mr. James E. Ogburn, Director, Port Operations (NB31) Naval Base Guam, and his staff for providing access and coordinating our movements to and from the various study sites in Apra Harbor. We thank Mr. Roberto E. Cabreza, Environmental Protection Specialist, Naval Facilities Marianas, for assisting our personnel in obtaining base passes and for facilitating access to the inner harbor.

Marine Technicians Chris Bassler and Jason Miller piloted the boats and served as diving safety officials. They also maintained communications with Port Operations during our field work.

Finally, we are especially grateful for the guidance provided by Dr. Mark Moese of Earth Tech, Inc. for acting as our liaison and project coordinator. His guidance and patience made the project possible.

INTRODUCTION

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault, separating the volcanic Tenjo Block in central Guam from the limestone Orote Block immediately to the west (see Tracey et al., 1964 for structural details). Rotation of the Orote Block resulted in subsidence of the eastern portion of the block adjacent to the Cabras Fault line. Accompanying rotation, the sea flooded into the slumped areas, forming Apra Harbor, a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers—the Apalacha and Atantano—drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974).

Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and landfills by the U.S. Navy since 1945 (Paulay et al., 2001a). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom. Fill projects created the Dry Dock Peninsula, Polaris Point, and manmade shorelines along the northeastern and southeastern boundaries of the harbor. These and other developments in the outer harbor (e.g., construction of Glass Breakwater) reduced water exchange between the harbor and the Philippine Sea, creating a gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments from the entrance to the outer harbor to the inner harbor environment. The only portion of the inner harbor remaining unchanged is the mangrove area at the mouth of the Atantano River.

Randall and Holloman (1974) reported living *Pocillopora* and *Porites* corals on the wharf and dock structures in the inner harbor. Paulay et al. (2001a) found that artificial surfaces in the inner harbor supported diverse fouling communities, including both indigenous and introduced species. They noted the presence of *Porites convexa*, known in Guam from only a few locations. They also remarked about the abundance of the hammer oyster *Malleus decurtatus* on wharf faces in Inner Apra Harbor.

Relocation of elements of the Marine Expeditionary Force (MEF) from Okinawa to Guam by the Marine Corps will require renovation of existing port facilities to accommodate MEF embarkation, as well as construction of various new operations facilities in support of the MEF mission. Furthermore, new training areas and associated facilities are proposed for selected areas on Guam. These developments require extensive surveys that locate, identify, and assesses the natural resources of Guam.

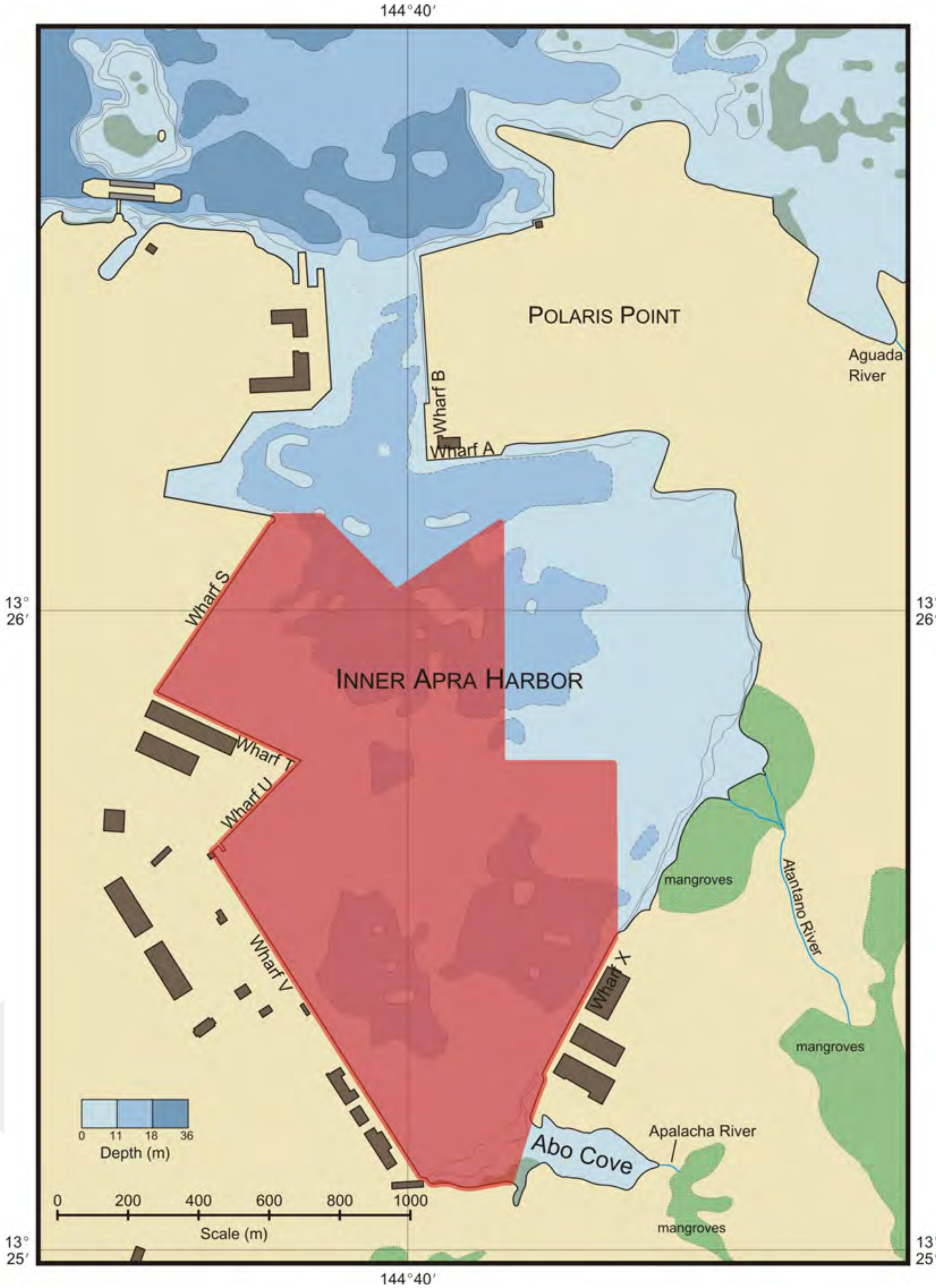

Figure 1. Map of Inner Apra Harbor showing geographic locations and the general survey area (shaded orange).

Scope of Work

The University of Guam Marine Laboratory was contracted to perform a study of marine communities in the southwestern half of Inner Apra Harbor (Figure 1) . The specific objectives of the study were:

- Quantitative assessments of corals
- Quantitative assessment of select macroinvertebrates
- Fish census
- Assessment of essential fish habitat
- Assessment of endangered species (both federally listed, proposed for listing, and candidate species and those similarly listed or otherwise recognized by Guam) to include abundance and preferred habitat, if any
- Survey areas will be subjectively evaluated using the four criteria for Habitat Areas of Particular Concern (HAPC): 1. the ecological function provided by the habitat is significant; 2. the habitat is sensitive to human-induced environmental degradation; 3. development activities are, or will be, stressing the habitat type; and 4. the habitat is rare

Data from the survey are expected to serve as a guide for decisions affecting land and coastal use for proposed construction and renovation of facilities and training sites on Department of Defense lands in Guam.

METHODS

Sampling Site Selection

The general ecological condition of an approximately 145 ha area (Figure 2) was assessed by a modified manta tow method. Two observers were towed behind a boat piloted along the 6,188-m boundary of the study area. Visibility was limited to less than 5 m because of high turbidity of the water. The locations and general surface coverage of corals were noted by the observers. Based upon these observations, three sites (Abo Cove, Transect 1, and Transect 2) were selected for benthic surveys, and five sites (Wharves S, T, U, V, and X) were selected for surveys of vertical wharf faces (Figure 2). A 100-m transect line was established along the 2-m isobath at Abo Cove. For Transects 1 and 2, in open areas of the harbor floor away from wharves or the shoreline, a GPS-tracking unit in a waterproof housing was towed by a diver swimming along the harbor floor. Lengths of the tracks were calculated with SigmaScan Pro 5.0 (SPSS, Inc., 1999). At Wharves S, V, and X, 100-m transects were established. At Wharves T and U, 50-m transects were established, because access to larger wharf areas was not granted. GPS coordinates were recorded for the ends of all transects.

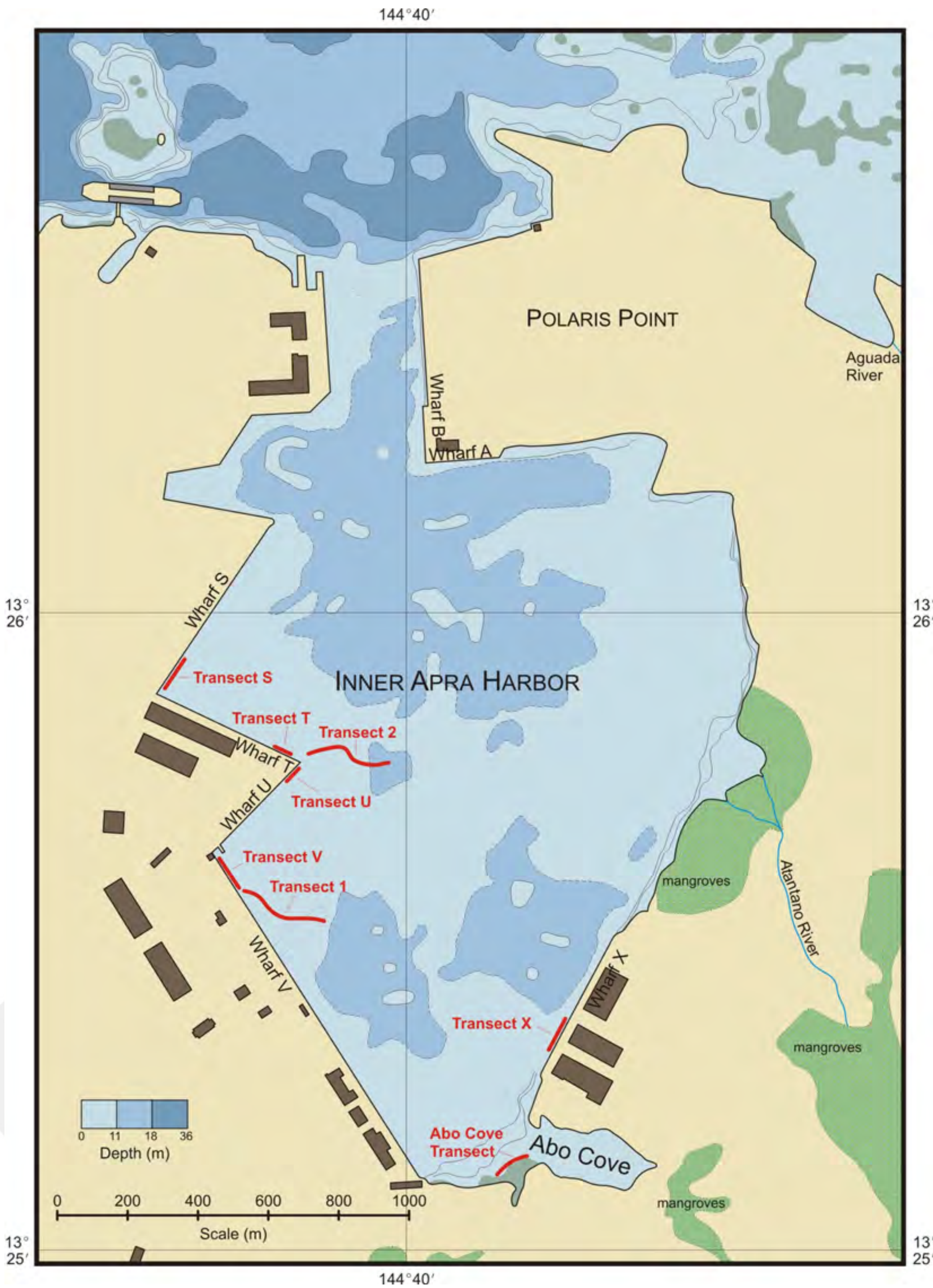

Figure 2. Map of Inner Apra Harbor showing locations of transects surveyed in this study.

Benthic Cover

Benthic quadrats were surveyed along transects established for coral, invertebrate, and fish surveys. Fifty-meter transects were installed at a fixed depth (3–5 m) at six sites throughout the inner harbor (Figure 2). Per transect, the percentage cover of algae, corals, and sponges in five 0.25-m^2 quadrats was quantified in situ, and the data were entered into a relational database (MS Access). The limited visibility in the inner harbor precluded documentation of benthic flora and fauna with photoquadrat records, but macro photographs of the representative species were taken. Voucher specimens of algae were collected to establish a reference collection of algae from Inner Apra Harbor. Explorative data analysis was performed through analysis of variance and non-metric multidimensional scaling. In situ cover estimates of turf algae were also troubled by poor visibility and, therefore, removed from the data set prior to analysis.

Corals

Coral communities were assessed quantitatively along the transects by an observer by the point-quarter method of Cottam et al. (1953). Points were assigned 3–10 m apart on each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals. From the recorded data, community and species-specific population density of colonies, percent coverage, and frequency of occurrence were then computed with the following equations from Cottam et al. (1953):

Total Density Of All Colonies = Unit Area / (Average Point-To-Colony Distance)^2
Relative Density Of A Species = 100 * Number Of Colonies Of The Species / Number Of All Colonies
Absolute Density Of A Species = Percent Density * Total Density / 100
Total Percent Coverage Of All Species = Total Density * Average Coverage Of All Species
Relative Coverage Of A Species = Species Density * Average Coverage of the Species

Population data for each species were also calculated, including the number of colonies, average colony size, standard deviation of colony size, and minimum and maximum colony size. To record the less common species not recorded by the quantitative survey, a list of species was also assembled by swimming along the entire transects and recording all species seen within 2 m of the line. Species names followed Veron (2000).

Macroinvertebrates

All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines at Abo Cove and Wharves S, T, U, V, and X were identified and enumerated by an observer swimming along the transect line. For Transects 1 and 2, species of conspicuous epibenthic macroinvertebrates were recorded within 1 m of an imaginary line in front of an observer swimming over the harbor floor, as described above. For this study, conspicuous is defined as being larger than 50 mm in size and as being clearly visible to an observer without need of overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line. Therefore, for statistical purposes, each belt transect consisted of five to ten 20-m^2 replicate plots, except where noted.

Similarities in structure of macroinvertebrate assemblages for all transects were calculated by the Bray-Curtis similarity method, and the resulting matrix subjected to cluster analysis (group average method, fourth root-transformed data) and multidimensional scaling (MDS) analysis (fourth root-transformed data bootstrapped with n = 100 iterations) to investigate relationships between transects. Cluster and MDS analyses were performed with PRIMER v5 (Clarke and Gorley, 2001). Species of macroinvertebrates observed in the study area, but not encountered along the transect line, were also recorded but not included in the similarity analyses.

Fishes

Fishes were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. At Abo Cove, the line was deployed along the bottom as the diver observed and counted fishes. Along wharf faces, three transects were run (where possible), respective of depth, just below the surface (subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5m above or below the line, were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the line were counted. At two stations located in open areas of the harbor away from wharves or the shoreline, GPS-tracking was used to census fishes. Here, one diver utilized a GPS unit set on timed-tracking mode and towed above him in a waterproof housing, recorded all benthic species observed within 1 m either side of an imaginary line directly in front of the diver (Colin and Donaldson, in review). Observations were recorded a during the course of the swim just above the bottom. Pelagic species could not be observed because of poor visibility. These methods provided estimates of density (no. individuals/m^2) for each species.

Fishes were identified to species. Identifications followed Myers (1999) and Myers and Donaldson (2003), except where more recent taxonomic studies were relevant. Reference photographs and video were taken with an underwater digital camera or underwater digital video camera, but image quality tended to be extremely poor because of turbid conditions.

For estimates of species diversity, standard measures of species richness, species diversity, and similarity were calculated and compared between stations with PRIMER vers. 5.2.2; DIVERSE PROCEDURE). Multidimensional scaling (PRIMER vers. 5.2.2; MDS procedure) was used to examine similarities between stations based upon Bray-Curtis coefficients calculated for each. This test indicates relative distances between samples based upon their similarities in assemblage structure. Points found close together represent samples that were very similar in species composition while those far away represented different assemblage structures (Clarke and Gorley, 2001). Analysis of Similarities (PRIMER, ver. 5.2.2;

ANOSIM procedure) was used to test the null hypothesis that there were no differences in assemblage structure between groups of samples at stations.

Essential Fish Habitat

Extremely poor visibility on transects at all stations limited the ability to collect data on essential fish habitat. Underwater photographs taken along the transect line to estimate benthic structure used by different species were essentially useless. Similarly, measures of rugosity (benthic structural complexity), limited to the edge of a shallow reef at Abo Cove, were made under near-zero visibility and were fraught with error. Therefore, it was possible only to make qualitative descriptions of habitats used by fishes.

RESULTS AND DISCUSSION

GPS coordinates for the locations of transects are reported in Table 2 and illustrated in Figure 1. No GPS data were captured for the distal ends of transects at Victor and X-ray wharves.

Table 1. GPS coordinates of transects surveyed in Inner Apra Harbor for this study.

			Start		Finish	
Study Site	Date	Length (m) (M)	Latitude (°N)	Longitude (°E)	Latitude (°N)	Longitude (°E)
Abo Cove	2008/05/29	100	13.41927	144.66937	13.41865	144.6692
Sierra Wharf	2008/05/29	100	13.25922	144.39646	13.25881	144.39616
Tango Wharf	2008/05/23	50	13.42973	144.66336	nd[1]	nd
Victor Wharf	2008/05/29	100	13.62535	144.66269	13.42627	144.66206
Uniform Wharf	2008/05/22	50	13.25687	144.39766	13.25706	144.39783
X-ray Wharf	2008/05/21	100	13.42399	144.67168	nd	nd
Transect 1	2008/05/29	260	13.42617	144.66239	13.42531	144.66441
Transect 2	2008/05/29	250	13.42946	144.66391	13.42916	144.66638

[1]No data recorded.

Benthic Cover

Table 2 shows the sampling effort of benthic surveys. The number of surveyed transects is a function of site accessibility, which was often limited by port operations and the size of the wharfs. Continued efforts to increase the number of transects at Uniform and Tango wharves were prevented as the team was denied access to the inner harbor on several occasions.

Table 2. Dates and sampling effort of benthic surveys.

Site	Date	# Transects	# Quadrats
Abo Cove	5-May-08	3	14
Sierra Wharf	21-May-08	2	10
X-ray Wharf	21-May-08	2	10
Uniform Wharf	22-May-08	1	5
Tango Wharf	23-May-08	1	5
Victor Wharf	23-May-08	2	10

Table 3 lists the 70 benthic taxa that were recorded and quantified during this study. The total number of taxa recorded is low compared to benthic surveys in other parts of the harbor. The average species richness of the quadrats is also low compared to similar studies in other parts of Guam. Figures 3 and 4 show a large difference in the total number of species and species richness between quadrats from Abo Cove and the wharf transects. The most authentic "natural" site (Abo Cove) is significantly less taxon-rich than the wharf sites (Tables 4 and 5). Turbidity and sediment deposition are most likely the most important causal factors for this difference. *Caulerpa verticillata* is a green alga that copes well with increased levels of sedimentation and reduced salinities. Exceptionally large specimens of this alga were found in Abo Cove, probably a result of relatively low herbivore pressure. The distribution of the seagrass species *Halophila japonica* also seems to be restricted to Abo Cove in the inner harbor.

Table 3. Taxonomic list of biotic categories observed in the benthic surveys.

Higher classification	Taxon
Chlorophyta - Ulvophyceae - Bryopsidales - Caulerpaceae	*Caulerpa serrulata*
Chlorophyta - Ulvophyceae - Bryopsidales - Caulerpaceae	*Caulerpa verticillata*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Halimeda gracilis*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Halimeda opuntia*
Chlorophyta - Ulvophyceae - Bryopsidales - Udoteaceae	*Rhipilia sinuosa*
Chordata - Ascidiacea - Phlebobranchia - Ascidiidae	*Phallusia julinea*
Chordata - Ascidiacea - Phlebobranchia - Ascidiidae	*Phallusia nigra*
Chordata - Ascidiacea - Phlebobranchia - Diazonidae	*Rhopalaea circula*
Chordata - Ascidiacea - Phlebobranchia - Diazonidae	*Rhopalaea* sp. 2–gold spot
Cnidaria - Anthozoa - Corallimorpharia - Actinodiscidae	*Discosoma* sp.

Higher classification	Taxon
Cnidaria - Anthozoa - Scleractinia - Acroporidae	*Astreopora* sp.
Cnidaria - Anthozoa - Scleractinia - Agariciidae	*Leptoseris mycetoseroides*
Cnidaria - Anthozoa - Scleractinia - Astrocoeniidae	*Stylocoeniella armata*
Cnidaria - Anthozoa - Scleractinia - Dendrophylliidae	*Tubastrea* sp.
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Goniastrea retiformis*
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Leptastrea bottae*
Cnidaria - Anthozoa - Scleractinia - Faviidae	*Leptastrea purpurea*
Cnidaria - Anthozoa - Scleractinia - Oculinidae	*Galaxea fascicularis*
Cnidaria - Anthozoa - Scleractinia - Pocilloporidae	*Pocillopora damicornis*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Alveopora* sp.
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites densa*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites horizontalata*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lichen*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lobata*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites lutea*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites rus*
Cnidaria - Anthozoa - Scleractinia - Poritidae	*Porites solida*
Cnidaria - Anthozoa - Scleractinia - Siderastreidae	*Psammocora superficialis*
Ectoprocta - Gymnolaemata - Cheilostomata - Bugulidae	*Celleporaria sibogae*
Ectoprocta - Gymnolaemata - Cyclostomata - Lichenoporidae	*Lichenopora* sp.
Magnoliophyta - Liliopsida - Alismatales - Hydrocharitaceae	*Halophila japonica*
Mollusca - Bivalvia - Pterioida - Malleidae	*Malleus decurtatus*
Mollusca - Bivalvia - Veneroida - Chamidae	*Chama lazarus*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota adnata*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota bartayresiana*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Dictyota friabilis*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Lobophora variegata*
Ochrophyta - Phaeophyceae - Dictyotales - Dictyotaceae	*Padina boryana*
Porifera - Demospongiae - Dendroceratida - Darwinellidae	*Aplysilla* sp.
Porifera - Demospongiae - Dendroceratida - Dysideidae	*Dysidea* cf. *avara*
Porifera - Demospongiae - Dictyoceratida - Spongiidae	*Aplysina* sp. (yellow)
Porifera - Demospongiae - Dictyoceratida - Thorectidae	*Hyrtios* sp.
Porifera - Demospongiae - Hadromerida - Spirastrellidae	*Spheciospongia vagabunda*
Porifera - Demospongiae - Halichondrida - Halichondriidae	*Halichondria* sp.
Porifera - Demospongiae - Poecilosclerida - Anchinoidae	*Phorbas* sp.
Porifera - Demospongiae - Poecilosclerida - Desmacellidae	*Biemna fistulosa*
Porifera - Demospongiae - Poecilosclerida - Desmacellidae	*Neofibularia hartmani*
Porifera - Demospongiae - Poecilosclerida - Desmacididae	*Iotrochota protea*
Porifera - Demospongiae - Poecilosclerida - Guitarridae	*Tetrapocillon* sp.
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria eurypa*
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria mima*
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Clathria* sp. 1
Porifera - Demospongiae - Poecilosclerida - Microcionidae	*Echinochalina* sp.
Porifera - Demospongiae - Poecilosclerida - Mycalidae	*Ulosa spongia*
Porifera - Demospongiae - Poecilosclerida - Phoriospongiidae	*Psammoclemma* sp.
Porifera - Demospongiae - Poecilosclerida - Raspailiidae	*Ceratopsion* sp. 1
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Calothrix scopulorum*
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Lyngbya penicilliformis*

Higher classification	Taxon
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Phormidium* cf. *dimorphum*
Prokaryota - Bacteria - Negibacteria - Cyanobacteria	*Symploca hydnoides*
Rhodophyta - Florideophyceae - Ceramiales - Rhodomelaceae	*Lophocladia* sp.
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Hydrolithon onkodes*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Lithophyllum kotschyanum*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Lithophyllum pygmaeum*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Mesophyllum funafutiense*
Rhodophyta - Florideophyceae - Corallinales - Corallinaceae	*Pneophyllum conicum*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia boergesenii*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia inamoena*
Rhodophyta - Florideophyceae - Halymeniales - Peyssonneliaceae	*Peyssonnelia rubra*
Turf algae	Turf algae

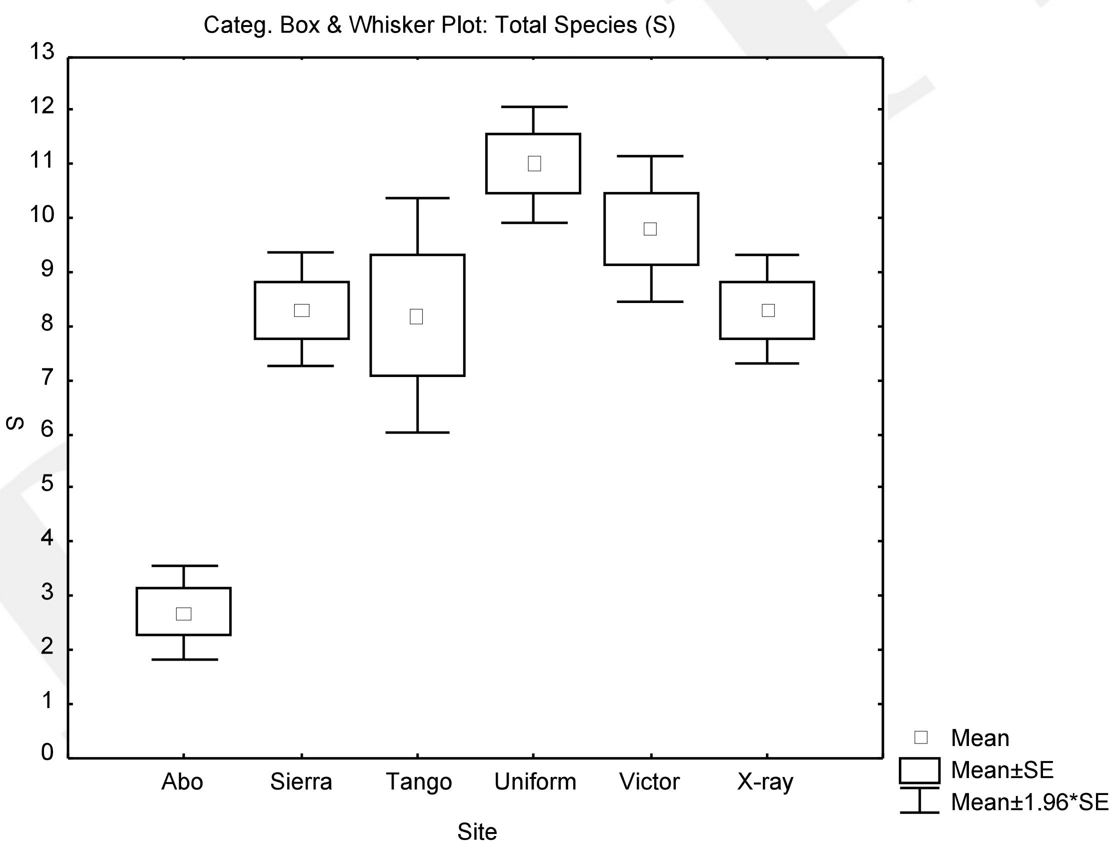

Figure 3. Total species (*S*) of quadrats per site. Abbreviations: Abo, Abo Cove; Sierra, Sierra Wharf; Tango, Tango Wharf; Uniform, Uniform Wharf; Victor, Victor Wharf; X-ray, X-ray Wharf.

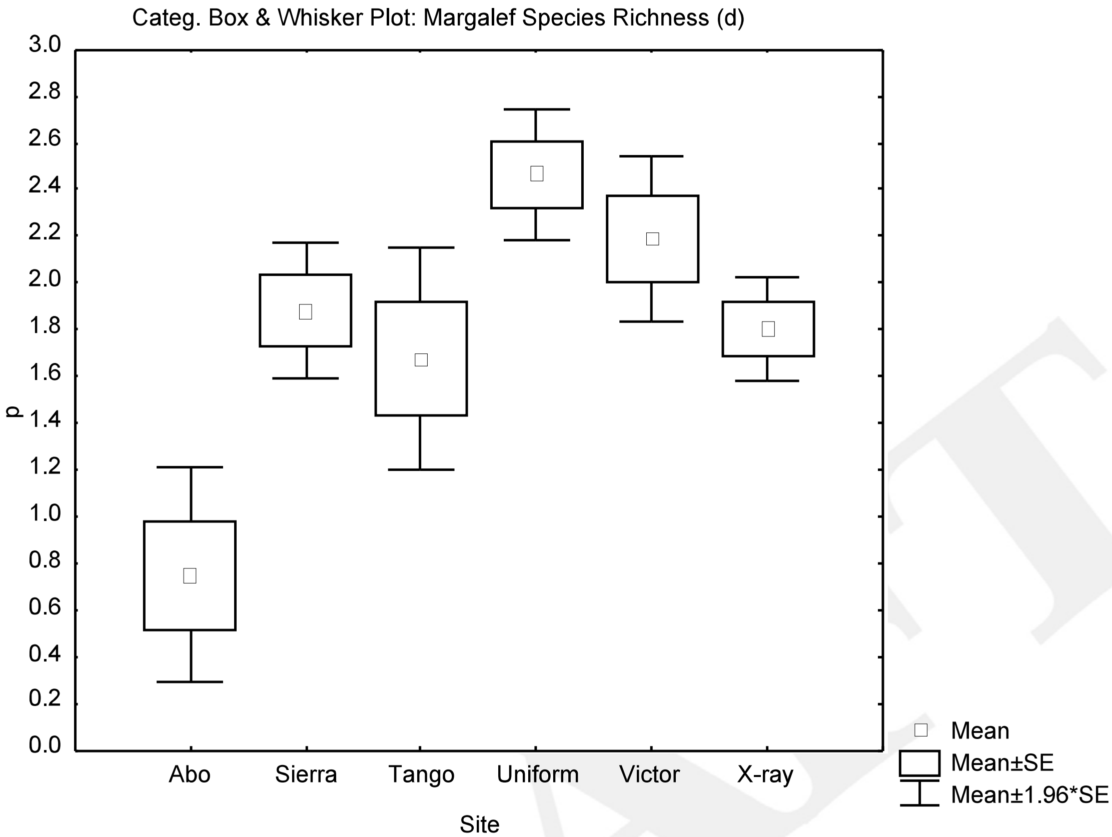

Figure 4. Margalef species richness (*d*) of quadrats per site. Abbreviations as in Figure 3.

Table 4. One-way Analysis of Variance (ANOVA) of *S* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Sierra	*0.00*		1.00	0.19	0.44	1.00
Tango	*0.00*	1.00		0.16	0.73	1.00
Uniform	*0.00*	0.19	0.16		0.90	0.19
Victor	*0.00*	0.44	0.73	0.90		0.44
X-ray	*0.00*	1.00	1.00	0.19	0.44	

Table 5. One-way ANOVA of *d* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	0.13	*0.00*	*0.00*	*0.00*
Sierra	*0.00*		0.99	0.59	0.83	1.00
Tango	0.13	0.99		0.27	0.72	1.00
Uniform	*0.00*	0.59	0.27		0.97	0.46
Victor	*0.00*	0.83	0.72	0.97		0.66
X-ray	*0.00*	1.00	1.00	0.46	0.66	

Turbidity is high throughout the inner harbor, but the vertical orientation of hard substrates (and probably ship activity) at the wharves results in a lower amount of sediment deposition, favoring the growth of epilithic biota adapted to low light conditions. Although very different from Abo Cove, the benthic assemblages of the wharves contain interesting taxa as well. Some of the taxa recorded here do not appear in the most recent taxonomic treatises for Guam. For example, the very abundant *Celleporaria sibogae* and the rather uncommon *Lichenopora* sp. are most likely new bryozoan records for Guam, as this group has been virtually unstudied in the region (Paulay, 2003). Diversity measures mimic the differences in species richness between the inner harbor sites (Figure 5; Table 6). Sponges contribute most to the benthic diversity of the wharves. A number of these probably also constitute new records for Guam, and others are infrequently encountered elsewhere around the island as they are typically confined to deep water, caves, or other cryptic habitats.

Table 6. One-way ANOVA of *H′* with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.01*	0.13	*0.00*	*0.00*	*0.00*
Sierra	*0.01*		1.00	0.64	0.14	0.73
Tango	0.13	1.00		0.69	0.53	0.94
Uniform	*0.00*	0.64	0.69		1.00	0.99
Victor	*0.00*	0.14	0.53	1.00		0.87
X-ray	*0.00*	0.73	0.94	0.99	0.87	

As found for taxonomic richness and diversity, the benthic assemblages of Abo Cove differ significantly from the wharf sites in having a low overall biotic cover (Figure 6; Table 7). As discussed before, this is a direct result of the Abo Cove site being a mostly horizontally oriented sedimentation flat. In contrast, the biotic assemblages of the wharfs are best developed on the shallow vertical surfaces. It is important to note, however, that corals are the main constituent of the biotic assemblages at Abo Cove, while the wharfs are predominantly covered by crustose algae and sponges (Figure 7).

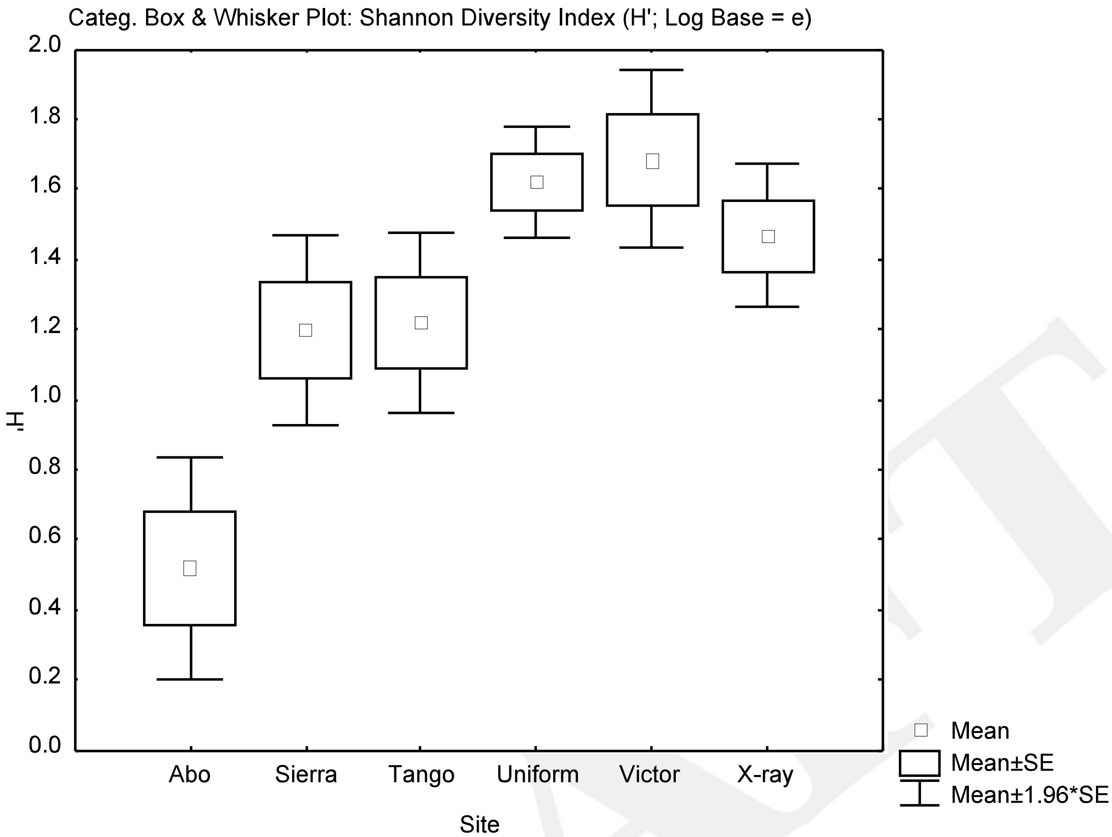

Figure 5. Shannon index (H') of quadrats per site. Abbreviations as in Figure 3.

Table 7. One-way ANOVA of biotic cover with Tukey HSD for unequal sample size as a post-hoc test. Differences significant at P < 0.05 are italicized. Abbreviations as in Figure 3.

	Abo	Sierra	Tango	Uniform	Victor	X-ray
Abo		*0.00*	*0.02*	0.21	*0.01*	*0.01*
Sierra	*0.00*		0.98	1.00	1.00	1.00
Tango	*0.02*	0.98		0.87	0.92	0.92
Uniform	0.21	1.00	0.87		1.00	1.00
Victor	*0.01*	1.00	0.92	1.00		1.00
X-ray	*0.01*	1.00	0.92	1.00	1.00	

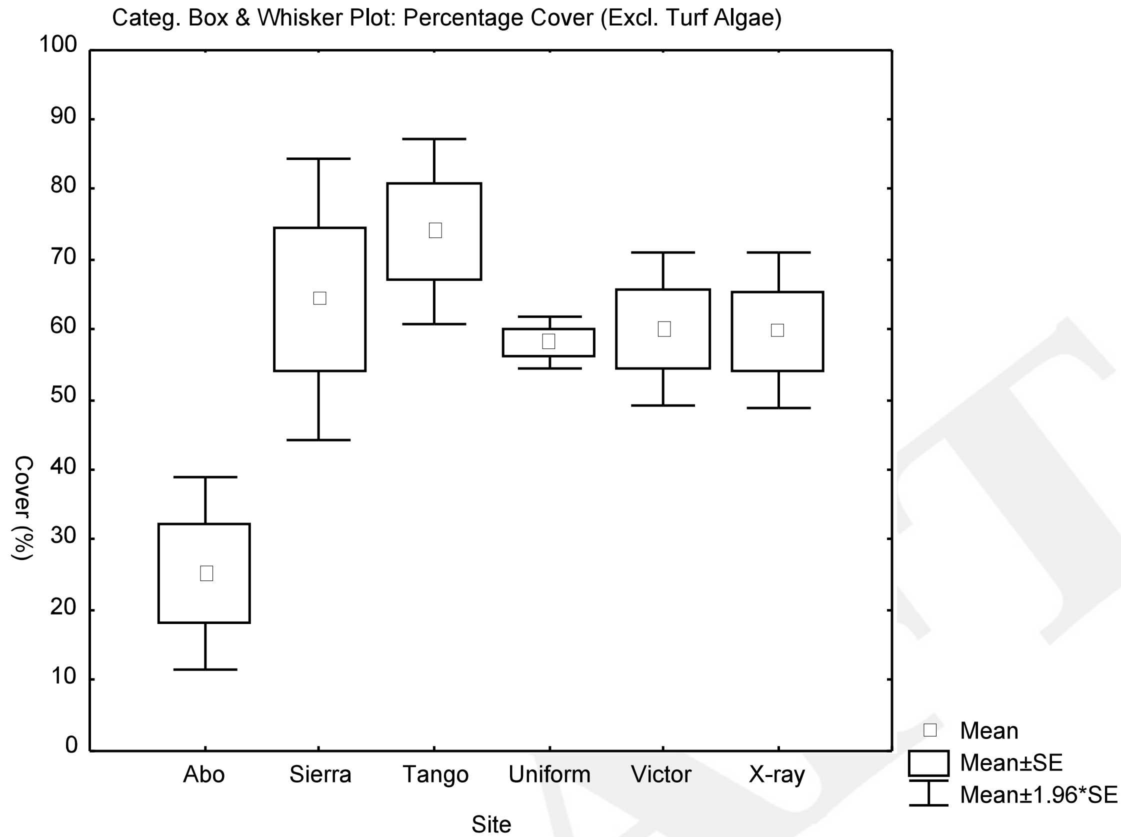

Figure 6. Biotic cover (excluding turf algae) of quadrats per site. Abbreviations as in Figure 3.

Non-metric multidimensional scaling (NMDS) was performed on the square root-transformed benthic data. The two-dimensional NMDS plot is an excellent representation of the biotic affinities between sites (low stress) and highlights the differences between Abo Cove and the Wharf sites in accordance with the above findings. Similarity is highest among the three southwestern wharves (Tango, Uniform, and Victor). Further multivariate analyses should reveal the main differences between the other sites and the most important indicator taxa in the data set.

Corals

Size-frequency distributions of the 13 species of scleractinian corals encountered on six transects in Inner Apra Harbor are presented in Table 8. An additional 13 species of scleractinian corals were observed on substrates adjacent to the transects (Table 3). Two species of non-scleractinian anthozoans were also recorded. Therefore, a cumulative total of 28 species of corals and related organisms, representing 11 families and 13 genera, was observed at the study site. This count represents a minimum, because several corals could be identified only to genus in the field and, therefore, may consist of more than one species.

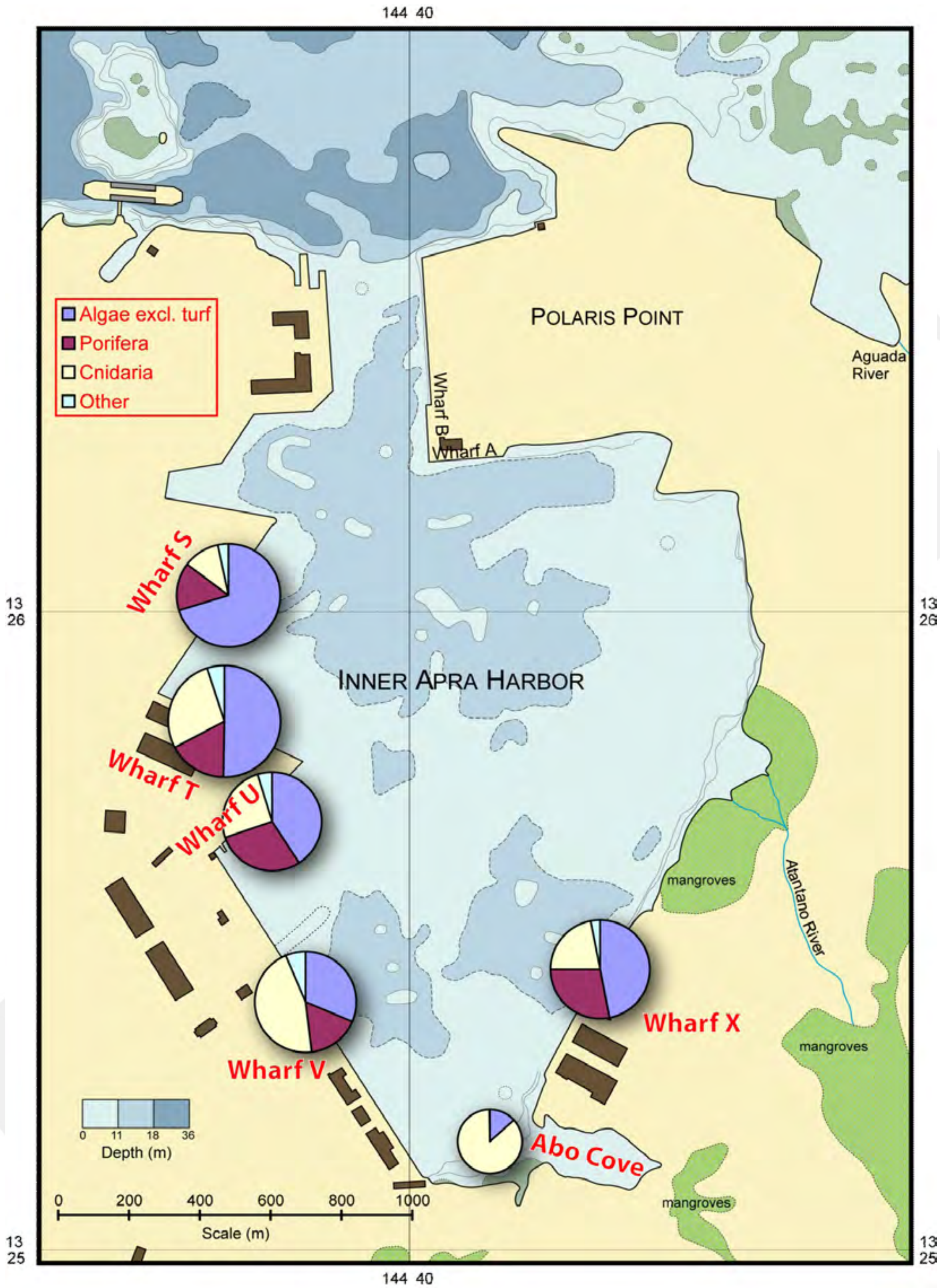

Figure 7. Pie charts displaying the percent cover of algae (Chlorophyta, Ochrophyta, Prokaryota, Rhodophyta), Porifera, Cnidaria, and other groups (Chordata, Magnoliophyta, Mollusca) for the different study sites. Size of the pie chart is proportional to the average total cover of benthic assemblages in the sampled quadrats. Biotic cover ranges from 25 % (Abo Cove) to 74 % (Tango Wharf).

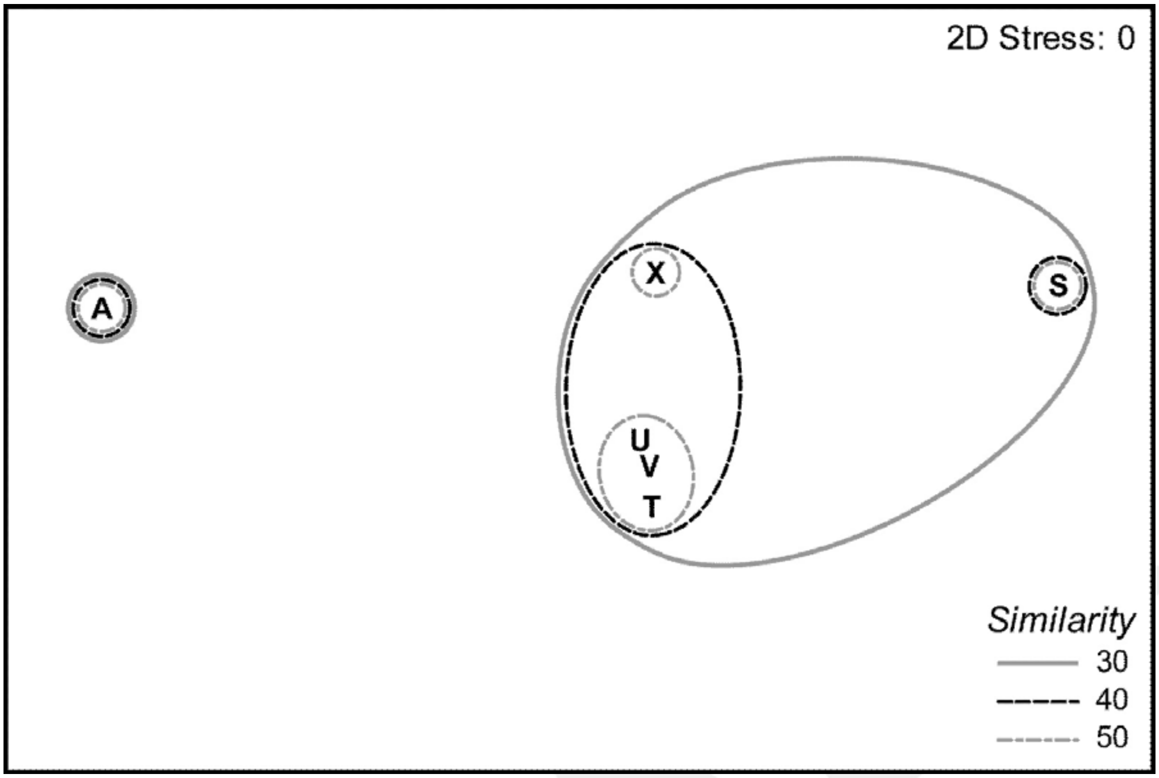

Figure 8. Non-metric multidimensional scaling (NMDS) plot of the six inner harbor sites. Bray-Curtis similarities obtained from a cluster analysis based on the benthic data (square root transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

Species richness was highest at X-ray Wharf, where eight species occurred on the transect; only four species occurred on transects at Above Cove and Tango, Uniform, and Victor Wharves. *Porites lutea* and *Pocillopora damicornis* were the most common species, occurring on five of the six transects. Seven species occurred on only one transect, and three of these species were represented by single observations.

Quantitative analysis of the coral species encountered on transect is presented in Table 9. Poritid corals were predominant in coverage, averaging some 83% relative coverage on transects. Similarly, *Porites* spp. occurred at high frequencies on transects, although smaller species, such as *Pocillopora damicornis* and *Leptastrea purpurea*, exhibited high frequencies, as well.

The harbor floor consists of fine-grain sediments unsuitable for settlement by coral larvae. Consequently, few corals were encountered on Transects 1 and 2 on the harbor floor. Small colonies of *Porites lutea* were observed on scattered pieces of debris and old pilings that provided the only hard substrate available for settlement of larvae. With the exception of what

Table 8. Size-frequency distributions of coral species recorded on transects in Inner Apra Harbor. N = number of colonies. Mean, SD (standard deviation), and Range refer to colony coverage in cm^2.

Location	Habitat	Species	N	Mean	SD	Range
Abo Cove	Reef	*Porites* sp.	10	1291.9	1703.2	74.02–5013.98
		Goniastrea retiformis	4	12.7	15.0	3.93–34.99
		Porites lutea	7	1472.2	2624.4	45.95–7242.94
		Porites murrayensis	2	27.7	10.8	20.01–35.34
Wharf S	Wharf face	*Porites rus*	8	19.7	10.7	7.42–39.25
		Lobophyllia hataii	1	9.9	–	9.88
		Stylocoeniella armata	3	25.8	18.1	7.15–43.28
		Leptastrea purpurea	3	8.7	2.6	5.72–10.60
		Pocillopora damicornis	1	0.3	–	0.31
Wharf T	Wharf face	*Leptastrea purpurea*	5	11.7	11.3	0.55–29.10
		Porites lutea	10	99.3	191.2	2.64–631.43
		Pocillopora damicornis	3	25.0	29.1	1.65–57.59
		Porites sp.	2	4.1	0.0	4.10–4.10
Wharf U	Wharf face	*Porites lutea*	12	134.9	282.7	1.53–978.21
		Pocillopora damicornis	10	46.3	43.1	1.98–129.59
		Leptastrea purpurea	15	8.7	9.4	0.20–37.70
		Porites rus	2	1165.7	855.0	561.10–1770.29
Wharf V	Wharf face	*Leptastrea purpurea*	10	2.8	2.4	0.33–8.91
		Pocillopora damicornis	14	46.4	66.0	0.44–253.68
		Porites lutea	12	256.3	434.0	4.67–1555.09
		Stylocoeniella guntheri	3	236.2	406.9	0.55–706.07
Wharf X	Wharf face	*Porites lutea*	11	25.7	26.9	1.96–74.30
		Porites rus	7	640.3	866.3	3.77–2172.16
		Leptastrea purpurea	15	5.3	6.5	0.20–25.40
		Porites sp.	1	1.04	–	3.77
		Montipora sp.	2	12.9	5.1	9.30–16.49
		Porites australiensis	1	4.9	–	4.90
		Pocillopora damicornis	2	32.6	28.3	12.53–52.59
		Pavona explanulata	1	1.0	–	1.04

appeared to be the remains of an old pier extending perpendicular from Victor Wharf (Transect 1, Figure 1), the amount of debris was greater near the wharves. No corals were observed on the harbor floor at distances of 20 m or more.

The fourth root-transformed relative coral coverage data were analyzed by non-metric multidimensional scaling (NMDS). The two-dimensional NMDS plot (Figure 9) shows the biotic affinities between the sites (low stress) and reveals differences not only between Abo Cove and the wharf sites, but between Sierra Wharf and the four remaining wharves. Uniform and X-ray

Table 9. Population density, frequency, and coverage of coral species recorded on transects in Inner Apra Harbor.

Location	Habitat	Species	N	Relative Density	Absolute Density	Frequency	Coverage	Relative Coverage
Abo Cove	Reef	*Porites* sp.	10	0.43	0.06	0.60	80.98	81.58
		Goniastrea retiformis	4	0.17	0.03	0.20	0.32	0.32
		Porites lutea	7	0.30	0.04	0.30	17.62	17.75
		Porites murrayensis	2	0.09	0.01	0.10	0.35	0.35
Wharf S	Wharf face	*Porites rus*	8	0.50	0.04	0.60	1.01	61.78
		Lobophyllia hataii	1	0.06	0.01	0.20	0.05	3.33
		Stylocoeniella armata	3	0.19	0.02	0.40	0.42	26.02
		Leptastrea purpurea	3	0.19	0.02	0.40	0.14	8.77
		Pocillopora damicornis	1	0.06	0.01	0.20	0.00	0.10
Wharf T	Wharf face	*Leptastrea purpurea*	5	0.25	0.03	0.80	0.39	5.11
		Porites lutea	10	0.50	0.07	0.80	6.63	86.85
		Pocillopora damicornis	3	0.15	0.02	0.40	0.56	7.37
		Porites sp.	2	0.10	0.01	0.20	0.06	0.72
Wharf U	Wharf face	*Porites lutea*	12	0.31	0.30	0.800	39.80	35.63
		Pocillopora damicornis	10	0.26	0.25	0.600	11.39	10.20
		Leptastrea purpurea	15	0.38	0.37	1.000	3.20	02.87
		Porites rus	2	0.05	0.05	0.100	57.32	51.31
Wharf V	Wharf face	*Leptastrea purpurea*	10	0.26	0.10	0.50	0.29	00.62
		Pocillopora damicornis	14	0.36	0.15	0.80	6.78	14.55
		Porites lutea	12	0.31	0.13	0.50	32.13	68.93
		Stylocoeniella guntheri	3	0.08	0.03	0.10	7.40	15.88
Wharf X	Wharf face	*Porites lutea*	11	0.28	0.05	0.50	1.15	05.66
		Porites rus	7	0.18	0.03	0.50	18.34	89.92
		Leptastrea purpurea	15	0.38	0.06	0.70	0.49	02.40
		Porites sp.	1	0.03	0.00	0.10	0.02	0.08
		Montipora sp.	2	0.05	0.01	0.10	0.11	0.52
		Porites australiensis	1	0.03	0.00	0.10	0.02	0.10
		Pocillopora damicornis	2	0.05	0.01	0.20	0.27	1.31
		Pavona explanulata	1	0.03	0.00	0.10	0.00	0.02

Wharves cluster together, as do Tango and Victor Wharfs. Coral communities on the four southern wharves are more similar to each other than to either Sierra Wharf or Abo Cove.

Macroinvertebrates

The distribution and abundance of conspicuous solitary epibenthic macroinvertebrates occurring on 8 transects in Inner Apra Harbor are reported in Table 10

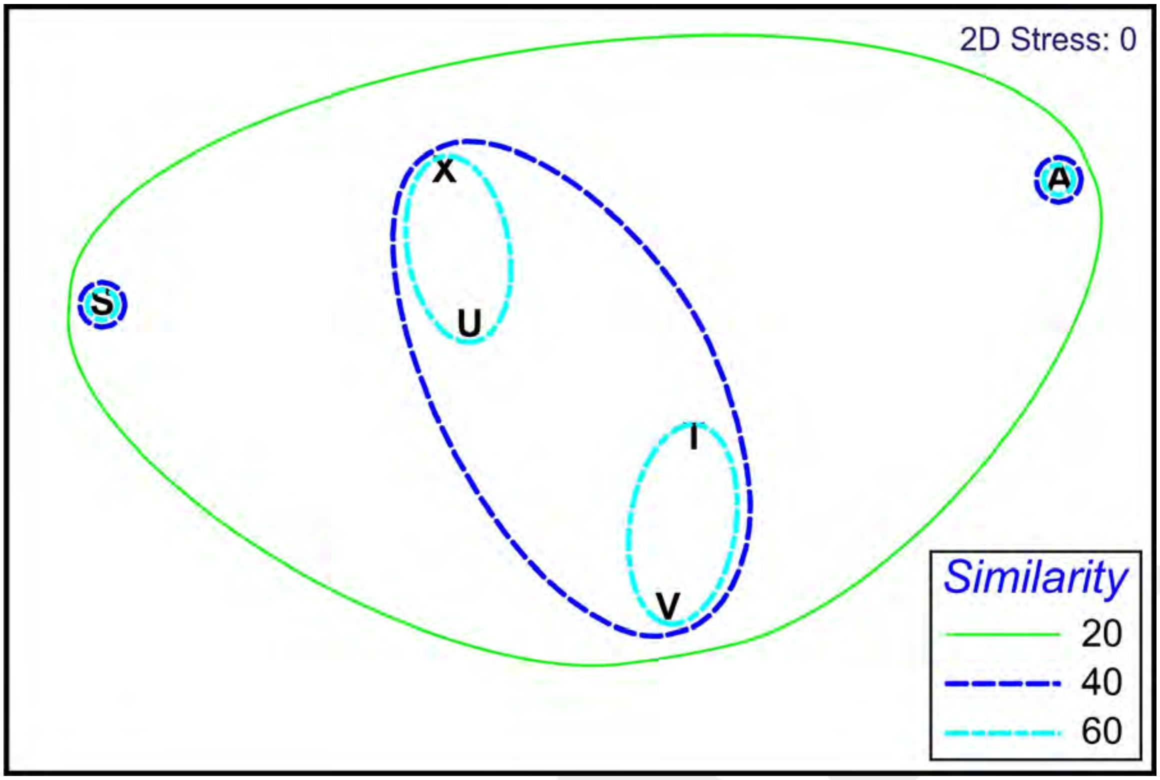

Figure 9. Non-metric multidimensional scaling (NMDS) plot of the six inner harbor transect sites. Bray-Curtis similarities obtained from a cluster analysis based on the coral data (fourth root-transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

(colonial invertebrates are included in Table 3). Twenty species of solitary macroinvertebrates in four phyla were encountered on the transects, and 10 additional species were observed in areas adjacent to the transects (Table 11). Three of the species on transects occurred as single observations, and one species, *Phallusia nigra*, is reported as nonindigenous (Paulay et al., 2001a; Lambert, 2002, 2003). The greatest á diversity (i.e., 16 species, or 80% of the á diversity on transects) was found on the vertical face at Victor Wharf (Transect V), and the least (i.e., 8 species) on the coral reef at Abo Cove (Transect A). Bivalve molluscs and ascidians dominated the macroinvertebrate fauna in terms of both diversity and density. Remarkably, 100% of the macroinvertebrate species encountered on transects were suspension feeders. Of the total 30 species of solitary macroinvertebrates listed in Table 11, all but three are suspension feeders—the three being detritus feeders. The predominance of suspension feeders in lagoonal environments, such as the inner harbor, may be a result of nutrient enrichment by terrestrial run-off and the extended residence time of waters in the lagoon.

Table 10. Mean densities of conspicuous epibenthic invertebrates observed on transects in Inner Apra Harbor, Guam. Densities are reported as mean ± standard deviation in twenty 10-m^{-1} quadrats sampled along a 100-m transect, except at Wharf T and Wharf U, where ten 10-m^{-1} quadrats were sampled along a 50-m transect.

	Abo Cove	Wharf S	Wharf T	Wharf U	Wharf V	Wharf X
Cirripathes sp.					0.05 ± 0.22	
Spirobranchus giganteus	0.05 ± 0.22		0.90 ± 0.74	1.20 ± 1.69	0.35 ± 0.67	0.10 ± 0.31
Sabellastarte sanctijosephi	0.05 ± 0.22					
Arca ventricosa					0.05 ± 0.22	
Barbatia spp.	0.30 ± 0.47		0.40 ± 1.26			0.35 ± 0.93
Chama lazarus		7.25 ± 4.30	9.70 ± 2.54	7.90 ± 4.36	11.50 ± 11.37	6.20 ± 3.32
Chama spp.	0.05 ± 0.22	0.35 ± 0.67		0.50 ± 0.85		0.75 ± 1.25
Malleus decurtatus	3.15 ± 2.43	0.20 ± 0.52	4.10 ± 1.73	31.90 ± 27.65	93.40 ± 91.23	54.60 ± 39.55
Spondylus multimuricatus		1.65 ± 2.46	3.10 ± 2.08	2.30 ± 1.49	3.75 ± 3.01	3.05 ± 1.76
Spondylus squamosus		0.65 ± 0.93	0.40 ± 0.52	1.70 ± 1.25	2.15 ± 2.18	5.90 ± 4.76
Spondylus spp.			28.10 ± 9.10	19.90 ± 5.92	10.95 ± 10.65	20.00 ± 9.21
ostreid spp.		0.20 ± 0.70		0.30 ± 0.48	0.65 ± 0.99	0.50 ± 1.15
Septifer bilocularis			0.30 ± 0.95			0.25 ± 0.72
Ascidia ornata	0.20 ± 0.52			0.10 ± 0.32	0.15 ± 0.37	
Ascidia sp. 1[a,b]					0.40 ± 0.60	
Phallusia julinea		0.05± 0.22	0.40 ± 0.70	2.70 ± 2.45	5.45 ± 5.58	
Phallusia nigra				0.20 ± 0.42	0.50 ± 0.83	
Polycarpa spp.	0.55 ± 0.69	0.20 ± 0.52	1.10 ± 1.10	2.20 ± 1.87	1.40 ± 1.43	0.50 ± 0.76
Rhopalaea circula	0.05 ± 0.22	2.45 ± 1.99	63.30 ± 18.09	8.20 ± 5.69	11.60 ± 8.09	4.50 ± 4.51
Rhopalaea sp. 2–gold spot[a,c]			31.90 ± 11.44		1.35 ± 1.69	

[a]These identifications follow the morphospecies designated by Paulay et al. (2001b).
[b]*Ascidia* sp. A of Lambert (2003).
[c]*Rhopalaea* sp. A (n.sp.?) of Lambert (2003).

Table 11. Species of conspicuous epibenthic invertebrates observed on or adjacent to transects in Inner Apra Harbor, Guam. Observations of live specimens are denoted by filled circles (●), and records based on dead specimens are denoted by open circles (○).

	Harbor Floor 1	Harbor Floor 2	Abo Cove	Wharf S	Wharf T	Wharf U	Wharf V	Wharf X
Mastigias papua							●	●
Scyphozoa sp.–transparent				●		●	●	
Cirripathes sp.							●	
Zoanthus sp.							●	
Spirobranchus giganteus	●		●		●	●	●	●
Sabellastarte sanctijosephi			●					
Bittium sp.	●							
cf. *Styliola subula*				●	●	●	●	●
Arca ventricosa							●	
Barbatia spp.	●		●		●	●		●
Chama lazarus				●	●	●	●	●
Chama spp.			●	●				●
Malleus decurtatus	●		●	●	●	●	●	●
Spondylus multimuricatus				●	●	●	●	●
Spondylus squamosus	●			●	●	●	●	●
Spondylus varius						○		
Spondylus spp.	●				●	●		●
Hyotissa hyotis						○		
Saccostrea cf. *cucullata*	●	●						
ostreid spp.				●			●	●
Septifer bilocularis					●	●		●
Mespilia globulus						●		
Parasalenia gratiosa						●		
Ascidia ornata			●			●	●	
Ascidia sp. 1[a]							●	
Phallusia julinea				●	●	●	●	
Phallusia nigra						●	●	
Polycarpa spp.			●	●	●	●	●	●
Rhopalaea circula			●	●	●	●	●	●
Rhopalaea sp. 2–gold spot[a]					●	●	●	

[a]These identifications follow the morphospecies designated by Paulay et al. (2001b).

Densities of solitary macroinvertebrates ranged from less than 1 individual of a species to more than 90 individuals/10 m^2, with bivalve molluscs and ascidians being predominant. The hammer oyster *Malleus decurtatus* occurred in the greatest densities (up to 9.3 oysters/m^2 at Victor Wharf), with thorny oysters, *Spondylus* spp., and jewel box clams, *Chama* spp., also abundant. Among ascidians, *Rhopalaea circula* reached a density of 6.3 individuals/m^2 at Tango Wharf. The greatest total density was observed Victor Wharf (Transect V), where there were 143.7 macroinvertebrates/10 m^2; the lowest total density was 4.4 macroinvertebrates/10 m^2 at Abo Cove (Transect V). As noted above for benthic coverage, this pattern may be explained by the greater availability of hard substrate for post-larval settlement on the vertical faces of the wharves, as compared to the sediment-laden horizontal substrate on the reef at Abo Cove.

The harbor floor is largely depauperate of epibenthic macroinvertebrates. The substrate of the harbor consists predominately of a sticky, fine silt/mud sediment that is easily resuspended. As a result, the transect line sank from sight into the soft sediments. Further, any contact or near contact with the bottom by divers resuspended sediments and reduced visibility markedly. Therefore, we were not able to quantify macroinvertebrates on the harbor floor. However, seven epibenthic species were observed during two swimming transects (Transects 1 and 2). Observed species were associated with debris that provided hard substrate, with the exception of the detritivorous snail *Bittium* sp. Generally, the volume of debris, and therefore the number of macroinvertebrates, diminished with distance from the wharves. Although few epibenthic macroinvertebrates were observed on the harbor floor, large numbers of burrow openings were present, indicating an abundance infaunal organisms.

Comparison of macroinvertebrate community structure across transects by cluster analysis indicates considerable contrast for horizontal and vertical substrates (Figure 10). The macroinvertebrate community on vertical faces of the wharves form a single, large clade that is distinctly different than the community inhabiting the horizontal substrate at Abo Cove. As noted for benthic cover, similarity is high for Uniform and Victor Wharves. However, for solitary macroinvertebrates, X-ray Wharf is more similar to these communities than to the community at Tango Wharf.

Non-metric multidimensional scaling (NMDS) on the fourth root-transformed data further demonstrate the dissimilarity of macroinvertebrate assemblages on horizontal and vertical substrates (Figure 11). The Abo Cove macroinvertebrate community is distinctly different from the communities on the wharf faces, which clustered together. A stress level of 0.01 indicates a high level of significance in the relationships represented by this analysis.

Possibly the most abundant solitary invertebrates were neither epibenthic nor conspicuous. The pelagic thecosomate gastropod cf. *Styliola subula* was abundant in surface waters adjacent to all the wharves that we surveyed. Commonly known as sea butterflies, these free-swimming gastropods feed upon plankton, exhibiting diurnal migrations in pursuit of their prey. Although small (<1 cm) and transparent, the snails are important in marine food webs (Seibel and Diersson, 2003). Their sensitivity to temperature and acidity have led scientists to express concern over the possible effects of global climate change and ocean acidification upon the survival of these organisms and the consequent impacts on marine food webs (Seibel and Diersson, 2003; Orr et al., 2005).

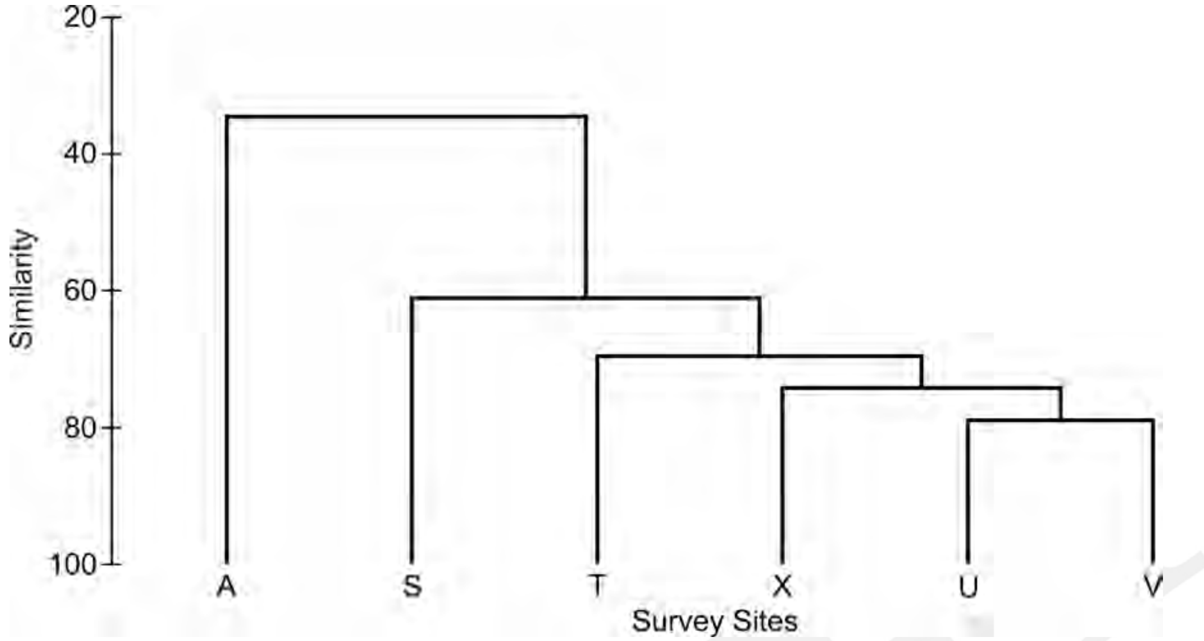

Figure 10. Cluster analysis (group averaging) of macroinvertebrate assemblage relationships between transects at Inner Apra Harbor study sites. Values of similarity (0 to 100%) were calculated in pair-wise comparisons with the Bray-Curtis similarity index and then assembled in a matrix prior to cluster analysis. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

We have no basis for statistical comparison of our data on macroinvertebrate populations in Inner Apra Harbor. The most recent survey (Paulay et al., 2001a) of the macroinvertebrate communities in the inner harbor focused primarily upon only three taxa (i.e., sponges, echinoderms, and ascidians), and their study was qualitative in structure.

Fishes

A checklist of species and their relative abundance (as percent) at each station is given in Table 12. Sixty-two species of fishes were observed on transects surveyed within the Apra Inner Harbor. While this number indicates an impoverished fish fauna (there are approximately 1,000 species of reef and nearshore fishes known from the Mariana Islands; Myers and Donaldson, 2003; unpublished data), the fauna seems representative of protected, turbid lagoons or bays of Guam (unpublished data). Further, at least three species appear to be invasive or new records for Guam and the Mariana Islands. One, *Neopomacentrus violescens* (Pomacentridae-damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). The other two, *Amblygliphididon ternatensis* (Pomacentridae) and *Rhamdia cypselurus* (Apogonidae-cardinalfishes) have not been reported previously from the Mariana Islands. Both occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999). Either both of these species have escaped detection

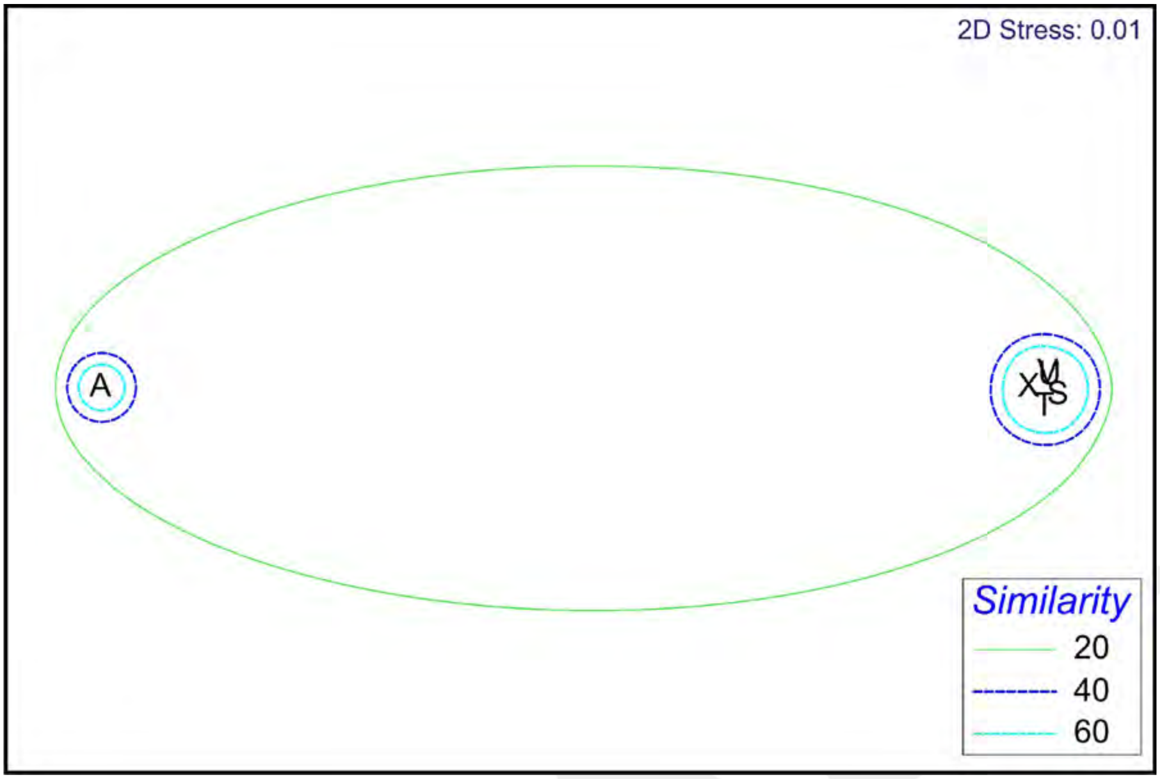

Figure 11. Non-metric multidimensional scaling (NMDS) plot of macroinvertebrate assemblages at the six inner harbor transect sites. Bray-Curtis similarities obtained from a cluster analysis based on the coral data (fourth root-transformed) are overlaid. Abbreviations: A, Abo Cove; S, Sierra Wharf; T, Tango Wharf; U, Uniform Wharf; V, Victor Wharf; X, X-ray Wharf.

previously, owing to the very turbid conditions found in the inner harbor, or they have been introduced, likely as larvae in bilge water of ships moored in the inner harbor, and have been seen for the first time during the present surveys,

Species richness (the number of species observed) between stations ranged from 2 (harbor floor, Transect 2) to 29 (UniformWharf–bottom, Transect U_B). Generally, species richness was greater on the bottom at stations, where debris provided shelter for various species. Some wharf walls (mid-depth transects), however, supported relatively high numbers of species, as well. Subsurface transects at all wharf stations tended to have the lowest number of species, with some exceptions, as did Abo Cove (Table F3). A measure of species diversity, Shannon's H' (Magurran, 1988), that adjusts species richness to consider also the influence of abundance, was highest along the mid-depth transect at Victor Wharf (Transect V_M), and then along the bottom transect at Uniform (Transect U_B). Species diversity was also relatively high on mid-depth transects at X-ray (Transect X_M) and Uniform (Transect U_M) Wharves, but also on subsurface transects at Tango (Transect T_S) and X-ray (Transect X_S) wharves. Corals, soft corals, and molluscs (mainly oysters) were present at these stations and appeared to be protected

Table 12. Relative abundance (%) of fishes observed on transects in Inner Apra Harbor. Survey sites are designated as follows: A = Abo Cove, S_M = Sierra Wharf mid-depth, S_S = Sierra Wharf subsurface, T_M = Tango Wharf mid-depth, T_S = Tango Wharf subsurface, T_B = Tango Wharf bottom, U_M = Uniform Wharf mid-depth, U_S = Uniform Wharf subsurface, U_B = Uniform Wharf bottom, V_M = Victor Wharf mid-depth, V_S = Victor Wharf subsurface, V_B = Victor Wharf bottom, X_M = X-Ray Wharf mid-depth, X_S = X-Ray Wharf subsurface, X_B = X-Ray Wharf bottom, O_1 = harbor floor 1, O_2 = harbor floor 2.

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
Family Clupeidae (herrings)																	
Spratelloides delicatulus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Mugilidae (mullets)																	
Moolgarda seheli	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Holocentridae (squirrelfishes)																	
Neoniphon opercularis	0	0	0	0	0.6	0	0	0	0.2	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Serranidae (groupers)																	
Epinephelus maculatus	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Family Apogonidae (cardinalfishes)																	
Apogon lateralis	0	97.5	64.4	28.2	0	5.8	0	0	44.6	0	0	75.4	58.9	0	89.2	0	0
Apogon leptacanthus	5.3	1	2.9	0	6	0	0	0	5	0	0	1	6	0	9	0	0
Archamia biguttata	0	0	0	0	1.2	0	0	0	2	0	0	0	0	0	0	0	0
Archamia fucata	0	0	0	0	0	5.8	0	0	0	0	0	14.1	0	0	0	0	0
Cheilodipterus quinquelineatus	68.2	0	0	0	1.2	0	0	3.1	0.2	5	0.6	3.6	0	0	0	0	0
Foa brachygramma?	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Rhabdamia cypselurus?	0	0	2.3	57.6	68.3	0	0	0	20	0	0	0	1.8	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Family Carangidae (trevallys)																	
Caranx ignobilis	0	0	0	0.9	0	0	0	0	0	0	0	0.1	1.8	0	0	0	0
Caranx melampygus	0	0	0	0.3	0	0	0	0	0.2	0	0	0.1	0	0	0	0	0
Scomberoides lysan	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnathanodon speciosus	0	0	0	0	0	0	0	0	0	0	0.6	0.1	0	0	0	0	0
Family Lutjanidae (snappers)																	
Lutjanus ehrenbergi?	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Lutjanus fulvus	5.3	0.1	0	0	0	11.6	0	0	0	0	0	0.3	0	0	0	0	0

Table 12. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
Family Lethrinidae (emperors)																	
Lethrinus harak	0	0	0	0	0	0	1.6	0	0	0	0	0.1	0	0	0	0	0
Family Haemulidae (sweetlips)																	
Plectorhinchus albovittatus	0	0	0	0	0	0	0	0	0.2	0	0	0.1	0	0	0	0	0
Family Chaetodontidae (butterflyfishes)																	
Chaetodon auriga	0	0	0	0	0	0	0	0	0.4	0	0	0.1	0.6	1	0	0	0
Chaetodon bennetti	0	0.1	0	0	0	0	1.6	0	0.6	6	7	0.1	0	0	0	0	0
Chaetodon ephippium	0	0	0	0.6	0	5.8	0	0	1.2	0	0	0.2	3	0	0	0	0
Chaetodon lunula	0	0	0	0	0.6	0	0	0	0	1	0.6	0	0.6	0	0	0	0
Chaetodon lunulatus	0	0	0	0	1.2	0	0	0	0	0	0	0	1.8	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Chaetodon ulietensis	0	0	0	0.3	0.6	0	4.8	0	0.6	0	0	1	0	0	0	0	0
Heniochus chrysostomus	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0	0
Family Pomacentridae (damselfishes)																	
Amblyglyphididon ternatensis	0	0	16.9	0	2.4	0	29	81.7	0	18	78.6	0	0	0	0	0	0
Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	1.2	0	2.4	0	0	0	0
Chromis viridis	0	0.2	11.7	0.3	0	0	0	0	0	19.4	0	0	0	0	0	0	0
Chrysiptera traceyi	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopomacentrus violascens	0	0	0	0	4.8	0	0	6.1	10	0	0	0	0	1	0	0	0
Pomacentrus blue spot	0	0	0	0	0	0	0	9.1	0	0	0	0	10.1	0	0	0	0
Pomacentrus amboinensis	0	0	0	0.6	6.8	0	1.6	0	0.6	9.7	9.7	0	0	1	0	0	0
Pomacentrus pavo	0	0	0.3	0	11.1	0	3.2	0	0	7.2	5.7	0	1.2	1	0	0	0
Family Labridae (wrasses)																	
Cheilinus fasciatus	0	0	0	0	0	5.8	1.6	0	0	0	0	0	0	0	0	0	0
Cheilinus trilobatus	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0
Family Blenniidae (blennies)																	
Ecsenius bicolor	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiacanthus atrodorsalis	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Petroscirtes mitratus	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue dorsal spot tube blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Table 12. Continued.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	O_1	O_2
	Survey Sites																
Family Gobiidae (gobies)																	
Amblygobius nocturnus	0	0	0	0	0	11.6	0	0	2.4	0	0	5	0	0	0	0	0
Amblygobius phaelena	0	0	1.5	0.3	0.6	0	1.6	0	0.2	0	1.2	0.2	0.6	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Cryptocentrus strigilliceps	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	1.8	0	0
Cristatogobius sp. A	0	0	0	0	0	11.6	0	0	0.4	0	0	6	0	0	0	0	0
Ctenogobiops feroculus	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62.5	90
Gnatholepis cauerensis	5.3	0	0	0	0	5.8	0	0	4.2	0	0	0	0	0	0	0	0
Oplopomus oplopomus	0	0	0	0	0	0	0	0	0.2	0	0	0.2	0	0	0	12.5	0
Oxyurichthys papuensis	0	0	0	0	0	0	0	0	2.6	0	0	0.2	0	0	0	25	10
Paragobiodon lacunicolus	0	0	0	0	0	0	1.6	0	0	0	0	0	0	0	0	0	0
Priolepis cincta	0	0	0	0	0.6	0	0	0	0	3	0.6	0	0	0	0	0	0
Family Zanclidae (Moorish Idol)																	
Zanclus cornutus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Siganidae (rabbitfishes)																	
Siganus argenteus	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Family Acanthuridae (surgeonfishes)																	
Acanthurus blochii	0	0	0	0.3	0	36.2	19.4	0	0	11.3	0	2.8	11.2	0	0	0	0
Acanthurus xanthopterus	0	0	0	2.5	0	0	32.4	0	0	15.4	0	0	0	1	0	0	0
Zebrasoma veliferum	0	0	0	0	0	0	0	0	0.6	0	0.6	0.1	1.8	0	0	0	0
Family Balistidae (triggerfishes)																	
Balistoides viridescens	0	0	0	0.3	0	0	0	0	0.6	0	0	0.1	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Tetraodontidae (pufferfishes)																	
Canthigaster solandri	0	0	0	0.3	0	0	0	0	0.2	0	0.6	0	1.2	0	0	0	0
Total individuals	**19**	**1025**	**343**	**346**	**162**	**17**	**62**	**33**	**528**	**97**	**157**	**632**	**179**	**17**	**56**	**16**	**10**

by ship fenders that effectively prevented ship hulls from damaging these microhabitats, thus making them available to fishes for shelter.

Densities of fish species (no. individuals/m^2) at each station are given in Table 13. Small, structure-associated cardinalfishes had the greatest density among stations. *Apogon lateralis* (Apogonidae) densities where high at Sierra Wharf (20/m^2 at mid-depth and 4.4/m^2 at subsurface depth), Victor Wharf (4.5/m^2 at the bottom), Uniform Wharf (2.5/m^2 at the bottom), and X-ray Wharf (2.06/m^2 at mid-depth). Another cardinalfish, the apparently invasive *Rhabdamia cypselerus*, had relatively high densities at Sierra Wharf (8/m^2 at subsurface depth) and Tango Wharf (4/m^2 at mid-depth and 2/m^2 at subsurface depth). Both species tended to occur in aggregations of several individuals. The invasive damselfish, *Amblyglyphididon ternatensis* (Pomacentridae), was relatively dense at Victor Wharf (2.24/m^2 at mid-depth) and Sierra Wharf (1.16 per m^2 subsurface depth). This species occurred in aggregations as well; many were juveniles. Densities of other species were low to very low and ranged from 0.0033/m^2 to1.0/m^2 (Table 13).

The similarity of species composition between stations and transect depths was examined with multiple dimension scaling analysis (Figure 12). The meager fish assemblages of the two harbor floor transects (Transect 1 and Transect 2) formed a distinct group. The fish assemblages on the Abo Cove and Tango Wharf-bottom transects formed a group, as well. The mid-depth and subsurface transects at Uniform and Victor wharves formed a distinct group, too, as did the subsurface transect at X-ray Wharf. Finally, the fish assemblages on the subsurface transects at Sierra and Tango wharves, the mid-depth transects at Sierra, Tango and X-ray wharves, and the bottom transects at Uniform, Victor, and X-ray wharves, all formed a distinct group. A stress level of 0.11 indicated a moderate confidence in the analysis results (Clarke and Gorley, 2001). Analysis of similarity (ANOSIM) between stations (locality and depth treated as a station) indicated that there were only weakly significant differences between them (Global $R = 0.21$). Thus, the fish faunas of each tended to share many of the same species typical of protected and turbid waters, while differences can be attributed to the presence of seemingly unusual species (i.e., butterflyfishes normally seen in clear or less-turbid reef systems) associated with structure on some transects or the simple absence of species, other than some burrowing gobies, on others (i.e., Transect 1 and Transect 2).

Essential Fish Habitat

Qualitative measures of habitat utilization by fishes were limited to observations of association between species and habitat and microhabitat types (Table 14). Major habitat types were reefs (Abo Cove), wharves (all stations except Abo Cove and the harbor floor transects), or harbor floor. Microhabitats included corals, debris (hanging and deposited on the bottom), rubble, rocks, soft corals, sand, shells, or the water column), and wharf faces and pilings. Corals, soft corals, and shells were usually found on the wharf faces, as well.

Overall, wharves provided considerable habitat for a diverse array of fishes compared to the reef at Abo Cove or the harbor floor offshore from the wharves (Table 14). Microhabitats associated with wharves included coral, debris, shell, and soft corals that were attached to a wharf, the wharf wall and associated structures (pilings, fenders, pipes, cables, etc.), debris, rubble, rock, and sand at the base of the wharf wall, and the water column directly adjacent to the wharf. Most species were associated with one or more of these microhabitats. Benthic

Table 13. Density of fishes (no./m^2) on transects in Inner Apra Harbor. Survey sites are designated as follows: A = Abo Cove, S_M = Sierra Wharf mid-depth, S_S = Sierra Wharf subsurface, T_M = Tango Wharf mid-depth, T_S = Tango Wharf subsurface, T_B = Tango Wharf bottom, U_M = Uniform Wharf mid-depth, U_S = Uniform Wharf subsurface, U_B = Uniform Wharf bottom, V_M = Victor Wharf mid-depth, V_S = Victor Wharf subsurface, V_B = Victor Wharf bottom, X_M = X-Ray Wharf mid-depth, X_S = X-Ray Wharf subsurface, X_B = X-Ray Wharf bottom, 1 = Transect 1 (harbor floor), 2 = Transect 2 (harbor floor).

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Clupeidae (herrings)																	
Spratelloides delicatulus	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Mugilidae (mullets)																	
Moolgarda seheli	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Holocentridae (squirrelfishes)																	
Neoniphon opercularis	0	0	0	0	0.02	0	0	0	0.01	0	0	0	0	0	0	0	0
Sargocentron spiniferum	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Serranidae (groupers)																	
Epinephelus maculatus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Family Apogonidae (cardinalfishes)																	
Apogon lateralis	0	20	4.4	2	0	0.01	0	0	2.5	0	0	4.5	2.06	0	0.5	0	0
Apogon leptacanthus	0.01	0.2	0.2	0	0.2	0	0	0	0.25	0	0	0.1	0.2	0	0.05	0	0
Archamia biguttata	0	0	0	0	0.04	0	0	0	0.1	0	0	0	0	0	0	0	0
Archamia fucata	0	0	0	0	0	1	0	0	0	0	0	0.89	0	0	0	0	0
Cheilodipterus quinquelineatus	0.13	0	0	0	0.04	0.01	0	0.02	0.01	0.1	0.02	0.23	0	0	0	0	0
Foa brachygramma?	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Rhabdamia cypselurus?	0	0	8	4	2	0	0	0	0.01	0	0	0	0.06	0	0	0	0
Sphaeramia orbicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0
Family Carangidae (trevallys)																	
Caranx ignobilis	0	0	0	0.06	0	0	0	0	0	0	0	0.01	0.06	0	0	0	0
Caranx melampygus	0	0	0	0.02	0	0	0	0	0.05	0	0	0.01	0	0	0	0	0
Scomberoides lysan	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnathanodon speciosus	0	0	0	0	0	0	0	0	0	0	0.02	0.01	0	0	0	0	0
Family Lutjanidae (snappers)																	
Lutjanus ehrenbergi?	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Lutjanus fulvus	0.01	0.02	0	0	0	0.02	0	0	0	0	0	0.03	0	0	0	0	0
Family Lethrinidae (emperors)																	
Lethrinus harak	0	0	0	0	0	0	0.02	0	0	0	0	0.01	0	0	0	0	0
Family Haemulidae (sweetlips)																	
Plectorhinchus albovittatus	0	0	0	0	0	0	0	0	0.01	0	0	0.01	0	0	0	0	0
Family Chaetodontidae (butterflyfishes)																	
Chaetodon auriga	0	0	0	0	0	0	0	0	0.02	0	0	0.01	0.02	0.02	0	0	0
Chaetodon bennetti	0	0.02	0	0	0	0	0.02	0	0.03	0.12	0.22	0.01	0	0	0	0	0

Table 13.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
	Survey Sites																
Family Chaetodontidae (butterflyfishes)																	
Chaetodon ephippium	0	0	0	0.04	0	0.02	0	0	0.06	0	0	0.02	0.1	0	0	0	0
Chaetodon lunula	0	0	0	0	0.02	0	0	0	0	0.02	0.02	0	0.02	0	0	0	0
Chaetodon lunulatus	0	0	0	0	0.04	0	0	0	0	0	0	0	0.06	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0
Chaetodon ulietensis	0	0	0	0.02	0.02	0	0.06	0	0.03	0	0	0.1	0	0	0	0	0
Heniochus chrysostomus	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0
Family Pomacentridae (damselfishes)																	
Amblyglyphididon ternatensis	0	0	1.16	0	0.08	0	0.36	0.54	0	0.36	2.24	0	0	0	0	0	0
Abudefduf sexfasciatus	0	0	0	0	0	0	0	0	0	0	0.04	0	0.08	0	0	0	0
Chromis viridis	0	0.04	0.8	0.02	0	0	0	0	0	0.4	0	0	0	0	0	0	0
Chrysiptera traceyi	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopomacentrus violascens	0	0	0	0	0.16	0	0	0.04	0.5	0	0	0	0	0.02	0	0	0
Pomacentrus blue spot	0	0	0	0	0	0	0	0.06	0	0	0	0	0.36	0	0	0	0
Pomacentrus amboinensis	0	0	0	0.04	0.22	0	0.02	0	0.03	0.2	0.3	0	0	0.02	0	0	0
Pomacentrus pavo	0	0	0.02	0	0.36	0	0.04	0	0	0.14	0.18	0	0.04	0.02	0	0	0
Family Labridae (wrasses)																	
Cheilinus fasciatus	0	0	0	0	0	0.01	0.02	0	0	0	0	0	0	0	0	0	0
Cheilinus trilobatus	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0
Family Blenniidae (blennies)																	
Ecsenius bicolor	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meiacanthus atrodorsalis	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Petroscirtes mitratus	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue dorsal spot tube blenny	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0
Family Gobiidae (gobies)																	
Amblygobius nocturnus	0	0	0	0	0	0.02	0	0	0.12	0	0	0.05	0	0	0	0	0
Amblygobius phaelena	0	0	0.1	0.02	0.02	0	0.02	0	0.01	0	0.04	0.02	0.02	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0
Cryptocentrus strigilliceps	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0	0
Cristatogobius sp. A	0	0	0	0	0	0.02	0	0	0.02	0	0	0.06	0	0	0	0	0
Ctenogobiops feroculus	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.03
Gnatholepis cauerensis	0.01	0	0	0	0	0.01	0	0	0.21	0	0	0	0	0	0	0	0
Oplopomus oplopomus	0	0	0	0	0	0	0	0	0.01	0	0	0.02	0	0	0	0.004	0
Oxyurichthys papuensis	0	0	0	0	0	0	0	0	0.13	0	0	0.02	0	0	0	0.008	0.0033
Paragobiodon lacunicolus	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0
Priolepis cincta	0	0	0	0	0.02	0	0	0	0	0.06	0.02	0	0	0	0	0	0

Table 13. Continued.

Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
	Survey Sites																
Family Zanclidae (Moorish Idol)																	
Zanclus cornutus	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0
Family Siganidae (rabbitfishes)																	
Siganus argenteus	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0
Family Acanthuridae (surgeonfishes)																	
Acanthurus blochii	0	0	0	0.02	0	0.05	0.24	0	0	0.22	0	0.18	0.4	0	0	0	0
Acanthurus xanthopterus	0	0	0	0.38	0	0	0.4	0	0	0.3	0	0	0	0.02	0	0	0
Zebrasoma veliferum	0	0	0	0	0	0	0	0	0.03	0	0.02	0.01	0.06	0	0	0	0
Family Balistidae (triggerfishes)																	
Balistoides viridescens	0	0	0	0.02	0	0	0	0	0.03	0	0	0.01	0	0	0	0	0
Rhinecanthus aculeatus	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
Family Tetraodontidae (pufferfishes)																	
Canthigaster solandri	0	0	0	0.02	0	0	0	0	0.01	0	0.02	0	0.04	0	0	0	0

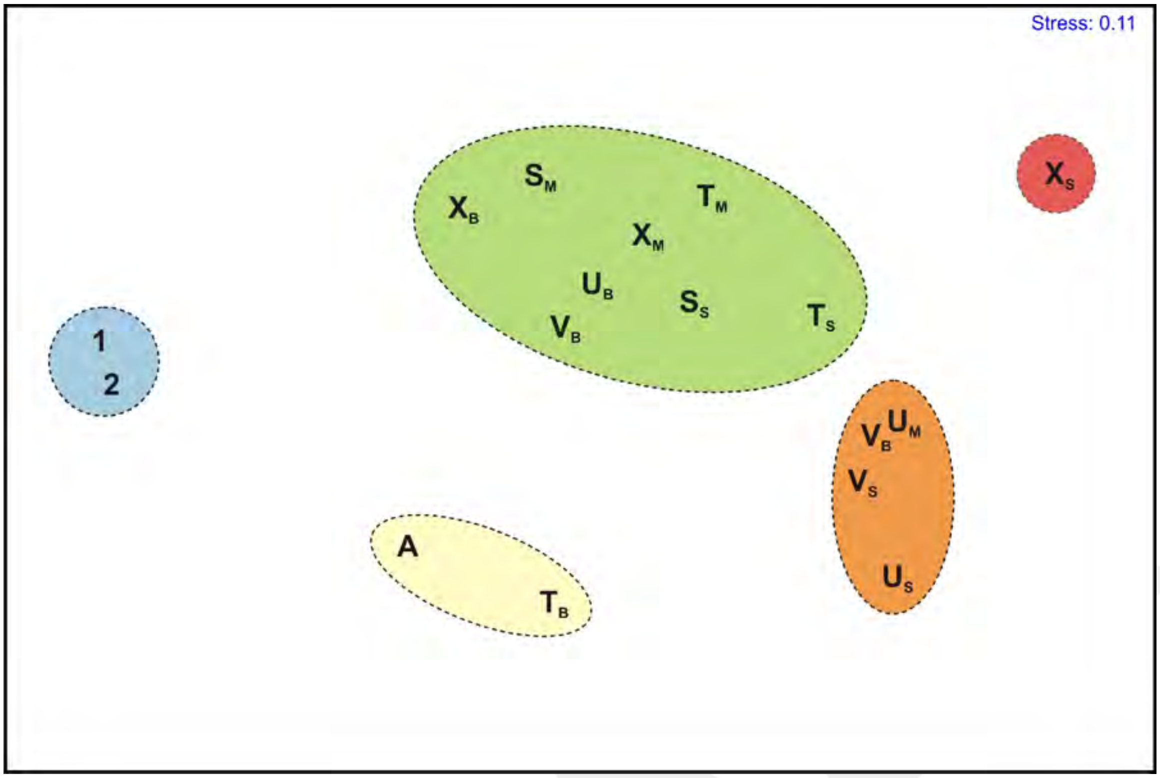

Figure 12. Multiple dimensional scaling (MDS) analysis of fish assemblages observed on transects in Inner Apra Harbor. Five distinct groups are recognized based upon similarities in fish faunal composition. Transect abbreviations are given in Table 12.

species such as cardinalfishes, damselfishes and gobies favored corals, debris, shells, sand, soft corals, and the wharf wall and pilings. Species that were active swimmers, such as butterflyfishes (Chaetodontidae), emperors (Lethrinidae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), sweetlips (Haemulidae), trevallys and jacks (Carangidae), etc., were found in the water column directly adjacent to the wharves.

On the reef at Abo Cove, cardinalfishes were observed with corals or rock, gobies with sand, mullet (Mugilidae) with rubble or sand, and a snapper with sand (Table 14). Visibility was exceptionally poor at Abo Cove during the survey, and it is expected that other species listed for the wharf transects would be present as well, particularly at high tide. The harbor floor transects, also surveyed under conditions of poor visibility, had burrowing gobies associated with fine sand, only (Table 14).

Threatened and Endangered Species

High turbidity levels in Inner Apra Harbor limited visibility (<5 m)of highly motile species, especially vertebrate organisms. Despite this constraint, we observed a single green

Table 14. Habitat and microhabitat associations of fishes in the Inner Apra Harbor. Associations listed are based upon qualitative observations. Station codes are defined in Table F1. Habitat codes are: SB = soft bottom (harbor floor), R = coral reef, and W = wharf. Microhabitat codes are: C = coral, D = debris, Rb = rubble, Rk = rock, Sc = soft coral, Sd = sand, Sh = shell, Wc = water column, and Wp = wharf wall and pilings.

	Survey Sites																
Taxon	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Clupeidae																	
Spratelloides delicatulus		W;Wc															
Family Mugilidae																	
Moolgarda seheli	R;Rb,Sd																
Family Holocentridae																	
Neoniphon opercularis					W;Wp				W;D								
Sargocentron spiniferum				W;Wp													
Family Serranidae																	
Epinephelus maculatus									W;D								
Family Apogonidae																	
Apogon lateralis		W;C,Wp	W;C,Wp	W;C,Wp		W;D			W;D			W;D	W;C		W;D		
Apogon leptacanthus	R;C,Rk	W;C,Sc	W;C,Wp		W;C,Wp				W;D			W;D	W;C		W;D		
Archamia biguttata					W;C,Wp				W;D								
Archamia fucata						W;D						W;D					
Cheilodipterus quinquelineatus	R;C,Rk				W;C,Wp			W;Wp	W;D	W;Wp	W;Wp	W;D					
Foa brachygramma?									W;D								
Rhabdamia cypselurus?			W;C,Wp	W;C,Wp	W;C,Wp				W;D				W;C				
Sphaeramia orbicularis														W;Wp			
Family Carangidae																	
Caranx ignobilis				W:Wc								W;Wc	W;Wc				
Caranx melampygus				W;Wc					W;Wc			W;Wc					
Scomberoides lysan				W;Wc													
Gnathanodon speciosus											W;Wc	W;Wc					
Family Lutjanidae																	
Lutjanus ehrenbergi?									W;Sd								
Lutjanus fulvus	R;Sd	W;Wc				W;Wc						W;Wc					
Family Lethrinidae																	
Lethrinus harak							W;Wc					W;Wc					
Family Haemulidae																	
Plectorhinchus albovittatus									W;D			W;Wc					
Family Chaetodontidae																	
Chaetodon auriga									W;D			W;Wc	W;Wp	W;Wp			
Chaetodon bennetti		W;Wc					W;Wc		W;D	W;Wc	W;Wc	W;Wc					
Chaetodon ephippium				W;Wc		W;Wc			W;D			W;Wc	W;Wp				
Chaetodon lunula					W;Wc					W;Wc	W;Wc		W;Wp				
Chaetodon lunulatus					W;Wc								W;Wp				
Chaetodon unimaculatus										W;Wc							
Chaetodon ulietensis				W;Wc	W;Wc		W;Wc		W;D			W;Wc					

Table 14. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Chaetodontidae																	
Heniochus chrysostomus									W;D								
Family Pomacentridae																	
Amblyglyphididon ternatensis			W;Wc		W;C,Sc		W;Wp	W;Wp		W;Wp	W;Wp						
Abudefduf sexfasciatus											W;Wp		W;Wp				
Chromis viridis		W;C,Wp	W;C,Wp	W;C,Wp						W;C,Wp							
Chrysiptera traceyi			W;Wp														
Neopomacentrus violascens					W;Wp			W;Wp	W;D					W;C,Wp			
Pomacentrus blue spot								W;Wp					W;Wp				
Pomacentrus amboinensis				W;Wp	W;Wp		W;Wp		W;D	W;Wp	W;Wp			W;Wp			
Pomacentrus pavo			W;D,Wp		W;C,Wp					W;Wp	W;Wp		W;Wp	W;Wp			
Family Labridae																	
Cheilinus fasciatus						W;Wc	W;Wc										
Cheilinus trilobatus												W;Wc					
Family Blenniidae																	
Ecsenius bicolor		W;Sh,Wp															
Meiacanthus atrodorsalis							W;Wp,Sh										
Petroscirtes mitratus				W;Sh,Wp													
Blue dorsal spot tube blenny														W;Wp			
Family Gobiidae																	
Amblygobius nocturnus						W;Wp			W;D,Sd			W;Sd					
Amblygobius phaelena			W;Wp	W;Wp	W;Wp		W;Wp		W;D,Sd		W;Wp	W;Sd	W;Wp				
Asterropteryx semipunctatus														W;Wp			
Cryptocentrus strigilliceps	R;Sd														W;Sd		
Cristatogobius sp. A						W;Sd			W;Sd			W;Sd					
Ctenogobiops feroculus	R;Sd															SB;Sd	SB;Sd
Gnatholepis cauerensis	R;Sd					W;Sd			W;Sd								
Oplopomus oplopomus									W;Sd			W;Sd				SB;Sd	
Oxyurichthys papuensis									W;Sd			W;Sd				SB;Sd	SB;Sd
Paragobiodon lacunicolus							W;C										
Priolepis cincta					W;Wp					W;Wp	W;Wp						
Family Zanclidae																	
Zanclus cornutus									W;Wc								
Family Siganidae																	
Siganus argenteus									W;Wc								
Family Acanthuridae																	
Acanthurus blochii				W;Wc		W;Wc	W;Wc			W;Wc		W;Wc	W;Wc				
Acanthurus xanthopterus				W'Wc			W;Wc			W;Wc				W;Wp			
Zebrasoma veliferum									W;Wc		W;Wc	W;Wc	W;Wc				

Table 14. Continued.

Taxon	Survey Sites																
	A	S_M	S_S	T_M	T_S	T_B	U_M	U_S	U_B	V_M	V_S	V_B	X_M	X_S	X_B	1	2
Family Balistidae																	
Balistoides viridescens				W;Wc					W;D,Wp			W;D,Wc					
Rhinecanthus aculeatus				W;Wp													
Family Tetraodontidae																	
Canthigaster solandri				W;Wp					W;D,Wp		W;D,Wc		W;Wp				

turtle from the boat in waters between Abo Cove and the southern end of Victor Wharf. *Chelonia mydas* is listed as a threatened species under the U.S. Endangered Species Act. The individual that we observed was small (0.5–1.0 m carapace length), and it dove immediately after a quick breath. Because of the fine-grained, muddy composition of the shoreline of Inner Apra Harbor, the beaches in the vicinity are not considered as potential nesting sites for endangered and threatened marine turtles known to occur in the seas around Guam. The nearest documented nesting beaches are near Gabgab Beach, in the outer harbor. Therefore, we presume the individual that we sighted was foraging.

Habitat Areas of Particular Concern (HAPC)

None of the three areas of Apra Harbor recognized by Paulay et al. (2001a) for their species richness and unique biota are encompassed by Inner Apra Harbor. These authors described the inner harbor as the most altered area with Apra Harbor, while remarking on the presence of uncommon species, such as *Porites convexa*, and the abundance of the hammer oyster *Malleus decurtatus* on wharf faces.

Inner Apra Harbor lies at the extreme end of the gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments. The harbor continues to support thriving marine communities, despite the extensive dredging and filling operations that significantly altered the area after World War II. Data from this study indicate that Abo Cove is unique and deserves special attention in managing the natural resources of the inner harbor. As Paulay et al. (2001a) noted, Apra Harbor is unlike other major ports, where communities of marine organisms tend to be greatly degraded. Therefore, we advise decision-makers not to extrapolate data from the current study to other areas within Inner Apra Harbor that were not within the scope of this study, especially the inner Abo Cove embayment and the mangrove area at the mouth of the Atantano River.

SUMMARY

This study shows a clear difference between the most authentic inner harbor habitats at Abo Cove and the manmade wharfs. Because of its restricted spatial extent, the distinct benthic assemblages, and the relatively high coral cover, Abo Cove deserves special attention in managing the natural resources of the inner harbor. Ironically, the artificial and most anthropogenically impacted habitats of the wharfs might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 30 species, or about 10% of the coral fauna of Guam (see Randall, 2003). The predominant corals were massive *Porites* spp., one of which exceeded 1 m in diameter at Abo Cove. The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea* *purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves.

Macroinvertebrates communities in the inner harbor were only moderately diverse, with 30 species observed on or near transects. As for corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surface. On the harbor floor, macroinvertebrates were limited to scattered debris that provided on the only hard substrate available. Macroinvertebrate assemblages in the inner harbor were dominated by suspension-feeding species, which comprised 100% of the species occurring on transects and 90% of all species observed. Except for a single species of marine snail, no macroinvertebrates were observed on the soft sediments of the harbor floor.

The species richness and diversity of the fish fauna within the Inner Harbor are relatively low compared to habitats elsewhere on Guam (Donaldson, unpublished data). However, the fauna is highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves, and the microhabitats found on or adjacent to those wharves was utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the stations. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

Perhaps the only relatively unique species present at most or all stations are the bottom-dwelling, burrowing goby species that may be specific only to sand bottoms in back bay or estuarine areas. The extent of the distribution of these species is not well known, however, because of the generally poor visibility encountered in such areas (i.e., Inner Apra Harbor and Sasa Bay in western Guam, and the estuaries of the Pago, Ylig, and Talofofo Rivers in eastern Guam).

RECOMMENDATIONS

During the planning phase for construction and renovation of facilities and training sites surveyed in Inner Apra Harbor in this study, the following recommendations should be given consideration.

1. **Abo Cove and its associated coral reefs deserve special attention in managing the natural resources of the inner harbor.**
   Despite its restricted spatial extent, Abo Cove is unique within the inner harbor because of the coral reefs that have developed there. The reef is characterized by relatively high coral cover and the largest coral colonies in the area studied. Further, Abo Cove supports distinct benthic assemblages of sponges, corals, and macroinvertebrates (see Figures 8, 9, and 11). Therefore, renovation and construction activities requiring dredging and filling in and adjacent to Abo Cove should have the lowest priority. A minimum buffer zone of 400 feet should be maintained between Abo Cove and all dredge and fill activities in the inner harbor.

If Abo Cove is selected for development, a compensatory mitigation plan should be developed for review by the appropriate agencies and authorities. To the extent possible and appropriate, any mitigation project should be “on-site” and “in-kind” (PBS&J, 2008), with consideration given to relocation of the corals to a similar environment, like that in the outer portion of Sasa Bay in the outer harbor. Biological monitoring should be required for any project that is proposed for construction in the vicinity of Abo Cove.

2. **Floating turbidity curtains, extending from the surface to the lagoon floor, should be placed completely around all dredge and fill sites, and turbidity curtains should be routinely monitored and maintained to contain silt produced by construction.** Dredge and fill operations produce large quantities of fine silt particles suspended in the water column. Turbidity and sedimentation are significant problems for coral reefs surrounding high islands or in coastal areas of continents. Sediments may have an energetic cost to the coral that must cleanse its surface, resulting in slower growth rates and in less energy available for reproduction (Tomascik and Sander, 1987; Wolanski et al., 2003). Sediments can also interfere with larval recruitment on coral reefs by interfering with the chemosensory ability of coral larvae seeking the appropriate chemical signals from preferred settlement substrates, such as coralline algae (Richmond, 1997). Turbidity curtains can be effective in confining suspended sediments when properly deployed and maintained. Removal of the turbidity barriers and the related components is vital once the project activities are complete. Failure to do so can cause the barrier to come loose from its anchors and entangle benthic and other marine organisms (PBS&J, 2008).

3. **All dredge and fill operations should be suspended during the period of the annual coral spawning event in Guam waters.** Some 85% of reef-building corals are spawners, i.e., reproduction occurs after the release of gametes into the water, where fertilization takes place (Richmond, 1997). Multispecies mass-spawning events occur during limited periods each year. To maximize reproductive success, most spawning species release their gametes over a 5–8-day period that is related to the lunar cycle. Studies in Guam revealed that peak spawning occurs 7–10 days after the full moon in July (Richmond and Hunter, 1990). Because suspended sediments may interfere with egg-sperm interactions in the fertilization process (Richmond, 1997; Wolanski et al., 2003), dredge and fill operations can affect coral reproduction on reefs far down current of the actual construction activities.

   Construction windows are a management tool to map out the times of year during which coastal construction may be limited due to the presence of threatened or endangered species or other sensitive marine life (PBS&J, 2008). Construction windows may consider wildlife activity such as coral spawning and coral bleaching. U.S. Army Corps of Engineers permits for maintenance dredging of the Naval Base require that dredging operations cease during annual coral spawning periods in Guam (M.E. Guarin, P.E., Construction Management Engineer, NAVFAC OICC Marianas, personal communication, April 27, 2004).

4. **Marine biological communities should be monitored during and after dredge and fill operations in Inner Apra Harbor.** Monitoring studies on small, tropical islands have shown that precautions for environmental protection can limit the effects of dredge and fill operations on nearby marine communities.

Amesbury et al. (1982) identified few measurable effects related to construction of the airport runway extension at Weno Island, Chuuk [= Moen Island, Truk]. However, these authors reported that fluctuations in species richness, percent cover, and population density of several taxa occurred during the construction period. Where siltation was heaviest, the decline in coral coverage was significant, and no evidence of new coral recruitment was found one year after the completion of runway construction. Marine plants, macroinvertebrates, and reef fishes also declined at those monitoring stations that were inundated with sediments.

Biological monitoring should be required for any project that is proposed for construction in Inner Apra harbor , especially in the vicinity of Abo Cove, so that any damage to coral communities caused by sedimentation can be identified promptly and so that the necessary measures can be taken to minimize any damage. Monitoring is necessary to determine any direct or indirect biological impacts to the ecosystem caused by physical and/or chemical changes to the environment as a result of the project.

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MARINE BIOLOGICAL SURVEY OF OSCAR AND PAPA WHARVES, INNER APRA HARBOR, GUAM

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INTRODUCTION

This report describes marine natural resources surveyed at Oscar and Papa Wharves, Inner Apra Harbor, Guam during March, 2010. This report compliments previous surveys conducted at other wharves, as well as patch reefs and the harbor bottom within the Inner Apra Harbor (Smith et al., 2008).

Inner Apra Harbor is a natural embayment formed by tectonic activity along the Cabras Fault, separating the volcanic Tenjo Block in central Guam from the limestone Orote Block immediately to the west (see Tracey et al., 1964 for structural details). Rotation of the Orote Block resulted in subsidence of the eastern portion of the block adjacent to the Cabras Fault line. Accompanying rotation, the sea flooded into the slumped areas, forming Apra Harbor, a deep-water lagoon bounded on the north by Cabras Island and the long, curving Glass Breakwater. Two rivers—the Apalacha and Atantano—drain the volcanic mountain land to the east of Apra Harbor and empty into the inner harbor (Randall and Holloman, 1974).

Although naturally formed, Inner Apra Harbor has been extensively modified by dredging, construction, and landfills by the U.S. Navy since 1945 (Paulay et al., 2001a). The inner harbor was dredged, changing the southernmost part of the original lagoon from a reef-choked, silty embayment into a harbor with a nearly uniform depth and mud bottom. Fill projects created the Dry Dock Peninsula, Polaris Point, and manmade shorelines along the northeastern and southeastern boundaries of the harbor. These and other developments in the outer harbor (e.g., construction of Glass Breakwater) reduced water exchange between the harbor and the Philippine Sea, creating a gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments from the entrance to the outer harbor to the inner harbor environment. The only portion of the inner harbor remaining unchanged is the mangrove area at the mouth of the Atantano River.

Randall and Holloman (1974) reported living *Pocillopora* and *Porites* corals on the wharf and dock structures in the inner harbor. Paulay et al. (2001a) found that artificial surfaces in the inner harbor supported diverse fouling communities, including both indigenous and introduced species. They noted the presence of *Porites convexa*, known in Guam from only a few locations. In a more recent survey, Smith et al. (2008) found both *Pocillopora* and *Porites* corals to be relatively abundant on wharf faces, as well, with *Pocillopora damicornis* and *Porites lutea* being especially common among the 13 species observed on wharf face transects. With the inclusion of non-scleractinian anthozoans, they found 28 species of corals and related organisms from 11 families and 13 genera on or adjacent to transects (including patch reefs on the harbor bottom and on miscellaneous scrap found there

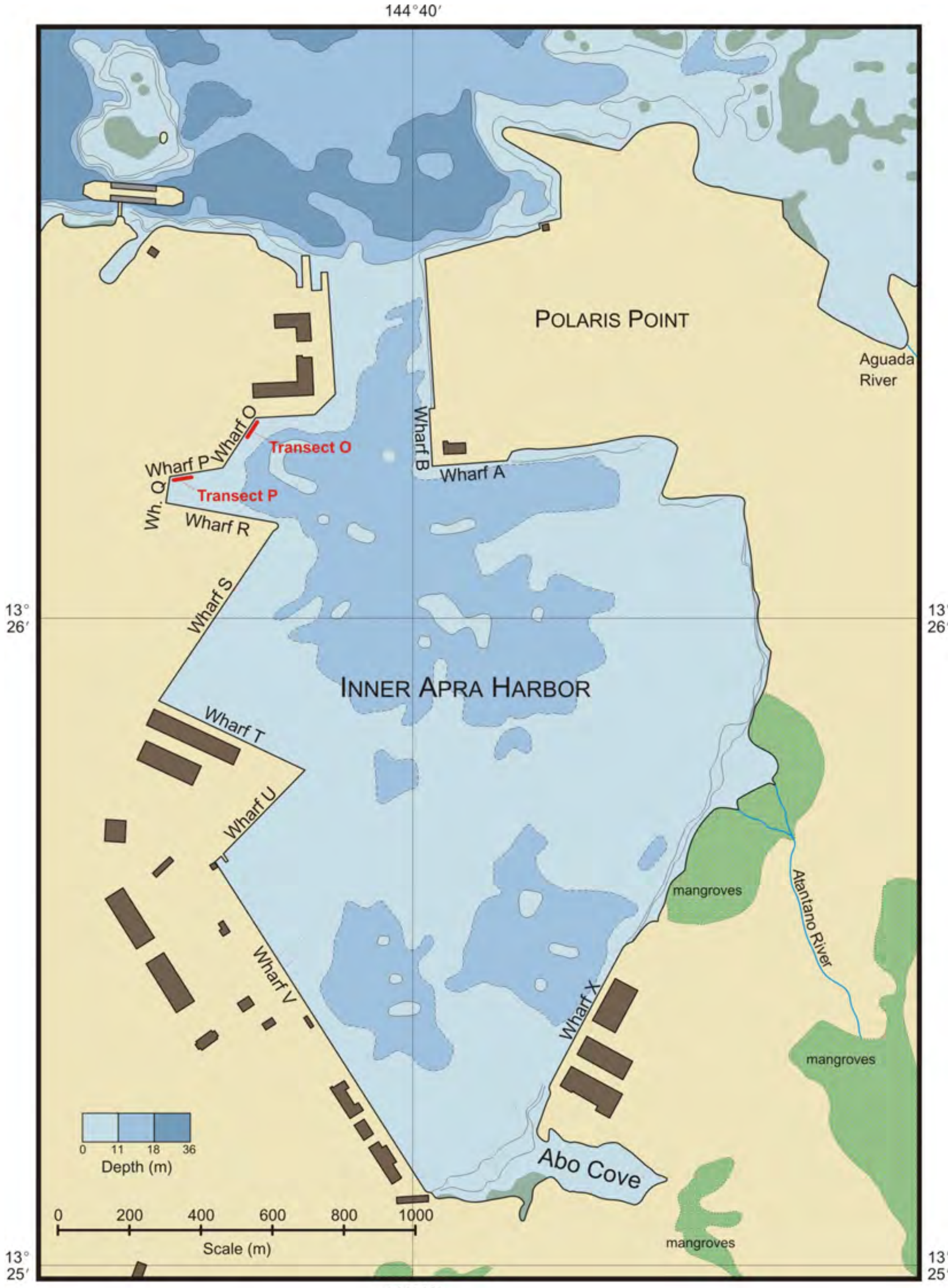

Figure 1. Map of Inner Apra Harbor showing geographic locations of transect sites at Oscar and Papa Wharves.

Randall and Holloman (1974) also remarked about the abundance of the hammer oyster *Malleus decurtatus* on wharf faces in Inner Apra Harbor. Smith et al. (2008) found this species to be very common, especially on Victor Wharf, as well.

Wharves and adjacent structures, including silt or fine sediment substrates at the base of wharves, support small assemblages of fishes (Smith et al., 2008). Juvenile fishes, especially damselfishes (Pomacentridae), such as *Chromis viridis* and *Pomacentrus pavo*, cardinalfishes (Apogonidae), and diminutive gobies (Gobiidae), seek shelter amongst corals, benthic algae, and man-made structures along wharf faces. Burrowing gobies may be common in the sediments at the base of these faces. Free-ranging fishes, such as the surgeonfish *Acanthurus blochii* (Acanthuridae), the snapper *Lutjanus fulvus* (Lutjanidae), and the trevallys *Caranx melampygus* and *C. sexfasciatus*, (Carangidae) were observed swimming near wharf faces and adjacent jetsam and debris. Three invasive fish species were found along some wharf faces, as well (Smith et al., 2008). These include two damselfishes, *Amblyglyphididon ternatensis* and *Neopomacentrus violescens*, and a cardinalfish, *Rhabdamia cypselerus*.

Relocation of elements of the Marine Expeditionary Force (MEF) from Okinawa to Guam by the Marine Corps will require renovation of existing port facilities to accommodate MEF embarkation, as well as construction of various new operations facilities in support of the MEF mission. Furthermore, new training areas and associated facilities are proposed for selected areas on Guam. These developments require extensive surveys that locate, identify, and assesses the natural resources of Guam, and also identify and assess invasive species that might expand their ranges within Guam's waters.

Data from these surveys are expected to serve as a guide for decisions affecting land and coastal use for proposed construction and renovation of facilities and training sites on Department of Defense and contractor-controlled lands in the Inner Apra Harbor of Guam.

Scope of Work

1. Conduct field surveys for fish, corals, macroinvertebrates, and macrophytes of harbor bottom and sheet piling wharf faces at Oscar and Papa Wharves in Inner Apra Harbor.

2. Prepare a technical report on fishes, corals, macroinvertebrates, macrophytes, essential fish habitat evaluation, and assessment of endangered species.

3. Attend project team meetings/conferences calls.

METHODS

Survey Site Selection

Both Oscar and Papa Wharves (Figure 1) are obstructed by large shipyard facilities that limited access to wharf faces. During the survey period, two large crane barges were moored at Oscar Wharf while a large dry dock occupies virtually all of Papa Wharf's main face. Therefore, transect lengths were limited to a 50-m stretch of wharf face at Oscar Wharf and a 50-m stretch of wharf face at the back of Papa Wharf where this wharf s with Romeo Wharf. GPS coordinates were recorded for transect locations at each wharf.

Benthic Cover

Benthic cover was surveyed along 50-m transects established at a depth of 6 m for coral, invertebrate, and fish surveys at Oscar and Papa Wharves. Marine plant communities and substrate types in each zone were quantified by a modified point-quadrat method (Tsuda, 1972). This method consists of identifying and recording substrate types and organisms under the points of intersection of strings stretched across a 0.25-m^2 (50 cm x 50 cm) quadrat. Four strings stretched from each side of the quadrat provide 16 points (intersections). The quadrat was placed randomly at 5-m intervals along the length of the transect. The quadrat was deployed a total of 10 times, providing 160 data points on a 50-m transect. Percent cover was calculated from these points. Limited visibility in the inner harbor precluded documentation of benthic flora and fauna with photoquadrat records. Species within the study area, but not encountered along the transect line, were also recorded.

Corals

Coral communities were quantified along the transects by an observer using the point-quarter method of Cottam et al. (1953). Points were assigned at 5-m intervals along each transect. Each point served as a focus of four equal-sized quadrants arrayed around the point. Within each quadrant, the coral closest to the central point was located. This coral's identity, distance from the point, length, and width were recorded. If no corals lay within 1 m of the point, that quadrant was recorded as having no corals. From the recorded data, community and species-specific population density of colonies, percent coverage, and frequency of occurrence were then computed with the following equations from Cottam et al. (1953):

Total Density Of All Colonies = Unit Area / (Average Point-To-Colony Distance)^2
Relative Density Of A Species = 100 * Number Of Colonies Of The Species / Number Of All Colonies
Absolute Density Of A Species = Percent Density * Total Density / 100
Total Percent Coverage Of All Species = Total Density * Average Coverage Of All Species
Relative Coverage Of A Species = Species Density * Average Coverage of the Species

Population data for each species were also calculated, including the number of colonies, average colony size, standard deviation of colony size, and minimum and maximum colony size. To record the less common species not recorded by the quantitative survey, a list of species was also assembled by swimming along the entire transects and recording all species seen within 2 m of the line.

Macroinvertebrates

All conspicuous solitary epibenthic macroinvertebrates occurring within 1 m of either side of the transect lines were identified and enumerated by an observer swimming along the transect line. For this study, conspicuous is defined as being larger than 50 mm in size and as being clearly visible to an observer without need of overturning rocks or digging into the substrate. Cryptic, microscopic, nocturnal, and highly motile species that avoid humans (e.g., crabs and shrimps) were not included within the scope of this study. Species diversity and abundance were recorded in 10-m intervals along the transect line. Therefore, for statistical purposes, each belt transect consisted of five 20-m^2 replicate plots, except where noted.

Similarities in structure of macroinvertebrate assemblages on the two transects were calculated by the Bray-Curtis similarity method with PRIMER ver. 6 (Clarke and Gorley, 2006). Species of macroinvertebrates observed in the study area, but not encountered along the transect line, were also recorded but not included in the similarity analyses.

Fishes

Fishes were surveyed visually along transect lines. Observations were constrained by poor visibility and all species had to be counted on a single pass along the transect line. Along both wharf faces, three transects were run (where possible), respective of depth, just below the surface(subsurface), at mid-depth (the principal transect line), and at the bottom of the wharf wall. All fishes observed 0.5m above or below the line, were counted on subsurface and mid-depth transects; at the bottom, all fishes observed 1 m to the seaward side (away from the wharf face) of the line were counted. These methods provided estimates of density (no. individuals/m_2) for each species. Fishes were identified to species. Identifications followed Myers (1999) and Myers and Donaldson (2003), except where more recent taxonomic studies were relevant. Reference photographs were taken with an underwater digital camera but image quality tended to be extremely poor because of turbid conditions. For estimates of species diversity, standard measures of species richness, species diversity, and similarity were calculated and compared between stations with PRIMER vers. 6; DIVERSE PROCEDURE; Clarke and Gorley, 2006). Multidimensional scaling (PRIMER vers. 6; MDS procedure) was used to examine similarities between stations based upon Bray-Curtis coefficients calculated for each. This test indicates relative distances between samples based upon their similarities in assemblage structure. Points found close together represent samples that were very similar in species composition while those far away represented different assemblage structures (Clarke and Gorley, 2006). Analysis of Similarities (PRIMER, ver. 6; ANOSIM procedure, square root transformed) was used to test the null hypothesis that there were no differences in assemblage structure between groups of observations (depth of transect) at the stations (wharves).

Essential Fish Habitat

Qualitative measures of habitat utilization by fishes were limited to observations of association between species and habitat and microhabitat types. Major habitat types were the vertical surfaces of both Oscar and Papa Wharves (= wharf) and the harbor floor (= soft bottom). Microhabitats included corals, mollusc shells (mainly *Malleus decurtatus* and *Spondylus squamosus*), debris (hanging and deposited on the bottom), silt, and the water column).

RESULTS AND DISCUSSION

Because of the length of the transects (50m) at each wharf, no attempt was made to determine the starting and ending coordinates of each transect. GPS coordinates describing the general location of each 50 m transect were N 13.43824, E 144.66241 for Oscar Wharf and N 13.43658, E 144.66032 for Papa Wharf.

Benthic Cover

Mean surface coverage of the vertical substrate along the transects at Oscar and Papa Wharves is presented in Figure 2. The harbor floor not sampled. Substrate coverage was divided into seven abiotic and biotic features at the sites. The mean biotic coverage in ten quadrat samples was 20.63 % at Oscar Wharf and 55.63 % at Papa Wharf. Sponges were the predominant biotic cover organisms at Oscar Wharf, ranging from 0–18.75 percent cover; macroalgae were predominant at Papa Wharf, ranging from 12.5–62.5 percent cover. Bray-Curtis similarity analysis (fourth root transform, cluster mode: group average) indicated 83.91% resemblance of the benthic cover data at the two wharves. A list of marine plants observed at the two sites is given in Table 1.

Corals

Size-frequency distributions of the six species of scleractinian corals encountered on transects at Oscar and Papa Wharves, Inner Apra Harbor are presented in Table 2. An additional 13 species of scleractinian corals were observed on wharf faces adjacent to the transects (Table 3). One species of non-scleractinian anthozoan and one species of hydrozoan were also recorded. Therefore, a cumulative total of 21 species of corals and related organisms, representing 13 families and 16 genera was observed at the study site.

Species richness was highest at Oscar Wharf, where six species occurred on the transect; only three species occurred on the transects at Papa Wharf. *Leptastrea purpurea*, *Pocillopora damicornis* and *Porites lobata* were the most frequently observed species. Three species, *Dendrophyllia* sp., *Psammocora haimeana, and Porites rus* occurred on the transect only at Oscar Wharf.

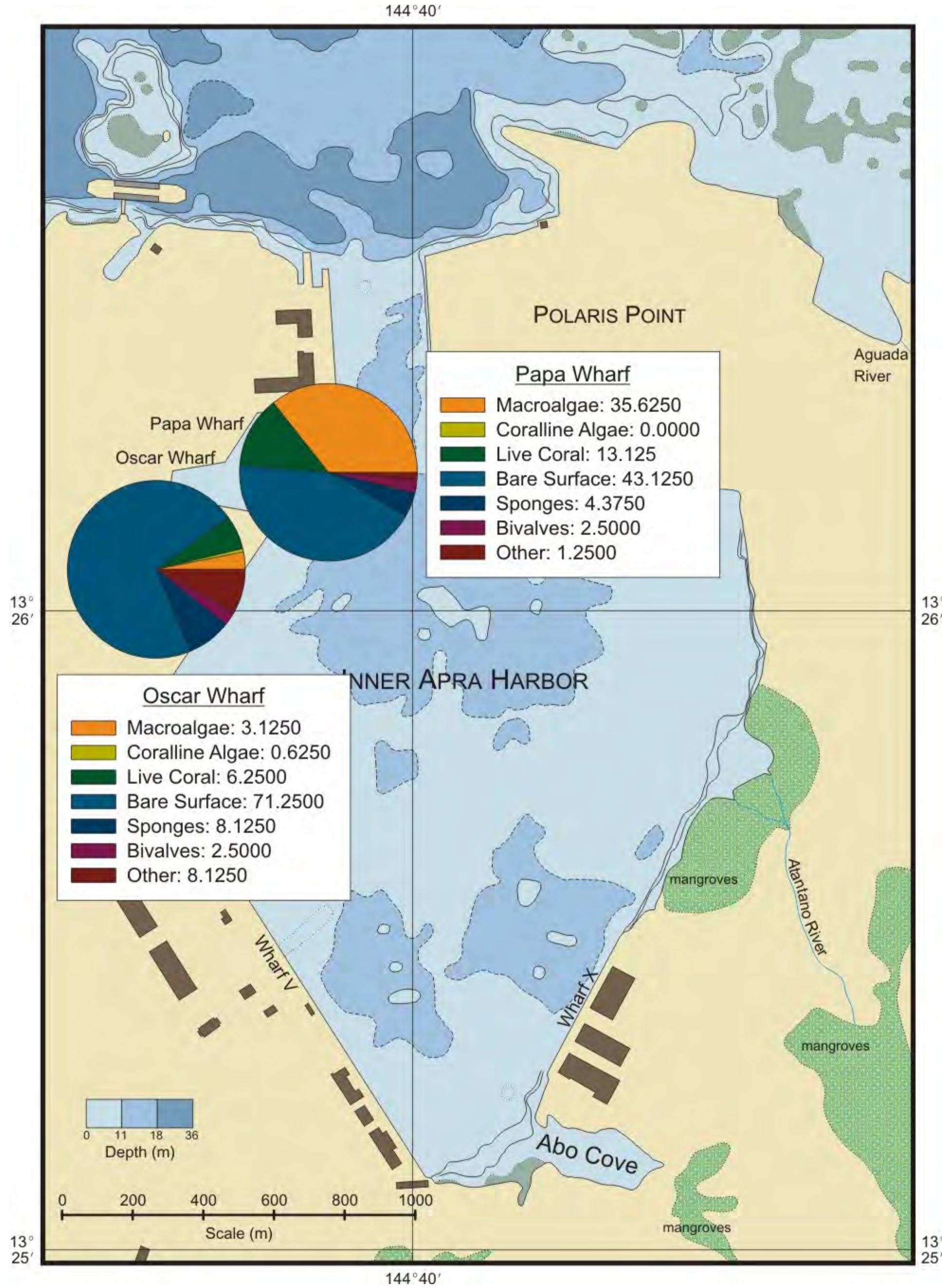

Figure 2. Mean surface coverage of the vertical substrate along the transects at Oscar and Papa Wharves

Table 1. Taxonomic list of marine plants observed at depths of 0–6 m on the faces of Oscar and Papa Wharves. Phylogenetic arrangement follows Lobban and Tsuda (2003).

	Oscar Wharf	Papa Wharf
Cyanophyta:Cyanophyceae		
cf. *Lyngbya aestuarii*	●	○
Rhodophyta:Rhodophyceae		
Galaxaura filamentosa	●	○
Peyssonnelia rubra		●
Heterokontophyta:Phaeophyceae		
Dictyota bartayersiana	●	●
Padina boryana	●	●
Chlorophyta:Chlorophyceae		
Enteromorpha clathrata	●	○
Bryopsis sp.	●	○

Table 2. Size-frequency distributions of coral species recorded on transects Oscar and Papa Wharves, Inner Apra Harbor. N_i = number of colonies. Mean, SD (standard deviation), and Range refer to colony size in cm^2.

Location	Species	N_i	Mean	SD	Range
Oscar Wharf	*Leptastrea purpurea*	15	7.36	9.355	1.18–29.45
	Pocillopora damicornis	7	24.15	20.627	4.71–65.97
	Porites lobata	7	4.82	5.038	0.79–14.14
	Tubastraea coccinea	2	3.63	1.805	2.36–4.91
	Porites rus	1	–	–	8.25
	Psammocora haimeana	1	–	–	1.18
Papa Wharf	*Pocillopora damicornis*	21	346.67	364.357	0.79–1,154.54
	Leptastrea purpurea	17	13.32	14.513	1.57–44.18
	Porites lobata	2	214.71	296.701	4.91–424.51

Table 3. Species of scleractinian and hydrozoan corals observed at Oscar and Papa Wharves. A filled circle (●) indicates presence of a species, and an open circle (○) indicates that the species was not recorded at that site. Phylogenetic arrangement follows Randall (2003).

	Oscar Wharf	Papa Wharf
Hydrozoa:Milleporidae		
Millepora tuberosa	●	○
Anthozoa:Pocilloporidae		
Pocillopora damicornis	●	●
Anthozoa:Acroporidae		
Astreopora myriophthalma	●	●
Astreopora randalli	○	●
Anthozoa:Agariciidaea		
Leptoseris mycetoseroides	●	○
Anthozoa:Siderastreidae		
Psammocora haimeana	●	●
Anthozoa:Fungiidae		
Herpolitha weberi	●	○
Anthozoa:Poritidae		
Porites compressa	○	●
Porites lichen	●	○
Porites lobata	●	●
Porites rus	●	●
Anthozoa:Faviidae		
Diploastrea heliopora	○	●
Leptastrea purpurea	●	●
Oulophyllia levis	○	●
Anthozoa:Rhizangiidae		
Culicia rubeola	●	○
Anthozoa:Mussidae		
Lobophyllia corymbosa	●	○
Lobophyllia hemprichii	○	●

Table 3, continued.

	Oscar Wharf	Papa Wharf
Anthozoa:Pectiniidae		
Pectinia paeonia	○	●
Anthozoa:Dendrophylliidae		
Dendrophyllia sp.	●	●
Turbinaria reniformis	○	●

Quantitative analysis of the coral species encountered on each transect is presented in Table 4. *Pocillopora damicornis* was predominant in coverage and averaged 71.5% relative coverage between the two transects. *Leptastrea purpurea* had the second highest relative coverage (18.2%) between the two transects. A Bray-Curtis Similarity Index value calculated from 4^{th}- root transformed relative coverage data indicated a similarity of 68.6% between coral assemblages at the two wharves. The data set was too small, however, to compare assemblage structures by non-metric multidimensional scaling (NMDS) analysis.

Macroinvertebrates

Mean densities of conspicuous, solitary invertebrates at Oscar and Papa Wharves are given in Table 5. Seventeen species of solitary macroinvertebrates were encountered on the transect at Papa Wharf, and 12 species were recorded on the transect at Oscar Wharf. As noted at other sites in Inner Apra Harbor (Smith et al., 2008), 100 percent of the macroinvertebrates encountered on the transects were suspension feeders. Bivalve molluscs (7 species) and solitary ascidians (8 species) dominated the macroinvertebrate fauna at both wharves, and mean densities were generally greater at Papa Wharf. The bivalves *Malleus decurtatus* and *Spondylus squamosus* were remarkably more abundant at Papa Wharf, as was the ascidian *Rhopalaea circula*. Mean densities ranged from <1.0 individual/20 m^2 (several species) to 55.0 individuals/20 m^2 (*Spondylus squamosus* at Papa Wharf). Spondylid bivalves occurred at the greatest density encountered at both sites, with a cumulative density of 70.0 ± 30.9 individuals/20 m^2. Mean density of all species at Oscar Wharf was 45.4 ± 43.71 solitary invertebrates/20 m^2, and 207.6 ± 199.47 solitary invertebrates/20 m^2 at Papa Wharf. Bray-Curtis similarity analysis (fourth root transform, cluster mode: group average) indicated 71.2% resemblance of the solitary invertebrate densities in the two communities.

α-level diversity of conspicuous epibenthic invertebrates, including both solitary and colonial forms, at Oscar and Papa Wharves is given in Table 6. A total of 36 species was observed during the survey, 28 species at Oscar Wharf and 33 species at Papa Wharf. The two wharves share 75% of the total recorded fauna. As noted above for invertebrate densities on transects, α-diversity was dominated by bivalve molluscs (12 species) and ascidians (10 species). Bray-Curtis similarity analysis (fourth root transform, cluster mode: group average) indicated 80.0% resemblance of the α-diversity in the two invertebrate communities.

Suspension-feeding invertebrates were predominant, making up some 86% of the fauna at the two sites. Grazing herbivorous gastropods were observed just above the water-line on the faces of both wharves, as was a browsing herbivorous grapsid crab. The deposit-feeding sea cucumber *Synapta maculata* was observed on the face of Papa Wharf. No predatory invertebrates were observed at either wharf.

Two noteworthy species of macroinvertebrates were observed at Oscar and Papa Wharves. The ahermatypic coral *Dendrophyllia* sp. was recorded on vertical wharf faces of both transects.

Table 4. Population density, frequency, and coverage of coral species recorded on transects at Oscar and Papa Wharves, Inner Apra Harbor, Guam.

Location	Species	N_i	Relative Density	Absolute Density	Frequency	Absolute Coverage	Relative Coverage
Oscar Wharf	*Leptastrea purpurea*	15	0.375	2.285	0.70	0.0021	0.3345
	Pocillopora damicornis	7	0.175	1.066	0.40	0.0033	0.5125
	Porites lobata	7	0.175	1.066	0.50	0.0007	0.1024
	No coral	7	0.175	1.066	0.40	0.0000	0.0000
	Dendrophylla sp.	2	0.050	0.305	0.20	0.0001	0.0220
	Psammocora haimeana	1	0.025	0.152	0.10	0.0000	0.0036
	Porites rus	1	0.025	0.152	0.10	0.0002	0.0250
Papa Wharf	*Pocillopora damicornis*	21	0.525	10.088	1.00	0.4453	0.9173
	Leptastrea purpurea	17	0.425	8.167	1.00	0.0139	0.0285
	Porites lobata	2	0.050	0.961	0.20	0.0263	0.0541

Table 5. Mean densities of conspicuous, solitary invertebrates at Oscar and Papa Wharves. Data given are means ± standard deviations of counts in five 10-m^2 quadrats. Phylogenetic arrangement follows Paulay (2003) for bivalves and Lambert (2003) for ascidians.

	Oscar Wharf	Papa Wharf
Cnidaria:Anthozoa		
Dendrophyllia sp.	1.40 ± 1.14	0.20 ± 0.45
Annelida:Polychaeta		
Sabellastarte spectabilis	0.20 ± 0.45	0.60 ± 0.89
Mollusca:Bivalvia		
Malleus decurtatus	2.00 ± 1.58	36.00 ± 23.69
Spondylus multimuricatus	4.00 ± 5.10	10.80 ± 2.77
Spondylus squamosus	13.00 ± 11.07	55.00 ± 23.98
Spondylus spp.	2.40 ± 2.61	11.20 ± 4.15
Ostreidae sp.	---	0.20 ± 0.45
Chama lazarus	6.20 ± 3.56	15.20 ± 7.05
Chama spp.	1.40 ± 1.34	1.20 ± 1.10
Chordata:Ascidiacea		
Ascidia ornata	---	0.40 ± 0.89
Phallusia julinea	0.20 ± 0.45	2.80 ± 1.30
Phallusia niger	---	1.20 ± 2.17
Rhopalaea circula	8.00 ± 8.57	50.60 ± 40.34
Rhopalaea crassa	---	1.00 ± 1.00
Rhopalaea sp. A	6.20 ± 7.29	10.80 ± 6.72
Polycarpa cryptocarpa	0.40 ± 0.55	7.40 ± 1.82
Polycarpa spp.	---	3.00 ± 0.71

Table 6. Species of conspicuous epibenthic invertebrates observed at Oscar and Papa Wharves. A filled circle (●) indicates presence of a species, and an open circle (○) indicates that the species was not recorded at that site. Phylogenetic arrangement follows Kelly et al. (2003) for sponges, Smith (2003) for gastropods, Paulay (2003) for bivalves, and Lambert (2003) for ascidians.

	Oscar Wharf	Papa Wharf
Porifera:Demospongiae		
Dysidea sp.	●	●
Hyrtios sp.	●	●
Haliclona sp.	●	●
Clathria sp. (orange)	●	○
Clathria sp. (pink)	●	●
Clathria sp. (red)	●	●
Cnidaria:Hydrozoa		
Leptolida spp.	●	●
Cnidaria:Anthozoa		
Dendrophyllia sp.	●	●
Carijoa sp.	○	●
Annelida:Polychaeta		
Sabellastarte spectabilis	●	●
Mollusca:Gastropoda		
Littoraria pintado	●	○
Littoraria scabra	●	●
Siphonaria guamensis	●	●
Mollusca:Bivalvia		
Brachidontes sp.	○	●
Pinctada sp.	○	●
Malleus decurtatus	●	●
Spondylus multimuricatus	●	●
Spondylus squamosus	●	●
Spondylus spp.	●	●
Chama lazarus	●	●
Chama spp.	●	●
Alectryonella plicatula	●	●
Saccostrea mordax	●	●
Saccostrea cucullata	○	●

Table 6, continued.

	Oscar Wharf	Papa Wharf
Mollusca:Bivalvia		
Ostreidae spp.	●	●
Arthropoda:Crustacea		
Metapograpsus latifrons	●	●
Echinodermata:Holothuroidea		
Synapta maculata	○	●
Chordata:Ascideacea		
Lissoclinum fragile	○	●
Ascidia ornata	○	●
Phallusia julinea	●	●
Phallusia niger	●	●
Rhopalaea circula	●	●
Rhopalaea crassa	○	●
Rhopalaea sp. A.	●	●
Polycarpa cryptocarpa	●	●
Polycarpa spp.	●	●

Ahermatypic corals tolerate dim light conditions like those of the turbid waters of the inner harbor, as well as caves and deeper waters. *Dendrophyllia* spp. are considered rare in shallow waters in Guam (Richard H. Randall, personal communication, 26 March 2010); however, they are more common in deeper, darker waters offshore.

The observation of the octocoral *Carijoa* sp. is just the third record of this species in Guam. Paulay et al. (2003) previously reported *Carijoa* sp. from mooring buoys in Outer Apra Harbor and from a submarine cave near the Shark's Pit at Orote Peninsula. Although there is no indication of proliferation of *Carijoa* sp. in Guam, the presence of the species is noteworthy because of the situation in Hawaii. *Carijoa riisei*, a native of the tropical Western Atlantic, has invaded mesophotic coral reefs in Hawaii and devastated black coral communities that have been sustainably harvested for the jewelry industry for more than 40 years (Grigg, 2003, 2004; Kahng and Grigg, 2005)

Fishes

A checklist of species and their relative abundance (as percent) at each station is given in Table 7. Thirty-five species of fishes were observed on transects surveyed at both wharves. As with other sites within the Inner Apra Harbor surveyed previously (Smith et al., 2008), this low level of species richness represents an impoverished fish fauna (there are ca. 1,000 species of reef and nearshore fishes reported from the Mariana Islands; Myers and Donaldson, 2003; unpublished data). Components of this fauna, however, are indicative of protected, turbid lagoons or bays of Guam, of which there are relatively few compared to clear water reefs (unpublished data), and thus constitute a relatively unique assemblage of fishes.

Two invasive species were observed at both wharves. One, *Neopomacentrus violescens* (Pomacentridae, damselfishes), has been reported previously (Myers, 1999; Myers and Donaldson, 2003). This species was found more recently on Tango, Uniform and X-ray Wharves (Smith et al., 2008). The second species, *Amblygliphididon ternatensis* (Pomacentridae) was reported from Sierra, Tango, Uniform and Victor Wharves, while a third, *Rhamdia cypselurus* (Apogonidae, cardinalfishes), was reported previously from Sierra, Tango, Uniform and X-ray Wharves (Smith et al., 2008). The latter species was not observed at Oscar or Papa Wharves. The two damselfishes occur elsewhere in the western Indo-Pacific region in natural habitats somewhat similar to those found in Inner Apra Harbor (Myers, 1999).

Data on species richness, diversity, and abundance for each transect are given in Table 8. Species richness (the number of species observed) ranged from 15 (n = 57 individuals) at Oscar Wharf to 29 (n = 1347 individuals) at Papa Wharf. Generally, species richness was greater on or adjacent to mid-wall and top-wall transects at both wharves, where corals, hanging debris, and oyster shells provided shelter for various species, but especially damselfishes, cardinalfishes and juvenile butterflyfishes. Bottom-transects at both wharves had the lowest number of species and individuals. These included burrowing gobies (mainly *Oplopomus oplopomus*) or transient snappers (*Lutjanus fulvus*).

Table 7. Fishes observed on transects at Oscar and Papa Wharves, Inner Apra Harbor. M = mid-transect, B = bottom transect, T = top transect, IS = invasive species.

	Oscar Wharf					Papa Wharf				
Species	IS	M	B	T	Total	M	B	T	Total	Grand total
Family Apogonidae										
Apogon lateralis		0	0	10	10	0	0	3	3	13
Apogon leptacanthus		0	0	0	0	0	0	1	1	1
Archamia fucata		0	0	0	0	1	0	6	7	7
Cheilodipterus quinquelineatus		1	1	0	2	0	0	9	9	11
Sphaeramia orbicularis		0	0	1	1	0	0	0	0	1
Family Carangidae										
Caranx melampygus		0	0	0	0	2	0	0	2	2
Caranx sexfasciatus		0	0	0	0	13	0	0	13	13
Family Lutjanidae										
Lutjanus fulvus		0	1	0	1	2	8	0	10	11
Family Mullidae										
Parupeneus ciliatus		0	0	0	0	1	0	0	1	1
Family Chaetodontidae										
Chaetondon bennetti		0	0	0	0	0	0	10	10	10
Chaetodon ephippium		2	0	0	2	2	0	0	2	4
Chaetodon ulietensis		0	2	0	2	0	0	0	0	2
Chaetodon unimaculatus		0	0	0	0	0	0	1	1	1
Chaetodon vagabundus		1	0	0	1	0	0	0	0	1
Family Pomacentridae										
Abudefduf sexfasciatus		0	0	2	2	0	0	0	0	2
Amblyglyphididon curacao		1	0	0	1	0	0	0	0	1
Amblyglyphididon ternatensis	1	1	0	0	1	50	0	47	97	98
Chromis viridis		0	0	12	12	98	0	1015	1113	1125
Dascyllus aruanus		0	0	0	0	0	0	14	14	14
Neoglyphididon violescens	1	0	0	0	0	0	0	1	1	1
Pomacentrus amboinensis		3	0	10	13	2	2	4	8	21
Pomacentrus pavo		2	0	4	6	0	1	6	7	13
Family Labridae										
Halichoeres trimaculatus		0	0	0	0	0	0	3	3	3
Family Labridae: Scarinae										
Chlorurus sordidus juv		0	0	0	0	0	0	4	4	4
Leptoscarus vaigiensis juv		0	0	0	0	0	0	6	6	6
Family Callionymidae										
Dactylopus dactylopus		0	0	0	0	0	1	0	1	1
Family Gobiidae										
Amblygobius phaelena		0	0	0	0	0	0	0	0	0
Asterropteryx semipunctatus		0	0	0	0	0	0	1	1	1

Table 7. Continued.

	Oscar Wharf					Papa Wharf				
Species	IS	M	B	T	Total	M	B	T	Total	Grand total
Eviota punctulata		0	0	0	0	2	0	0	2	2
Eviota sp.		0	0	0	0	3	0	8	11	11
Exyrias bellissmus		0	0	0	0	0	1	0	1	1
Oplopomus oplopomus		0	0	0	0	0	6	0	6	6
Family Acanthuridae										
Acanthurus blochii		0	0	3	3	0	2	7	9	12
Zebrasoma veliferum		0	0	0	0	0	0	1	1	1
Family Tetraodontidae										
Canthigaster solandri		0	0	0	0	0	1	2	3	3
Total individuals		11	4	42	57	176	22	1149	1347	1404

Table 8. Species richness (S), diversity (H'), and abundance (N) of fishes at Oscar (O) and Papa (P) Wharves, Inner Apra Harbor. M = mid-transect, B = bottom-transect, and T = top-transect.

Transect	S	H'	N
OM	7	1.85	11
OB	3	1.04	4
OT	7	1.69	42
PM	11	1.26	176
PB	8	1.72	22
PT	20	0.63	1149

Shannon's H', a measure of species diversity that adjusts species richness to consider also the influence of abundance (Magurran, 1988), was highest on the mid-transect at Oscar Wharf. Here, low abundance of fishes (n = 11) but relatively high species richness (7 species) accounted for high diversity. The top-transect at Papa Wharf, on the other hand, had high abundance (n = 1149) and also the greatest overall species richness (S = 20), but the most individuals were of a single species, *Chromis viridis* (Table 7). At both wharves, corals, soft corals, and molluscs (mainly oysters) were present and appeared to be protected from ship or barge damage by fenders, thus making them available to fishes for shelter.

At Oscar Wharf, relative abundance, the percentage of a single individual out of the total number of individuals observed (Table 9), was greatest for the juvenile butterflyfish, *Chaetodon ulietensis* (50% on the top-transect), followed by the damselfish *Pomacentrus amboinensis* (27.3 % on the mid-transect) and the cardinalfish *Cheilodipterus quinquelineatus* (25% on the bottom transect). At Papa Wharf, relative abundance was greatest for the damselfish *Chromis viridis* (88.4 % on the top-transect), followed by the snapper *Lutjanus fulvus* (37% on the bottom-transect) and the invasive damselfish *Amblyglyphididon ternatensis* (28.4% on the mid-transect).

Densities of fish species (number of individuals/m^2) at each wharf are given in Table (10). The damselfish *Pomacentrus amboinensis* had the greatest density at Oscar Wharf, followed by another damselfish, *Chromis viridis* and a cardinalfish, *Apogon lateralis*. Most of the damselfishes, particularly *C. viridis*, were juveniles or sub-adults. At Papa Wharf, *C. viridis* had, by far, the greatest density, followed by two water-column dwelling species, the trevally *Caranx sexfasciatus* and the snapper *Lutjanus fulvus*. A previous survey of other wharves within the Inner Apra Harbor (Smith et al., 2008) found that the small, structure-associated cardinalfish *Apogon lateralis* had the highest densities, followed by another cardinalfish, the apparently invasive *Rhabdamia cypselerus,* and the invasive damselfish, *Amblyglyphididon ternatensis*.

The similarity of species composition between stations and transect depths was examined with group cluster analysis (Figure 3) and multiple dimension scaling analysis (Figure 4). The fish assemblages revealed the following pattern: Oscar bottom-transect had a similarity of 20% with all other transects; Papa bottom and Oscar mid- and top transects had a 30% similarity with one another; Papa mid- and top transects had a similarity of 35%; Oscar top and Papa bottom transects were the most similar (40%) because of the presence of the surgeonfish *Acanthurus blochii* on both transects (Table 7). A stress level of 0.00 indicated a high degree of confidence in the MDA results (Clarke and Gorley, 2001).

Analysis of similarity (ANOSIM) between fish assemblage structure of both wharves in relation to depth of transect indicated that there were only minor differences between them (Global R = 0.167) and these were not significant. Thus, the fish faunas of each tended to share many of the same species typical of protected and turbid waters, while differences can be

Table 9. Relative abundance (RA, %) of fishes on transects at Oscar and Papa Wharves, Inner Apra Harbor, Guam. M = mid-transect, B = bottom transect, and T = top transect.

	Oscar Wharf Transect			Papa Wharf Transect		
Family and Species	M	B	T	M	B	T
Family Apogonidae						
Apogon lateralis	0.0	0.0	23.8	0.0	0.0	0.3
Apogon leptacanthus	0.0	0.0	0.0	0.0	0.0	0.1
Archamia fucata	0.0	0.0	0.0	0.5	0.0	0.5
Cheilodipterus quinquelineatus	9.1	25.0	0.0	0.0	0.0	0.8
Sphaeramia orbicularis	0.0	0.0	2.4	0.0	0.0	0.0
Family Carangidae						
Caranx melampygus	0.0	0.0	0.0	1.1	0.0	0.0
Caranx sexfasciatus	0.0	0.0	0.0	7.1	0.0	0.0
Family Lutjanidae						
Lutjanus fulvus	0.0	25.0	0.0	1.1	53.3	0.0
Family Mullidae						
Parupeneus ciliatus	0.0	0.0	0.0	0.5	0.0	0.0
Family Chaetodontidae						
Chaetondon bennetti	0.0	0.0	0.0	0.0	0.0	0.9
Chaetodon ephippium	18.2	0.0	0.0	1.1	0.0	0.0
Chaetodon ulietensis	0.0	50.0	0.0	0.0	0.0	0.0
Chaetodon unimaculatus	0.0	0.0	0.0	0.0	0.0	0.1
Chaetodon vagabundus	9.1	0.0	0.0	0.0	0.0	0.0
Family Pomacentridae						
Abudefduf sexfasciatus	0.0	0.0	4.8	0.0	0.0	0.0
Amblyglyphididon curacao	9.1	0.0	0.0	0.0	0.0	0.0
Amblyglyphididon ternatensis	9.1	0.0	0.0	27.3	0.0	4.1
Chromis viridis	0.0	0.0	28.6	53.6	0.0	88.3
Dascyllus aruanus	0.0	0.0	0.0	0.0	0.0	1.2
Neoglyphididon violescens	0.0	0.0	0.0	0.0	0.0	0.1
Pomacentrus amboinensis	27.3	0.0	23.8	1.1	13.3	0.3
Pomacentrus pavo	18.2	0.0	9.5	0.0	6.7	0.5
Family Labridae						
Halichoeres trimaculatus	0.0	0.0	0.0	0.0	0.0	0.3
Family Labridae: Scarinae						
Chlorurus sordidus juv	0.0	0.0	0.0	0.0	0.0	0.3
Leptoscarus vaigiensis juv	0.0	0.0	0.0	0.0	0.0	0.5
Family Callionymidae						
Dactylopus dactylopus	0.0	0.0	0.0	0.0	6.7	0.0
Family Gobiidae						
Amblygobius phaelena	0.0	0.0	0.0	0.0	0.0	0.0
Asterropteryx semipunctatus	0.0	0.0	0.0	0.0	0.0	0.1
Eviota punctulata	0.0	0.0	0.0	1.1	0.0	0.0
Eviota sp.	0.0	0.0	0.0	1.6	0.0	0.7
Exyrias bellissmus	0.0	0.0	0.0	0.5	0.0	0.0
Oplopomus oplopomus	0.0	0.0	0.0	3.3	0.0	0.0

Table 9. Continued.

Family and Species	Oscar Wharf Transect M	Oscar Wharf Transect B	Oscar Wharf Transect T	Papa Wharf Transect M	Papa Wharf Transect B	Papa Wharf Transect T
Family Acanthuridae						
Acanthurus blochii	0.0	0.0	7.1	0.0	13.3	0.6
Zebrasoma veliferum	0.0	0.0	0.0	0.0	0.0	0.1
Family Tetraodontidae						
Canthigaster solandri	0.0	0.0	0.0	0.0	6.7	0.2
Total number of individuals	11	4	42	183	15	1149

Table 10. Density (no. /sq m) of fishes observed on transects at Oscar and Papa Wharves, Inner Apra Harbor, Guam. IS = invasive species, M = mid-transect, B = bottom transect, T = top transect.

	Oscar Wharf Transect				Papa Wharf Transect			
Family and Species	M	B	T		M	B	T	
Family Apogonidae								
Apogon lateralis	0	0	0.1	0.1	0	0	0.03	0.03
Apogon leptacanthus	0	0	0	0	0	0	0.01	0.01
Archamia fucata	0	0	0	0	0.01	0	0.06	0.07
Cheilodipterus quinquelineatus	0.01	0.01	0	0.02	0	0	0.09	0.09
Sphaeramia orbicularis	0	0	0.01	0.01	0	0	0	0
Family Carangidae								
Caranx melampygus	0	0	0	0	0.02	0	0	0.02
Caranx sexfasciatus	0	0	0	0	0.13	0	0	0.13
Family Lutjanidae								
Lutjanus fulvus	0	0.01	0	0.01	0.02	0.08	0	0.1
Family Mullidae								
Parupeneus ciliatus	0	0	0	0	0.01	0	0	0.01
Family Chaetodontidae								
Chaetondon bennetti	0	0	0	0	0	0	0.1	0.1
Chaetodon ephippium	0.02	0	0	0.02	0.02	0	0	0.02
Chaetodon ulietensis	0	0.02	0	0.02	0	0	0	0
Chaetodon unimaculatus	0	0	0	0	0	0	0.01	0.01
Chaetodon vagabundus	0.01	0	0	0.01	0	0	0	0
Family Pomacentridae								
Abudefduf sexfasciatus	0	0	0.02	0.02	0	0	0	0
Amblyglyphididon curacao	0.01	0	0	0.01	0	0	0	0
Amblyglyphididon ternatensis	0.01	0	0	0.01	0.5	0	0.47	0.97
Chromis viridis	0	0	0.12	0.12	0.98	0	10.15	11.13
Dascyllus aruanus	0	0	0	0	0	0	0.14	0.14
Neoglyphididon violescens	0	0	0	0	0	0	0.01	0.01
Pomacentrus amboinensis	0.03	0	0.1	0.13	0.02	0.02	0.04	0.08
Pomacentrus pavo	0.02	0	0.04	0.06	0	0.01	0.06	0.07
Family Labridae								
Halichoeres trimaculatus	0	0	0	0	0	0	0.03	0.03
Family Labridae: Scarinae								
Chlorurus sordidus juv	0	0	0	0	0	0	0.04	0.04
Leptoscarus vaigiensis juv	0	0	0	0	0	0	0.06	0.06
Family Callionymidae								
Dactylopus dactylopus	0	0	0	0	0	0.01	0	0.01
Family Gobiidae								
Amblygobius phaelena	0	0	0	0	0	0	0	0
Asterropteryx semipunctatus	0	0	0	0	0	0	0.01	0.01
Eviota punctulata	0	0	0	0	0.02	0	0	0.02
Eviota sp.	0	0	0	0	0.03	0	0.08	0.11
Exyrias bellissmus	0	0	0	0	0.01	0	0	0.01
Oplopomus oplopomus	0	0	0	0	0.06	0	0	0.06

Table 10. Continued.

Family and Species	Oscar Wharf Transect M	Oscar Wharf Transect B	Oscar Wharf Transect T		Papa Wharf Transect M	Papa Wharf Transect B	Papa Wharf Transect T	
Family Acanthuridae								
Acanthurus blochii	0	0	0.03	0.03	0	0.02	0.07	0.09
Zebrasoma veliferum	0	0	0	0	0	0	0.01	0.01
Family Tetraodontidae								
Canthigaster solandri	0	0	0	0	0	0.01	0.02	0.03
Total density of all fishes	0.11	0.04	0.42	0.57	1.83	0.15	11.49	13.47

attributed to the presence of seemingly unusual species (i.e., butterflyfishes normally seen in clear or less-turbid reef systems) associated with structure on some transects or the simple absence of most species, other than some burrowing gobies, on others (i.e., bottom transects).

Essential Fish Habitat

Overall, both wharf faces provided some considerable habitat for most species of fishes observed compared to the harbor floor offshore from the wharves (Table 11). Microhabitats associated with wharves included coral, debris, and shells that were attached to a wharf, the wharf wall and associated structures (pilings, fenders, pipes, zinc electrodes, etc.), debris, and silt at the base of the wharf wall, and the water column directly adjacent to the wharf. Most species were associated with one or more of these microhabitats. Benthic species such as cardinalfishes (Apogonidae), damselfishes (Pomacentridae), and gobies (Gobiidae) favored corals, debris, shells, soft corals, and the wharf wall and pilings. Species that were active swimmers, such as butterflyfishes (Chaetodontidae), a snapper (Lutjanidae), a surgeonfish (Acanthuridae), trevallys and jacks (Carangidae), etc., were found in the water column directly adjacent to the wharves. Burrowing gobies and a dragonet (Callionymidae) were found on the silt bottom.

Threatened and Endangered Species

High turbidity levels at Oscar and Papa Wharves, as with elsewhere within Inner Apra Harbor (Smith et al., 2008), limited visibility (<5 m) prevented the detection of highly motile species, especially vertebrate organisms. No threatened or endangered species were observed at either of these survey sites.

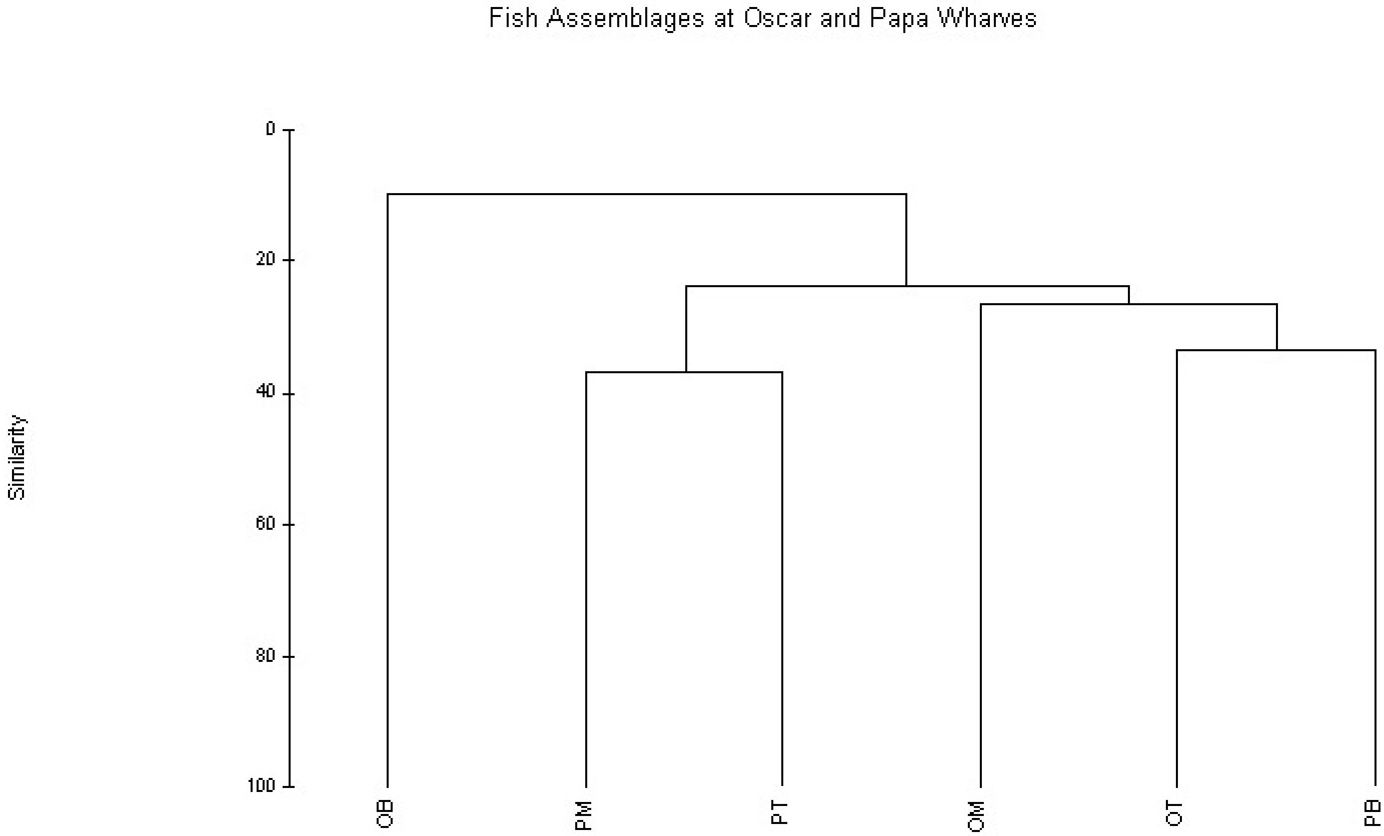

Figure 3. Cluster analysis of similarity between fish assemblages on transects at Oscar and Papa Wharves. See Table 7 for station definitions.

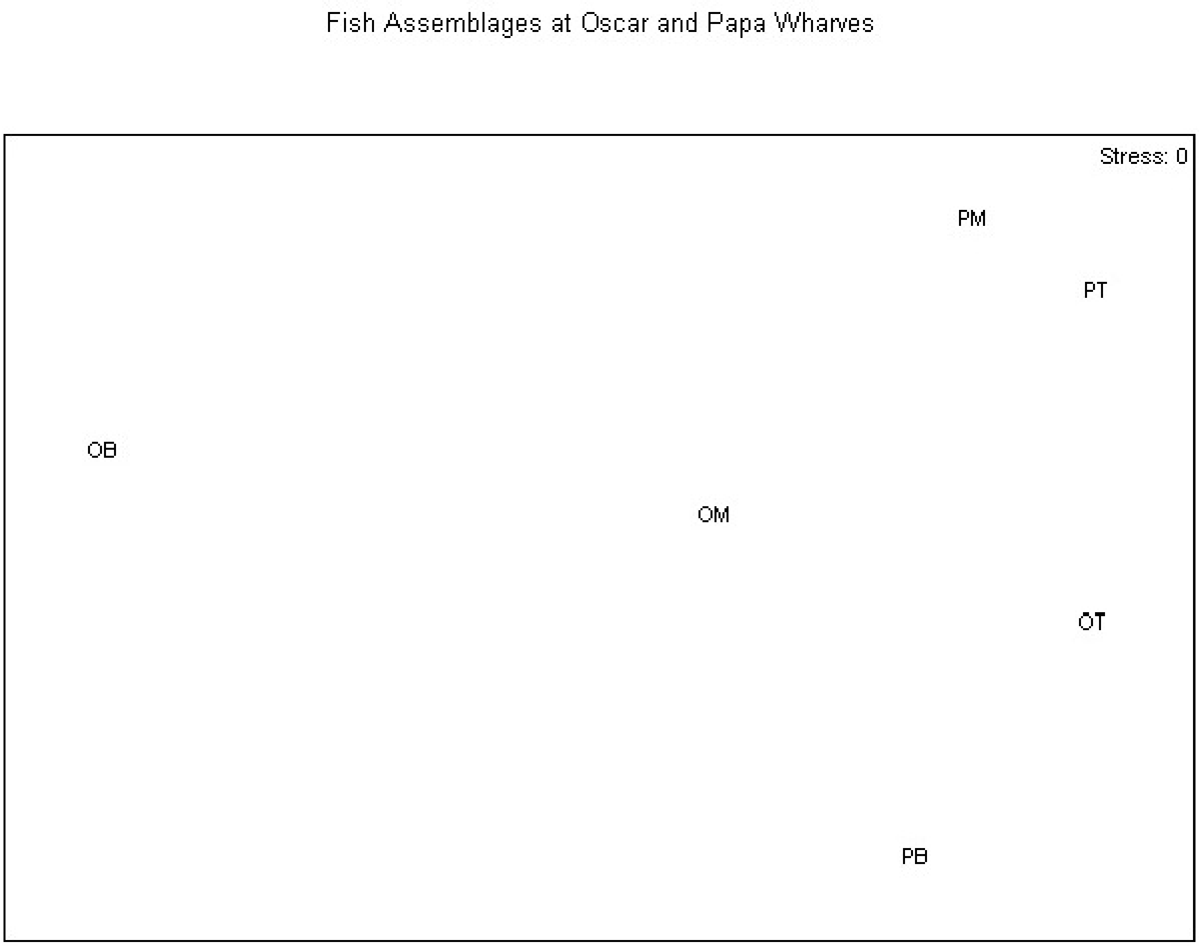

Figure 4. Multiple dimensional scaling (MDS) analysis of fish assemblages observed on transects at Oscar and Papa Wharves. See Table 7 for station definitions.

Table 11. Habitat and microhabitat associations of fishes observed at Oscar and Papa Wharves, Inner, Apra Harbor, Guam. Station codes are defined in Table . Habitat codes are W = wharf, B = soft , bottom. Microhabitat codes are c = coral, sh = shell, d = debris, st = silt, and wc = water column.

	Oscar Wharf Transect			Papa Wharf Transect			
Family and Species	M	B	T	M	B	T	
Family Apogonidae							
Apogon lateralis	0	0	Wc	0	0	Wc	
Apogon leptacanthus	0	0	0	0	0	Wc	
Archamia fucata	0	0	0	Wc	0	Wc	
Cheilodipterus quinquelineatus	1	1	0	0	0	Wc	d
Sphaeramia orbicularis	0	0	1	0	0	0	
Family Carangidae							
Caranx melampygus	0	0	0	Wwc	0	0	
Caranx sexfasciatus	0	0	0	Wwc	0	0	
Family Lutjanidae							
Lutjanus fulvus	0	1	0	Wwc	Wwc	0	
Family Mullidae							
Parupeneus ciliatus	0	0	0	Wc	0	0	
Family Chaetodontidae							
Chaetondon bennetti	0	0	0	0	0	Wc	
Chaetodon ephippium	Wwc	0	0	Wwc	0	0	
Chaetodon ulietensis	0	Wwc	0	0	0	0	
Chaetodon unimaculatus	0	0	0	0	0	Wwc	
Chaetodon vagabundus	Wwc	0	0	0	0	0	
Family Pomacentridae							
Abudefduf sexfasciatus	0	0	Wc	0	0	0	
Amblyglyphididon curacao	Wc	0	0	0	0	0	
Amblyglyphididon ternatensis	Wc	0	0	Wc	0	Wc	d
Chromis viridis	0	0	Wc	d	98	0	Wcd
Dascyllus aruanus	0	0	0	0	0	Wc	sh
Neoglyphididon violescens	0	0	0	0	0	Wsh	
Pomacentrus amboinensis	Wc	sh	0	Wc	2	Wd	Wsh
Pomacentrus pavo	Wc	0	Wc	0	Wd	Wc	
Family Labridae							
Halichoeres trimaculatus	0	0	0	0	0	Wd	
Family Labridae: Scarinae							
Chlorurus sordidus juv	0	0	0	0	0	Wd	
Leptoscarus vaigiensis juv	0	0	0	0	0	Wd	
Family Callionymidae							
Dactylopus dactylopus	0	0	0	0	Bst	0	
Family Gobiidae							
Amblygobius phaelena	0	0	0	0	0	0	
Asterropteryx semipunctatus	0	0	0	0	0	Wc	
Eviota punctulata	0	0	0	Wc	0	0	
Eviota sp.	0	0	0	Wc	sh	0	Wc
Exyrias bellissmus	0	0	0	0	Bst	0	
Oplopomus oplopomus	0	0	0	0	Bst	0	

Table 11. Continued.

Family and Species	Oscar Wharf Transect M	B	T	Papa Wharf Transect M	B	T
Family Acanthuridae						
Acanthurus blochii	0	0	Wwc	0	Wwc	Wwc
Zebrasoma veliferum	0	0	0	0	0	Wwc
Family Tetraodontidae						
Canthigaster solandri	0	0	0	0	Wc	Wc

Habitat Areas of Particular Concern (HAPC)

None of the three areas of Apra Harbor recognized by Paulay et al. (2001a) for their species richness and unique biota are encompassed by Oscar or Papa Wharves within the Inner Apra Harbor. These authors described the inner harbor as the most altered area with Apra Harbor, while remarking on the presence of uncommon species, such as *Porites convexa*, and the abundance of the hammer oyster *Malleus decurtatus* on wharf faces. Inner Apra Harbor lies at the extreme end of the gradient of increasing turbidity, abundance of plankton and benthic suspension feeders, and finer sediments. The harbor continues to support thriving marine communities, despite the extensive dredging and filling operations that significantly altered the area after World War II.

SUMMARY

As shown in a previous study (Smith et al., 2008), the artificial and most anthropogenically-impacted habitats, wharves, might contribute most to the biotic richness and diversity of the inner harbor. The synoptic account of the benthic invertebrates is indicative of unique benthic fauna, especially so for the sponges. Hence, more extensive taxonomic surveys are warranted to assess the biological value of the inner harbor, as well as its potential as an area for potential establishment of invasive species.

The coral fauna of the study area consisted of 19 species of scleractinian corals, and an additional two taxa including a stony hydrozoan, and an octocoral. The predominant corals were *Pocillopora damicornis*, *Porites lobata*, and *Leptastrea purpurea*. The coral assemblage in Inner Apra Harbor is characteristic of environments with high levels of sedimentation and turbidity, with the most common species, in order of tolerance to these conditions, being *Porites lutea*, *Pocillopora damicornis*, and *Leptastrea purpurea* (Amesbury et al., 1977). Coral species richness is highest on relatively sediment-free, hard substrates on vertical faces of wharves (Smith et al., 2008; this report).

Macroinvertebrates communities on the vertical surfaces of Oscar and Papa Wharves were only moderately diverse, with species observed on or near transects. This pattern is consistent with that reported for similar localities within the inner harbor (Smith et al., 2008). For corals, availability of sediment-free hard substrate for sessile and sedentary macroinvertebrates is a limiting factor on horizontal surfaces. Macroinvertebrate assemblages on both wharves were dominated by suspension feeding species, which comprised 100% of the species occurring on transects and 90% of all species observed.

The species richness and diversity of the fish faunas of Oscar and Papa Wharves, like elsewhere in the inner harbor (Smith et al., 2008), are relatively low compared to habitats elsewhere on Guam (Donaldson, unpublished data). These faunas are highly adapted and representative of protected and turbid habitats usually associated with mangroves, estuaries, and back reefs, with some exceptions. A considerable amount of habitat is provided by artificial shelter in the form of wharves and jetsam and debris (pilings, frames, storage units, etc.), and the microhabitats found on or adjacent to these were utilized by many species of fishes. Larval fishes of these species could have settled and recruited to these habitats and microhabitats, either through natural stochastic processes or by transport (i.e., bilge water), and became established at each of the wharves. Many of the individuals of these species were juveniles or subadults. Alternatively, some species, particularly those that swim actively in the water column, may have colonized these habitats as adults after swimming to them from outside of the inner harbor.

RECOMMENDATIONS

During the planning phase for construction and renovation of facilities at Oscar and Papa Wharves, the following recommendations should be given consideration.

1. Floating turbidity curtains, extending from the surface to the lagoon floor, should be placed completely around all dredge and fill sites, and turbidity curtains should be routinely monitored and maintained to contain silt produced by construction.

Dredge and fill operations produce large quantities of fine silt particles suspended in the water column. Turbidity and sedimentation are significant problems for coral reefs surrounding high islands or in coastal areas of continents. Sediments may have an energetic cost to the coral that must cleanse its surface, resulting in slower growth rates and in less energy available for reproduction (Tomascik and Sander, 1987; Wolanski et al., 2003). Sediments can also interfere with larval recruitment on coral reefs by interfering with the chemosensory ability of coral larvae seeking the appropriate chemical signals from preferred settlement substrates, such as coralline algae (Richmond, 1997). Turbidity curtains can be effective in confining suspended sediments when properly deployed and maintained. Removal of the turbidity barriers and the related components is vital once the project activities are complete. Failure to do so can cause the barrier to come loose from its anchors and entangle benthic and other marine organisms (PBS&J, 2008).

2. All dredge and fill operations should be suspended during the period of the annual coral spawning event in Guam waters.

Some 85% of reef-building corals are spawners, i.e., reproduction occurs after the release of gametes into the water, where fertilization takes place (Richmond, 1997). Multispecies mass-spawning events occur during limited periods each year. To maximize reproductive success, most spawning species release their gametes over a 5–8-day period that is related to the lunar cycle. Studies in Guam revealed that peak spawning occurs 7–10 days after the full moon in July (Richmond and Hunter, 1990). Because suspended sediments may interfere with egg-sperm interactions in the fertilization process (Richmond, 1997; Wolanski et al., 2003), dredge and fill operations can affect coral reproduction on reefs far down current of the actual construction activities.

Construction windows are a management tool to map out the times of year during which coastal construction may be limited due to the presence of threatened or endangered species or other sensitive marine life (PBS&J, 2008). Construction windows may consider wildlife activity such as coral spawning and coral bleaching. U.S. Army Corps of Engineers permits for maintenance dredging of the Naval Base require that dredging operations cease during annual coral spawning periods in Guam (M.E. Guarin, P.E., Construction Management Engineer, NAVFAC OICC Marianas, personal communication, April 27, 2004).

3. Marine biological communities should be monitored during and after dredge and fill operations at Oscar and Papa Wharves.

Monitoring studies on small, tropical islands have shown that precautions for environmental protection can limit the effects of dredge and fill operations on nearby marine communities. Amesbury et al. (1982) identified few measurable effects related to construction of the airport runway extension at Weno Island, Chuuk [= Moen Island, Truk]. However, these authors reported that fluctuations in species richness, percent cover, and population density of several taxa occurred during the construction period. Where siltation was heaviest, the decline in coral coverage was significant, and no evidence of new coral recruitment was found one year after the completion of runway construction. Marine plants, macroinvertebrates, and reef fishes also declined at those monitoring stations that were inundated with sediments.

Biological monitoring should be required for any project that is proposed for construction in Oscar and Papa Wharves, so that any damage to coral communities along vertical surfaces caused by sedimentation can be identified promptly and so that necessary measures can be taken to minimize any damage. Monitoring is necessary to determine any direct or indirect biological impacts to the ecosystem caused by physical and/or chemical changes to the environment as a result of the project.

4. Invasive species should be monitored.

Because invasive species have been detected on both wharves, and on others surveyed previously (Smith et al., 2008), monitoring studies should emphasize early detection and eradication/management of invasive species and the possible expansion of their ranges locally.

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APPENDIX G
Avian Surveys

Avian Survey Report. AECOM, Inc. June 28, 2010

Avian Survey Report

June 28, 2010

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Naval Facilities Engineering Command
NAVFAC PACIFIC

AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives Contract Number N62742-06-D-1870, TO 0016

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1 METHODS AND MATERIALS

Avifaunal communities were surveyed on specific areas identified by NAVFACMAR as having potential future use by the U.S. Military on the island of Guam. Survey sites were located on private, Government of Guam, U.S. military leasehold, and U.S. military properties. Specific areas included; North Finegayan, South Finegayan, Naval Munitions Site, Andersen South, Orote Point, AAFB NW Field and Route 9, Navy Barrigada, GLUP 77, FAA, Cabras, North Barrigada, and Route 15. All transect maps are presented in

Survey sites, transect number, and stations, as well as survey protocol, were established by NAVFACMAR biologists in coordination with TEC, Inc. and AECOM, Inc. Three basic types of field surveys were conducted: Roadside Surveys, Forest Bird Surveys and Endangered Species Surveys.

Field surveys were conducted during five time periods during 2008: February 16-25; March 27-April 6; June 24-28; and December 9-19. There were two field surveys during 2009 (July 16-19 and September 21-24), while one survey was carried in 2010 (January 15).

Three different types of field surveys were conducted; Roadside, Forest Bird, and Endangered Species. All avifaunal surveys were conducted by Mr. Rick Spaulding (TEC), Mr. John Gourley (AECOM) and/or Mr. Glenn Metzler (TEC).

1.1 Roadside Surveys

A modified point count methodology, in conjunction with a fixed line transect was used to enumerate bird detections (Bibby, *et. al*. 2000) for roadside surveys. Total number of detections (no detection direction or distance data was collected) were recorded (visual observations and/or by song) within one 3-minute period at each pre-determined station; no surveys were replicated. In order to minimize double counting, survey stations were positioned a minimum of 150 meters apart.

Roadside Surveys were conducted on seven project site areas during YR 2008 with a total of 102 stations (Table 1). All surveys were conducted either during the morning from sunrise to 1000 hours, or evening after 1700 hours. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

TABLE 1
Overview of Roadside Surveys: area surveyed, date, number of stations surveyed, and survey time

Survey Site	Survey Date *(YR 2008)*	Number of Survey Stations	Survey Time *(morning vs. evening)*
North Finegayan	February 16	13	*Morning*
South Finegayan	February 17	11	*Morning*
Navy Magazine	February 24, 25	23	*Morning*
Andersen South	March 29; June 26	21	*Morning*
Orote Point	April 6	5	*Morning*
North Ramp	June 24, 28	6	*Morning*
AAFB NW Field	June, 28	17	*Morning*
WCTS Barrigada	February 18	6	*Evening*

1.2 Forest Bird Surveys:

In forested habitat, bird detections were enumerated using a point count methodology along variable-length straight line transects (Bibby, *et al*. 2000). Survey stations were placed a minimum of 150 meters apart to minimize double counting. All bird species were recorded (visual observations and/or by song) within one 8-minute period at each pre-determined station; no surveys were replicated. Although detection direction and distance estimates were recorded, only relative abundance among species will be discussed.

Forest Bird Surveys were conducted during YRS 2008, 2009, and 2010 on 14 project site areas with a total of 133 stations (Table 2). All surveys were conducted during the morning hours from sunrise to 1000 hours. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

Table 2

Overview of the YR 2008 – 2010 Forest Bird Surveys: area surveyed, date, number of transects and stations surveyed

Survey Sites	Survey Date	Number of Survey Transects/Stations
North Finegayan	February 21, 22, 23, 2008 July 16, 2009	9 /21
South Finegayan	February 21, 2008	2 / 4
Navy Munitions Site	February 24, 25, 2008 March 28, 2008 December 15, 18, 19, 2008 July 19, 2009	11 / 29
Navy Munitions Site (Maagas River)	January 15, 2010	1 / 7
Andersen South	March 29, 30, 2008 September 21, 2009	6 / 14
Orote Point	April 6, 2008	4 / 8
AAFB NW Field	June 25, 2008	2 / 4
AAFB NW Field	June 24, 2008	2 / 4
AAFB Route 9	September 22, 23, 24, 2009	3 / 12
Navy Barrigada	February 20, 2008	2 / 4
GLUP 77	March 27, 30, 2008	2 / 4
Federal Aviation Administration	December 9, 11, 2008	3 / 6
Route 15	December 10, 11, 2008	3 / 10
Cabras	July 17, 2009	1 / 4
North Barrigada	September 21, 2009	1 / 2

1.3 Endangered Species Surveys:

The Camp Covington (U.S. Navy) wetland was identified as a unique and limited habitat resource requiring special surveys to determine whether the federally endangered Mariana Common Moorhen (G*allinula chloropus guami*) was present. In order to cover the entire wetland, eleven listening stations were strategically positioned around the perimeter of the wetland. Stations were placed a minimum of 150 meters apart to minimize double counting. All moorhen detections were recorded (visual observations and/or by song) within one 8-minute period; no stations were replicated. A single survey was conducted on December 13 and 16, 2009 during the morning hours between sunrise and 1000 hours. Though weather conditions were variable, data quality was not compromised by surveying in inclement weather.

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2 FEDERAL AND TERRITORY LISTED ENDANGERED and THREATENED SPECIES

The Endangered Species Act (ESA) was initially passed by the US Congress in 1973 and has been re-authorized and amended several times. The purpose of the ESA is to conserve "*the ecosystems upon which endangered and threatened species depend*" and recover listed species. Those wildlife species which have been determined to have dangerously low population levels or are in imminent threat of extinction are protected by the U.S. Federal Government under authority of the ESA. Populations of those wildlife species requiring Federal protection are either classified as endangered or threatened. Endangered is defined in Section 3(6) of the ESA as:

> *"...any species [including subspecies or qualifying distinct population segment] which is in danger of extinction throughout all or a significant portion of its range."*

A threatened species is defined in Section 3(19) of the ESA and is defined as:

> *".... any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."*

With respect to Guam terrestrial wildlife resources, the U.S. Fish and Wildlife Service (USFWS) have classified eight bird species as endangered (Table 3). Of these species, the Micronesian Megapode and Nightingale Reed Warbler were not listed in the Endangered Species Act of Guam as they were considered extirpated from Guam prior to passage of the Act.

The Endangered Species Act of Guam (Guam Public Law 15-36) was passed on 18 June 1979. Presently, there are 12 bird species recognized as having endangered status. This protected species list contains six species not found on the federal endangered species list: White-throated Ground Dove, Mariana Fruit Dove, Rufous Fantail, Micronesian Starling, Micronesian Myzomela, and the Guam Broadbill. Although the Guam Broadbill is considered extinct by the USFWS and subsequently de-listed during 2004 (USFWS 2004b), Guam retained this species on their list (Table 3).

Brief species accounts for Federal endangered/threatened species that may have been encountered during the surveys follow.

1. Common Moorhen (*Gallinula chloropus guami*)

The Mariana subspecies of the Common Moorhen was classified endangered by the USFWS and listed on August 27, 1984 {49 FR 33885}. Takano and Haig (2004) estimated Guam's population of adult moorhens as 90 individuals during a 2001 island population survey. Critical habitat has not been designated for this species. The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

2. Mariana Swiftlet (*Aerodramus bartschi*)

The Mariana Swiftlet was classified as endangered and listed by the USFWS on August 27, 1984 {49 FR 33885}. Even with the restricted range and low population numbers in Guam, Chantler (1999) does not consider this species globally threatened. No critical habitat has been designated for this species. The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

Table 3

Federal and Territorial Listed Endangered Species for Guam

PROTECTED AVIFAUNAL SPECIES [1]	U.S. FEDERAL GOVERNMENT	TERRITORY OF GUAM	GUAM POPULATION STATUS
(Mariana) Common Moorhen (*Gallinula chloropus guami*)	Endangered	Endangered	90 adults in 2001 [2]
Mariana swiftlet (*Aerodramus bartschi*)	Endangered	Endangered	low numbers
Guam Rail (*Gallirallus owstoni)*	Endangered	Endangered	*extirpated in wild captive breed*
Micronesian Megapode (*Megapodius l. laperouse)*	Endangered	*- not listed -*	*Extirpated*
Nightingale Reed Warbler (*Acrocephalus luscinius)*	Endangered	*- not listed -*	*Extirpated*
(Guam) Micronesian Kingfisher *(Todiramphus c. cinnamominus)*	Endangered	Endangered	*extirpated in wild* [3] *captive population* [3]
Mariana Crow *(Corvus kubaryi)*	Endangered	Endangered	< 5 [4]
(Guam) Bridled White-eye (*Zosterops c. conspicillatus)*	Endangered	Endangered	*extirpated* [3]
Guam Broadbill (*Myiagra freycineti*)	Delisted	Endangered	*extinct* [5]
White-throated Ground Dove *(Gallicolumba xanthonura)*	*- not listed -*	Endangered	*extirpated* [3]
Mariana Fruit Dove *(Ptilinopus roseicapilla)*	*- not listed -*	Endangered	*extirpated* [3]
Rufous Fantail *(Rhipidura rufifrons)*	*- not listed -*	Endangered	*extirpated* [3]
Micronesian Starling *(Aplonis opaca)*	*- not listed -*	Endangered	very low numbers [3]
Micronesian Myzomela *(Myzomela rubratra)*	*- not listed -*	Endangered	*extirpated* [3]

[1] *Classification and nomenclature follows* Gill and Donsker (2010)
[2] Takano and Haig (2004)
[3] USFWS (2008)
[4] SWCA (2008)
Information obtained from USFWS TESS web site; accessed 10 February 2009, Pacific Animals Plants and Animals Update August 29, 2005 (Listed, Proposed or Candidate species, as designated under the U.S. Endangered Species Act), and GDAWR, Department of Agriculture (2006)

3. Guam Rail (*Rallus owstoni*)

The Guam Rail is classified as endangered and was listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. Presently, the Guam Rail only exists in captive breeding populations on Guam, stateside zoos, and as an experimental population on the island of Rota in the Commonwealth of the Northern Mariana Islands (CNMI) (Drahos 2002). No critical habitat has been designated for this species. The

Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

4. Micronesian Megapode *(Megapodius l. laperouse*)

The Marianas Islands subspecies of the Micronesian Megapode was listed as an Endangered species by the USFWS on June 2, 1970 {35 FR 8491-8498}. The megapode was extirpated from Guam "*in the 19th and early 20th centuries*." (USFWS 1998a). Critical habitat has not been designated for this species. The Endangered Species Act of Guam (Guam Public Law 15-36) did not include this species when the Public Law was passed.

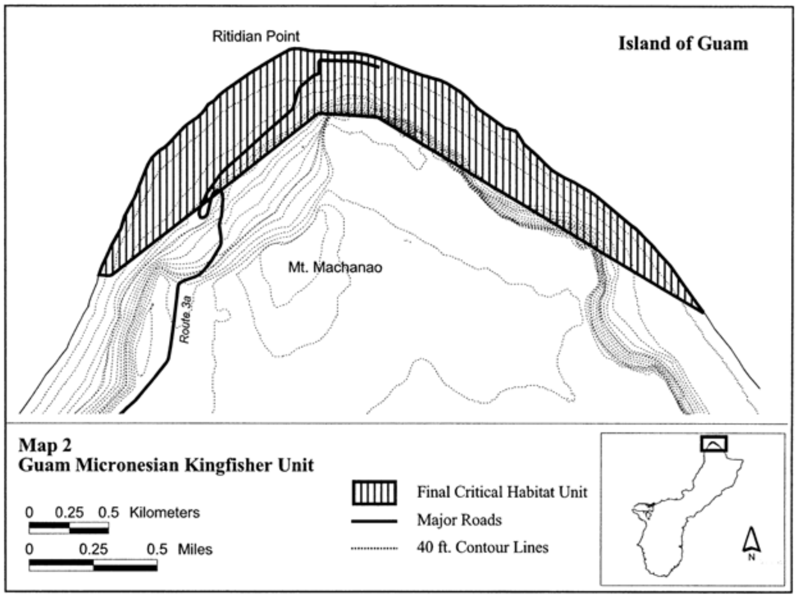
5. Nightingale Reed Warbler (*Acrocephalus luscinius)*

The Nightingale Reed Warbler is classified as endangered and was listed by the USFWS on June 2, 1970 {35 FR 8495}. Although six islands within the Marianas archipelago have historically contained reed-warbler populations, Guam's population was extirpated sometime during the late 1960's. The largest remaining population occurs on Saipan (CNMI) (USFWS 1998b). No critical habitat has been designated for this species (USFWS 1998b). The Endangered Species Act of Guam (Guam Public Law 15-36) did not include this species when the Public Law was passed.

6. Micronesian Kingfisher (*Todiramphus c. cinnamominus)*

The Guam Micronesian Kingfisher was classified as endangered and listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. This sub-species is considered extirpated from Guam as the last sighting of a Micronesian Kingfisher was in 1989. Presently, there are approximately 50 individuals in captivity at various US mainland zoos. Critical habitat, designated in 2004, lies along in the extreme northern coastline (Figure 1) encompassing an area of approximately 376 acres (152 hectares) (USFWS 2004b). The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

Figure 1: Critical habitat map for the Guam Micronesian Kingfisher (USFWS 2004b).



7. Mariana Crow (*Corvus kubaryi*)

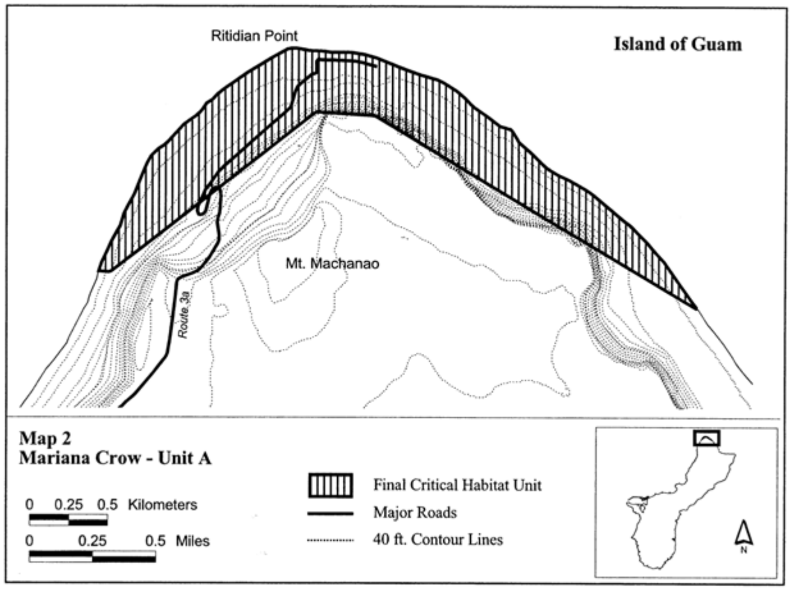
The Mariana Crow was classified as endangered and listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. This species is limited to the islands of Guam and Rota (CNMI). In 2006, ten Mariana Crows were known to reside on Guam, all located on Andersen AFB and the Guam National Wildlife Refuge, Ritidian Unit (GDAWR 2006). Extensive surveys carried out between June 2007 and April 2008 indicates the Mariana Crow population may have declined to less than half the 2006 population estimate (SWCA 2008).

Critical habitat was later designated for both Guam and Rota on 28 October 2004 (USFWS 2004b). On Guam, critical habitat lies along in the extreme northern coastline (Figure 2) and encompasses an area of approximately 376 acres (152 hectares). None of the Guam critical habitat is currently occupied by the Mariana crow (USFWS 2004b). The Endangered Species Act of Guam (Guam Public Law 15-36) also classified this species as endangered.

8. Bridled White-eye (*Zosterops c. conspicillatus*)

The Guam sub-species of Bridled White-eye is classified as endangered and was listed by the USFWS in 1984 {50 CFR 17; 49 FR 33881}. The Guam sub-species is endemic to Guam and is now considered extinct as the last observation was recorded during 1983 (USFWS 2008). The species continues to be found on other islands in the Marianas archipelago (i.e., the CNMI). The Endangered Species Act of Guam (Guam Public Law 15-36) also classified the Guam Bridled White-eye sub-species as endangered.

Figure 2: Critical habitat map for the Mariana Crow on Guam (USFWS 2004b).



3 GUAM FEDERAL ESA CANDIDATE SPECIES

A candidate species is a plant or animal species for which USFWS or National Marine Fisheries Service (NMFS) has on file sufficient information on biological vulnerability and threats to support a proposal to list as endangered or threatened, but has not yet done so. A candidate species receives no statutory protection under the ESA; however USFWS or NMFS encourages planners to conserve these species that may warrant future protection under the ESA.

The USFWS Threatened and Endangered Species System was accessed December 2009 and no bird species were identified as Candidate Species for Guam.

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4 RESULTS AND DISCUSSION

Twelve avifaunal species were documented from the Roadside and Forest Bird Surveys (Table 4). A total of 549 unique detections (visual and/or audio) were recorded from the 228 stations comprising the Roadside and Forest Bird Surveys (Table 5).

Seven species were common to both the Roadside and Forest Bird Surveys. Unique to the Roadside Surveys included the Whimbrel, Western Cattle Egret, and Common Pigeon, while the Micronesian Starling and Grey-tailed Tattler were identified only during the Forest Bird Surveys (Table 5).

No federally listed endangered or threatened species were identified during any of the surveys. One Guam listed endangered/threatened species was recorded from the Forest Bird Survey. The Micronesian Starling was detected during the AAFB Route 9 survey (Transect B; Station 3) on September 24, 2009. This species was also observed in the same area the day before when the transect was being cut.

TABLE 4:
Avifaunal species Identified During the Surveys

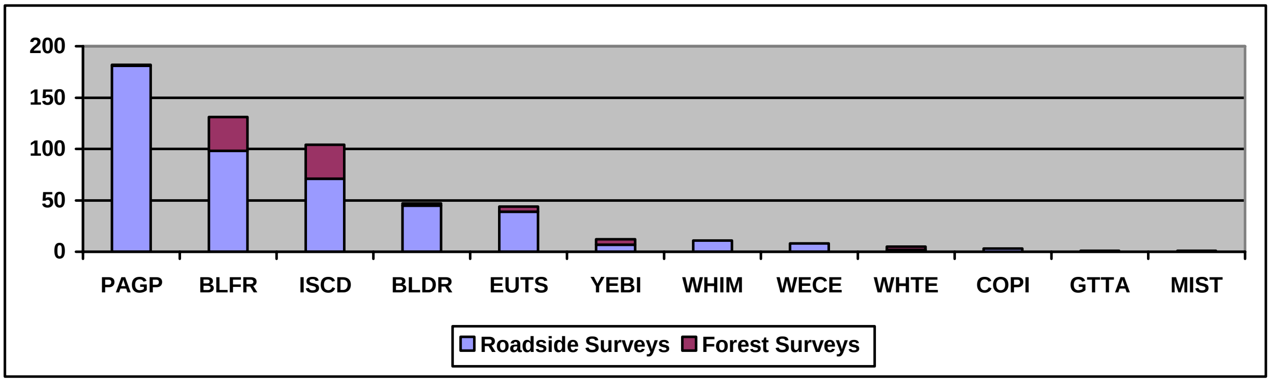
Avifaunal Species	Residence Status[1]
Micronesian Starling *(MIST) (Aplonis opaca)*	Guam listed endangered/threatened species Uncommon resident native - breeding
Yellow Bittern (YEBI) *(Ixobrychus sinensis)*	Common resident native - breeding
White Tern *(WHTE) (Gygis alba)*	Uncommon native resident - breeding
Whimbrel (WHIM) (*Numenius phaeopus)*	Common visitor – not breeding
Pacific Golden Plover (PAGP) *(Pluvialis fulva)*	Common visitor – not breeding [2]
Western Cattle Egret (WECE) *(Bubulcus ibis)*	Common visitor – not breeding
Grey-tailed Tattler (GTTA) (*Tringa brevipes*)	Common visitor – not breeding
Common *Pigeon* (COPI) *(Columba livia)*	Common introduced resident - breeding
Island Collared Dove (ISCD) *(Streptopelia bitorquata)*	Common introduced resident - breeding
Black Drongo (BLDR) *(Dicrurus macrocercus)*	Common introduced resident - breeding
Eurasian Tree Sparrow (EUTS) *(Passer montanus)*	Common introduced resident - breeding
Black Francolin (BLFR) *(Francolinus francolinus)*	Common introduced resident - breeding

NOTES:
[1] Residence status obtained from: Reichel and Glass (1991)
[2] Residence status obtained from: Johnson, *et al.* (2006)
species code follows name. *Taxonomy and nomenclature follows Gill and Donsker (2010).*

4.1 Roadside Surveys:

Roadside Surveys consisted of 102 stations; less than half (41%) of the total number of survey stations (N=246). Yet, detections from the Roadside Surveys (N=465) comprised 85% of the total detections recorded from both surveys. In addition, Roadside Surveys consistently had a higher species diversity and detection rate when compared with the Forest Bird Surveys (Figure 3).

Figure 3. Total number of detections by species by survey type in decreasing order of abundance. Species codes are found in Table 4.



Five species dominated the Roadside Surveys and comprised 93% of all detections. In decreasing order of abundance, the dominate species included: the Pacific Golden Plover (42%); Black Francolin (22%); Island Collared Dove (16%); Black Drongo (10%); and the Eurasian Tree Sparrow (9%) (Figure 3 and Table 5). Of these, only one is classified as a non-exotic: the Pacific Golden Plover. The other four species are introductions and have well established breeding populations (Table 4).

The Black Francolin, native to Southern Asia, was introduced as a game bird to Guam in 1961 by the local Division of Fish and Wildlife in coordination with the U.S. Fish and Wildlife Service (Drahos 2002). The Island Collared Dove, native to the Philippines, Borneo and surrounding islands, was believed to have been introduced by the Spanish perhaps as long as 200 years ago (Engbring and Ramsey 1984). The Black Drongo, native to Taiwan, was first introduced to Rota (CNMI) by the Japanese South Seas Development Company in 1935 in order to control destructive insects (Baker 1951). Since Rota lies approximately 50 km north of Guam, it is believed that the drongo either flew on its own accord or possibly purposely introduced to Guam as the species first appeared in Northern Guam in the early 1960's (Engbring and Ramsey 1984). An Old World native, the Eurasian tree Sparrow was introduced to Guam from 1945-1960 and is commonly found in the urban areas (Engbring and Ramsey 1984).

Habitat typically found during the Roadside Survey would be characterized as urban. This includes disturbed fields, regularly maintained areas, and overgrown (i.e., abandoned) areas.

4.2 Forest Bird Surveys

The Forest Bird Surveys included 126 stations and recorded a total of 84 detections; approximately 15% of all detections from combined Forest Bird and Roadside Surveys.

The Black Francolin and Island Collared Dove dominated the Forest Bird Surveys and comprised 78% of all detections (Figure 3 and Table 5) with each species having an equal number of detections. As previously discussed, these species were intentionally introduced to Guam and have well established breeding populations.

Though not unexpected, surveys in several forested areas documented no birds. For example, no detections were recorded from the 23 stations surveyed in Navy Barrigada, North Barrigada, Navy Munitions Site (Maagas River) and Route 15 areas. Another three areas (Cabras, South Finegayan, and Federal Aviation Administration) only recorded one species from a total of 14 stations; the Island Collared Dove. This species is usually found in disturbed habitat or fields.

TABLE 5:

Overview of the 2008-2010 Guam field survey data: area surveyed, survey type, number stations, species and detections, number of unique species/area, and total number of detections/area

Survey Site	Survey Type	No. of Stations	Species and No. of Detections	No. Species	Total No. Detections
North Finegayan	Roadside Survey	13	Pacific Golden Plover (53) Black Francolin (13) Eurasian Tree Sparrow (7) Island Collared Dove (6) Black Drongo (2)	5	81
North Finegayan	Forest Bird Survey	21	Island Collared Dove (7) Black Francolin (3) Eurasian Tree Sparrow (1)	3	11
South Finegayan	Roadside Survey	11	Pacific Golden Plover (53) Island Collared Dove (28) Black Drongo (16) Eurasian Tree Sparrow (14) Common Pigeon (3) Yellow Bittern (1)	5	115
South Finegayan	Forest Bird Survey	4	Island Collared Dove (4)	1	4
Navy Munitions Site	Roadside Survey	23	Island Collared Dove (13) Black Francolin (11) Pacific Golden Plover (6) Black Drongo (3) White Tern (2)	5	35
Navy Munitions Site	Forest Bird Survey	29	Black Francolin (8) White Tern (3) Island Collared Dove (2) Yellow Bittern (1) Grey-tailed Tattler (1)	5	15
Navy Munitions Site (Maagas River)	Forest Bird Survey	7	*- none -*	*- none -*	*- none -*
Anderson South	Roadside Survey	21	Eurasian Tree Sparrow (5) Black Francolin (4) Pacific Golden Plover (1) Island Collared Dove (2) Yellow Bittern (1)	5	13
Anderson South	Forest Bird Survey	14	Pacific Golden Plover (1) Island Collared Dove (1) Yellow Bittern (1) Black Francolin (3)	4	6
Orote Point	Roadside Survey	5	Pacific Golden Plover (50) Black Francolin (12) Whimbrel (11) Island Collared Dove (1) Black Drongo (4)	5	78
Orote Point	Forest Bird Survey	8	Island Collared Dove (1) Yellow Bittern (1) Black Francolin (1)	3	3
AAFB NW Field	Roadside Survey	17	Black Francolin (41) Island Collared Dove (11) Yellow Bittern (2)	3	54
AAFB NW Field	Forest Bird Survey	4	Black Francolin (5)	1	5

AAFB North Ramp	Roadside Survey	6	Black Francolin (14) Island Collared Dove (4) Black Drongo (11) Eurasian Tree Sparrow (7)	4	36
AAFB North Ramp	Forest Bird Survey	4	Black Francolin (12) Island Collared Dove (6) Eurasian Tree Sparrow (4) Black Drongo (1)	4	23
AAFB Route 9	Forest Bird Survey	12	Micronesian Starling (1) Island Collared Dove (1) Black Drongo (1) Yellow Bittern (1)	4	4
Glup 77	Forest Bird Survey	4	Island Collared Dove (3) Black Francolin (1) Yellow Bittern (1)	3	5
WCTS Barrigada	Roadside Survey	6	Pacific Golden Plover (18) Black Drongo (9) Western Cattle Egret (8) Island Collared Dove (6) Eurasian Tree Sparrow (6) Black Francolin (3) Yellow Bittern (3)	7	53
Navy Barrigada	Forest Bird Survey	4	*- none -*	*- none -*	*- none -*
Federal Aviation Administration	Forest Bird Survey	6	Island Collared Dove (7)	1	7
Route 15	Forest Bird Survey	10	*- none -*	*- none -*	*- none -*
Cabras	Forest Bird Survey	4	Island Collared Dove (1)	1	1
North Barrigada	Forest Bird Survey	2	*- none -*	*- none -*	*- none -*
Camp Covington	Endangered Species Survey	11	*No Common Moorhens detected*	*- N/A -*	*- none -*

Habitat typically found during the Forest Bird Survey was characterized as various types (or grades) of forest (limestone, strand, coconut, secondary, etc.), however disturbed areas, even fields, were often encountered as the transects were walked. Although all stations were sited in forested habitat, other habitat types (i.e., open field, disturbed areas) occurred nearby. For this reason and the fact that certain species of birds can be heard from a distance may help explain the dominance of Black Francolin and Island Collared Dove detections in the Forest Bird Surveys.

4.3 Endangered Species Surveys

No federal endangered Mariana Common Moorhen were detected during the Endangered Species Survey conducted at the Camp Covington wetland complex (U.S. Navy) on December 13 and 16, 2009.

5 CONCLUSIONS

1. No federally listed endangered/threatened species were encountered during the Roadside and Forest Bird surveys.

2. One Guam listed endangered species was recorded during the survey period. One Micronesian Starling was observed during the AAFB Route 9 survey (Transect B; Station 3) on September 24, 2009. This species was also observed area the day prior when the transect was being cut.

3. The five most abundant species identified during Roadside Surveys comprised 93% of all detections and included: the Pacific Golden Plover (42%); Black Francolin (22%); Island Collared Dove (16%); Black Drongo (10%); and the Eurasian Tree Sparrow (9%). The latter four species are introduced species that have well established breeding populations.

   The Pacific Golden Plover is a common non-breeding visitor to Guam.

   The Black Francolin is a common introduced resident that has an established breeding population. A native to Southern Asia, this species was introduced as a game bird to Guam in 1961 (USFWS 1984). The Black Francolin, native to Southern Asia, was introduced as a game bird to Guam in 1961 (USFWS 1984).

   The Island Collared Dove is a common introduced resident that has an established breeding population. A native to the Philippines, Borneo and surrounding islands, this species was believed to have been introduced by the Spanish perhaps as long as 200 years ago. (Engbring and Ramsey 1984).

   The Black Drongo, native to Taiwan, was first introduced to Rota (CNMI) by the Japanese South Seas Development Company in 1935 in order to control destructive insects (Baker 1951). Since Rota lies approximately 50 km north of Guam, it is believed that the drongo either flew on its own accord or was possibly purposely introduced to Guam as the species first appeared in northern Guam in the early 1960's (Engbring and Ramsey 1984).

   An Old World native, the Eurasian tree Sparrow was introduced to Guam from 1945-1960 and is commonly found in the urban areas (Engbring and Ramsey 1984).

4. Habitat typically found during the Roadside Survey was characterized as urban. This includes disturbed fields, regularly maintained areas, and overgrown (i.e., abandoned) areas.

5. The Forest Bird Surveys were dominated by the Black Francolin and Island Collared Dove; comprising 78% of all detections with each species having an equal number of detections.

6. No detections were recorded from 23 Forest Bird stations in Navy Barrigada, North Barrigada, Navy Munitions Site (Maagas River) and Route 15 areas. Only one species, the Island Collared Dove, was documented from 14 stations in three areas; Cabras, South Finegayan, and Federal Aviation Administration.

7. The federally endangered Mariana Common Moorhen was not detected during the Endangered Species Survey around the Camp Covington wetland complex (U.S. Navy) on December 13 and 16, 2009.

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APPENDIX H
Tree Snail Surveys

Tree Snail Surveys on Department of Defense Lands, Guam, in Support of a Marine Corps Relocation Initiative to Various Locations on Guam SWCA Environmental Consultants, Inc. February, 2010; and

Survey of Endangered Tree Snails on Navy-Owned Lands in Guam. Marine Laboratory, Laboratory, University of Guam, UOG Station, Mangilao. 2008

2010

TREE SNAIL SURVEYS ON DEPARTMENT OF DEFENSE LANDS, GUAM, IN SUPPORT OF A MARINE CORPS RELOCATION INITIATIVE TO VARIOUS LOCATIONS ON GUAM

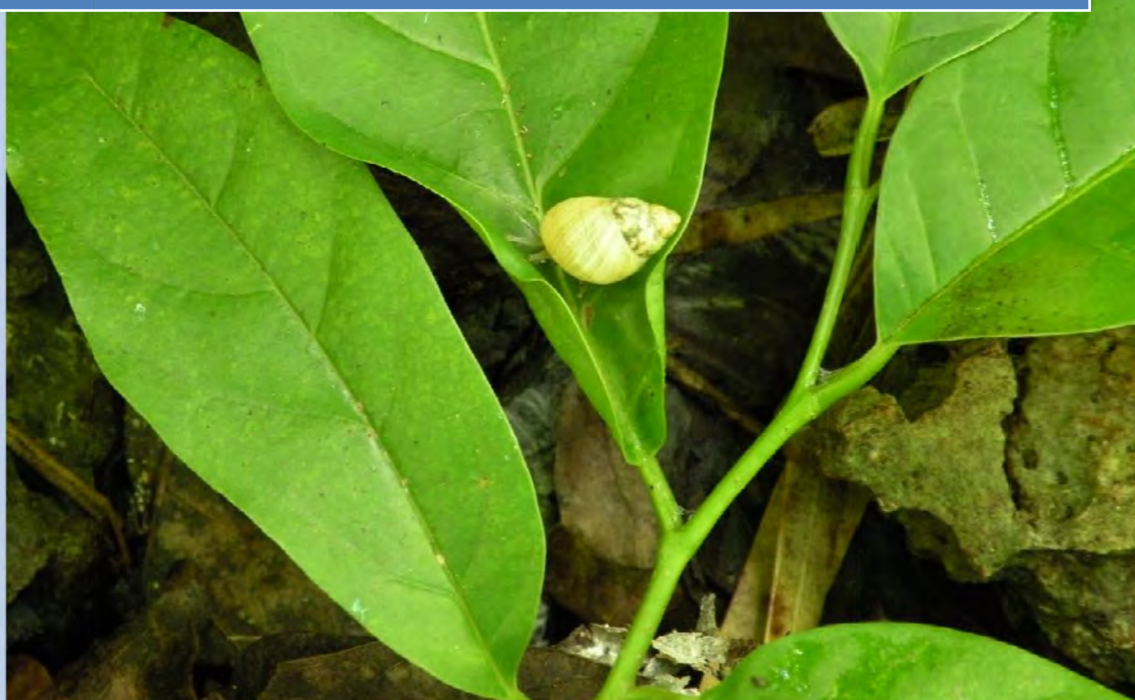

Photo: SWCA

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2/17/2010

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1.0 INTRODUCTION

Between September and November 2009, surveys for partulid tree snails were conducted as part of the biological inventory for the Joint Guam Program Office (JGPO) Guam and Commonwealth of the Northern Mariana Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). Surveys were designed to locate, identify, and assess the distribution and abundance of partulid tree snails on Guam's Department of Defense (DoD) lands.

1.1 Species Description, Distribution, and Status

Surveys targeted four species of partulid tree snail (Gastropoda: Partulidae):

- Mariana Islands tree snail (*Partula gibba*)
- Pacific tree snail (*Partula radiolata*)
- Guam tree snail (*Partula salifana*)
- Mariana Islands fragile tree snail (*Samoana fragilis*)

Three of these tree snails (Mariana Islands tree snail, Pacific tree snail, and Mariana Islands fragile tree snail) are federal candidate species for listing under the U.S. Endangered Species Act (USFWS 2005). The Government of Guam identified all four species in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as species of greatest conservation need (SOGCN) (GDAWR 2006).

1.1.1 Mariana Islands Tree Snail (*Partula gibba*)

The Mariana Islands tree snail is the most widely distributed tree snail in the archipelago, known from nine islands: Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan (Smith et al. 2008). Once considered the most abundant of the partulids in some areas on Guam (Crampton 1925), the only extant population on the island is known from the Haputo Beach region (Hopper and Smith 1992, Smith et al. 2008). Host plants on Guam the Mariana Islands tree snail are known to associate with include *Alocasia macrorrhiza, Asplenium nidus, Cocos nucifera, Hernandia nymphaeifolia, Neisosperma oppositifolia, Phymatodes scolopendria,* and *Piper guamensis* (Hopper and Smith 1992, Smith et al. 2008).

1.1.2 Pacific Tree Snail (*Partula radiolata*)

The Pacific tree snail is endemic to Guam (Smith et al. 2008). This species replaced *P. gibba* as the predominant partulid species on the island by 1989 (Smith and Hopper 1994). The Pacific tree snail is presently the most abundant partulid on Guam and can be found in the northern, central, and southern regions of the island (Hopper and Smith 1992, Smith et al. 2008). Host plants on Guam the Pacific tree snail are known to associate with include *Annona reticulata, Barringtonia asiatica, C. nucifera, Cycas micronesica, H. nymphaeifolia, Intsia bijuga, Mammea odorata, N. oppositifolia, Pandanus dubius,* and *P. guamensis* (Hopper and Smith 1992, Smith et al. 2008).

1.1.3 Guam Tree Snail (*Partula salifana*)

The Guam tree snail is the most geographically restricted of the partulids in the Mariana Islands. The species is only known from Mt. Alifan (Guam) and two adjacent peaks on the southwest coast of the island (Smith et al. 2008). The species was unexpectedly discovered in 1920, with the collection of 22 individuals (19 adults, three adolescents) just below the peak of Mt. Alifan (Crampton 1925). Despite numerous visits and surveys in regions where the Guam tree snail had been previously collected, this species has not been observed since and is believed to be extinct (Hopper and Smith 1992, Smith and Hopper 1994).

1.1.4 Mariana Islands Fragile Tree Snail (*Samoana fragilis*)

The Mariana Islands fragile tree snail is the only member of its genus to occur outside southeastern Polynesia (Smith et al. 2008). This species was originally deemed widespread but uncommon on the islands of Guam and Rota. In 1989, the Mariana Islands fragile tree snail was considered the least abundant of the three partulids on Guam (Smith and Hopper 1994). Not observed on Guam since 1996, this species was recorded in the Pugua Point region (northern Guam) in 2008 (Smith et al. 2008). This colony of Mariana Islands fragile tree snails is the only one currently known on Guam (Smith et al. 2008). The status of the only other known colony, located on Rota, is undetermined (Smith et al. 2008). Host plants of the Mariana Islands fragile tree snail on Guam include *A. reticulata, A. nidus, B. asiatica, C. nucifera, Derris trifoliata,* and *Triphasia trifolia* (Hopper and Smith 1992, Smith et al. 2008).

2.0 METHODS

2.1 Survey Locations

Tree snail surveys were carried out along transects situated at four DoD locations on Guam: Andersen Air Force Base, Andersen South, Navy Barrigada, and North Finegayan (Figure 1). To increase the possibility of detecting the four target species, transects were set up within habitat containing known host plants utilized by partulid tree snails.

2.2 Tree Snail Surveys

Three survey methods were used to determine the presence of partulid tree snails at each survey location: general visual surveys, detailed visual surveys, and quadrat surveys. These methods are specifically designed to target partulid tree snails and are adapted from those utilized in previous tree snail assessments (Hopper and Smith 1992, Smith et al. 2008).

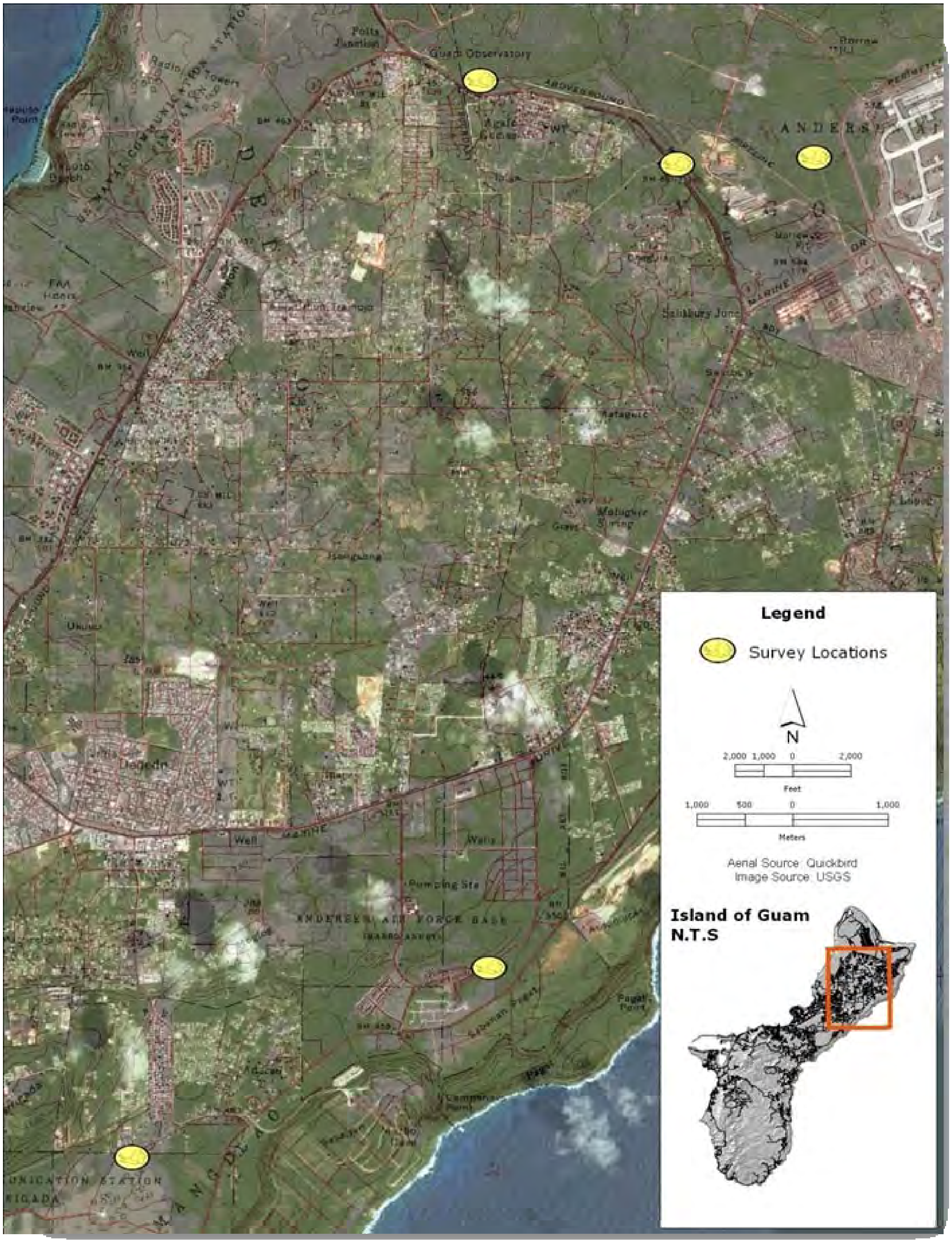

Figure 1. Partulid tree snail surveys were undertaken at five locations on Department of Defense Lands, Guam.

2.2.1 General Visual Surveys

General visual surveys involved up to two trained observers walking each transect searching likely tree snail habitat for the presence of snails. During the general visual survey period, observers also noted specific areas that included an abundance of known partulid host plants, and areas where detailed visual surveys (see Section 2.2.2) would subsequently occur. Information on known partulid host plant species was obtained from Hopper and Smith (1992) and Smith et al. (2008).

2.2.2 Detailed Visual Surveys

Detailed visual surveys were conducted at locations along each transect where known partulid host plants were abundant. At each location, observers intensively examined the leaves and stems of known partulid host plants for up to 30 minutes. If live tree snails were observed, quadrat surveys (see Section 2.2.3) were completed. Following each plant examination, leaf litter was investigated for partulid shells for up to 10 minutes. If snail shells were observed, we noted location and condition of the shell (e.g., weathering, fragmentation, color intensity or bleaching) that may indicate recent presence of the snails. If live partulid tree snails or their empty shells were found during the detailed visual survey period, the location was recorded as supporting tree snails.

2.2.3 Quadrat Surveys

If live partulid tree snails were located within the 30-minute detailed visual survey period, four 25-m^2 quadrats were established under the densest understory, as determined by a spherical densiometer. All partulid tree snails occurring within the quadats and to a height of six feet (ft) (two meters (m)) above were identified to species, and their shell length and height measured to the nearest 0.1 millimeter (mm) with sliding vernier calipers. Host plant species and vertical height of the host plant to 1.6 ft (0.5 m) were recorded for each partulid tree snail observed.

During the quadrat surveys, temperature (°C), relative humidity (RH), and air movement (Beaufort scale) were measured with miniature probes in microhabitats inhabited by partulid tree snails to quantify inhabited microhabitat features (Crampton 1925). Temperature, humidity, and air movement measurements were also taken in uninhabited areas to assess their suitability for supporting tree snail populations. Comparisons of data from inhabited and uninhabited forest will provide a clearer characterization of suitable microclimatic conditions suitable for tree snail survival.

3.0 RESULTS

Between 25 September 2009 and 21 January 2010, a general and detailed visual survey was completed along six transects: three at Andersen Air Force Base, one at Andersen South, one at Navy Barrigada, and one at North Finegayan (Table 1). Total surveyed area was 2450 linear meters (8036 linear feet). No living partulid tree snails (or their shells) were observed during any of the surveys conducted along the five transects (Table 1).

Table 1. Partulid tree snail general and detailed visual survey results on Department of Defense Lands, Guam. AAFB = Andersen Air Force Base, ANDS = Andersen South, NBAR = Navy Barrigada, NFIN = North Finegayan. (m) = meters

General Visual Survey Date	Detailed Visual Survey Date	Transect	Transect Length (m)	# of Partulid Tree Snails Observed
12 October 2009	23 October 2009	AAFB - 5	400	0
1 October 2009	2 October 2009	AAFB - 6[2]	400	0
25 September 2009	25 September 2009	AAFB - 7	400	0
1 October 2009	9 October 2009	ANDS – 7	500	0
29 September 2009[1]	29 October 2009[1]	NBAR - 3[2]	250	0
7 October 2009[1]	6 November 2009[1]	NBAR - 3[2]	250	0
21 January 2010	21 January 2010	NFIN - 9	500	0

[1] Survey was completed over the course of two days due to poor weather conditions.

[2] Flatworms recorded along the transect.

Live introduced lined tree snails (*Drymaeus multilineatus*) were commonly observed along the Navy Barrigada transect (Figure 2). Shells of the introduced giant African snail (*Achatina fulica*) were seen on all five transects. Both live individuals and shells of the introduced snail *Satsuma mercatoria* (no common name) were seen at all five transects. Additionally, live introduced Manokwar flatworms (*Platydemus manokwari*) were observed along two transects (Table 1).

Because no live partulid tree snails were observed during general or detailed visual surveys, no quadrat surveys were completed; therefore, temperature, humidity, and air movement measurements were not taken in areas not inhabited by tree snails.

Figure 2. Lined tree snails (*Drymaeus multilineatus*) were common along the Navy Barrigada transect. Photo: SWCA.

4.0 DISCUSSION

No partulid tree snails were observed during any of the visual surveys conducted on the six transects distributed in four disparate areas (Andersen Air Force Base, Andersen South, Navy Barrigada, and North Finegayan). However, since there were several known host plant species present throughout the survey area, the possibility that tree snails are present in habitat associated with the surveyed transects cannot be dismissed. When development projects arise along or near the survey locations, more extensive surveys should be considered as existing tree snail habitat occurs throughout the area and could support tree snail colonies.

Flatworms were recorded at Navy Barrigada and Andersen Air Force Base. Because the species was not targeted during the tree snail surveys and are more likely seen nocturnally when they are active, flatworms were likely present but undetected at all locations. This flatworm is known to feed on juvenile partulid tree snails in the wild on Guam and Pacific tree snails in captivity, and is believed to be the primary threat to the continued existence of partulid tree snails on Guam, the Mariana Islands, and potentially Oceania (Hopper and

Smith 1992). The authors reported that on Guam where flatworm abundance was high, partulid tree snail colonies were rapidly declining.

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SURVEY OF ENDANGERED TREE SNAILS ON NAVY-OWNED LANDS IN GUAM

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INTRODUCTION

The land snail faunas on islands of the tropical Pacific exhibit spectacular evolutionary radiations (Cowie, 1996), although they are dominated by relatively few families. Despite their diversity, native land snail faunas of the Pacific islands are composed almost entirely of narrow-range endemics. The same factors that favored rapid evolution of endemic land snail biotas from colonists dispersing successfully to islands also imposed extreme sensitivity to environmental disturbances and high rates of extinction on the resulting populations. These constraints among insular endemic species are consequences of small geographic ranges and small populations (Diamond, 1984; Tracy and George, 1992).

These unique native snail faunas are now disappearing rapidly (Lydeard et al., 2004). In the Mariana Islands, Bauman (1996) recorded at least 39 native species of land snails in Rota, and Kurozumi (1994) recorded at least 16 species on the islands north of Saipan. Sixty-eight percent of the Rota snail species are extinct or declining (Bauman, 1996). These and other data suggest that overall perhaps 50% of the land snail fauna has disappeared throughout the Pacific islands as a whole, mostly in recent times (Lydeard et al., 2004).

The family Partulidae consists of predominantly arboreal snails that are limited in geographic distribution to volcanic high islands of the tropical Pacific, ranging from the Marquesas and Austral Islands in the east to the Mariana Islands and Belau in the west (Kondo, 1968; Cowie, 1992). Members of the most primitive order of pulmonate snails, the Partulidae is speciose; Kondo (1968) recognized 126 species. Partulids are also highly endemic, with most species restricted to single islands. Only one species occurs in more than one island group (Cowie, 1992; Johnson et al., 1993).

Partulid populations have declined throughout their range in recent years, in some cases to extinction (Clarke et al., 1984; Murray et al., 1988; Hopper and Smith, 1992; Miller, 1993). In Guam, the endemic Mt. Alifan tree snail, *Partula salifana*, is thought to be extinct (Hopper and Smith, 1992). The tree snail *Partula gibba* has disappeared from historical locations in Guam and Saipan studied by Crampton (1925) in 1920 and by Kondo in 1949 (Smith and Hopper, 1994). No living *Partula gibba* were found in previously reported habitations in Rota, Tinian, and Aguiguan, as well (Smith and Hopper, 1994; Smith, 1995, In Review). Major factors contributing to this broad decline include loss of habitat to agricultural and urban development and introductions of invasive species, including predators intended as biological controls for the giant African snail *Achatina fulica* (Smith and Hopper, 1992; Cowie, 2000, 2001).

The objectives of this survey are to determine the location of Guam tree snails on Navy-owned lands in Guam and to identify the location of suitable habitat and inventory areas that have the highest probability of supporting snail populations. The areas of interest are on NCTS and the Ordnance Annex. Three species of Guam's native tree snails—*Samoana fragilis*, *Partula gibba*, and *Partula radiolata*—are candidate species under the federal Threatened and Endangered Species Act (Federal Register, 1994). All four species, including *Partula salifana*, are listed as endangered species under the Endangered Species Act of Guam (5 GCA, Section 63205.(c)).

TAXONOMIC REVIEW

The Mariana Archipelago (Figure 1) historically supported five species of partulids scattered across seven small islands lying at the northwestern limit of the geographical range of the Partulidae. In the first systematic study of the distribution of Mariana partulids, Crampton (1925) reported four species of partulids from Guam and Saipan. Kondo (1970) added five smaller islands to the range of partulids in the Mariana Islands and described a fifth species endemic to the tiny island (<3 mi^2) of Aguiguan [also known as Aguijan]. However, recent surveys indicate that as many as three of the five Mariana species are either extinct or on the brink of extinction (Hopper and Smith, 1992; Smith and Hopper, 1994; Smith, In Review).

Partula gibba Férussac, 1821 (FIGURE 2)
Synonymy:
Partula mastersi Pfeiffer, 1857
Partula bicolor Pease, 1872

Description: Shell dextral or sinistral, conic-ovate, perforate, pellucid. Spire acute, 4 to 4½ whorls, the last gibbous. Sculpture of spiral striae, crossed by weak longitudinal growth striae; suture slightly adpressed, white or brown. Aperture oblong-ovate, subquadrangular; peristome reflexed, broadly dilated, white. Background color variable, chestnut brown to whitish-yellow; also purple. Adult length 14 to 18 mm, width 10 to 14 mm.

Range: *Partula gibba* is the most widely distributed tree snail in the Mariana Islands, occurring on nine islands. This species is known from Guam, Rota, Aguiguan, Tinian, Saipan, Anatahan, Sarigan, Alamagan, and Pagan.

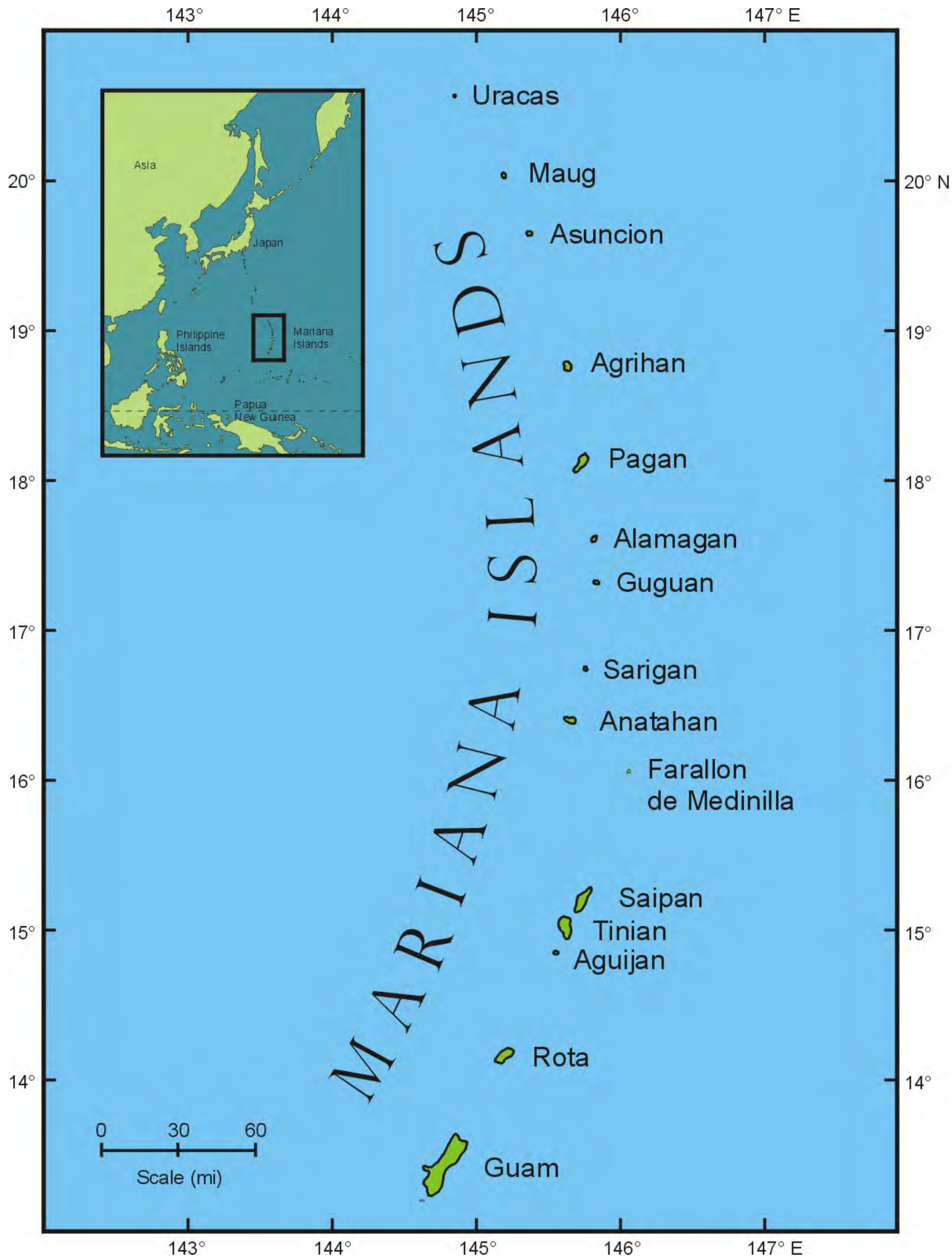


Figure 1. Map of the Mariana Islands. Inset shows the position of the Mariana Islands in relation to Asia and the western Pacific.

Figure 2. *Partula gibba* on *Alocasia macrorrhiza* leaf at Haputo, Guam.

Partula radiolata (Pfeiffer, 1846) (FIGURE 3)

Synonymy:

Bulimus (*Partula*) *radiolata* Pfeiffer, 1846.

Description: Shell dextral, oblong-tapering, subperforate, thin. Spire obtuse, whorls typically 5, slightly convex, the last about equal to the spire. Sculpture of faint, impressed lines. Aperture obliquely oval; peristome simple, thin, white, expanded, the right margin somewhat straightened, columellar margin dilated above, spreading above the umbilicus. Background color pale straw-colored with darker axial rays and brown lines. Adult length 13 to 18.5 mm, width 8 to 12 mm.

Range: *Partula radiolata* is a Guam endemic. It has been erroneously reported to occur on the island of New Ireland in the Bismarck Archipelago by Pfeiffer (1846), Hartman (1881), and Parkinson et al. (1987).

Partula salifana Crampton, 1925 (FIGURE 4)

Synonymy:

None.

Description: Shell dextral, ovate-conic, thick and heavy. Umbilicus open, slightly flattened. Spire somewhat protracted, whorls 5 to 5¼, slightly impressed below the suture. Sculpture of spiral striae on embryonic whorls becoming weaker on postembryonic whorls. Aperture elongate, interior purplish and shining, peristome expanded and flattened, gradually narrowing as

Figure 3. *Partula radiolata* on *Alocasia macrorrhiza* at Haputo, Guam.

Figure 4. *Partula salifana* (paratype, Bishop Museum, Honolulu).

it approaches contact with body whorl, color variable from white to yellowish brown or purple. Background color is a rich chestnut-brown or seal-brown to yellowish or olive; the apex color is often purple as a result of decortication. Adult length 17 to 19 mm, width 10.5 to 11.7 mm.

Range: *Partula salifana* is the most geographically restricted of the partulids in the Mariana Islands. It is known only from the summit of Mount Alifan and two adjacent peaks on the southwest coast of Guam.

Samoana fragilis (Férussac, 1821) (FIGURE 5)
Synonymy:
Partula quadrasi Möllendorff, 1894

Description: Shell dextral, ovate-conic, narrowly and half-covered perforate, fragile, pellucid. Spire conic, the apex somewhat obtuse; whorls typically 4, slightly convex, separated by adpressed, marginated suture; last whorl distinctly convex, nearly tumid. Sculpture of delicate spiral striae intersected by transverse growth striae. Aperture oblique, oval, a little excised; peristome simple, thin, well expanded, the columella dilated above, recurved, forming a distinct angle with the parietal wall. Background color buff-tinted, semi-transparent; narrow darker maculations and whitish banding due to colors of viscera visible through the shell. Adult length 12 to 16 mm, width 10 to 12 mm.

This species exhibits several reproductive characteristics that are unique among Mariana Islands partulids. The eggs are large (4.2 mm × 3.3 mm), and they are encapsulated by a tough, calcareous shell (Crampton, 1925). Further, *Samoana fragilis* reaches sexual maturity before it expands the varical lip that characterizes adults of terminal size (Crampton, 1925; Kondo, 1955). The latter trait has not been reported for any other partulid species.

Range: *Samoana fragilis* is the only member of the genus to occur outside southeastern Polynesia. In the Mariana Islands, *Samoana fragilis* has been reported from Guam and Rota.

METHODS

Forested areas of NCTS and the Guam Ordinance Annex were surveyed by visual census methods adapted from Hopper and Smith (1992) between 21 May and 30 August 2008, plus a resurvey of the Kitts Road area of the ORdinance Annex on 26 February 2008. Mixed mesophytic forest predominated by native species identified as partulid habitat by Hopper and Smith (1992) were the focus of this project. Survey sites were selected from satellite images after consultation with botanists acquainted with the areas. Special attention was given to sites where partulids were previously reported.

Figure 5. *Samoana fragilis* observed on *Annona reticulata* at NCTS, Guam.

At survey sites, broad-leafed tree species were inspected for 30 min, and leaf litter was examined for 10 min in search of fresh ground shells; Hopper and Smith (1992) reported that, when present in an area, snails are generally found within the first 5 min of searching. Search area tracks were recorded by GPS when possible. If no live snails or fresh ground shells were found during the timed search, the site was recorded as not supporting tree snails. When live tree snails were located within the 30-min visual census period, four 25-m^2 quadrats were established under the densest understory, as determined by a spherical densiometer. All snails occurring within the quadrats were identified to species, and their shell length was measured to the nearest 0.1 mm with sliding vernier calipers. Host tree species were recorded for each snail observed.

Temperature, humidity, and air movement were measured with miniature probes in microhabitats inhabited by tree snails to quantify the "more ultimate ecological conditions which determine the distribution of suitable vegetation," and presumably the distribution of tree snails, alluded to by Crampton (1925). Measurements were also taken in uninhabited areas to assess their suitability for supporting snail populations. These data from inhabited and uninhabited forest were compared to elucidate the minimum conditions for the survival of snail populations.

RESULTS

Four partulid colonies were located during the survey, two at NCTS (Figure 6) and two at the Ordinance Annex (Figure 7). Of the four colonies, only the Haputo colony was previously known.

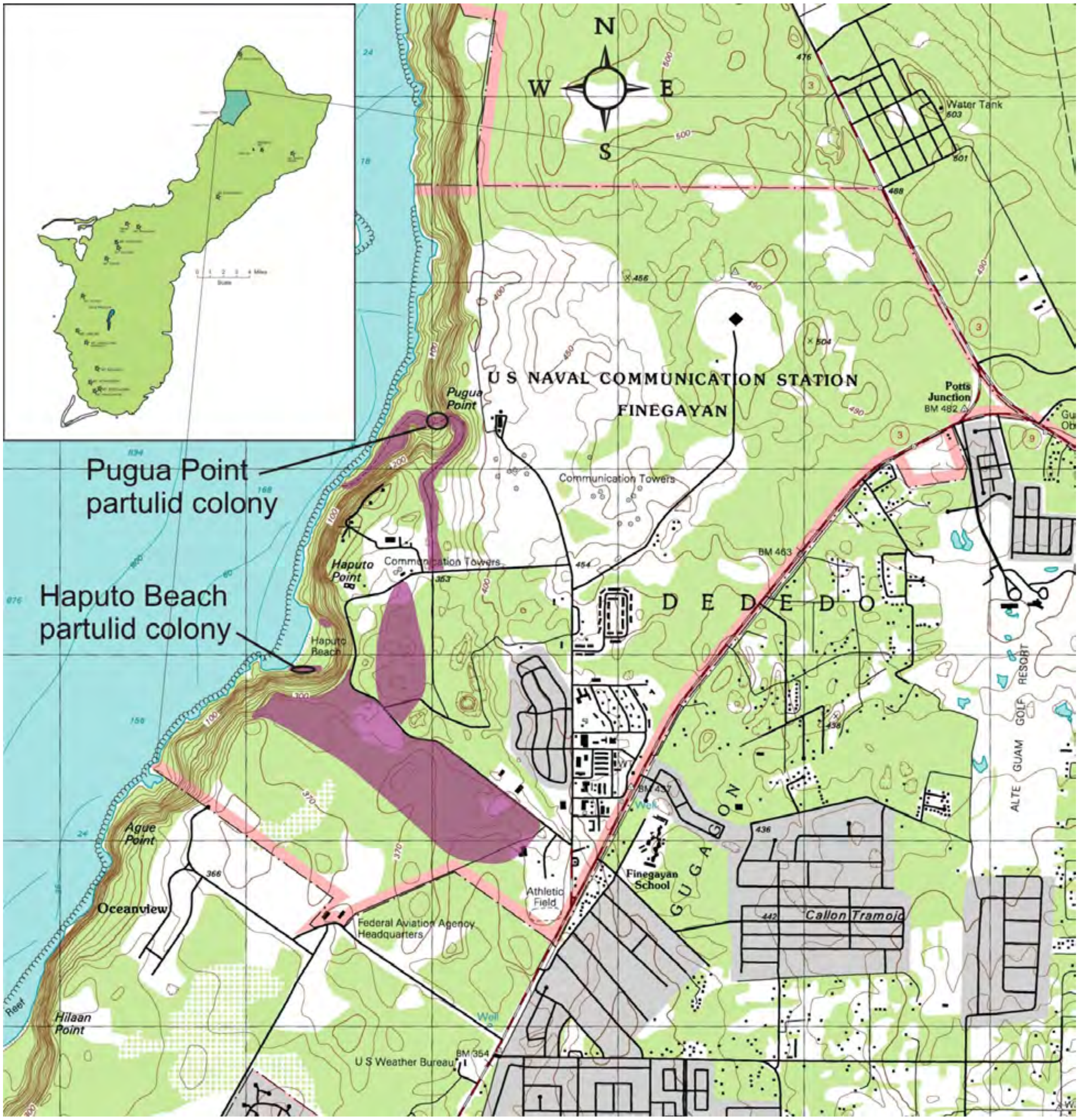


Figure 6. Map of Naval Computer and Telecommunications Station, Finegayan. Surveyed areas are shaded in purple, and locations of partulid colonies are indicated by ellipses.

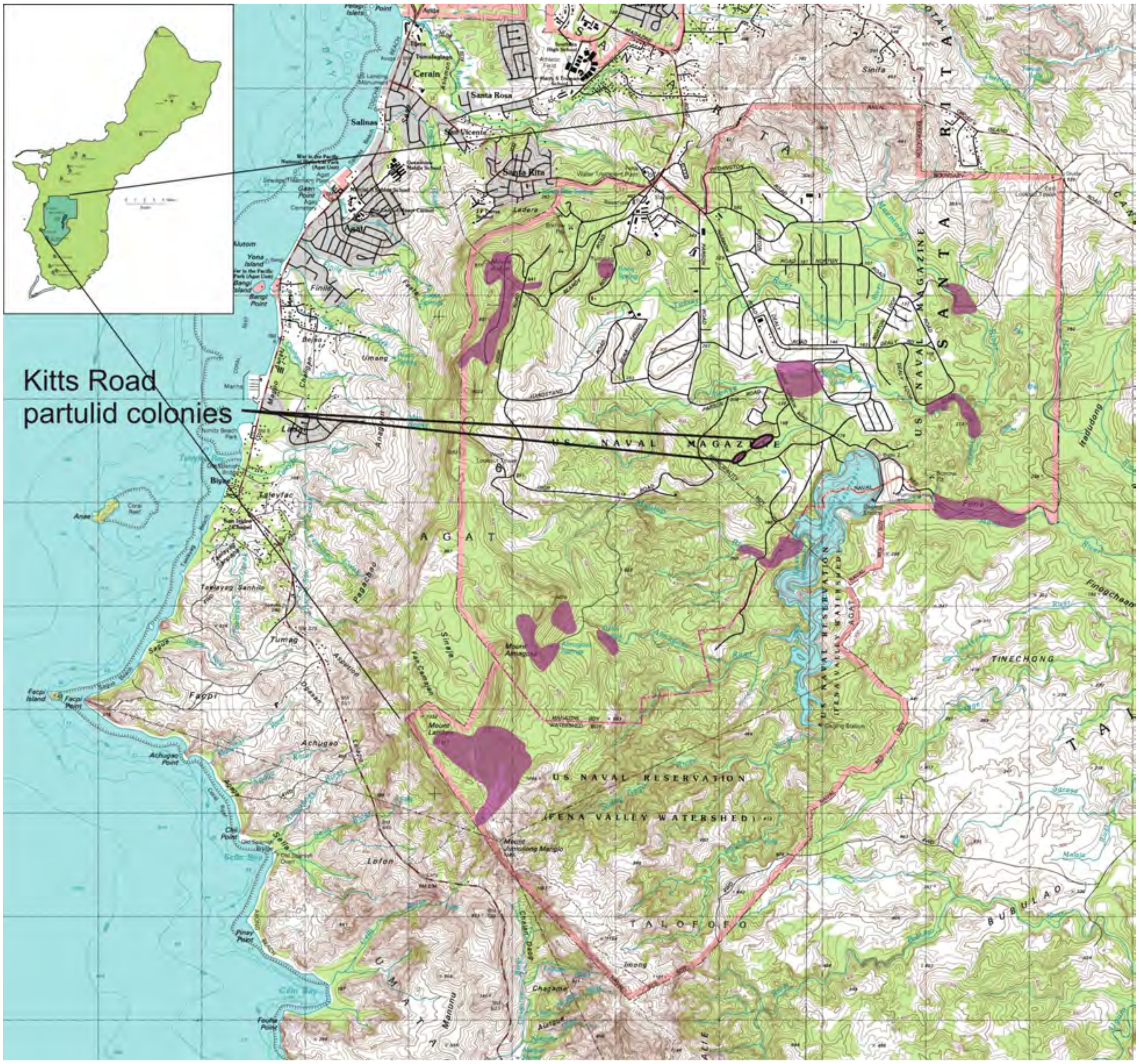


Figure 7. Map of Naval Ordinance Annex. Surveyed areas are shaded in purple, and locations of partulid colonies are indicated by ellipses.

Size-frequency distributions for partulids at the Pugua Point, Haputo Beach, and N. Kitts Road sampling stations are presented in Figures 8, 9, and 10, respectively. In the Pugua Point colony, all three *Partula radiolata* were reproductively mature, as indicated by the presence of a varical lip (see Crampton, 1925). It is not possible to determine the percentage of mature individuals in the *Samoana fragilis* colony because of the unique characteristic of this species to reach maturity before the formation of the varical lip. In the Haputo Beach colonies, some 43% of the *Partula gibba* were reproductively mature, while about 40% of the *Partula radiolata* were mature. Some 33% of the *Partula radiolata* in the N. Kitts Road colony were reproductively mature.

Box plots of the size data for partulid colonies are presented in Figures 11,12, and 13. Box plots provide excellent visual summaries of the smallest observation, the lower quartile (Q1), the median, the upper quartile (Q3), the largest observation, and observations that are considered unusual, or outliers (Tukey, 1977). The box stretches from the lower hinge (defined

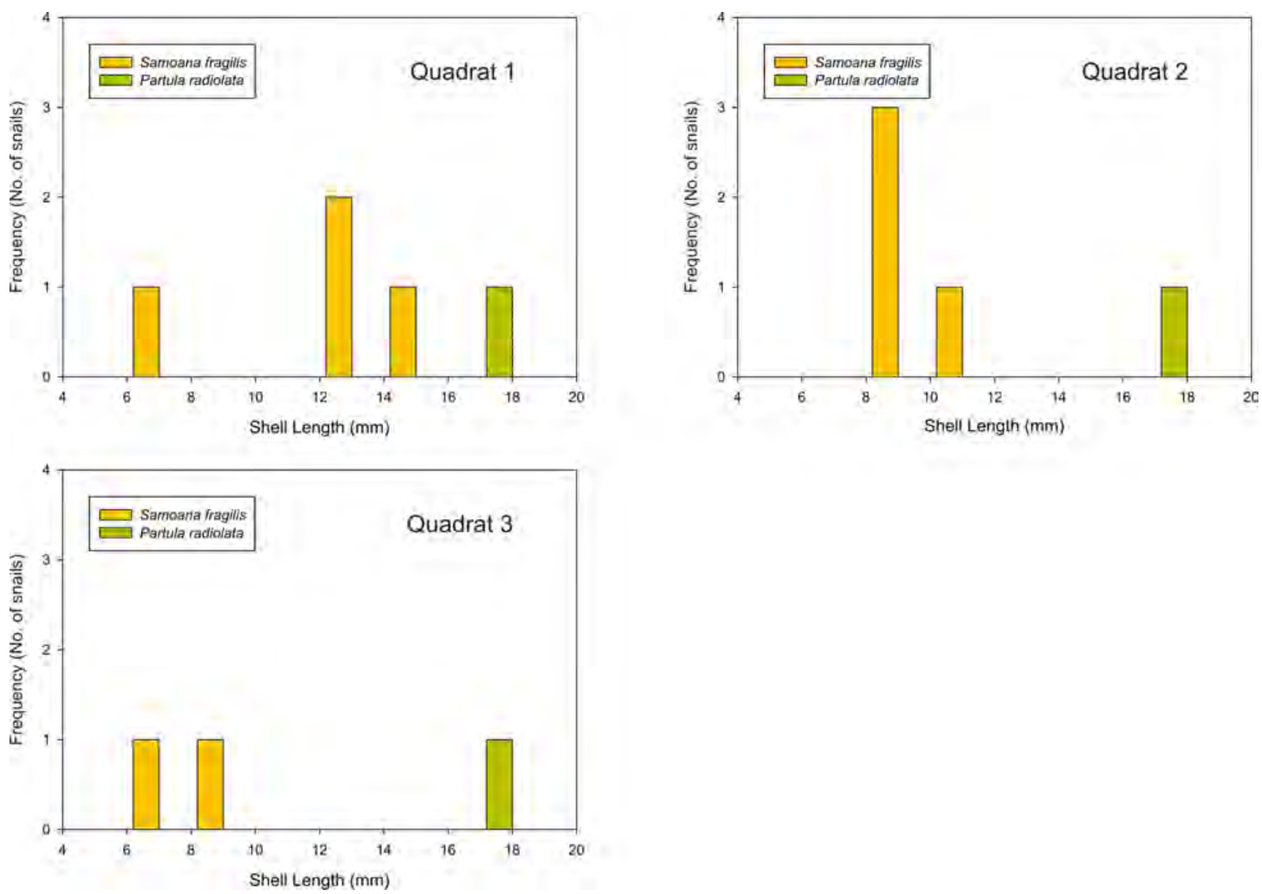


Figure 8. Size-frequency distributions of partulid species at the Pugua Point sampling station, NCTS, Guam. No tree snails were observed in Quadrat 4.

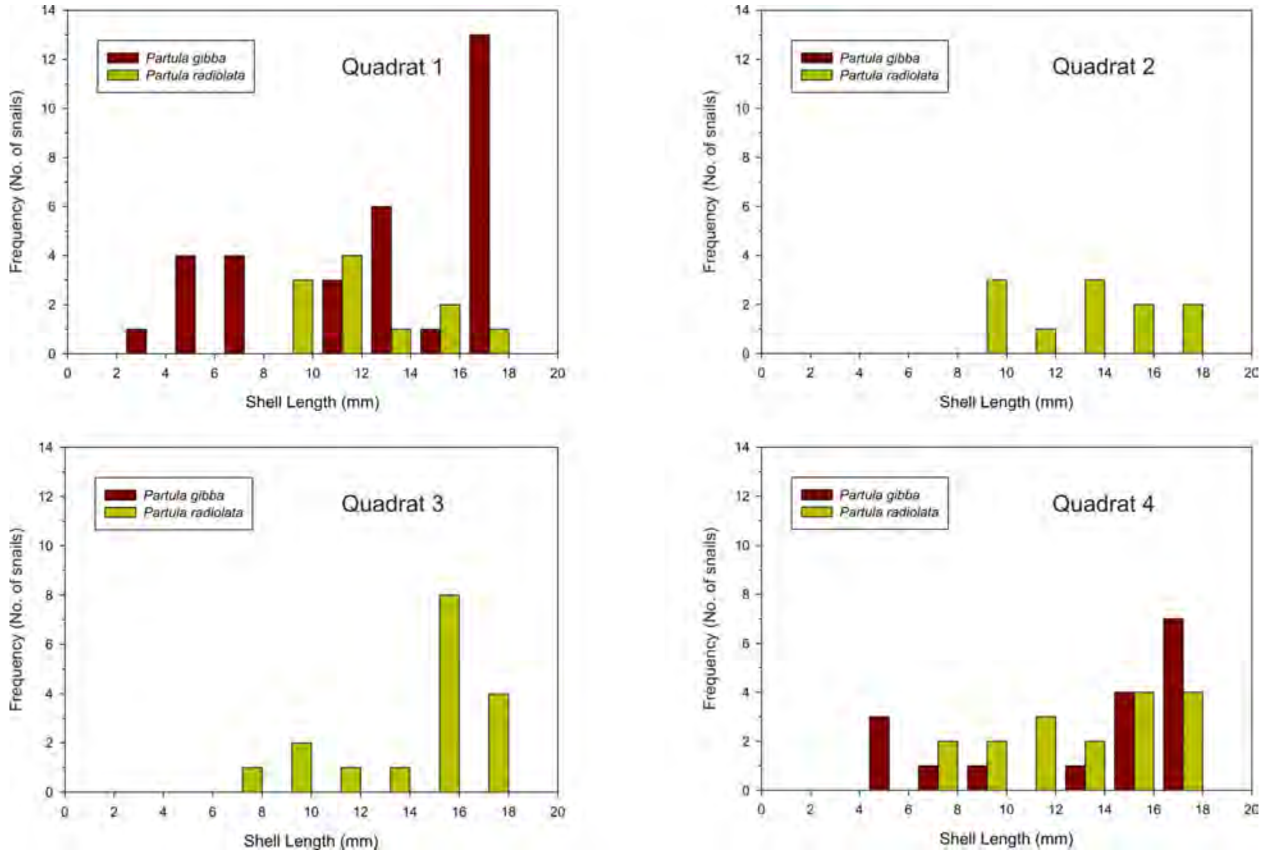
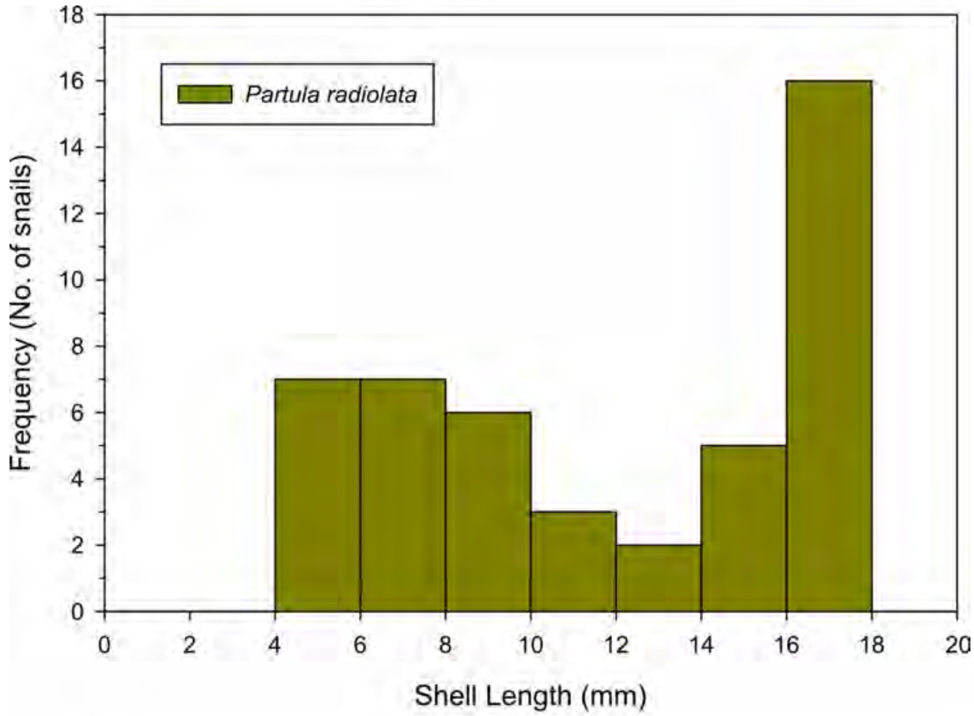


Figure 9. Size-frequency distributions of partulid species at the Haputo Beach sampling station, NCTS. *Partula gibba* was not observed in Quadrats 2 and 3.

as Q1, or the 25th percentile) to the upper hinge (Q3, or the 75th percentile) and therefore contains the middle half of the scores in the distribution. The median is shown as a line across the box. Therefore, one-fourth of the distribution is between this line and the top of the box, and one-fourth of the distribution is between this line and the bottom of the box.

Host plant species for the four colonies of tree snails are presented in Table 1. Of the host plants observed in this study, *Thelypteris* sp. is reported for the first time.

Environmental parameters of the microhabitat of the tree snails are given in Tables 2, 3, and 4, respectively, for Pugua Point, Haputo Beach, and Ordinance Annex. Average canopy cover at Pugua Point was 79% (n=15), and ranged from56% to 97%. At Haputo Beach, average canopy cover was 80% (n=19), and ranged from 67% to 92%.



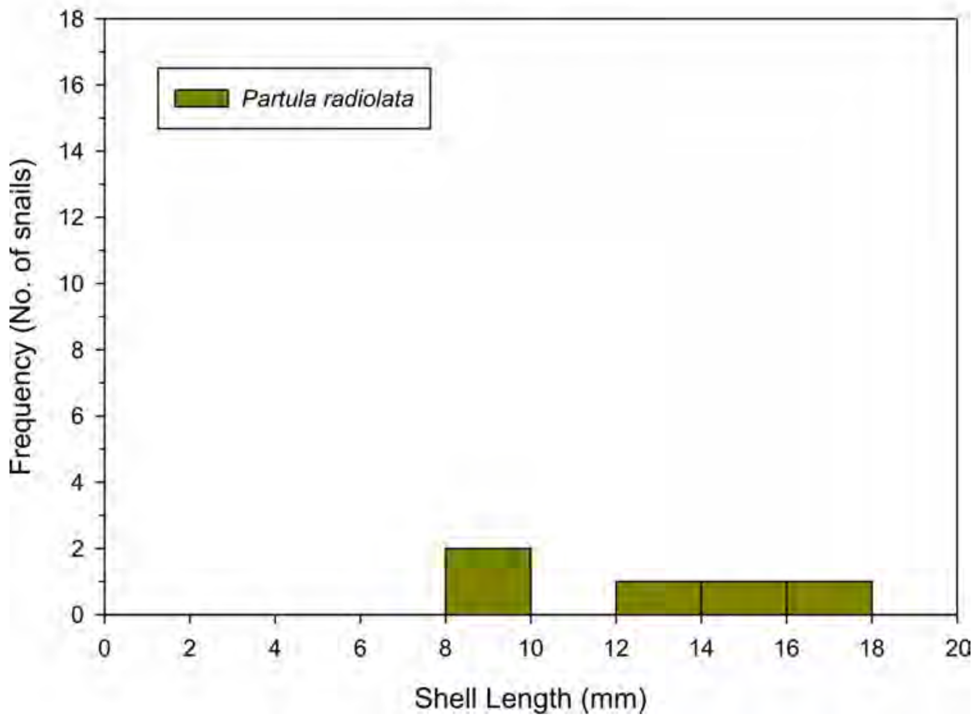


Figure 10. Size-frequency distributions of *Partula radiolata* colonies at the N. Kitts Road sampling station, Naval Ordinance Annex.

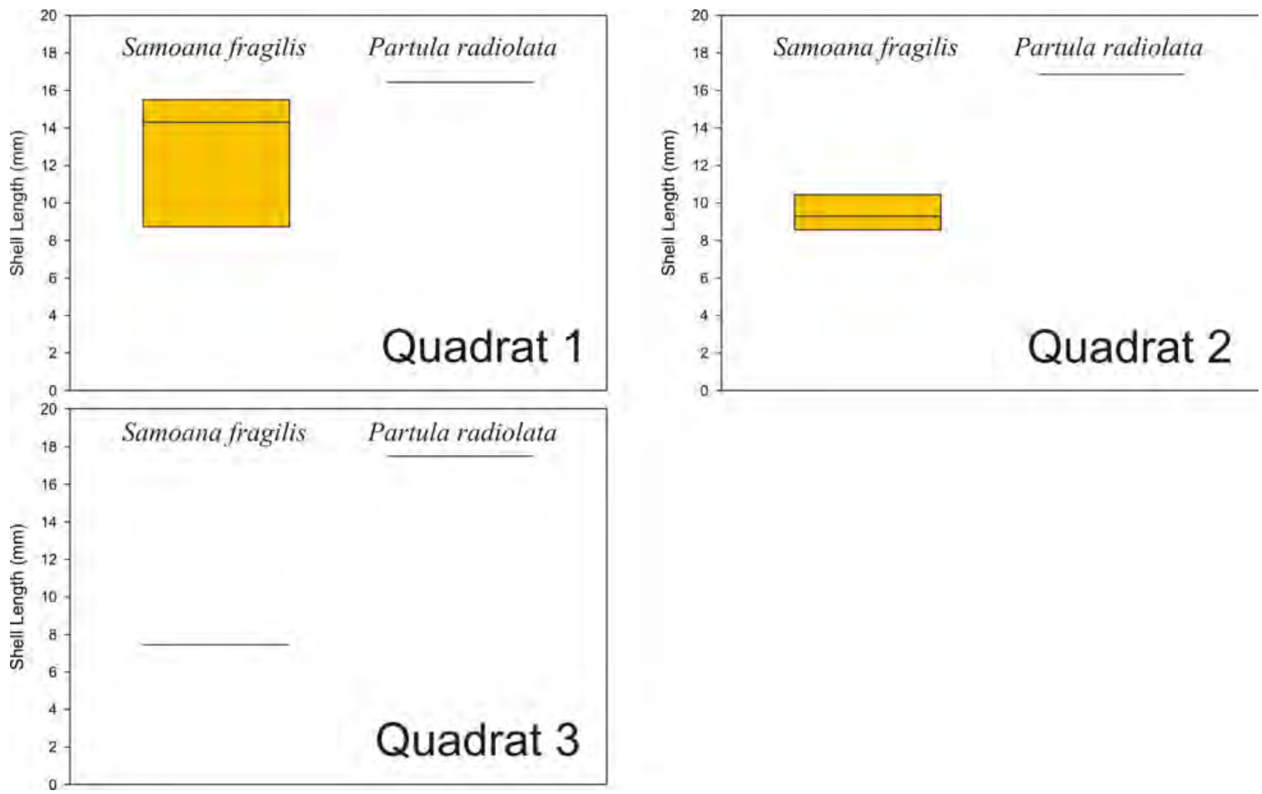


Figure 11. Box plots of shell length of partulid species at the Pugua Point, NCTS sampling station. Lines represent two few data to generate a box.

DISCUSSION

Four colonies of tree snails were observed during this study. The Pugua Point colony is distinct in being dominated by *Samoana fragilis*, a species that has not been observed in Guam since 1996 (A. Asqwith and S.E. Miller, personal communication, March 1996; Smith unpublished data). This is the only colony of *Samoana fragilis* presently known in Guam, and the status of only other reported colony, in Rota, remains to be determined.

Of the four colonies of tree snails found on Naval lands in this study, only the Haputo Beach colony was previously reported (see Hopper and Smith, 1992). None of the colonies were densely populated, and the Haputo Beach population has declined markedly since 1996. In three years of monthly population sampling at Haputo Beach from 1993 to 1995, Smith (unpublished data) found snail densities ranged from a minimum of 4.7 m^{-1} to a maximum of 17.2 m^{-1}. We re-examined the same plot during this survey, and we found that snail density has declined to 2.2 m^{-1}, or fewer than half the minimum density previously observed. This decline has been accompanied, or possibly caused by, a change in forest structure from an understory dominated

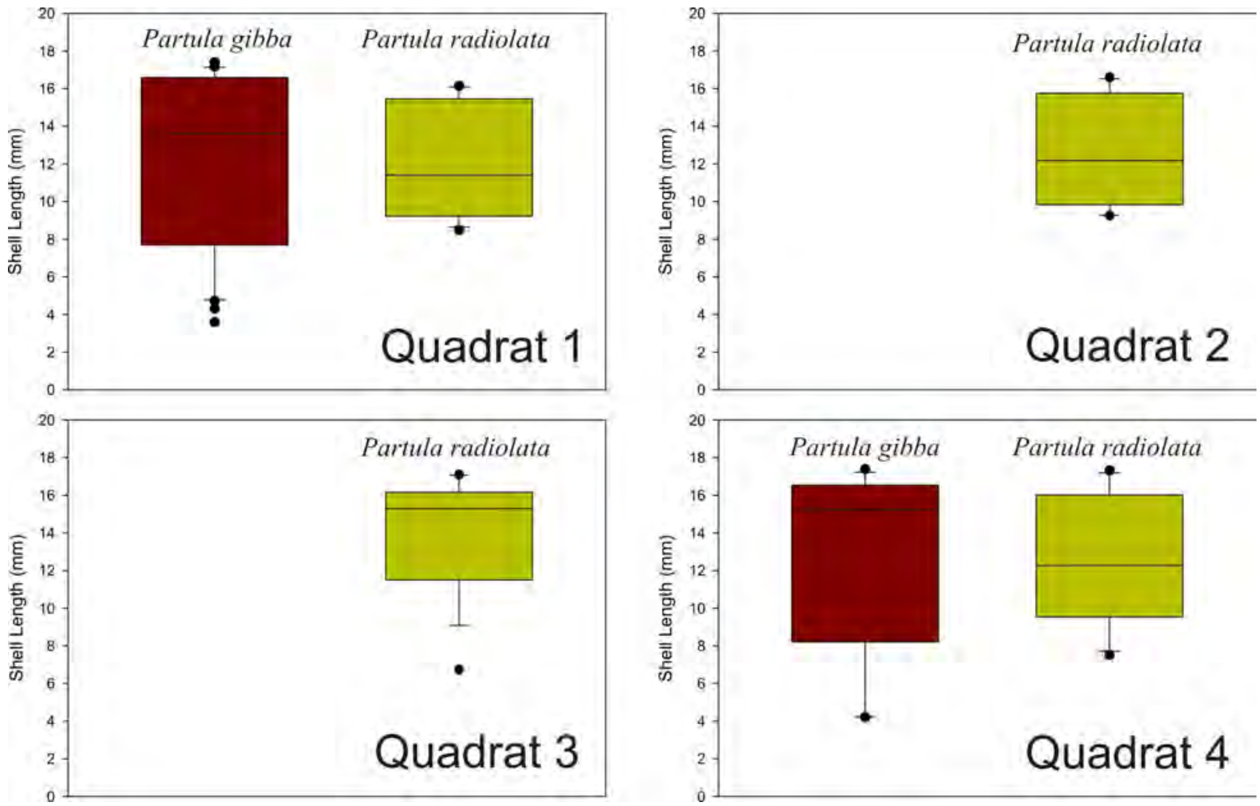
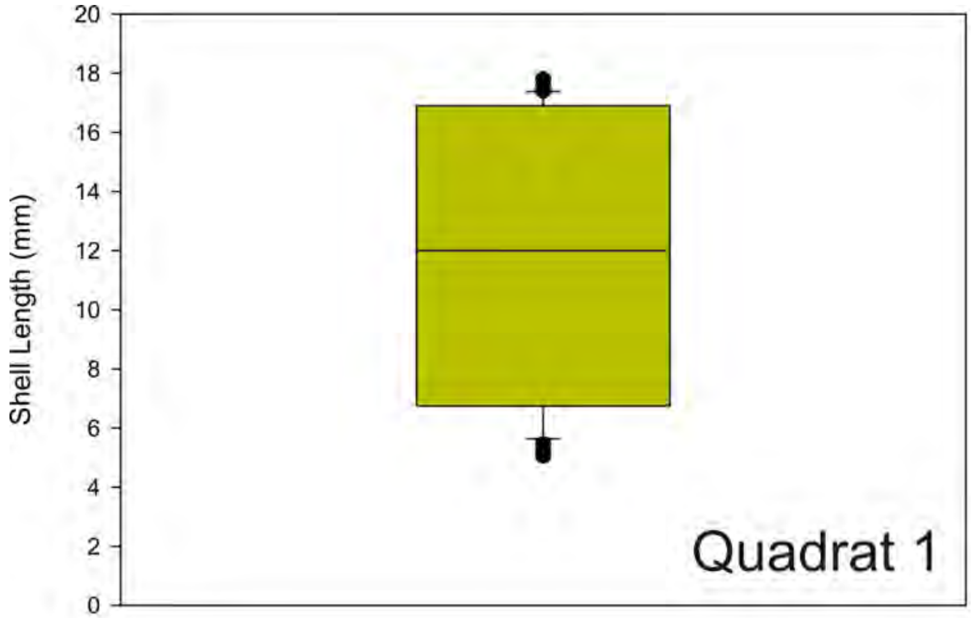


Figure 12. Box plots of shell length of partulids at the Haputo Beach, NCTS sampling station. No *Partula gibba* were observed in Quadrats 2 and 3.

by *Neisosperma oppositifolia*, a preferred host plant species (Hopper and Smith, 1992; Smith, 2007), to one dominated by the fern *Thelypteris* sp., which is here reported as a host plant for the first time. Although partulids were observed on *Thelypteris* sp., only a few snails inhabited them.

Partulids were found throughout the island when Crampton visited Guam in 1920. At sites from Merizo to Ritidian, and from coastal areas to highest elevations. Crampton found snails typically 1 to 3 m above the ground in cool, shaded forest habitats (Crampton 1925; Hopper and Smith, 1992) with high humidity and reduced air movement that might promote dessication. Crampton (1925) described the habitat requirements of the partulid trees snails of the Mariana Islands as: "a sufficiently high and dense growth to provide shade, to conserve moisture, and to effect the production of a rich humus. Hence, the limits to the areas occupied by Partulae are set by the more ultimate ecological conditions which determine the distribution of suitable vegetation." Crampton (1925) further described the intact structure of native Mariana forests as having four general levels: the high trees; the shrubs and *Pandanus*; the cycads and taller ferns; and the succulent herbs. He noted that the Mariana Islands partulid tree snails



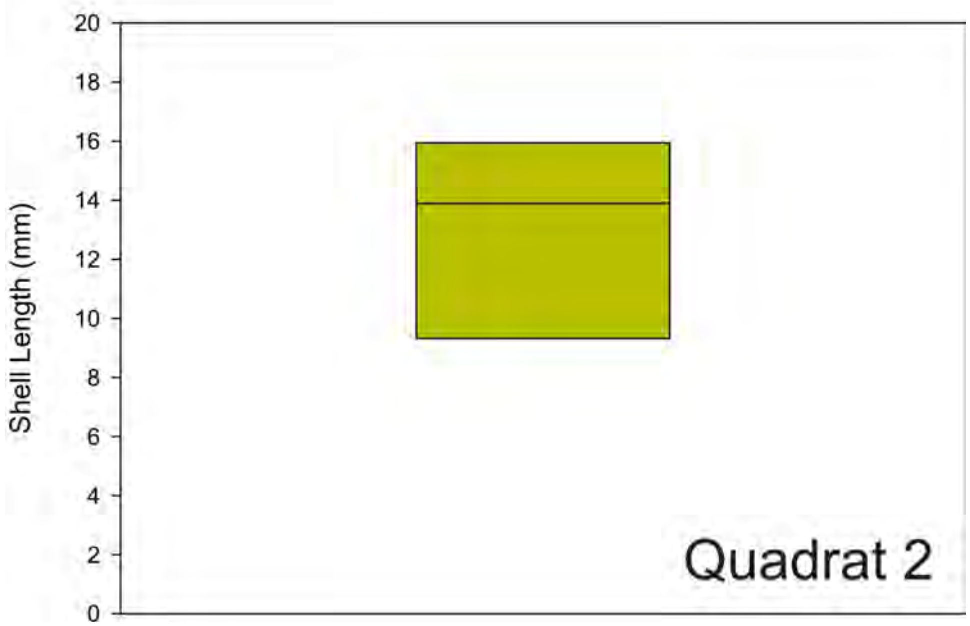


Figure 13. Box plots of *Partula radiolata* shell lengths at the N. Kitts Road, Ordinance Annex sampling station.

Table 1. Plant species hosting arboreal snails at Pugua Point, Haputo Beach, and N. Kitts Road. A filled circle (●) indicates that the snail species was observed on the host plant within one or more quadrats.

Plant taxa	*Partula gibba*	*Partula radiolata*	*Samoana fragilis*
<u>Pugua Point, NCTS</u>			
Annona reticulata		●	●
<u>Haputo Beach, NCTS</u>			
Alocasia macrorrhiza	●	●	
Hernandia sonora	●	●	
Neisosperma oppositifolia	●	●	
Piper guahamense	●	●	
Thelypteris sp.	●	●	
<u>N. Kitts Road, Ordinance Annex</u>			
Hernandia sonora		●	

preferentially live on understory vegetation and did not inhabit the high canopy trees. Habitats satisfying the environmental requirements for tree snails were numerous in the Mariana Islands prior to World War II, including coastal strand vegetation, limestone forest, forested river borders, and lowland and highland forests (Crampton 1925).

Tragically, we found no areas on NCTS or the Ordinance Annex that resemble Crampton's descriptions. While the high trees remain in some areas, the understory has been severely damaged or removed altogether by feral ungulates. Ungulate scats were ubiquitous from the floors of ravines to the summit of Mt. Lamlam. Removal of the understory trees and shrubs has resulted in more xerophytic conditions by allowing greater air motion under the canopy. Air motion promotes desiccation, thereby making conditions unsuitable for the survival of land snails. Data in Tables 2–4 support this conclusion. Ambient temperatures and humidities at the sampling stations are very similar to microhabitat temperatures and humidities. However, ambient air velocities are markedly greater than air velocities in the snails' microhabitat on the undersides of the leaves.

Conclusions and Recommendations

Native tree snails in Guam have continued to decline in the last decade. Previously reported colonies at Mt. Alifan have been extirpated since the late 1980s. Elsewhere on Naval

Table 2. Ambient and microhabitat environmental parameters in quadrats at the Pugua Point, NCTS sampling station.

	Temperature (°C)	Relative Humidity (%)	Air Motion (m • sec^{-1})
Quadrat #1			
Ambient	34.7	73.5	0.0–1.1
Annona reticulata	30.5	70.3	0.02
Annona reticulata	30.1	75.5	0.24
Annona reticulata	30.2	75.1	0.06
Annona reticulata	30.3	77.0	0.03
Annona reticulata	31.9	71.2	0.41
Quadrat #2			
Ambient	35.5	77.6	0.0–0.9
Annona reticulata	32.3	61.0	0.25
Annona reticulata	32.3	65.7	0.14
Annona reticulata	31.5	66.2	0.22
Annona reticulata	31.5	66.2	0.62
Quadrat #3			
Ambient	35.9	70.7	0.1–1.0
Annona reticulata	34.1	56.6	0.42
Annona reticulata	33.1	61.6	0.79
Annona reticulata	31.8	69.1	0.34
Quadrat #4			
Ambient	38.0	65.6	0.3–0.8
Annona reticulata	33.9	61.5	0.46
Annona reticulata	33.5	61.9	0.62
Annona reticulata	32.8	60.5	0.23
Annona reticulata	32.4	64.6	0.29
Annona reticulata	32.2	63.4	0.32

Table 3. Ambient and microhabitat environmental parameters in quadrats at the Haputo Beach, NCTS sampling station.

	Temperature (°C)	Relative Humidity (%)	Air Motion (m • sec^{-1})
Quadrat #1			
Ambient	30.9	81.5	0.7–1.0
Alocasia macrorrhiza	28.7	81.1	0.10
Alocasia macrorrhiza	28.4	81.1	0.32
Piper guahamense	28.6	84.2	0.32
Piper guahamense	28.7	84.7	0.03
Thelypteris sp.	28.7	83.7	0.18
Thelypteris sp.	28.7	82.8	0.09
Quadrat #2			
Ambient	31.3	82.1	1.2–1.8
Alocasia macrorrhiza	30.6	75.6	0.56
Alocasia macrorrhiza	30.5	76.0	0.03
Piper guahamense	31.3	74.6	0.21
Piper guahamense	30.9	74.8	0.50
Hernandia nymphaeifolia	30.5	76.3	1.22
Hernandia nymphaeifolia	30.7	75.7	0.44
Quadrat #3			
Ambient	32.4	76.8	0.8–1.4
Neisosperma oppositifolia	31.4	71.5	0.62
Neisosperma oppositifolia	30.9	73.1	0.42
Piper guahamense	30.6	73.5	0.28
Piper guahamense	30.6	74.0	0.21
Quadrat #4			
Ambient	32.5	82.2	0.5–0.8
Alocasia macrorrhiza	30.5	77.9	0.16
Alocasia macrorrhiza	30.4	77.9	0.09
Piper guahamense	30.6	78.5	0.12
Piper guahamense	30.6	77.3	0.29
Thelypteris sp.	30.4	76.9	0.15
Thelypteris sp.	30.6	77.2	0.22

Table 4. Ambient and microhabitat environmental parameters in quadrats at the N. Kitts Road, Ordinance Annex sampling station.

	Temperature (°C)	Relative Humidity (%)	Air Motion (m • sec^{-1})
Quadrat #1			
Ambient	28.1	69.5	0.6–2.9
Hernandia sonora	27.42	69.7	0.1–0.4
Hernandia sonora	26.32	69.7	0.36–0.7
Hernandia sonora	27.12	69.5	0.01–0.02
Hernandia sonora	26.82	69.1	0.01–0.17

lands, dead ground shells are all that remain of once-robust colonies studied by Crampton in 1920. These observations lead to the following recommendations for terrestrial gastropods on Naval lands in Guam.

1. **Conservation management policies should be developed for colonies of endangered snails on Naval lands.**

   Although population declines and extinctions of native taxa are characteristic of the human-populated islands, tree snail colonies on Naval lands should be surveyed on a regular basis to monitor populations of these unique species. Management and conservation efforts should include protection and enhancement of the forest habitat that supports these species. This is especially important for the Pugua Point colony for two reasons: 1) this is the only colony of *Samoana fragilis* known to exist in Guam, and 2) between visits to the Pugua Point site during this survey, a large ifit log (*Intsia bijuga*) was removed from the forest floor in Quadrat 1, indicating that the habitat is at risk of degradation not only by ungulates, but by humans, as well.

2. **Protocols should be developed to manage populations of feral ungulates on Naval lands.**

   Environmental damage resulting from large populations of feral pigs, carabao, and deer at NCTS and Ordinance Annex is extensive. The forested areas of these lands are shrinking, and the structure of the remaining forests has been compromised by overgrazing. In Sarigan in the northern Mariana Islands, the eradication of feral goats was followed by recovery of tree snail populations along with the recovery of the forest in as little as six years (Smith, 2007).

3. Consideration should be given to construction of ungulate exclusion areas to restore tree snail populations to their former range and former abundance.

In the absence of ungulate removal, areas fenced to exclude ungulates have been shown to be very effective for restoration of native forests, and, therefore, snail habitat. As noted above, the eradication of feral goats in Sarigan resulted in the growth of dense *Partula gibba* populations, as well as other species of native snails. We examined a small forested area near Bonya Spring on the Ordinance Annex that would be suitable for an exclosure and and habitat enhancement followed by a trial relocation of *Partula gibba*.

ACKNOWLEDGMENTS

We are most grateful for the guidance of Dr. Anne P. Brooke during this survey. She advised us on the locations of forested tracts on both NCTS and Ordinance Annex, and she assisted us in gaining access to the bases. Gretchen Grimm also provided information about forested areas and accompanied us into the field to survey Mt. Lamlam and Mt. Almagosa. We thank the staff of SAIC for their generous support and assistance in seeing that the project was completed.

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APPENDIX I
Mariana Fruit Bat Surveys

Mariana Fruit Bat Surveys in the Lumuna/Asdonlucas/Pagat Region Adjacent to Route 15 in Support of a Marine Corps Relocation Initiative to Various Locations on Guam SWCA Environmental Consultants, Inc. February, 2010

Mariana Fruit Bat Surveys on Navy Properties, Guam, 2008. NAVFAC Marianas Environmental, Guam

2010

MARIANA FRUIT BAT SURVEYS IN THE LUMUNA/ASDONLUCAS/PAGAT REGION ADJACENT TO ROUTE 15, IN SUPPORT OF A MARINE CORPS RELOCATION INITIATIVE TO VARIOUS LOCATIONS ON GUAM

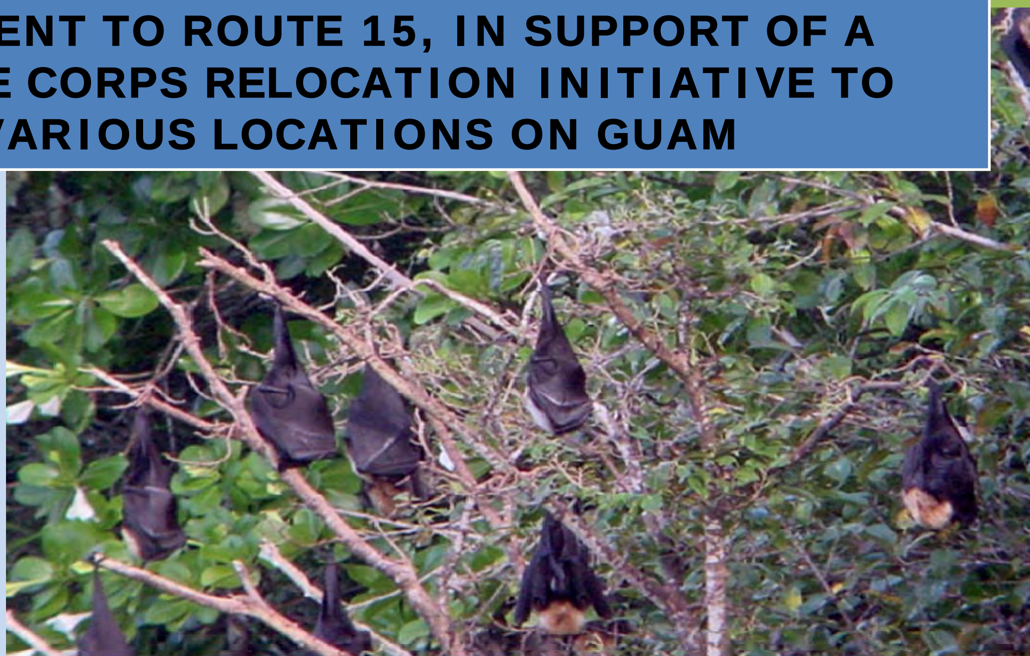

Photo: N. Johnson – SWCA

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17 February 2010

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1.0 INTRODUCTION

Surveys for the Mariana fruit bat, locally known as fanihi, (*Pteropus mariannus mariannus*) were carried out in October 2009 in the Lumuna/Asdonlucas/Pagat region (adjacent to Route 15), Guam. These surveys were part of the biological inventory for the Joint Guam Program Office (JGPO) Guam and Commonwealth of the Northern Mariana Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS).

1.1 Mariana Fruit Bat: Species Description, Distribution, and Status

The Mariana fruit bat is a medium-sized colonial flying fox, averaging 7.7 to 9.8 inches (19.6 - 24.9 cm) in body length and 33.9 to 41.9 inch (86.1 - 106.4 cm) wingspan. Adult body weight varies from 11.6 to 20.4 oz (328.9 - 578.3 g) (USFWS 1990). In 1984, the Mariana fruit bat was listed as federally endangered on Guam by the U.S. Fish and Wildlife Service (USFWS) (USFWS 1984). However, in 2005 the USFWS determined that movement of fruit bats between all islands in the Mariana archipelago occurs, resulting in exchange of genetic material. Consequently, Mariana fruit bats on Guam and throughout the CNMI comprise one subspecies and are now listed as federally threatened throughout their entire range (USFWS 2005b). The Government of Guam included the fanihi in the Guam Comprehensive Wildlife Conservation Strategy (GCWCS) as a species of greatest conservation need (SOGCN) (GDAWR 2006). In the Mariana Islands, the Mariana fruit bat is known to occur on all islands extending northward from Guam to Maug (Wiles et al. 1989, Johnson 2001).

While solitary roosting Mariana fruit bats are somewhat common, the species is considered colonial and form colonies of a few to as many as 2,000 individuals (Wiles 1987, Wiles et al. 1989, Worthington and Taisacan 1995). Large colonies containing more than 1,000 fruit bats occur infrequently. Islands with low fruit bat numbers usually feature smaller roosts with fewer than 75 individuals (Wiles and Johnson 2004).

The Mariana fruit bat is typically found in association with a number of forest types, including primary and secondary limestone forest, *Cocos nucifera* forest, *Casuarina equisetifolia* groves, and ravine forest (Wiles et al. 1989, Johnson 2001, Worthington et al. 2001, Wiles and Johnson 2004). Tree species known to be used for roosting include *Barringtonia asiatica, C. equisetifolia*, *C. nucifera*, *Cordia subcordata, Elaeocarpus joga, Erythrina variegata, Ficus prolixa, Intsia bijuga, Macaranga thompsonii, Mammea odorata, Neisosperma oppositifolia, Ochrosia mariannensis, Premna obtusifolia, Pisonia grandis,* and *Terminalia catappa* (Johnson 2001, Janeke 2006, SWCA 2008a, b).

Thirty-nine species of plants have been documented as fruit bat food sources in the Mariana Islands; foods consist of fruits (29 species), flowers (15 species), and leaves (two species). Known food plants of the Mariana fruit bat include *Artocarpus altilis*, *A. mariannensis*, *B. asiatica*, *C. nucifera, Cycas micronesica*, *E. joga*, *E. variegata, F. prolixa, F. tinctoria, Freycinetia reineckei, M. odorata, N. oppositifolia, O. mariannensis, Pandanus tectorius,* and *T. catappa* (Wiles and Fujita 1992).

In 1931, W. Coultas (in USFWS 1990) reported that fruit bats on Guam were most abundant in the northern region of the island. However, in 1945, R. Baker (in USFWS 1990) determined that fruit bats were uncommon and primarily restricted to the forested cliff lines in northern Guam, and scarce in southern Guam. In 1958, D. Woodside (in USFWS 1990) estimated Guam's entire Mariana fruit bat population to be less than 3,000 individuals. Throughout the 1960s and 1970s, Guam's fruit bat population decreased considerably, plummeting to less than 50 animals in 1978 (Wiles et al. 1989). However, between 1980 and 1982, the population rapidly increased to approximately 850-1,000 individuals, potentially resulting from immigration of fruit bats due to illegal hunting activities on neighboring Rota (Wiles 1987, Wiles et al. 1989). Following a 1984 Guam fruit bat census, 425-500 individuals were recorded, indicating a population decline since the early 1980s (Wiles 1987).

From 1987 to 1995, Guam's fruit bat population fluctuated between 200 and 750 individuals that were primarily confined to the limestone forest near the cliff lines on Andersen Air Force Base (AFB) (Wiles et al. 1995). Throughout 1981-1994, Mariana fruit bat colonies were documented at 21 sites on Andersen AFB, 11 at Pati Point and 10 between Ritidian Point and the northern region of Tarague basin (Wiles et al. 1995). In 2006, Guam's population had decreased to less than 100 individuals, primarily restricted to a single colony and satellite individuals inhabiting the limestone forest on Andersen AFB (Janeke 2006). Between July 2007 and April 2008, multiple counts of the single remaining colonial roost on Andersen AFB tallied an average of 40 individuals (SWCA 2008a). Further counts of the same colony between July and August 2008 recorded an average of 32 fruit bats (SWCA 2008b). Illegal hunting appears to be the key reason for the fruit bat's dramatic decline on Guam, while habitat destruction and predation by introduced brown treesnakes (*Boiga irregularis*) may also be contributing factors (Wiles et al. 1989, Wiles et al. 1995, Morton and Wiles 2002, Brooke 2008)

2.0 METHODS

2.1 Survey Locations

Mariana fruit bat surveys were conducted from three locations positioned in forest areas containing known Mariana fruit bat roosting and foraging vegetation (Figure 1). The survey locations were situated on the east side of Route 15 in the northeast region of Guam, stretching from the Lumuna region through the Asdonlucas area south to Pagat Point. These locations were not associated with any of the designated transects used for vegetation, bird, tree snail, or herpetological surveys.

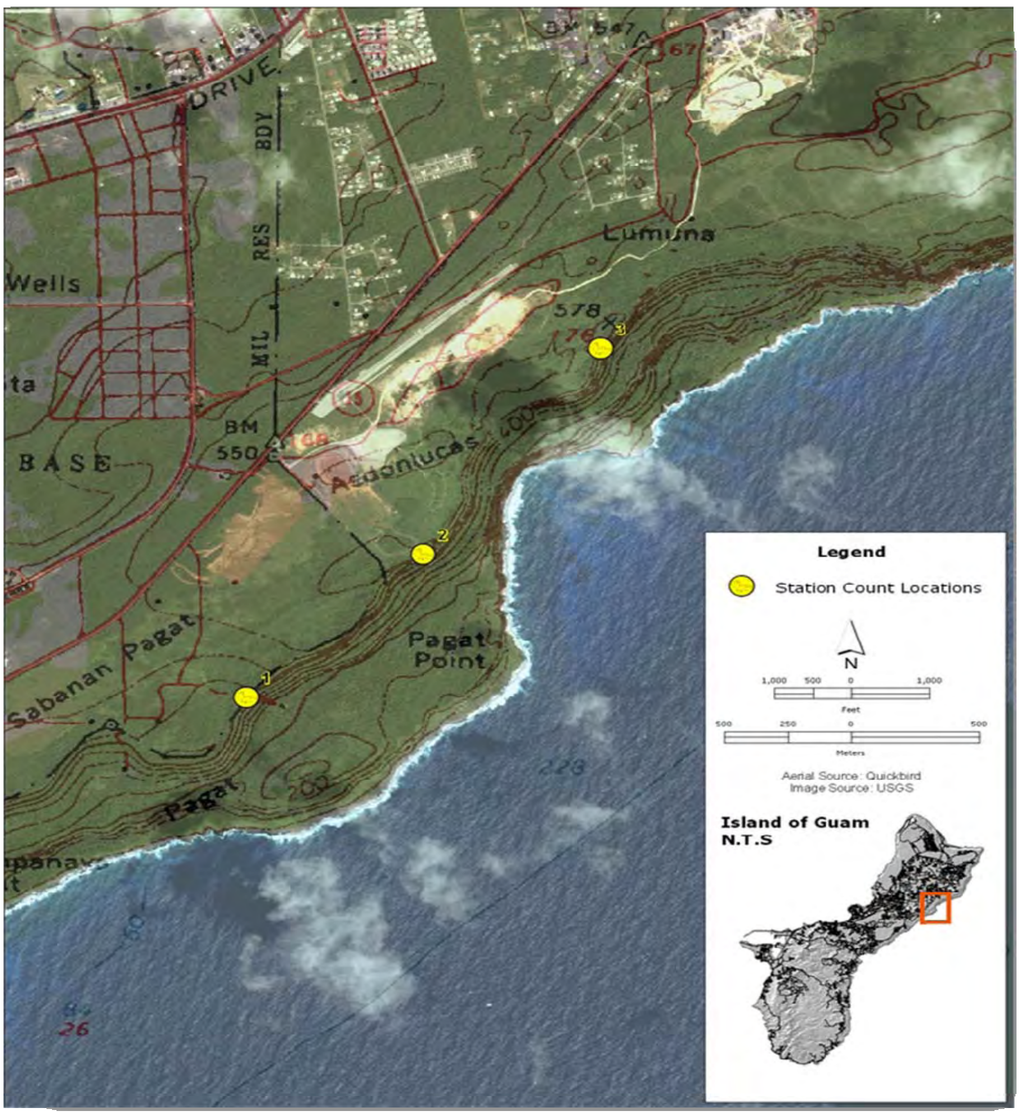

Figure 1.Mariana fruit bat station count locations in the Lumuna/Asdonlucas/Pagat region, Guam. Note the designated count location numbers: Transect 1 is furthest south, transect 3 is furthest north.

Essentially the entire survey area was described as "forest on elevated limestone" by H. I. Manner in 1995 (an update to F.R. Fosberg's 1954 mapping efforts) (Mueller-Dombois and Fosberg 1998). This habitat community is typically a moist, broad-leaved forest with a variable canopy height that may reach up to 75 ft (23 m), dominated by *Artocarpus* spp. and *Ficus* spp., with some *Pandanus* spp. present (Mueller-Dombois and Fosberg 1998). A forest inventory and analysis of Guam by the U.S. Forest Service in 2002 described four vegetation types in the survey area: "urban cultivated" and "scrub forest" above the cliff line; below the cliff line, "limestone forest" was considered to be the dominant vegetation type, while "plantations" occupied a small portion (USFWS 2005a). General habitat descriptions of each of the survey locations are discussed below.

<u>Location 1 (UTMs = 0270725, 1493041)</u>
This count station was situated along the cliff line overlooking a forested basin below and mixed forest above. Vegetation below and along the cliff line was primarily *Bikkia tetrandra*, *Cocos nucifera*, *Ficus prolixa, Hibiscus tiliaceus, Macaranga thompsonii, Mammea odorata, Neisosperma oppositifolia, Pandanus tectorius,* and *Premna obtusifolia*. Flora above the cliff line included *Citrus* sp., *Eugenia reinwardtiana*, *H. tiliaceus*, *Musa* sp., *P. obtusifolia,* and *Vitex* sp. Other trees of interest recorded from this survey location were *Aglaia mariannensis, Barringtonia asiatica, Cycas micronesica, Cynometra ramiflora, Eugenia palumbis*, *Guamia mariannae, Guettarda speciosa*, *Intsia bijuga*, and *Maytenus thompsonii.*

<u>Location 2 (UTMs = 0271418, 1493715)</u>
Count station 2 was located along the cliff line and provided an unobstructed view of a forested basin below, as well as mixed forest above. Flora below and along the cliff line consisted mostly of *B. tetrandra, F. prolixa, H. tiliaceus, Macaranga thompsonii, M. odorata*, *N. oppositifolia, P. tectorius*, and *P. obtusifolia*. Vegetation above the cliff line was largely composed of *H. tiliaceus*, *Macaranga thompsonii, P. obtusifolia*, *Triphasia trifolia*, and *Vitex* sp. Other trees recorded from this survey location that may be of interest were *Aglaia mariannensis, Artocarpus altilis, B. asiatica, C. micronesica, C. ramiflora, G. mariannae*, and *G. speciosa.*

<u>Location 3 (UTMs = 0272113, 1494684)</u>
Count station 3 was situated along the cliff line and afforded a clear view of a forested basin below, and mixed forest and a cleared region above. Vegetation below and along the cliff line was comprised principally of *B. tetrandra, Casuarina equisetifolia, C. nucifera, F. prolixa, H. tiliaceus, Macaranga thompsonii, M. odorata, N. oppositifolia*, and *P. tectorius.* A large portion of forest above the cliff line had been cleared for unknown operations possibly associated with the racetrack, and the surrounding flora included *Carica papaya, H. tiliaceus, Macaranga thompsonii, P. obtusifolia*, and *Vitex* sp. Other trees recorded from this survey location that may be of interest were *Aglaia mariannensis, A. altilis, B. asiatica, C. micronesica, C. ramiflora, Erythrina variegata, I. bijuga, Ochrosia mariannesis,* and *Pisonia grandis*.

2.2 Mariana Fruit Bat Surveys

Station count surveys (Utzurrum et al. 2003) were conducted to 1) determine the presence of solitary Mariana fruit bats, 2) attempt to locate aggregations or colonies, and 3) assess the location of fruit bat flight paths. These surveys were carried out at the three locations mentioned above (Figure 1) between 0510 h and 0745 h. Each location was surveyed four times, twice each by two trained observers. The survey locations were chosen as vantage points that provided wide and unimpeded views of potential fruit bat habitat and flight paths. Binoculars and a spotting scope were used to detect and count fruit bats at each location.

2.3 Phenological Phases of Plants

While carrying out station count surveys for Mariana fruit bats, the observers collected anecdotal observational data on the phenological phases (flowering and fruiting) of plants, focusing on species that may be used as food sources by Mariana fruit bats.

2.4 Avian Species

During the station count surveys for Mariana fruit bats, observers also searched for federally endangered, and Government of Guam endangered and threatened Mariana swiftlets (*Aerodramus bartschi*). Searches were used to determine whether this species utilized the region for foraging, flights, and roosting or nesting purposes. All avian species heard or observed were recorded during station count surveys.

3.0 RESULTS

3.1 Mariana Fruit Bat Surveys

Between 6 and 22 October 2009, 12 station count surveys were completed at three locations in the Lumuna/Asdonlucas/Pagat region (Figure 1 and Table 1). No Mariana fruit bats were observed during any of the surveys.

Table 1. Mariana fruit bat station count results in the Lumuna/Asdonlucas/Pagat region, Guam.

Survey Date	Survey Location	Start Time	Stop Time	# of Bats Observed
6 October 2009	1	0545 h	0745 h	0
6 October 2009	2	0545 h	0745 h	0
13 October 2009	2	0525 h	0740 h	0
13 October 2009	3	0530 h	0740 h	0
14 October 2009	3	0515 h	0745 h	0
14 October 2009	1	0530 h	0740 h	0
20 October 2009	2	0510 h	0740 h	0
20 October 2009	1	0520 h	0740 h	0
21 October 2009	3	0510 h	0740 h	0
21 October 2009	2	0520 h	0740 h	0
22 October 2009	1	0520 h	0740 h	0
22 October 2009	3	0520 h	0740 h	0

3.2 Phenological Phases of Plants

Table 2 depicts the phenological phases of 18 plant species in the Route 15 survey area during Mariana fruit bat surveys. While not part of the contracted work, we considered this valuable information that may be of future use in terms of understanding movements and behaviors of Mariana fruit bats in relation to known and potential food sources.

Table 2. Phenological phases of plant species in the Lumuna/Asdonlucas/Pagat region, Guam: 6 - 22 October 2009. (F = flowering; S = fruiting).

Plant Species	Phenological Phase
Aglaia mariannensis[1]	S
Barringtonia asiatica[1]	F, S
Bikkia tetrandra	F
Carica papaya[1]	F, S
Citrus sp.	S
Cocos nucifera[1]	F, S
Eugenia palumbis	F
Ficus prolixa[1]	S
Guettarda speciosa[1]	F, S
Hibiscus tiliaceus	F
Intsia bijuga	F
Maytenus thompsonii	F
Musa sp.[1]	S
Neisosperma oppositifolia[1]	F, S
Ochrosia mariannensis[1]	S
Pandanus tectorius[1]	S
Premna obtusifolia[1]	F, S
Triphasia trifolia	F

[1] Known food plant of Mariana fruit bats (Wiles and Fujita 1992)

3.3 Avian Species

During the station count surveys, no endangered Mariana swiftlets were recorded. However, avian species that were identified in flight or vocalizing within habitat associated with the station count locations are shown in Table 3.

Table 3. Avian species detected during Mariana fruit bat station count surveys in the Lumuna/Asdonlucas/Pagat region, Guam: 6 - 22 October 2009. Status and nomenclature follow (Wiles 2005).

Avian Species	Status on Guam
Black francolin (*Francolinus francolinus*)	Introduced resident, breeding
Yellow bittern (*Ixobrychus sinensis*)	Native resident, breeding
Pacific reef heron (*Egretta sacra*)	Native resident, breeding
Pacific golden-plover (*Pluvialis fulva*)	Migratory or wintering species, non-breeding
White tern (*Gygis alba*)	Native resident, breeding
Island collared-dove (*Streptopelia bitorquata*)	Introduced resident, breeding

4.0 DISCUSSION

The survey method utilized during this project relies on observing fruit bats in low light and daytime conditions. Any fruit bats that were using the area prior to or after the survey period would not have been detected. No fruit bats were observed during the 12 station count surveys. However, the survey area is suitable for Mariana fruit bat to roost and forage because is situated away from dense human habitation and includes several known Mariana fruit bat roosting and food tree species. The survey area is also close (about 7.5 mile [12.1 km]) to the last remaining colonial roost location of fruit bats known on Guam. Therefore it would be prudent not to dismiss the possibility that fruit bats use the area for roosting and/or foraging as well as flight paths. When potential development projects arise in this area, consideration should be given to the suitability of the existing native and secondary forest habitat not only for Mariana fruit bats, but Mariana swiftlets, Micronesian starlings, yellow bitterns, white terns, and tree snails.

Noise associated with construction and rock-blasting activities on the property adjacent to survey location 3 was loud. The associated noise and possibility of hunting may prevent Mariana fruit bats from establishing permanent roosts in the area.

It is worth recognizing that three native, breeding resident and one migratory avian species were detected flying above habitat associated with the survey area.

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Mariana Fruit Bat Surveys on Navy Properties, Guam, 2008

Anne Brooke
NAVFAC Marianas Environmental, Guam

Introduction

Surveys of Mariana fruit bat or fanihi (*Pteropus mariannus mariannus*) were conducted on Navy properties on Guam in 2008 as part of the biological inventory for the Joint Guam Program Office (JGPO) Guam and Commonwealth of the Northern Marina Islands (CNMI) Military Relocation Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) that is currently in preparation.

Once common throughout the Mariana archipelago, Mariana fruit bats have declined from overhunting, forest loss and predation by brown tree snakes (BTS) (reviewed in U.S. Fish and Wildlife Service [USFWS] 2005; Wiles and Brooke in press). Mariana fruit bats may be found during the day in large colonies, in small groups or solitarily (Wheeler and Augon 1978; Wiles et al 1989; Morton and Wiles 2002; Janeke 2006). Hunting pressure has pushed bats to roost in areas that are not frequented by people. This survey was designed to search for colonial roost sites and survey solitary bats on the Naval Munitions Site (NMS) (previously known as the Ordnance Annex), Waterfront Annex (or Navy Main Base), Naval Computer and Telecommunications Station Finegayan (NCTS), and Navy Barrigada.

At the time of this survey, less than 100 bats are believed to remain on Guam primarily in the northern forests of Andersen Air Force Base (AFB), the Guam National Wildlife Refuge, NCTS, and adjacent private lands (Janeke 2006). Surveys of the single remaining colonial roost at Pati Point have counted 19-40 bats since 2004 (N. Johnson, pers. com.). Small groups and solitary bats are known to be widely dispersed throughout Guam but are no longer commonly reported (Wheeler 1979; Wiles et al 1989; Johnson 2001; Morton and Wiles 2002; Janeke 2006).

Methods

Station count surveys were conducted at dawn as bats return to preferred roosting sites and at dusk as they disperse to forage (Utzurrum et al. 2003). Locations for station counts were selected for wide and unimpeded forest views. During each survey, a single observer actively scanned the area for bats in flight or roosting with Swarovski 10 x 40 binoculars. Surveys were conducted at dawn from ca. 0515 to 0630 and dusk from ca. 1730 to 1900. Between February and July 2008, 41 station counts were conducted at 15 locations on the NMS, 1 on the Waterfront Annex, 3 at NCTS, and 2 at Barrigada (Fig. 1). Replicate counts were done at most locations although three sites were surveyed only once. Seven of the sites on the NMS had been previously surveyed by Morton and Wiles (1996).

Results

Three solitary bats were sighted on Navy lands during 90 hours of observations at 14 different survey locations (Table 1). Two sightings were on NCTS, one below the cliff line in the northern section of the Haputo Ecological Reserve near Falcona, and the other was seen flying westward across Route 3A from Andersen AFB onto NCTS (Fig. 1). A single bat sighted on the NMS three times in the same location at ca 0540 each day is likely the same individual and not treated as separate sightings (Table 1).

Discussion

The survey method used in this study relies on seeing bats flying during daytime or in low light. Any bats that were present but not flying during the counts would not have been observed. A radio tracking study of bats on Andersen AFB found bats dispersed after nightfall and returned to the roost sites before dawn

(Janeke 2006). Consequently, the lack of bat sightings on Navy lands suggests few bats are present but is not an accurate indicator of the number.

The number of fruit bats on Guam has declined since the 1950s when potentially 3,000 bats were thought to be present (Woodside 1958). This time frame corresponds with post-World War II island development and spread of BTS. By 1972 the number of bats was estimated at less than 1,000 (Wiles 1987b) and by the late 1970s the estimated number had declined to less than 50 with no known colonies (Wheeler and Aguon 1978). In 1980, several hundred bats appeared at a Pati Point roost site and during the 1980s several colonies were present along the northern coast but after 1994, only the Pati Point site was used (Wiles 1987a; Janeke 2006).

The number of bats at the Pati Point colony has declined since the mid-1990s although there have been occasional increases thought to be bats coming from Rota (Wiles 1987b; Wiles and Glass 1990; Janeke 2006). In addition to colonies of roosting bats, small groups and solitary bats are known to be occur throughout Guam, however they are difficult to locate and monitor (Wheeler 1979; Wiles et al 1989; Johnson 2001; Morton and Wiles 2002; Janeke 2006). Because of the difficulty in monitoring solitary bats, the Pati Point colony is used as the indicator of the island-wide population.

The NMS and the Haputo Ecological Reserve at NCTS encompass some of the best remaining native forest on Guam and could support a large number of fruit bats. That only three bats were observed after extensive surveys is consistent with the steady decline in number of bats at the Pati Point colony and potentially indicates a very low number of bats remaining on Guam. Illegal hunting and predation from BTS are widely accepted as reasons for lack of fruit bat recovery on Guam (USFWS 2005; Wiles and Brooke in press).

Fruit bats continue to be a highly prized Chamorro delicacy and hunting is credited for the decline of bats in the southern Mariana Islands as well as on Guam (Wiles and Brooke in press). Between 1975 and 1989, over 200,000 fruit bats were sold in markets on Guam that had been hunted throughout the Pacific region (Wiles 1992). This international trade was stopped in 1999 with the local enforcement of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). In 1984, fruit bats on Guam were listed as federally endangered but were downlisted to threatened in 2005 as fruit bats in the CNMI and Guam are considered a single population (USFWS 2005).

Consumer demand remains the driving force for illegal hunting and has prevented the recovery of fruit bats in the southern CNMI. Fruit bats are reported to sell for $50 on Tinian in 2008 and $140 on Saipan in 2006; the value of bats on Guam is beyond a monetary value with payment made by in-kind favors. The high value of bats to the Chamorro people makes recovery unlikely. Without support from leading government officials and law enforcement in the immediate future, the small number of remaining fruit bats will be gone.

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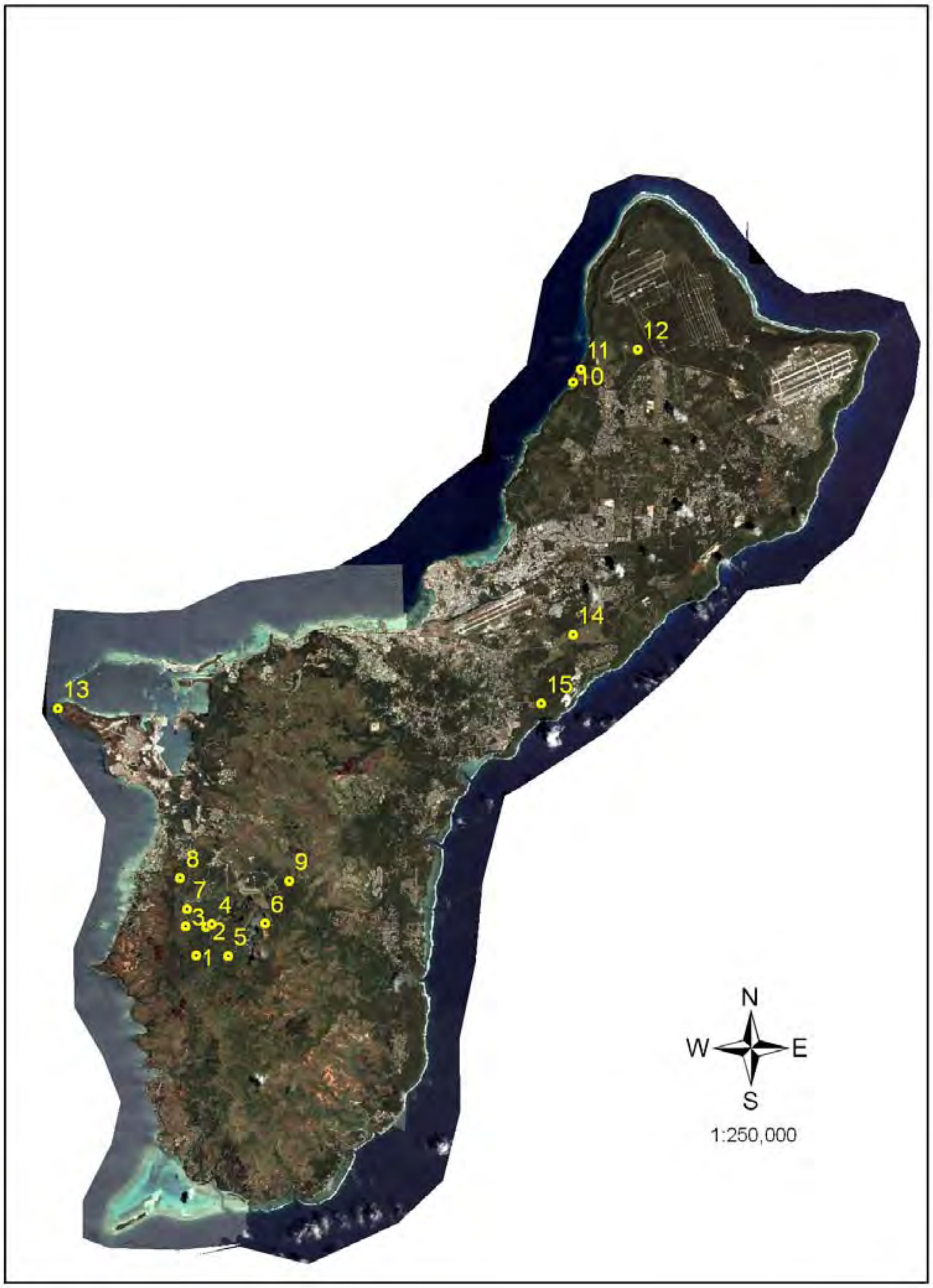
Table 1. Marina Fruit Bat Survey Results, Navy Properties, Guam (2008)

Date	*Map Number*	*Location*	*Latitude*	*Longitude*	*Start time*	*End time*	*Bats observed*
6/7	1	Almagosa Springs	13°20'45.42"N	144°40'39.07"E	0520	0630	
4/10	2	Almagosa Road	13°21'25.74" N	144°40'54.06"E	0550	0630	1 at 0553
4/29	2	Almagosa Road			0530	0630	1 at 0540
4/30	2	Almagosa Road			0515	0630	
5/5	2	Almagosa Road			0515	0630	1 at 0540
3/10	3	Breacher House	13°21'26.49"N	144°40'22.97"E	0600	0730	
3/12	3	Breacher House			0600	0730	
3/13	3	Breacher House			0600	0730	
5/6	3	Breacher House			0515	0630	
3/18	4	Bunker 21 @ 19	13°21'31.30"N	144°41'2.47"E	0600	0730	
5/1	5	EOD Road	13°20'44.98"N	144°41'26.50"E	0515	0630	
5/3	5	EOD Road			0515	0630	
5/9	5	EOD Road			0515	0630	
5/31	5	EOD Road			0500	0630	
7/14	6	Fena Dam	13°21'32.45"N	144°42'21.09"E	0510	0630	
2/19	7	High Rd forest	13°21'52.10"N	144°40'25.36"E	0545	0730	
2/20	7	High Rd forest			0545	0730	
2/22	7	High Rd forest			0545	0730	
5/7	7	High Rd forest			0515	0630	
7/6	7	High Rd forest			0550	0715	
3/6	8	Japanese overlook	13°22'37.81"N	144°40'14.41"E	0600	0730	
5/13	9	Maemong overlook	13°22'35.53"N	144°42'56.42"E	0500	0630	
5/14	9	Maemong overlook			0500	0630	
3/20	10	Haputo Bay	13°34'45.21"N	144°49'51.61"E	0600	0730	
3/29	10	Haputo Bay			0600	0730	
2/23	11	Double Reef overlook	13°35'4.03"N	144°50'3.25"E	0600	0745	
3/1	11	Double Reef overlook			0600	0800	1 at 0708
6/15	11	Double Reef overlook			1800	1910	
5/11	11	Double Reef overlook			0515	0630	
6/8	11	Double Reef overlook			0520	0630	
5/17	12	NCTS Rt 3A	13°35'33.66"N	144°51'47.21"E	0515	0630	1 at 0552
5/18	12	NCTS Rt 3A			0520	0630	
5/25	12	NCTS Rt 3A			0520	0630	
4/2	13	Orote Point	13°26'42.90"N	144°37'10.55"E	0550	0715	
4/3	13	Orote Point			0550	0715	
4/4	13	Orote Point			0550	0715	
4/7	13	Orote Point			1730	1900	
4/9	13	Orote Point			1730	1900	
5/19	14	Navy Barrigada	13°28'37.70"N	144°49'54.94"E	0515	0630	
5/23	14	Navy Barrigada			0515	0630	
6/11	15	Rt 15	13°26'56.57"N	144°49'8.66"E	0520	0630	

Figure 1. 2008 Mariana Fruit Bat Station Count Locations on Navy Properties, Guam: Waterfront Annex, NMS, Navy Barrigada, and NCTS Finegayan.



Preliminary Wetland Identification

for Various Locations on Guam

In Support of the Guam Military Buildup EIS

Laguas River along Marine Corps Drive

Prepared for: NAVFAC Pacific

Prepared by: TEC Joint Venture, Honolulu Hawaii

Contract N62742-06-D-1870, TO 046

June 2010

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Preliminary Wetland Identification for Various Locations on Guam
In Support of the Guam Military Buildup EIS

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SECTION 1
INTRODUCTION

1.1 INTRODUCTION

The purpose of this report is to conduct a preliminary identification of wetlands that may be subject to the regulatory jurisdiction of the U.S. Army Corps of Engineers (USACE) in areas on Guam that may be affected by the proposed alternatives in the Guam and CNMI Military Relocation Environmental Impact Statement (EIS). USACE jurisdiction would be under section 404 of the Clean Water Act (CWA) codified at 33 Code of Federal Regulations, parts 320-330. The preliminary identification was conducted with remote sensing using multispectral imagery and field determinations.

Under section 404 of the CWA, wetlands are defined as areas that are "inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Wetlands are recognized as a special aquatic site under the section 404(b)(1) guidelines, and a "no net loss" policy continues to guide federal regulatory actions affecting wetlands under section 404. Potential Section 404 wetlands are identified and delineated according to the USACE's (1987) Wetlands Delineation Manual, which requires that, under normal conditions, positive indicators of wetland hydrology, soil, and vegetation are all present.

Study areas for the work are shown in Figure 1. Areas identified as "2010 Field Study Area" were investigated through field studies. Areas outside these areas that are identified as "Wetland Study Areas" were investigated with remote sensing, aerial imagery, and in some cases general on-the-ground visual observation.

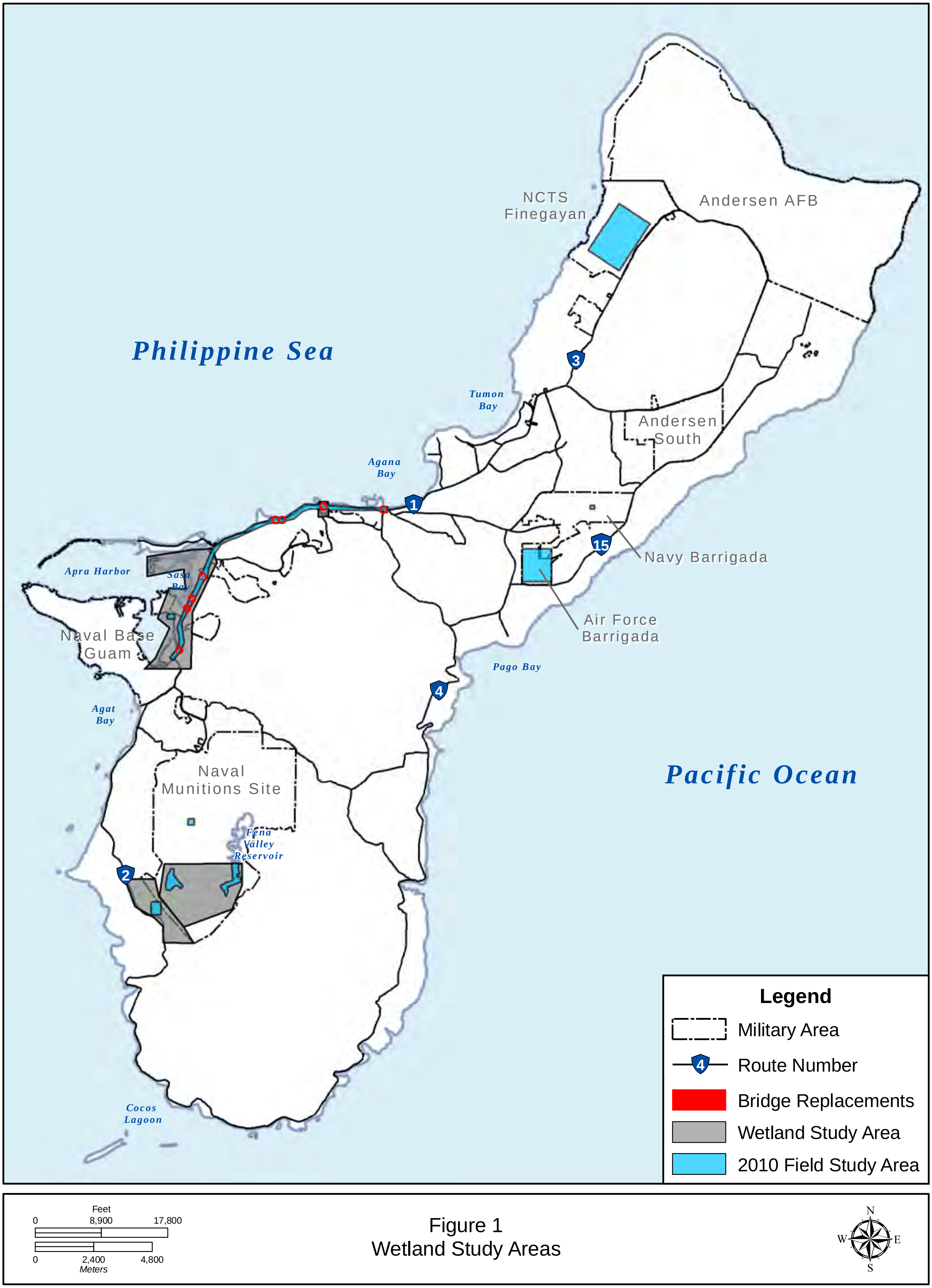

Figure 1
Wetland Study Areas

SECTION 2
METHODOLOGY

2.1 SCOPE

In accordance with the Scope of Work (SOW) for this Task Order, the TEC JV team conducted a wetland remote sensing study on Guam in May 2010 in support of the EIS for the Guam and CNMI Military Relocation. During the preparation of the EIS it was determined that additional data was needed for support in determining the Least Environmental Damaging Practicable Alternative (LEDPA) for wetland impacts.

Tasks were as follows:

- Conduct a multispectral analysis of DoD GeoEye imagery provided by DoD.
- Conduct ground-truthing of a limited number of wetlands identified in areas that are accessible in a short time frame.
- Refine the initial mapping based on multispectral analysis based on the ground-truthing.
- Produce a draft and final report.
- Conduct a briefing with the NTR for the Army Corps of Engineers in Honolulu.

In accordance with the SOW the work was conducted at the following sites:

- Air Force Barrigada.
- Along Marine Corps Drive near Apra Harbor.
- Southern Naval Magazine Site (NMS).
- West of NMS between Highway 2 and the NMS boundary from approximately the point where NMS extends furthest west to the point where NMS extends furthest south.

Table 1. Wetland Areas Investigated

Location	*acres*	*hectares*
Apra	1,837	744
AF Barrigada	400	162
NMS	1,696	687
Southwest of NMS	716	290
Total	4,649	1883

An initial remote sensing effort was specified for 2010 Field Study Areas, followed by field work for these areas. 2010 Field StudyArea sites total approximately 750 acres and they include areas described below and shown in Figure 1.

- A 500 ft corridor along Marine Drive corridor from Agana Bay in the north to the southern tip of inner Apra Harbor in the south. This is approximately 8 miles in length and 500 acres.
- Potential wetland areas identified in previous mapping in southern NMS readily accessible by foot including the large wetland in western NMS and the Imong River drainage at the southern end of Fena Lake that is accessible by canoe or kayak. The acreage is approximately 130 acres.
- An area around the proposed western NMS access road, roughly square with the northeast corner on the intersection of the NMS access road and the NMS boundary, approximately 100 acres.
- Potential wetlands that are already known from NWI maps at AF Barrigada

Additional field investigations were conducted at the proposed amphibious, all-terrain vehicle site at Polaris Point, at one of the proposed magazine sites on NMS, and at NCTS Finegayan.

2.2 FIELD INVESTIGATION

Field investigations were conducted at the 2010 Field Study Areas from May 3 to May 14, 2010 by two teams of 2 personnel each. At each field study area various features were documented and they are listed below.

- Plant species including the dominant species and estimates of dominant species cover.
- Hydrology at the location.
- A soil description at the location from a rapid observation of soils to 1 foot depth collected with a soil probe or shovel, provided the soil were readily observed (e.g. not excessively hard or extensive roots).
- Rare plant and animal species observed.
- Level of disturbance of the habitat and type of disturbance.
- A GPS location - All field-identified locations will be based on a minimum hand held GPS accuracy of +/- 30 feet; the goal will be submeter accuracy.
- Views of the area – multiple photographs were taken.

Field forms and photographs were used to document the information. A modified 1987 Corps of Engineers wetland delineation form was used for recording plot data. The field form was modified primarily for the soils investigation. Soils were not completely documented as would be required under a full wetland delineation study. Typically soils were investigated with a shallow pit or soil probe to 12 inches depth only. Consequently, a definitive wetland soils determination for full wetland delineation purposes could not be made. Location of soil investigation sites and preliminary wetland boundaries were recorded with Trimble Geo XH GPS units.

The Draft Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Hawaii and Pacific Islands Region (USACE 2009) was reviewed for general information on changes proposed to the 1987 manual. The Regional Supplement provides additional technical guidance for identifying and delineating wetlands while accounting for climate, geology, soils, and hydrology in the Pacific region.

This report was prepared for NAVFAC Pacific by TEC JV. Members of the team are shown in Table 2.

Table 2. TEC JV Team Members

Role	*Company*	*Name*
Project manager	TEC JV	Glenn Metzler (TEC Inc)
Spectral imaging lead	SpecTIR	William Bernard, Lee Watson
Wetland ground-truthing (team A)	TEC JV	Glenn Metzler (TEC Inc) and Samuel Walker (TEC Inc)
Wetland ground-truthing (team B)	Duenas, Camacho, & Assoc. and TEC JV	Claudine Camacho (DCA) and Richard Dwerlkotte (AECOM)
Reporting leads	TEC JV	Glenn Metzler(TEC Inc) and Richard Dwerlkotte (AECOM)

2.2.1 Vegetation

Wetland ratings were taken from the unofficial University of Guam (undated) list of wetland plant ratings supplied by Dr. Lynn Raulerson. These ratings for all plants in this survey are shown in Appendix D.

2.2.2 Soils

Soils were evaluated using the criteria in the USACE 1987 manual. Soil colors were identified using a Munsell soil color chart.

2.3 REMOTE SENSING ANALYSIS

Remote sensing scientists conducted a remote sensing imagery analysis with the ENVI software using the National GeoSpatial Intelligence Agency GeoEye-1 satellite multispectral imagery provided by DoD (a detailed description of this imagery is included in Appendix E). The spectral analysis also used currently available information on soils, geology, hydrology, wetlands, and vegetation to map potential wetlands.

All areas evaluated through remote sensing are shown in Figures 1 and approximate acreages are listed in Table 1.

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SECTION 3
RESULTS

3.1 GENERAL GUAM WETLAND INFORMATION

3.1.1 National Wetland Inventory and Wetland Classification

National Wetland Inventory (NWI) data for Guam downloaded from the NWI website (http://www.fws.gov/wetlands) was used as a preliminary indicator of wetlands present in project areas. NWI wetlands are shown in Figure 2.

Detailed wetland classification was not conducted for this study. General determinations corresponding to the USFWS Cowardin system (USFWS 1979) were made. These are listed in Section 3.2.

3.1.2 Soils

Soils on Guam have been mapped by the NRCS. Soils information from the NRCS website (NRCS 2010). Mapped hydric soils were identified and these are shown in Figure 2. Specific Hydric soils present in the project areas are:

- Apra Harbor Area – Inarajan clays and clay loam, 0 to 4 percent slopes, poorly or very poorly drained
- Alamagosa Basin – Ylig clay, 3 to 7 percent slopes, poorly or very poorly drained
- Barrigadas (extreme southern end of Navy Barrigada only) – Chacha clay, 0 to 5 percent slopes, poorly or very poorly drained

3.1.3 Previous Wetland Studies

A recent wetlands inventory report was completed by Aecos Inc. and Wil Chee Planning Inc. (Aecos and Wil Chee 2009) for the Navy to document wetlands on Navy land. All areas were not investigated in the field for that study. Wetlands identified in that study are shown in Figures 3 and 4.

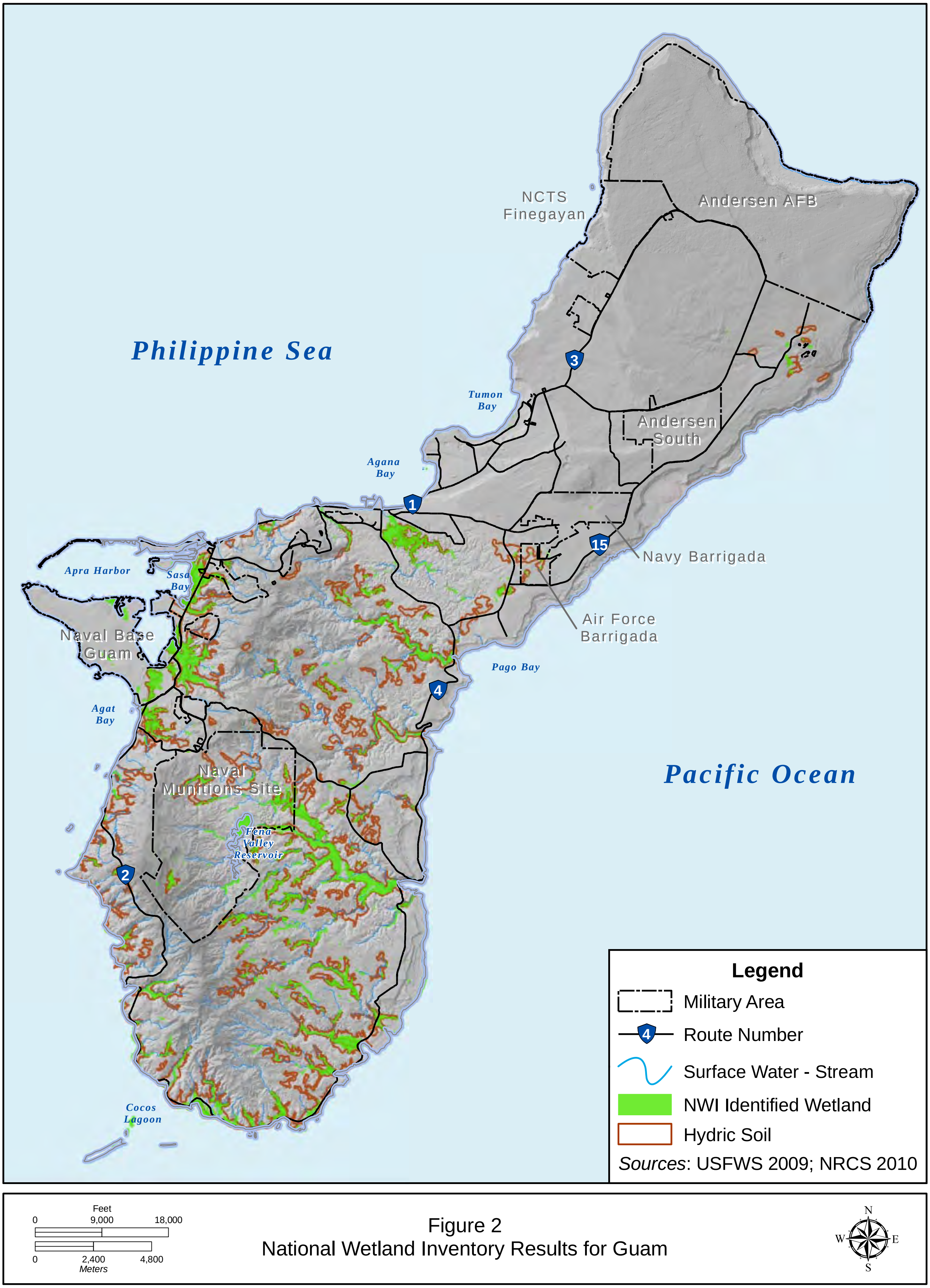


Figure 2
National Wetland Inventory Results for Guam

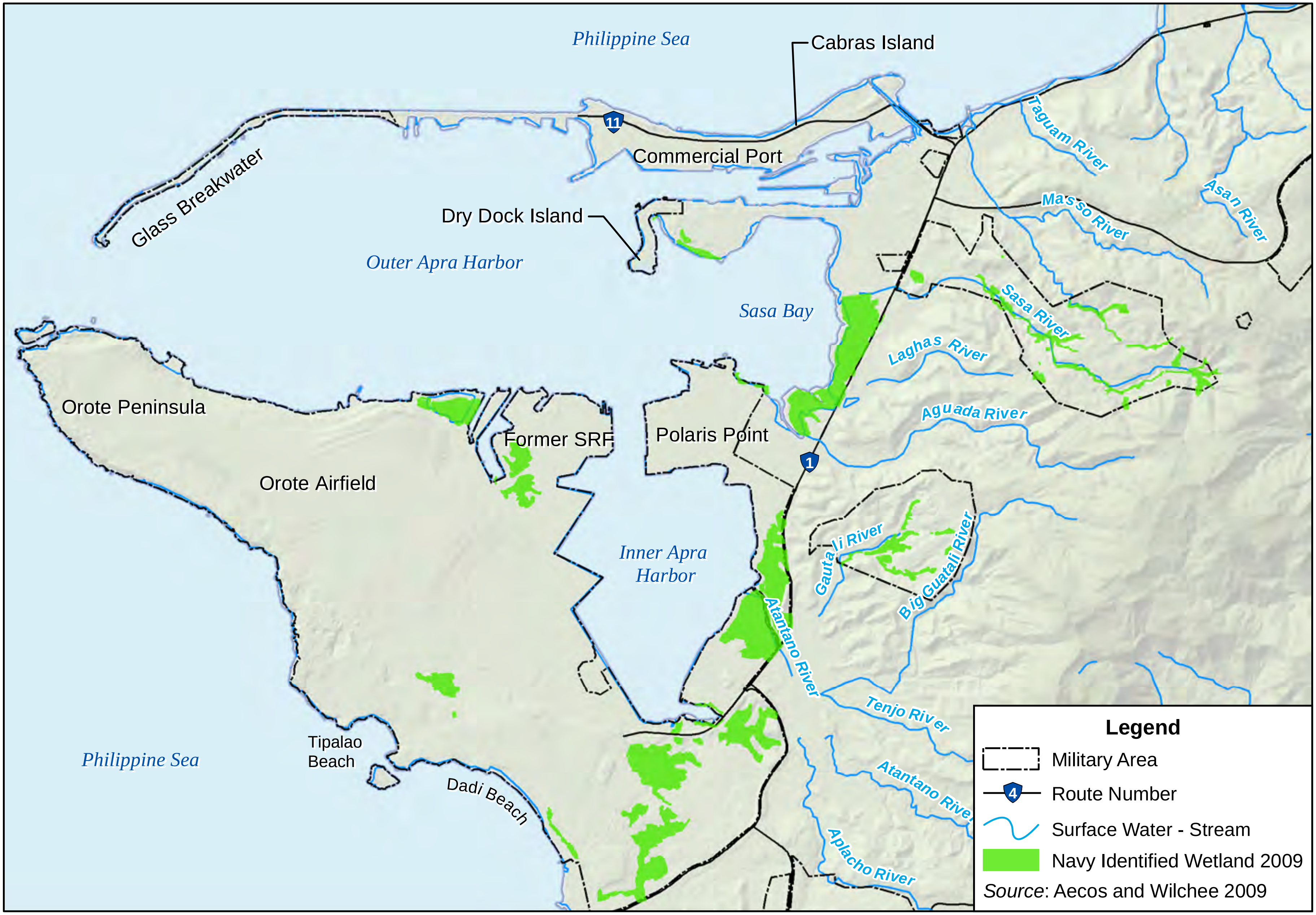
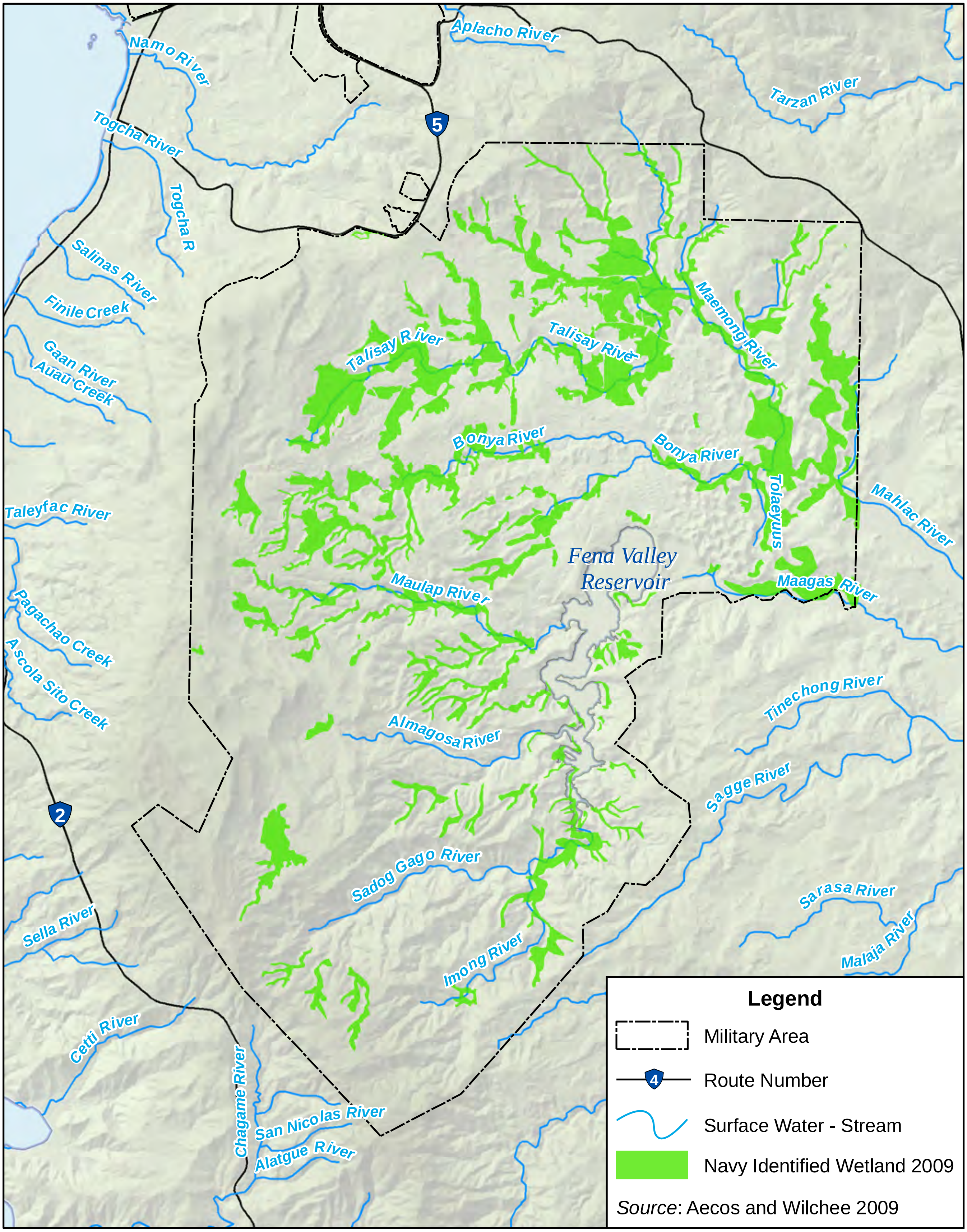


Figure 3
Wetlands Identified in Previous Studies at Navy Apra Harbor



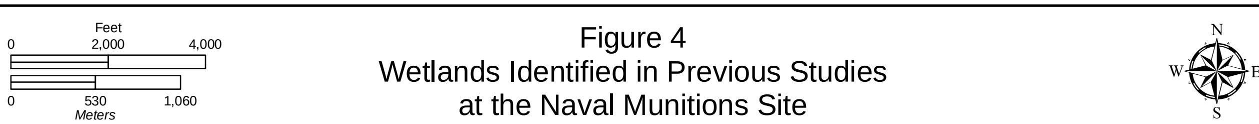


Figure 4
Wetlands Identified in Previous Studies
at the Naval Munitions Site

3.2 FIELD INVESTIGATION

The field investigation documented wetlands in each 2010 Field Study Area. A brief overview of each area is provided in this section. Wetlands identified are shown in overview format in Figures 5 and 6. Detailed figures for subareas are shown in Appendix A. A photo log for all wetland areas is provided in Appendix B and wetland data sheets with more detailed information for each wetland is available in Appendix C. A plant list for the areas investigated is provided in Appendix D.

Wetlands were found in most areas investigated. Results in each field study area are summarized below.

- Apra Harbor Marine Corps Drive - Numerous wetlands were identified along the Apra Harbor Marine Corps Drive corridor in addition to those previously identified on Navy land by the Navy 2009 study. Some 2009 boundaries in this area were also adjusted, although there were no major changes. Wetlands within the field study area were a mix of palustrine emergent, scrub/shrub, forested, and a few estuarine intertidal wetlands. In some cases the wetlands were probably created by restriction of drainage due to Marine Corps Drive.

- Polaris Point Proposed Armored Amphibious Vehicle Area - A small palustrine forested wetland dominated by *Hibiscus tiliaceus* was found in this area at the shoreline around a man-made drainage feature.

- NMS High Road Proposed Magazine Area – The wetland in this area was found to be less extensive than shown in the Navy 2009 wetland study. The wetland was a mix of palustrine emergent and scrub/shrub.

- South of Fena Lake - The drainage along the Imong River south of Fena Lake had far less wetlands than had previously been mapped. Numerous ravines and river floodplains had been mapped as wetlands and review of previous documentation did not indicate soils had ever been examined in these determinations. In nearly all areas, except for seeps, soils were bright and were not hydric. It is likely these areas are inundated for short periods during high rainfall events but not for periods long enough to develop hydric soils. Seeps were generally palustrine emergent wetlands.

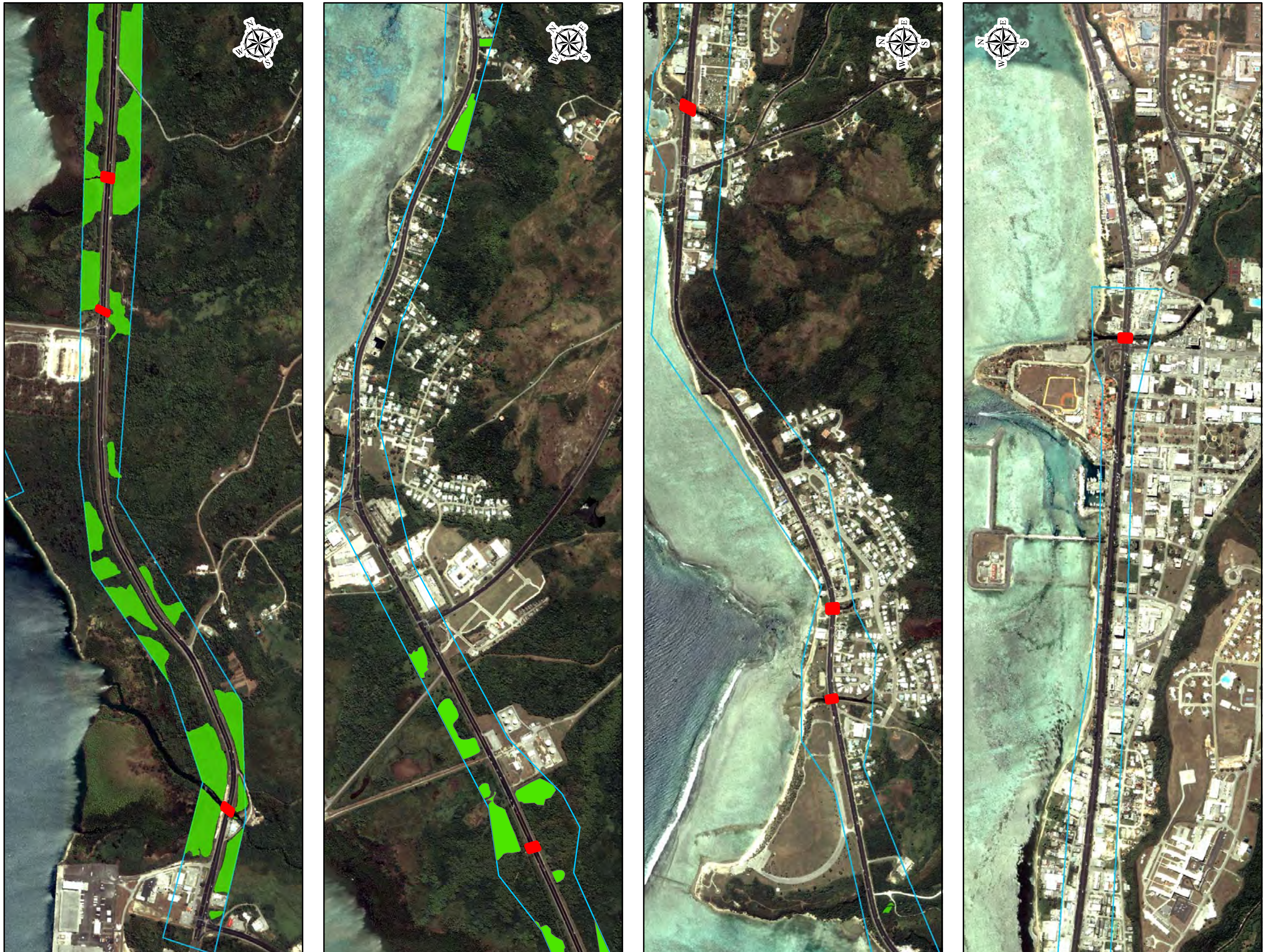
- Almagosa Basin - The large wetland in Almagosa basin was confirmed to have boundaries similar to those previously identified. An additional smaller wetland was found to the east of the large wetland. The large palustrine emergent wetland interior is almost exclusively *Phragmites karka* with various shrubs or trees such as *Hibiscus tiliaceus,* and *Pandanus tectorius,* and in some cases the swamp fern *Acrostichum aureum,* around the perimeter. The smaller wetland to the east had less *Phragmites karka*.

- Access Route to West NMS - Only one small wetland was documented in the field study areas west of NMS; most of this drainage was steep and the stream channel deeply cut. The wetland was on the boundary of a forested and open area and therefore was a mix of palustrine scrub/shrub and emergent.

- Barrigadas - On Air Force Barrigada and the southern portion of Navy Barrigada the NWI identified wetlands were found to meet the three USACE wetland criteria (NWI boundaries were adjusted), although the jurisdictional status of these wetlands remains to be determined because they are isolated. These wetlands were typically palustrine emergent but in some cases were scrub/shrub. Typically they occupied slightly depressed topographic areas. The NWI wetland identified in north-central Navy Barrigada was not found to meet wetland criteria.

- NCTS Finegayan - Several areas, including two sinkholes, a major storm drainage route, and a flat area that appeared to be a slight topographic low were investigated by observation and documentation of with wetland plots on NCTS Finegayan but no wetlands were found there. NCTS Finegayan has no surface waters, no NWI-identified wetlands, and no hydric soils mapped. Soils observed were typically brightly colored with little indication of any saturation. Soils throughout are typically thin over the limestone bedrock in the area.

Figure 5
Overview of Wetlands
Identified in the Present
Field Study along
Marine Corps Drive



Legend

- Wetland 2010
- Bridge Replacements
- 2010 Field Study Area

Feet
0 1,100 2,200
0 310 620
Meters

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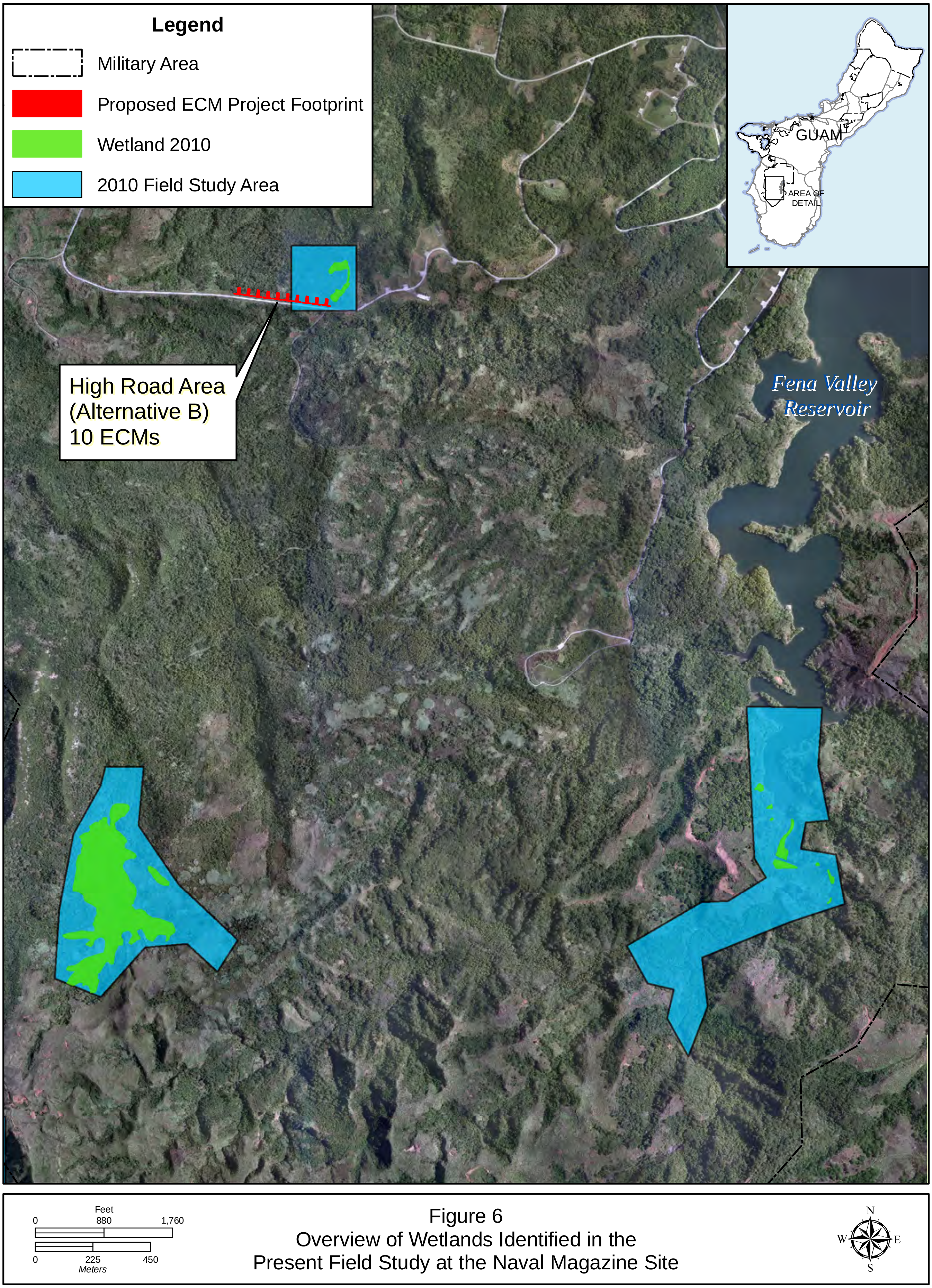

Figure 6
Overview of Wetlands Identified in the
Present Field Study at the Naval Magazine Site

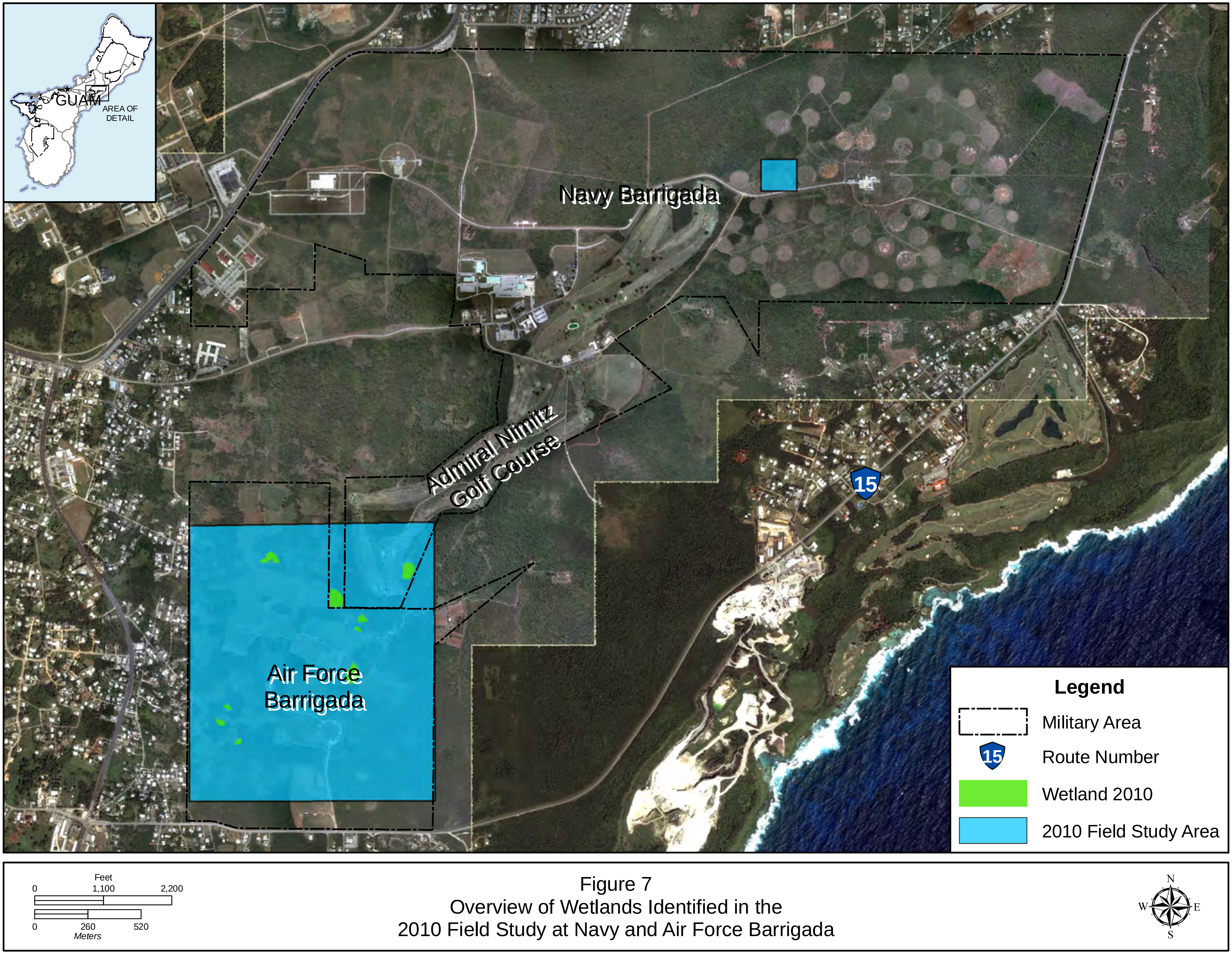

Figure 7
Overview of Wetlands Identified in the
2010 Field Study at Navy and Air Force Barrigada

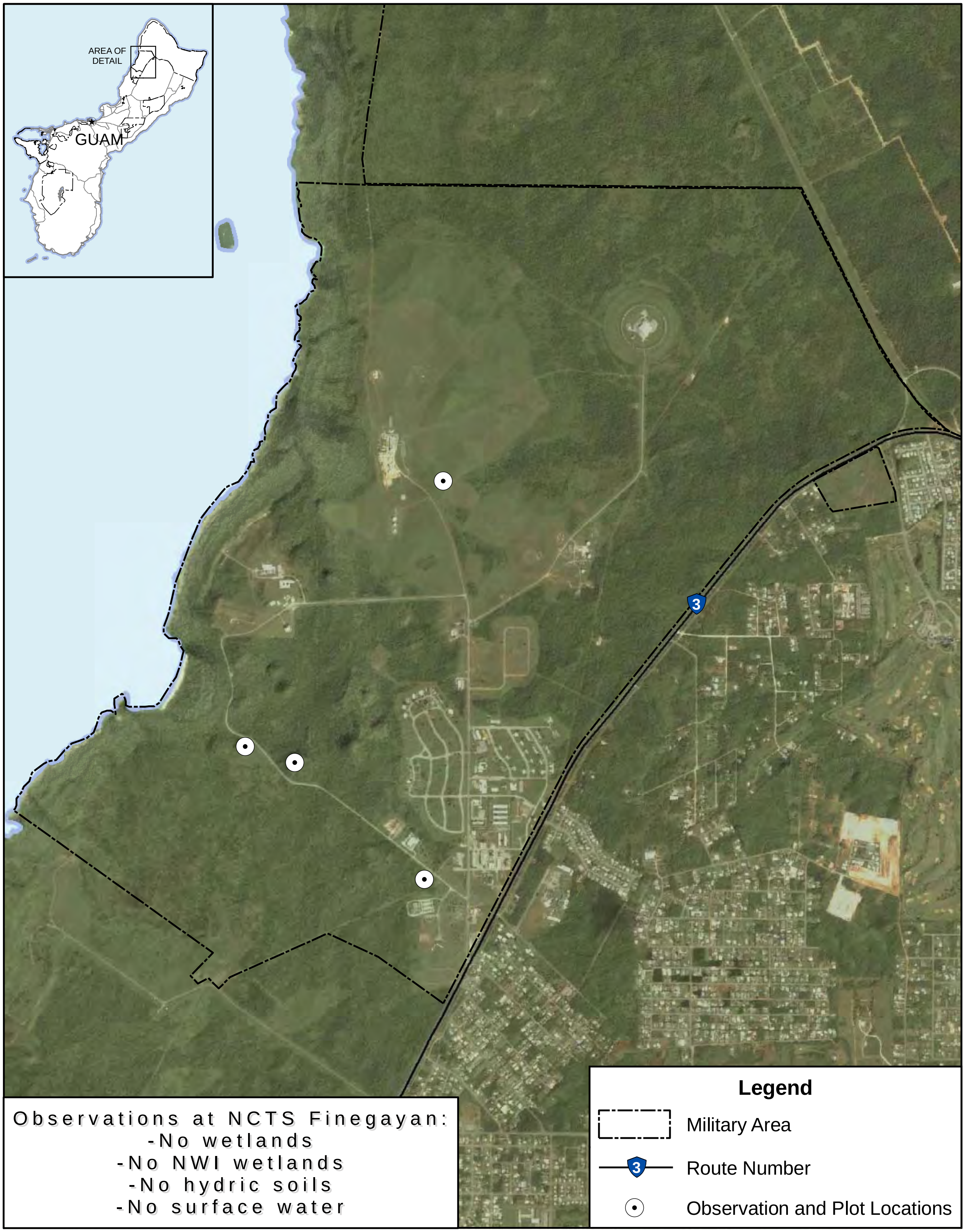

Figure 8
Observations at NCTS Finegayan

3.3 Remote Sensing

Satellite multispectral imagery was obtained from the U.S. Navy. This imagery was taken by the Satellite Imaging Corporation using the new GeoEye-1 satellite sensor that launched on September 6, 2008. Resolution is 1.65 m for multispectral data. GeoEye multi-spectral data consist of four rather broad spectral channels positioned in the visible and near infrared portions of the electromagnetic spectrum – blue, green, red, and near infrared. Additional information about the imagery is provided in Appendix E.

The subcontracting firm contracted to perform this work was supplied with ancillary data provided to serve as reference sources and initial input for base classifications attempts. These included the GIS data listed below.

- Study areas.
- Vegetation mapping for the island of Guam (USFS 2006).
- Topography at 2 ft and 5 ft intervals.
- Wetland mapping for Navy facilities on Guam (Aecos and Wil Chee 2009) (the subcontractor was informed that areas mapped in the southern portion of the NMS site could not be relied upon as accurate).
- Hydric soils for Guam.
- Hydrology layers for Guam.
- 2007 Geoeye aerial color imagery for the island of Guam.
- 2009 aerial color imagery for Navy facilities on Guam.

Preliminary classifications were performed using unsupervised clustering algorithms (Isodata and K-means methods) in the absence of training site data, however the Aecos and Wil Chee (2009) data in the Apra Harbor vicinity, areas identified therein as “wetlands”, were used as surrogate training areas. All non-wetland areas were masked, allowing the inclusion of only “wetland” polygons in unsupervised classifications. This strategy was adopted in an attempt to segregate designated wetland areas into spectrally distinct classes with signatures that could be used as input for statistically identifying wetlands across other areas using supervised classification techniques.

Multiple attempts to improve classification accuracy were made using various combinations of spectral and non-spectral image channels, and by trying several classification techniques. The ten image channels used during the first phase of classification included the four original spectral channels, four principal components channels, red well depth, and topographic slope.

Overall, the results of the classification attempts were largely unsuccessful. Attempts to classify wetlands in a mix of palustrine wetland types in the Apra Harbor area proved highly unreliable. After fieldwork in the southern NMS indicated that many previously classified wetlands in this area were not wetlands and fieldwork in the area west of NMS found very little wetlands due to the high topographic relief in the area, it was decided to concentration on classification of mangrove wetlands in the Apra Harbor area.

These attempts to classify mangroves in the Apra Harbor area were partially successful, but there were still errors which could not be resolved. As a result, the spectral imaging was used as a foundation to develop initial areas with the potential to be mangroves. This classification was further refined with the Navy 2009 aerial imagery. The results of this classification is shown in Figure 9.

Uncertainty associated with classification accuracy is most likely attributable to the following:

1. The nature of the vegetation on Guam. Most of the common plant species found in freshwater wetland areas on Guam (unless soils are permanently saturated) are rated facultative. Examples are pago (*Hibiscus tiliaceus*), *Pandanus tectorius*, and sugarcane (*Saccharum officinarum*). These species are ubiquitous and often found in large stands in upland areas but also grow readily in wetland areas, particularly pago which is highly adaptable. Consequently, vegetation can be a very unreliable indicator of wetland status and spectral imaging signatures primarily reflect vegetation. In addition, there were problems of similarity of species, e.g. sugarcane has a very similar spectral signature to the obligate wetland species *Phragmites karka* and this proved problematic.

2. Timing of data acquisition could be optimized for wetland delineation given the physical nature of Guam – distinct wet/dry seasons along with moderately to highly permeable soils across most of the island. It would seem the best time for capturing data for wetland studies is soon after a rain event. Unfortunately, the periodicity of satellite coverage and frequent cloud cover over the tropics severely limit opportunities for data collection. The GeoEye coverage of the island consists of several separate scenes put together in a mosaic. Conditions at the time of these collections are unknown and may not be optimal.

3. The nature of the GeoEye-1 data, in terms of spatial resolution, radiometric resolution, and especially spectral resolution, may be insufficient for accurately mapping most wetlands on Guam. The four broad spectral bands provide little discriminatory capability for many of the wetland/non-wetland communities and features. Hyperspectral imagery (versus the multispectral imagery used) may provide much better resolution for wetland determination.

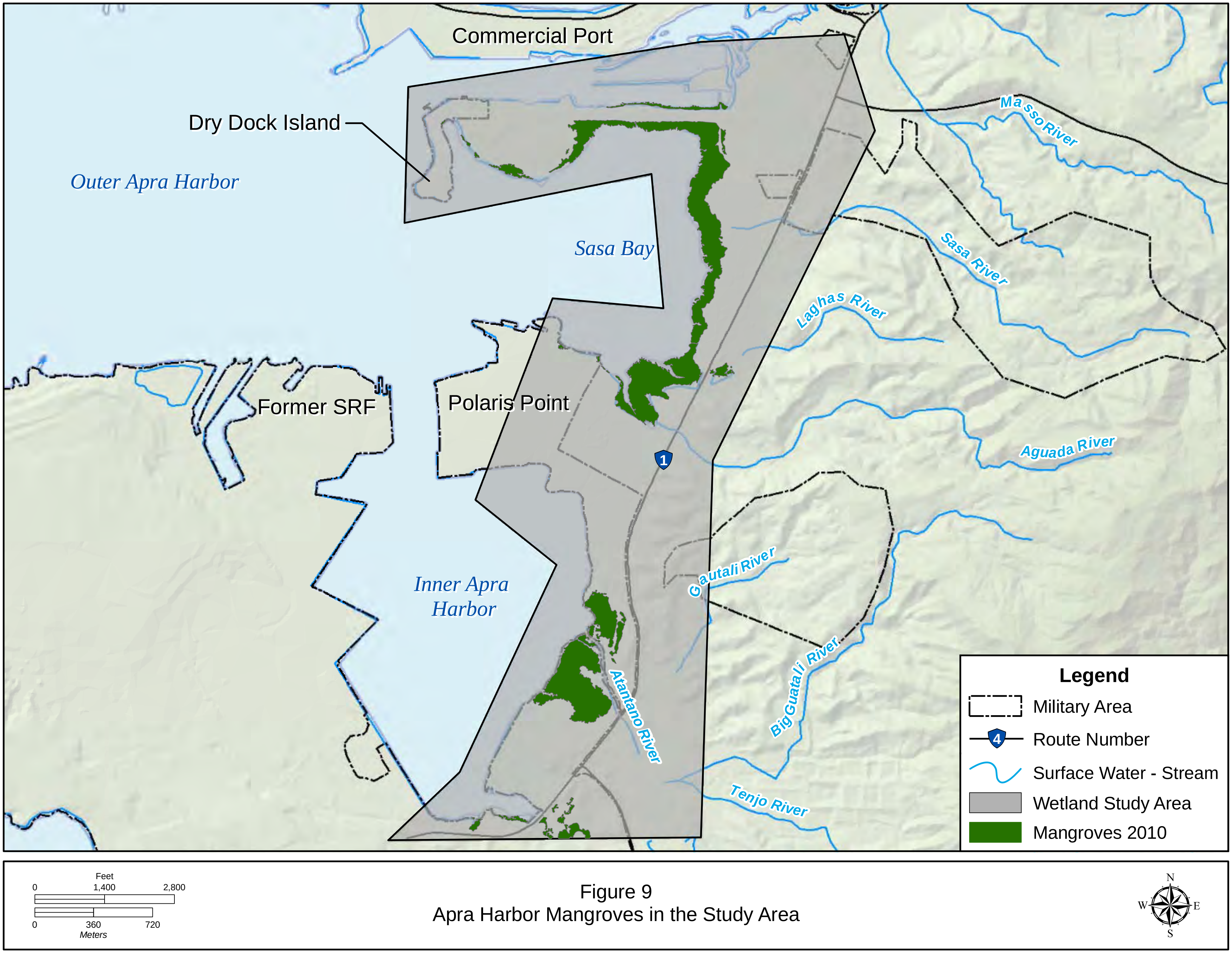

Figure 9
Apra Harbor Mangroves in the Study Area

SECTION 4
REFERENCES

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Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 131pp.

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APPENDIX A
FIGURES SHOWING WETLANDS IDENTIFIED IN 2010 FIELD STUDY AREAS

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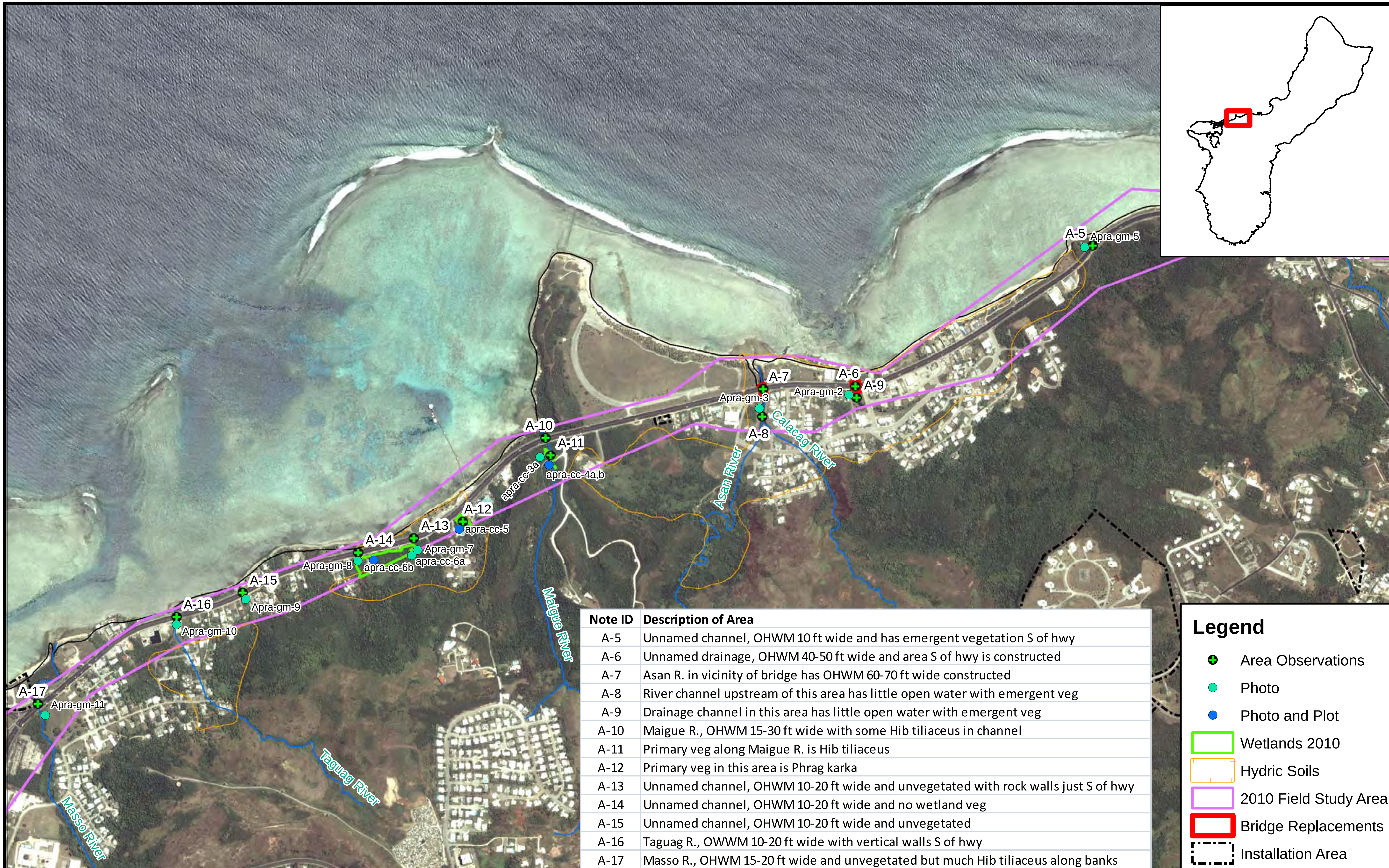
Note ID	Description of Area
A-1	Hib tiliaceus in OHWM just upstream of bridge at this location
A-2	Agana R. in vicinity of bridge has OHWM 40-50 ft wide
A-3	Fonte R. in vicinity of bridge has OHWM 70-80 ft wide
A-4	Unnamed constructed vertical-sided channel, 15 ft wide
A-5	Unnamed channel, OHWM 10 ft wide and has emergent vegetation S of hwy

0 500 1,000 2,000 Feet

N W E S

Apra North Area

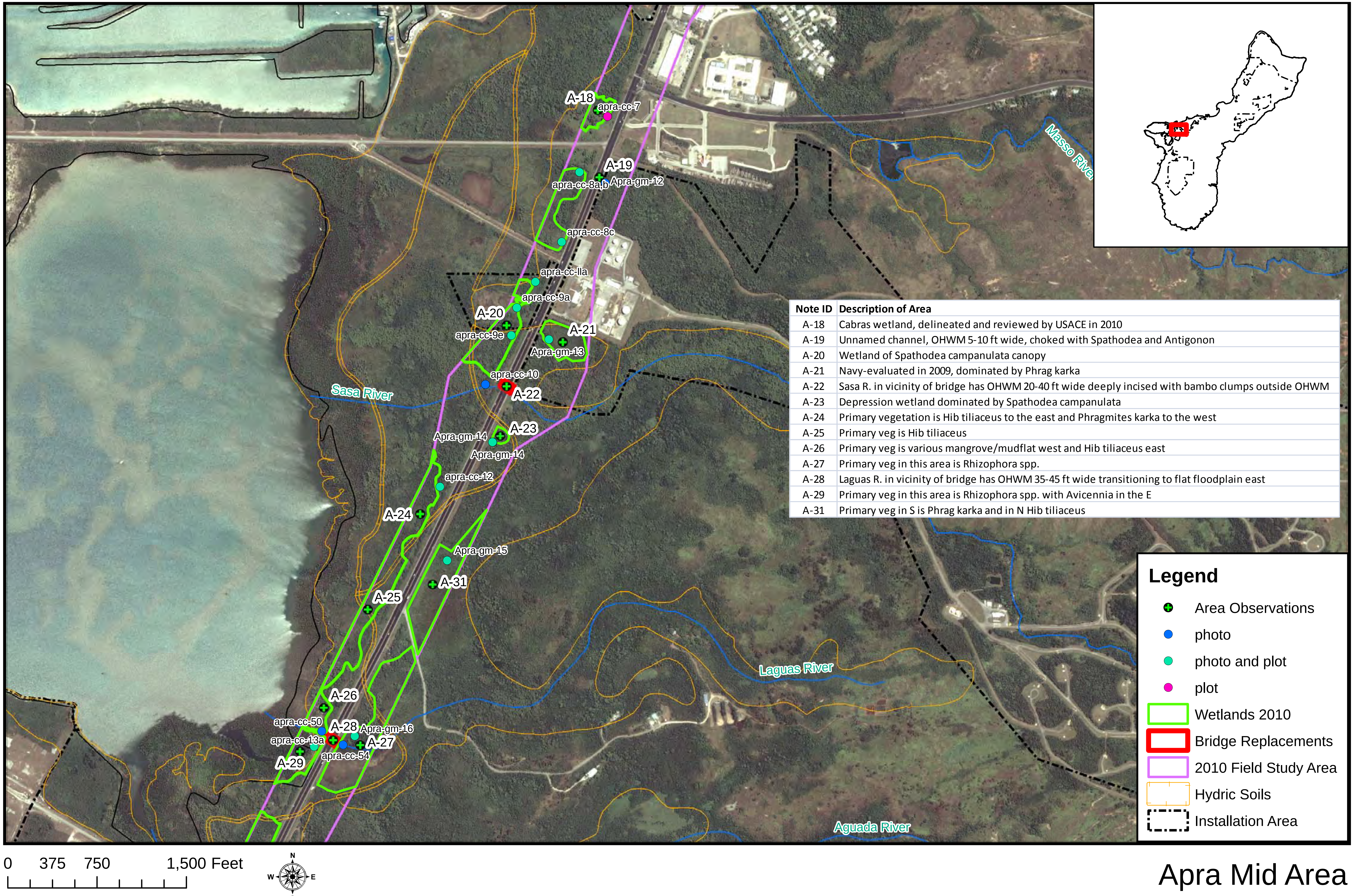


Note ID	Description of Area
A-5	Unnamed channel, OHWM 10 ft wide and has emergent vegetation S of hwy
A-6	Unnamed drainage, OHWM 40-50 ft wide and area S of hwy is constructed
A-7	Asan R. in vicinity of bridge has OHWM 60-70 ft wide constructed
A-8	River channel upstream of this area has little open water with emergent veg
A-9	Drainage channel in this area has little open water with emergent veg
A-10	Maigue R., OHWM 15-30 ft wide with some Hib tiliaceus in channel
A-11	Primary veg along Maigue R. is Hib tiliaceus
A-12	Primary veg in this area is Phrag karka
A-13	Unnamed channel, OHWM 10-20 ft wide and unvegetated with rock walls just S of hwy
A-14	Unnamed channel, OHWM 10-20 ft wide and no wetland veg
A-15	Unnamed channel, OHWM 10-20 ft wide and unvegetated
A-16	Taguag R., OWWM 10-20 ft wide with vertical walls S of hwy
A-17	Masso R., OHWM 15-20 ft wide and unvegetated but much Hib tiliaceus along banks

0 500 1,000 2,000 Feet

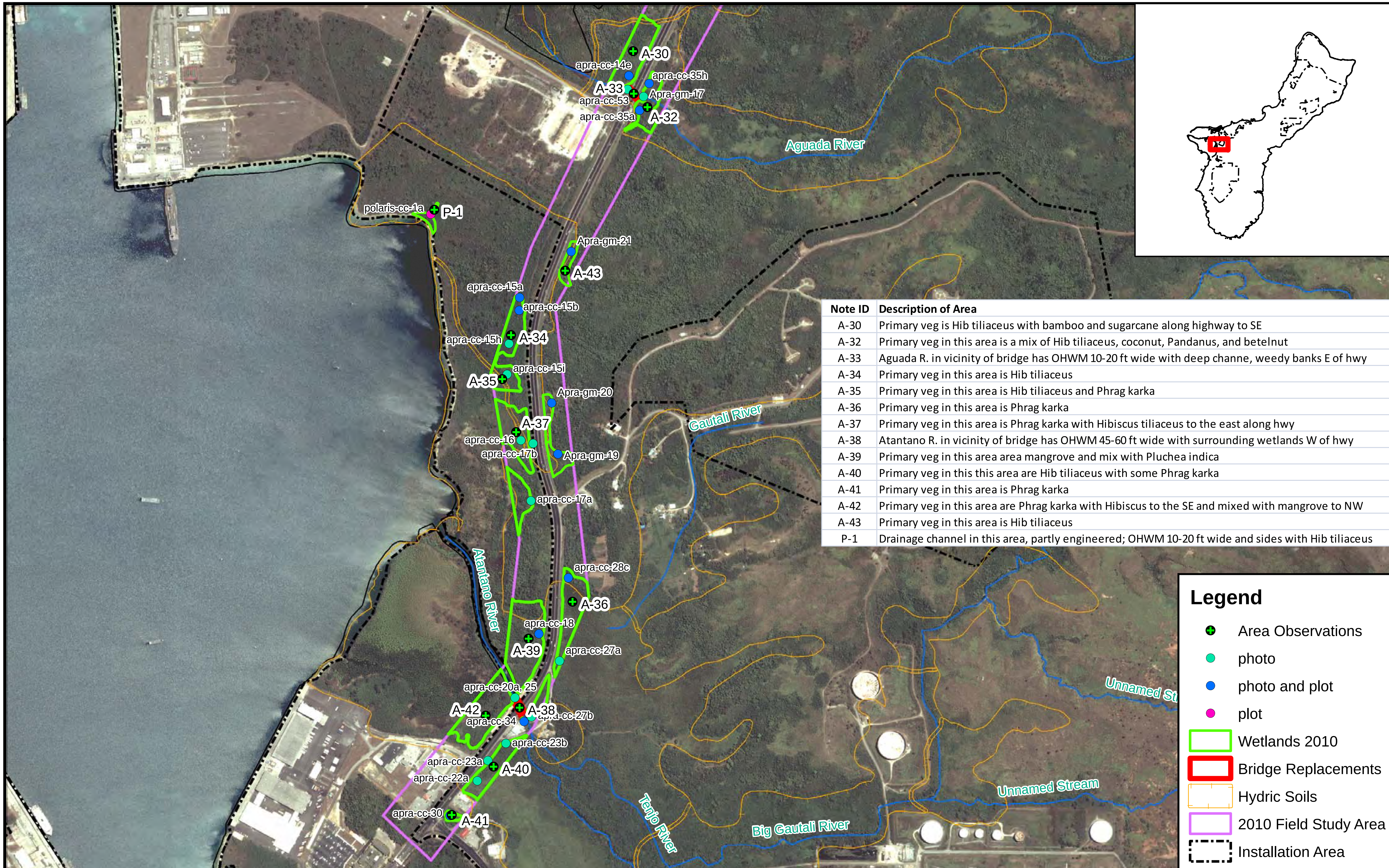
N W E S

Apra Mid-North Area



Note ID	Description of Area
A-18	Cabras wetland, delineated and reviewed by USACE in 2010
A-19	Unnamed channel, OHWM 5-10 ft wide, choked with Spathodea and Antigonon
A-20	Wetland of Spathodea campanulata canopy
A-21	Navy-evaluated in 2009, dominated by Phrag karka
A-22	Sasa R. in vicinity of bridge has OHWM 20-40 ft wide deeply incised with bambo clumps outside OHWM
A-23	Depression wetland dominated by Spathodea campanulata
A-24	Primary vegetation is Hib tiliaceus to the east and Phragmites karka to the west
A-25	Primary veg is Hib tiliaceus
A-26	Primary veg is various mangrove/mudflat west and Hib tiliaceus east
A-27	Primary veg in this area is Rhizophora spp.
A-28	Laguas R. in vicinity of bridge has OHWM 35-45 ft wide transitioning to flat floodplain east
A-29	Primary veg in this area is Rhizophora spp. with Avicennia in the E
A-31	Primary veg in S is Phrag karka and in N Hib tiliaceus

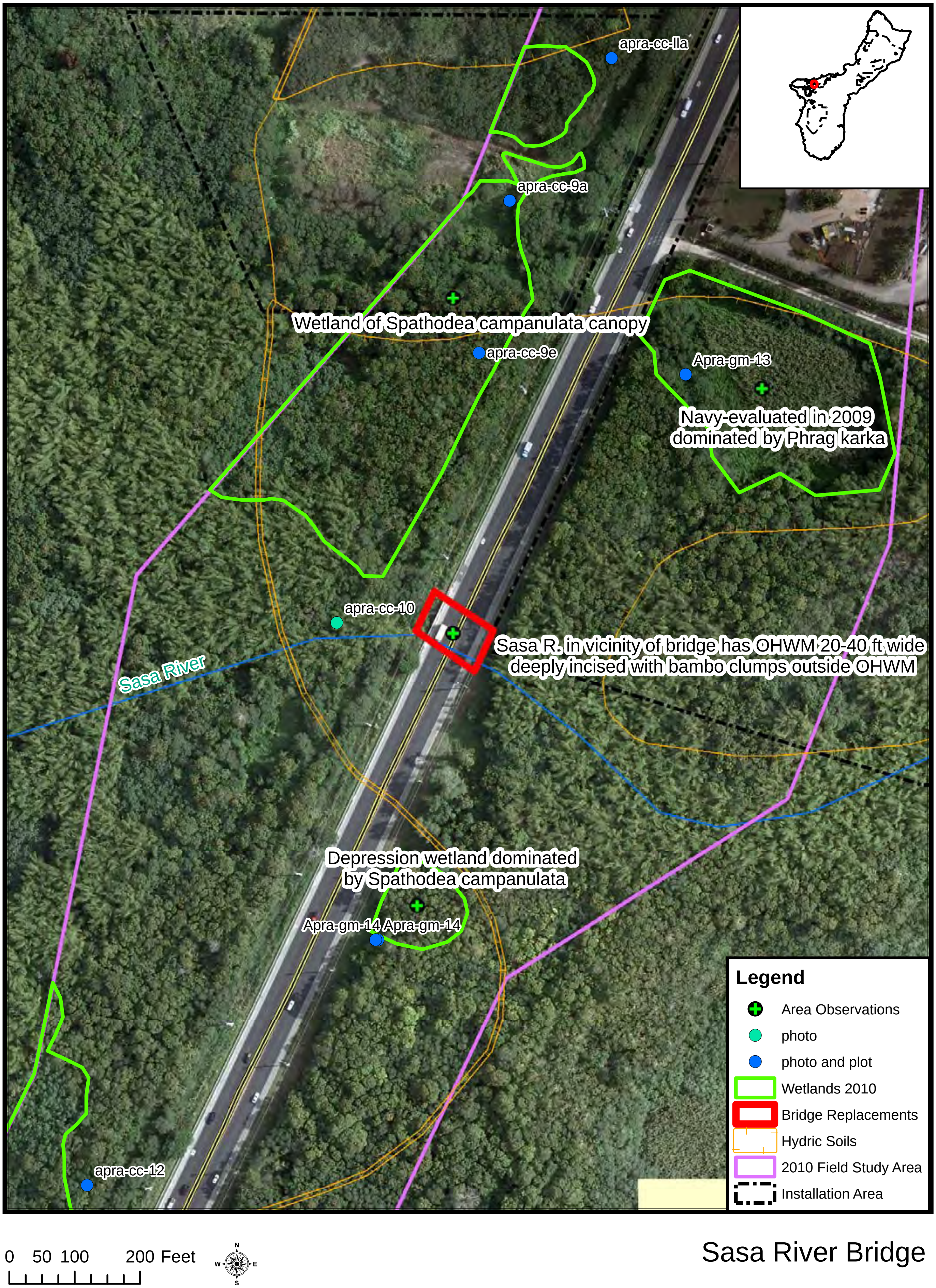
Apra Mid Area



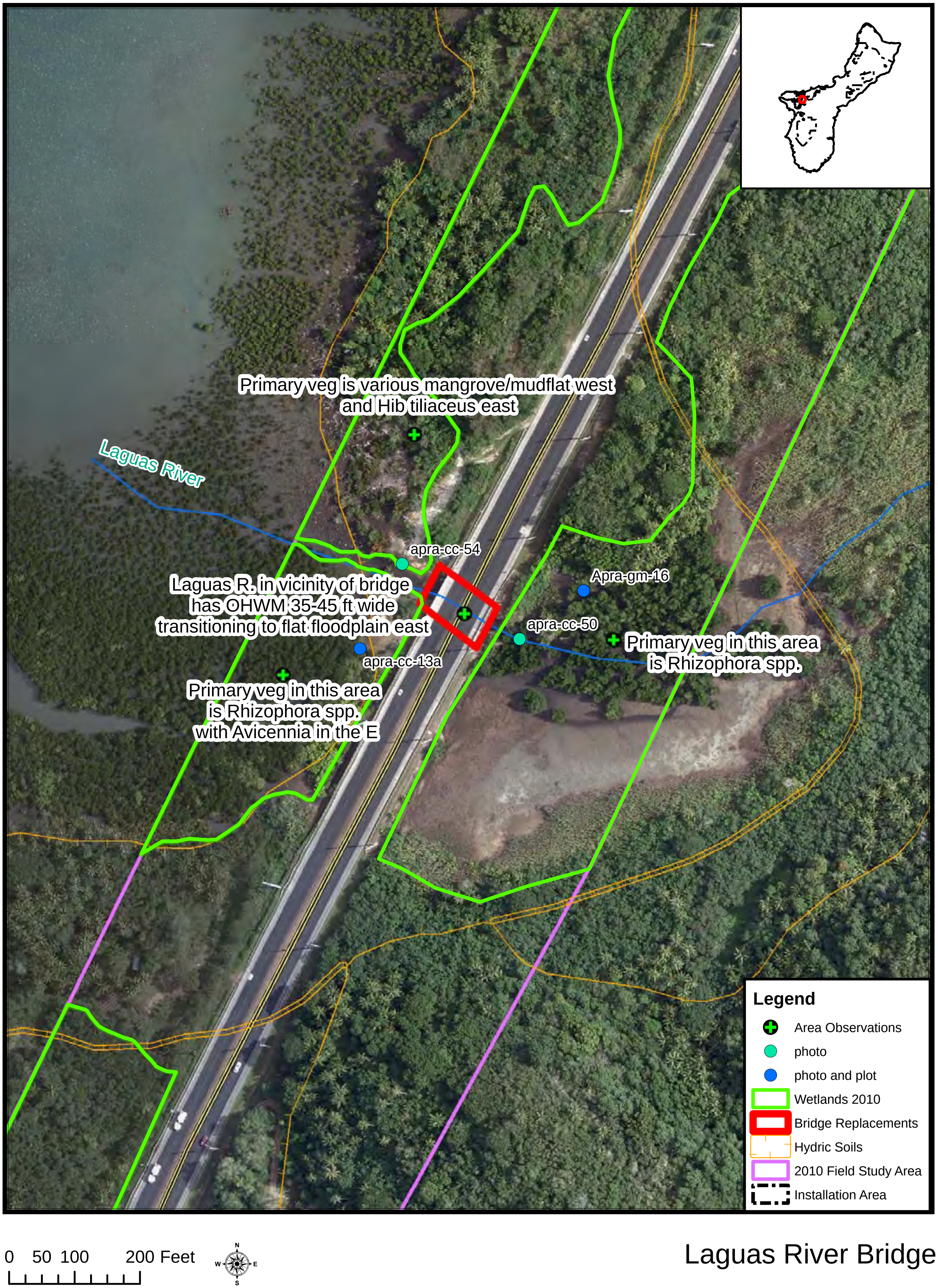
Note ID	Description of Area
A-30	Primary veg is Hib tiliaceus with bamboo and sugarcane along highway to SE
A-32	Primary veg in this area is a mix of Hib tiliaceus, coconut, Pandanus, and betelnut
A-33	Aguada R. in vicinity of bridge has OHWM 10-20 ft wide with deep channe, weedy banks E of hwy
A-34	Primary veg in this area is Hib tiliaceus
A-35	Primary veg in this area is Hib tiliaceus and Phrag karka
A-36	Primary veg in this area is Phrag karka
A-37	Primary veg in this area is Phrag karka with Hibiscus tiliaceus to the east along hwy
A-38	Atantano R. in vicinity of bridge has OHWM 45-60 ft wide with surrounding wetlands W of hwy
A-39	Primary veg in this area area mangrove and mix with Pluchea indica
A-40	Primary veg in this this area are Hib tiliaceus with some Phrag karka
A-41	Primary veg in this area is Phrag karka
A-42	Primary veg in this area are Phrag karka with Hibiscus to the SE and mixed with mangrove to NW
A-43	Primary veg in this area is Hib tiliaceus
P-1	Drainage channel in this area, partly engineered; OHWM 10-20 ft wide and sides with Hib tiliaceus

0 375 750 1,500 Feet

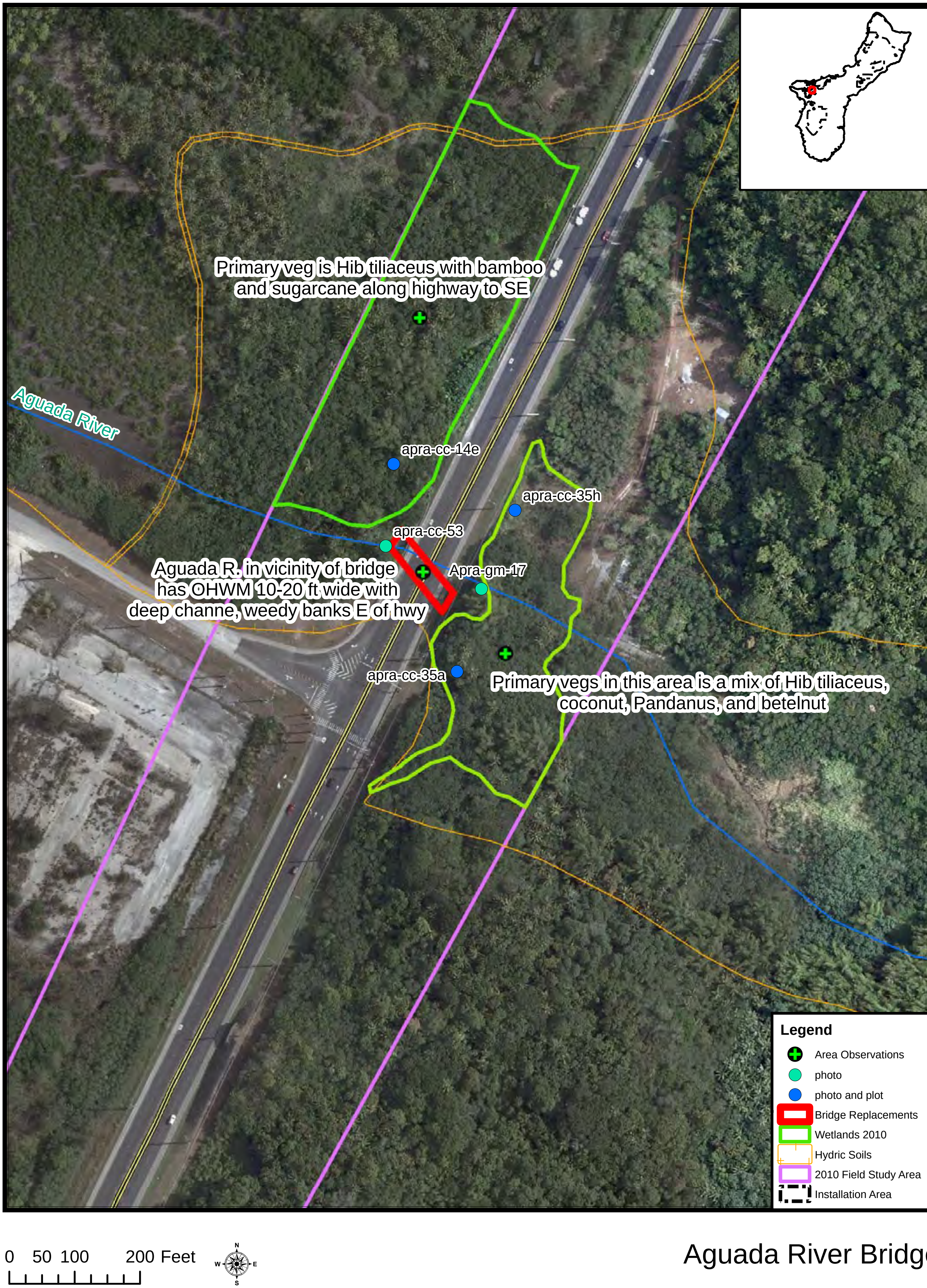
Apra South Area



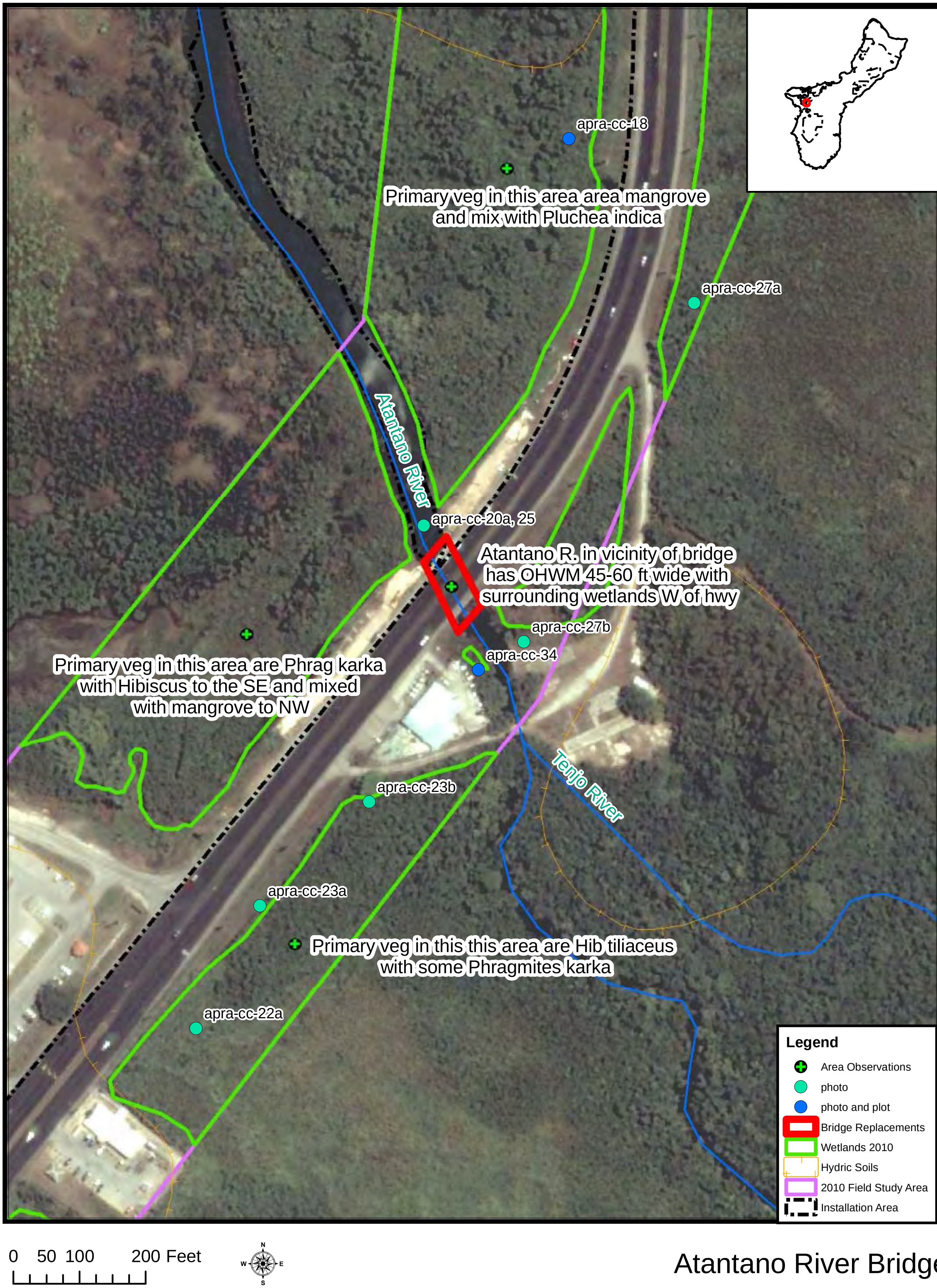
Sasa River Bridge



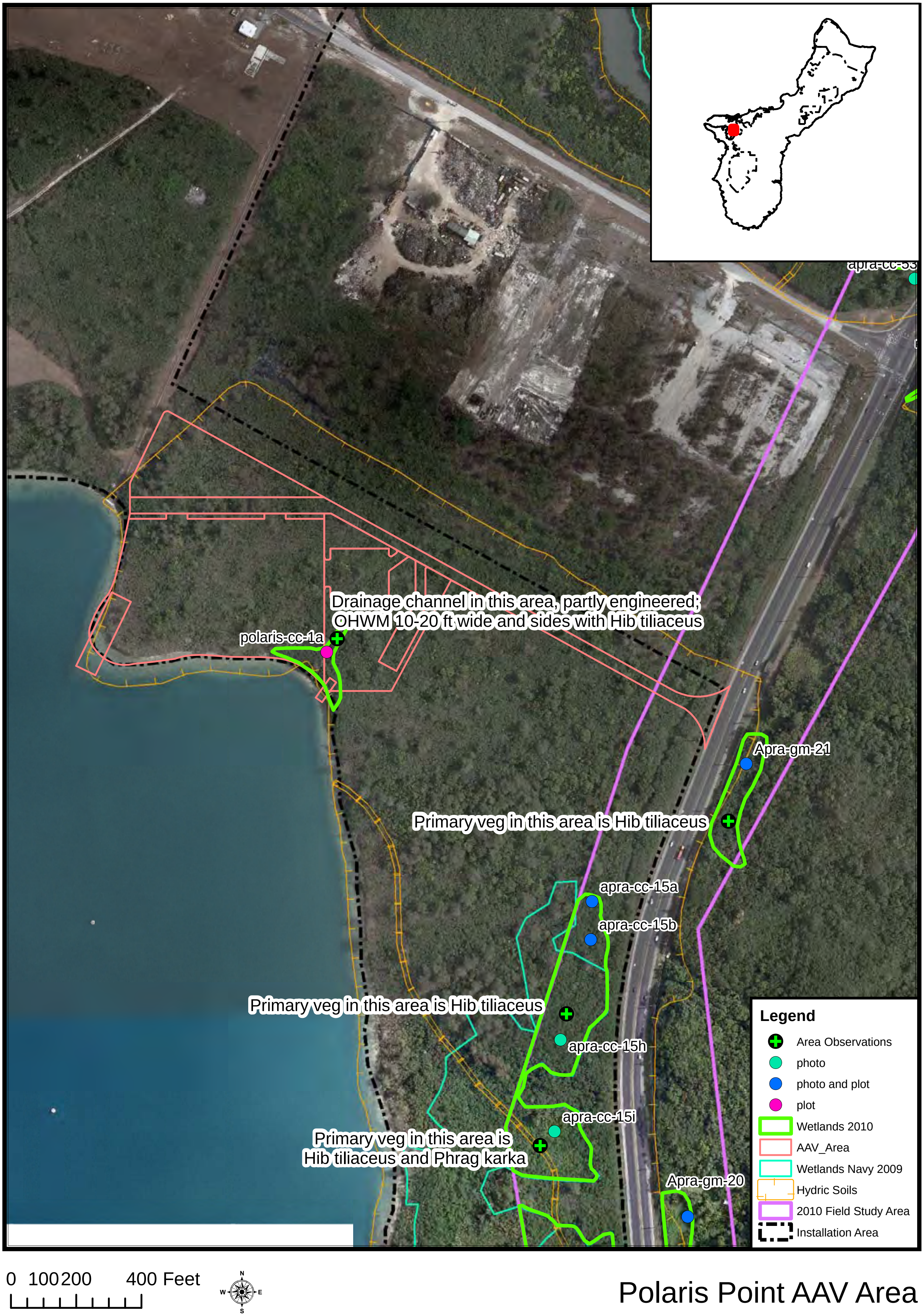
Laguas River Bridge



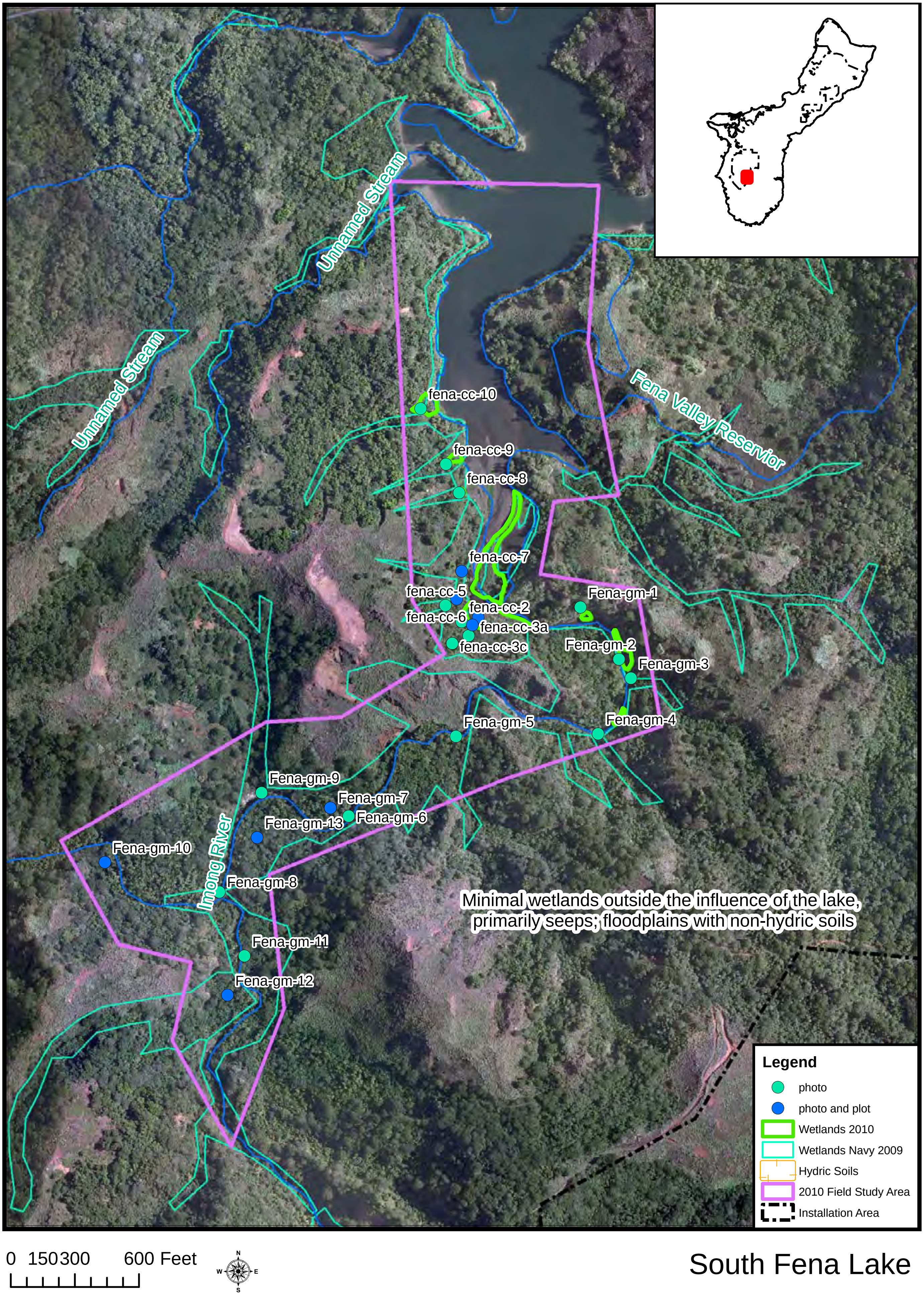
Aguada River Bridge



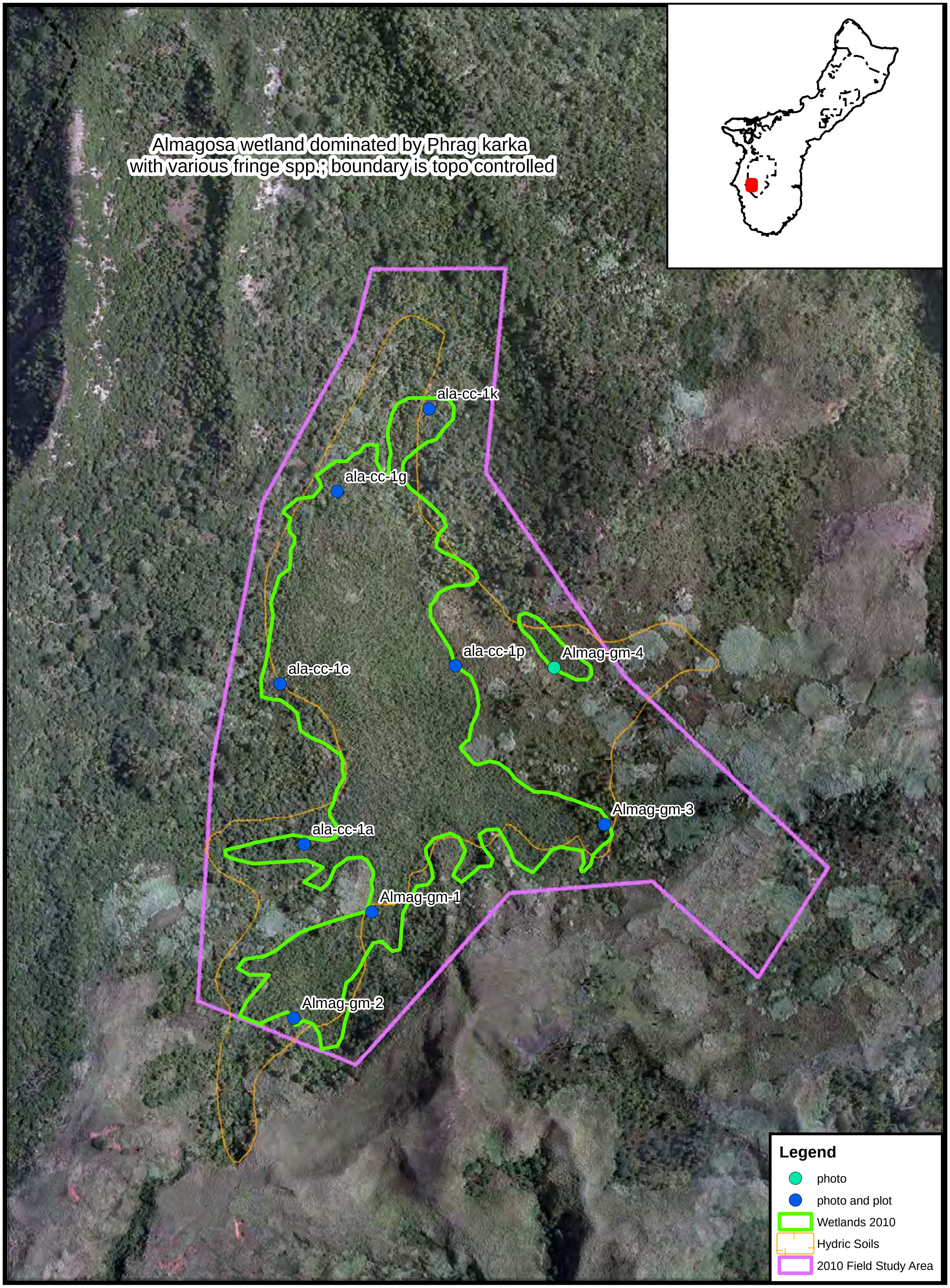
Atantano River Bridge



Polaris Point AAV Area

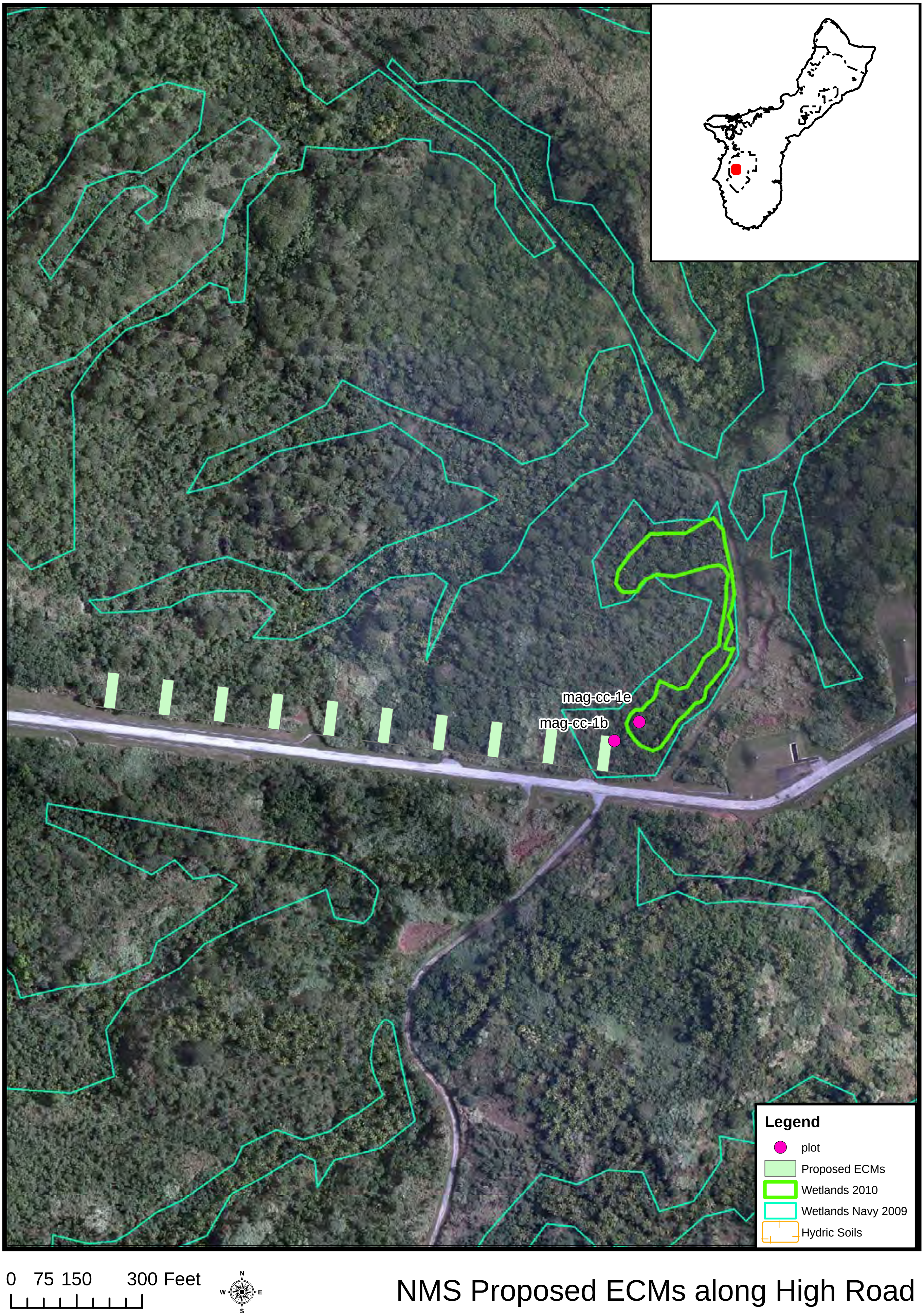


South Fena Lake

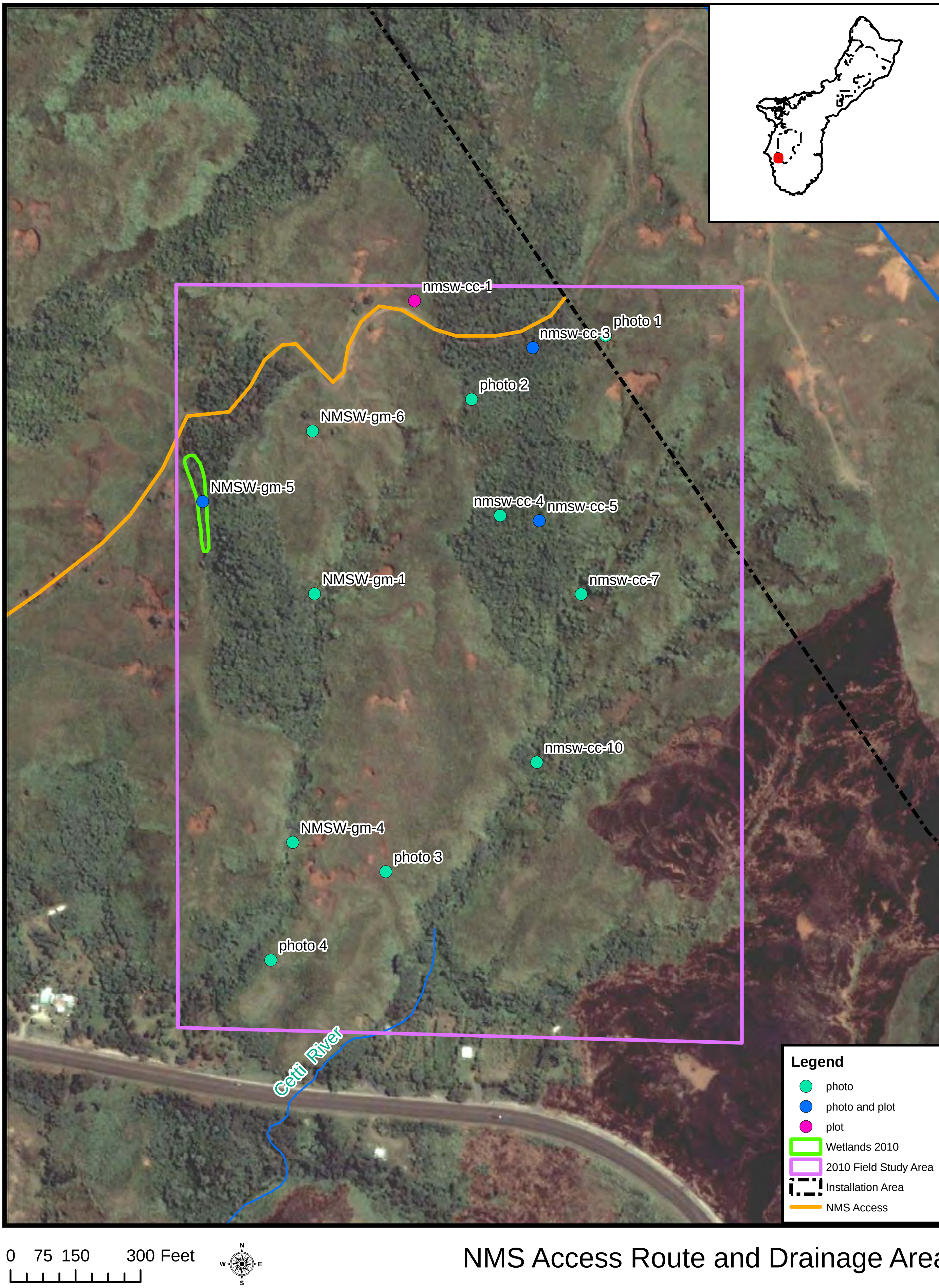


0 125 250 500 Feet

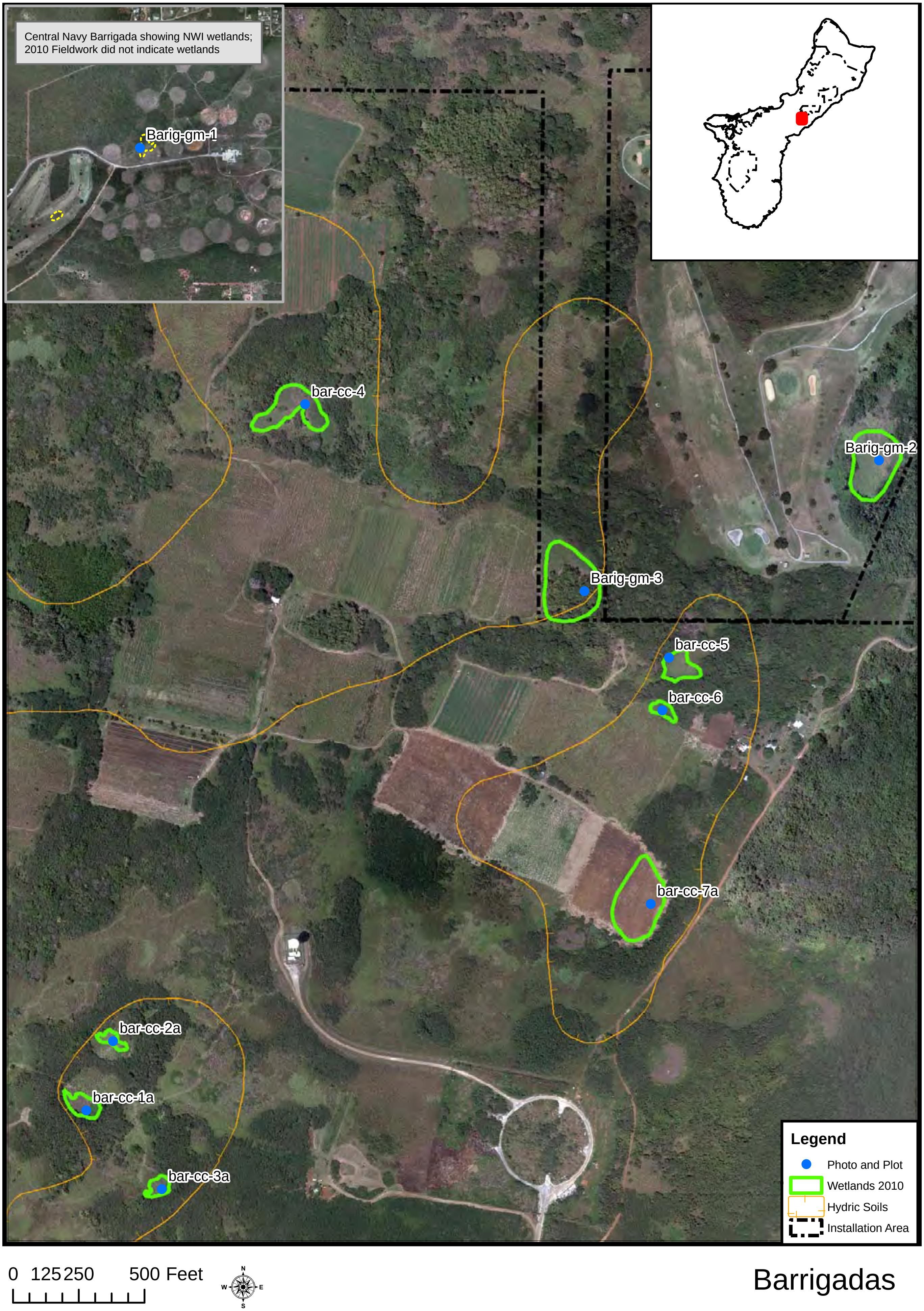
Almagosa Basin on NMS



NMS Proposed ECMs along High Road



NMS Access Route and Drainage Area



Central Navy Barrigada showing NWI wetlands;
2010 Fieldwork did not indicate wetlands
Barig-gm-1
bar-cc-4
Barig-gm-2
Barig-gm-3
bar-cc-5
bar-cc-6
bar-cc-7a
bar-cc-2a
bar-cc-1a
bar-cc-3a
Legend
Photo and Plot
Wetlands 2010
Hydric Soils
Installation Area
0 125 250 500 Feet
N
W
E
S

Barrigadas

NCTS Finegayan

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APPENDIX B
PHOTO LOG FOR 2010 FIELD STUDY AREAS

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Apra-gm-1.

Fonte River east of highway with patches of emergent and shrub vegetation with OHWM.

Apra gm-2.

Emergent vegetation within OHWM of unnamed drainage east of highway and north of Asan River.

Apra-gm-3.

Asan River east of highway within USACE floodway project

Apra-gm-4.

Drainage just west of highway at governors complex

Apra-gm-5.

Unnamed drainage choked with weeds

Apra-gm-7.

Unnamed drainage, east of highway; unvegetated

Apra-gm-8.

Unnamed drainage, east of highway

Apra-gm-9.

Small unnamed drainage east of highway with debris

Apra-gm-10.

Maigue River east of highway

Apra-gm-11.

Masso River east of highway with deeply cut banks

Apra-gm-12.

Unnamed channel, east of highway

Apra-gm-13.

Wetland south of Navy tank farm dominated by *Phragmites karka*

Apra-gm-14.

Small wetland in depression east of highway dominated by *Spathodea campanulata*

Apra-gm-15.

Sasa River east of highway with deeply cut channel and bamboo along banks

Apra-gm-16N.

Forested wetland in floodplain along north side of Laguas River, east of highway

Apra-gm-16.

Laguas River east of highway showing broad, flat drainage with no defined channel; mangroves present at left of photo (north)

Apra-gm-17.

Aguada River just east of highway; channel with vegetation overhanging and weeds near highway but less vegetation along channel further east within the forest

Apra-gm-18.

Wetland east of highway dominated by *Hibiscus tiliaceus* with fern epiphytes

Apra-gm-19.

Hibiscus tiliaceus dominated wetland east of highway

Apra-gm-20.

Gleying in hydric soil

Apra-gm-20.

Mixed vegetation community in wetland east of highway

Apra-gm-21.

Hibiscus tiliaceus dominated wetland east of highway

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-1.

Agana River downstream of MCD.

Apra-cc-3a.

Maigua River downstream of MCD.

Apra-cc-4a.

Pago wetland on floodplain adjacent Matgua River.

Apra-cc-4b.

Cyperus on very narrow wetland strip above OHWM along Matgua River. Opening of concrete box culvert under driveway bridge barely visible in background.

Apra-cc-5.

Phragmites wetland bounded by a constructed berm supporting tangantangan along the west boundary.

Apra-cc-6.

A mixture of pago wetland growing on low, dark hummocky soils, patches of *Cyperus alternifolia*, and abandoned residential development ripe with cultivated, and escaped ornamental species.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-8.

A dense pago forest mixed with small isolated patches of emergent wetland dominated by *Phragmites karka* (cc-8c) and *Panicum muticum* (cc-8b).

Apra-cc-9.

A forested wetland dominated by the invasive *Spathodea campanulata*. The understory is dominated by *Paspalum conjugialis* and *Thelypteris interrupta* and forest openings support *Ipomoea indica* and *Panicum muticum* (cc-9a).

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-10.

Sasa River downstream of MCD. Pipeline and debris buildup obstructs flows and contributes to overbank high flows into wetland cc-9.

Apra-cc-11a.

Pago wetland. Spathodea campanulata is invading wetland. Rebar and flagging represent boundary established by previous wetland delineation.

Apra-cc-12a.

An emergent wetland with *Phragmites karka* and *Spathodea campanulata* growing in a linear strip along the low-lying edge of pipeline route and toe of the MCD road bank.

Apra-cc-12b.

A pago wetland previously delineated by Navy contractors. The mapped wetland boundary remains true to the previous mapping.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-54.

Laguas River showing excavated channel downstream of MCD. Excavated channel bisects historical mangrove mudflat habitat to facilitate high flows and high water past the bridge and bridge abutments.

Apra-cc-13.

Mangrove wetland with Rhizophora and Avicennia adjacent MCD and Laguas River.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-14e.

Pago wetland north of the Aguada River downstream of MCD. Barringtonia racemosa seedlings are abundant here.

Apra-cc-53.

Aguada River impounded by dirt berm downstream of MCD. High river flows exceed berm and disperse into several channels within wetland Apra-cc-14.

Apra-cc-15.

Pago wetland previously mapped as a Navy wetland along long stretch west of MCD. Previous boundary expended slightly on north end based on topography, vegetation and drainage patterns.

Apra-cc-16.

Unnamed drainage blocked by dirt berm.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-17.

Mangrove wetland. One of only a few observations of *Bruguiera gymnorrhiza*. Previously mapped by Navy.

Apra-cc-18a.

Mangrove edge dense with *Achrostichum*, *Phragmites* and *Pandanus*. Previously mapped by Navy.

Apra-cc-18b.

Phragmites wetland viewed from mangrove wetland 18a as a dense wall of phragmites.

Apra-cc-19.

Unnamed drainage under MCD. 30 inch concrete tunnel under road and downstream, excavated and bermed, depression impounds green water during the dry season.

Apra-cc-20a.

Atantano River bridge. Tall steep banks with no abutting floodplain wetland. Wetlands cc-18 and cc-21 are wetlands adjacent to Atantano River downstream of MCD.

No photograph available.

Apra-cc-21a.

Wetland mosaic comprised of mangrove, pago and emergent phragmites wetland types.

Apra-cc-30.

Phragmites wetland surrounded by tangantangan south of Taco Bell.

Apra-cc-22a.

Phragmites portion of wetland. Pago (in background) is dominant species to north portion of wetland cc-22.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-23.

Unnamed ditch tributary to Atantano River. Runs along roadside perimeter of phragmites and pago portions of wetland cc-22.

Apra-cc-25.

Atantano River upstream of Marine Corps Drive. Steep banks except where small floodplain above OHWM supports pago (cc-34).

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-34.

Pago wetland on small left bank floodplain of Atantano River upstream of MCD.
.

Apra-cc-26a.

Pago wetland bordered by MCD, the shrine road (and cc-27), and the cut banks above the Atantano River.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-27.

Looking south at unnamed 10-feet-wide ditch between shrine road and wetland cc-26. This is a flood control ditch, tributary to Atantano River.

Apra-cc-28a.

Emergent wetland dominated by phragmites with significant amounts of pago. Large privately owned wetland east of MCD and north of the Atantano River.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-28c.

Shrub scrub wetland dominated by pago with significant amounts of phragmites. Large privately owned wetland east of MCD and north of the Atantano River.

Apra-cc-36a.

Aguada River upstream of MCD. Dug out depression at bridges pools green water in dry season.

Apra-cc-35a.

Disturbed pago and pandanus- dominated wetland area dominated by various, mostly facultative, species along the Aguada River which pool here as high flows back up against the MCD bridge.

Apra-cc-35h.

A weedy, emergent wetland with hummocky ground and wetland soils that have been cleared and used to graze carabao.

Photo Log: Team B
Site Location: APRA
Dates: May 4, 5, 7, 12

Apra-cc-50.

"Laguas River" has no channel and OHWM east of MCD. The area east of MCD is mangrove swamp.

Photo Log: Team A
Site Location: Fena
Dates: May 6,7

Fena-gm-1.

Fena-gm-2.

Photo Log: Team A
Site Location: Fena
Dates: May 6,7

Fena-gm-3.

Fena-gm-4.

Photo Log: Team A
Site Location: Fena
Dates: May 6,7

Fena-gm-5.

Fena-gm-6.

Fena-gm-7.

Fena-gm-8.

Sadog Gago branch

Photo Log: Team A
Site Location: Fena
Dates: May 6,7

Fena-gm-9.

Fena-gm-10.

Fena-gm-11.

Fena-gm-12.

Photo Log: Team A
Site Location: Fena
Dates: May 6,7

Fena-gm-12.

Fena-gm-13.

Photo Log: Team A
Site Location: Fena
Dates: May 6,7

Fena-gm-13.

Photo Log: Team B
Site Location: Fena Reservoir
Date: May 6

Fena-cc-1.

Emergent Saccharum wetland on stable floodplain surface in Imong River. Previously mapped Navy wetland meets soil, hydrology and vegetation criteria.

Fena-cc-2.

Steep, cascading dry ephemeral drainage on slopes above Fena Reservoir. Lined with *Pandanus dubius*, *Scleria polycarpa* and *Pteris quadriaurita*.

Photo Log: Team B
Site Location: Fena Reservoir
Date: May 6

Fena-cc-3, -6, -7.

Sampled previously mapped Navy wetland on slopes above Fena Reservoir and Imong River. None of the samples had hydric soils. The slopes were dry and hydrologic indicators were too few.

Fena-cc-4a.

Emergent Saccharum wetland on high floodplain surface along Imong River.

Fena-cc-5.

Steep, cascading rocky ephemeral draiange above Imong River. Drainage is lined with ferns: *Thelypteris parasitica*, *Pteris ensiformis* and *Nephrolepis hisutula*.

Fena-cc-8.

Intermittent drainage is 3 to 4 feet wide upstream but transitions to a 20 feet wide, pago-covered alluvial fan. View of lower reach from Fena Reservoir showing fresh red alluvium and the fern species *Ceratopteris gaudichaudii* (bright green).

Fena-cc-9.

Pago stand on 40-feet-wide alluvial fan. Upstream the drainage ravine has two narrow channels 1 to 3 feet wide. One is muddy, the other carries 2 to 3 inches of seepage flow originating offsite. All perennial seepage is absorbed at a pig wallow located on the alluvial fan.

Fena-cc-10.

A perennial drainage up to 6 feet wide upstream and transitions into 125 feet of pago-filled alluvial fan up to 100 feet wide. Pictured is "badlands" red alluvium at the edge of Fena Reservoir.

Almag-gm-1

Overlook of large Almagosa wetland within large basin

Almag-gm-1

Mixed vegetation at wetland boundary at the southwest edge of wetland

Photo Log: Team A
Site Location: Alamagosa
Date: May 11, 2010

Almag-gm-3

Looking upslope from edge of wetland boundary at the south end of wetland

Almag-gm-4

Edge of wetland in a large bamboo grove

Photo Log: Team A
Site Location: Alamagosa
Date: May 11, 2010

Almag-gm-5

Edge of smaller wetland area east of main wetland; Soil is saturated and vegetation includes *Acrostichum aureum*.

Photo Log: Team B
Site Location: Alamagosa
Date: May 11, 2010

Ala-cc-1.

Alamagosa emergent wetland in ravine dominated by Phragmites and Hibiscus. Hydric soils in ravine along west side.

Ala-cc-1c.

Emergent wetland on gentle slope above main Alamagosa wetland depression. Navy wetland boundary positively confirmed here.

Photo Log: Team B
Site Location: Alamagosa
Date: May 11, 2010

Ala-cc-1g.

Similar to sample cc-1c with emergent wetland vegetation on a gentle grade located above and outside the main Alamagosa wetland depression.

Ala-cc-1k.

A scrub shrub wetland dominated by Hibiscus and Pandanus. Marginal wetland soils but retained wetland boundary as previously mapped by Navy based on positive indicators for hydrology and vegetation as well as subtle depressional relief on this wetland “lobe” at the north end of Alamagosa wetland.

Photo Log: Team B
Site Location: Alamagosa
Date: May 11, 2010

Ala-cc-1p.

Samples the most abundant emergent wetland within Alamagosa. It is dominated by *Phramites karka*, *Hibiscus tiliaceus* and *Achrostichum aureum*.

Photo Log: Team A
Site Location: Barrigadas
Date: May 10, 2010

Barrigada-gm-1.

Open area of grasses near antenna. NWI identified area. Not a wetland based on field plot.

Barrigada-gm-2.

Depression dominated by *Panicum muticum*.

Photo Log: Team A
Site Location: Barrigadas
Date: May 10, 2010

Barrigada-gm-3.

Burned grasses in low area wetland containing bamboo stand.

Barrigada-gm-3.

Edge of wetland at shrub border. Recently burned grasses.

Photo Log: Team B
Site Location: Barrigada
Date: May 10

Bar-cc-1a.

Emergent wetland in partially burned depression.

Bar-cc-2a.

Emergent wetland dominated by Panicum muticum. Depression is further impounded by old dirt berm at south end.

Photo Log: Team B
Site Location: Barrigada
Date: May 10

Bar-cc-3a.

Emergent wetland in partially burned depression.

Bar-cc-4.

Emergent wetland dominated by *Panicum muticum*. Past land use is unknown.

Photo Log: Team B
Site Location: Barrigada
Date: May 10

Bar-cc-5.

Emergent wetland dominated by *Panicum muticum*.

Bar-cc-6.

Emergent wetland dominated by *Panicum muticum*. Crude farm road runs through wetland the edge of a Sorghum field.

Photo Log: Team B
Site Location: Barrigada
Date: May 10

Bar-cc-7a.

Emergent wetland dominated by *Panicum muticum*. Partially cultivated in 2007.

Photo Log: Team A
Site Location: NMSW
Date: May 13

NMSW-gm-1.

Steep drainage at edge of forested area showing 5 ft drop and some erosion

NMSW -gm-4.

Typical channel of rock and high gradient

Photo Log: Team A
Site Location: NMSW
Date: May 13

NMSW -gm-5.

Soil pit showing dark surface soils and mottling deeper in profile

NMSW -gm-5.

Mixed vegetation in wetland area at edge of forest

Photo Log: Team A
Site Location: NMSW
Date: May 13

NMSW -gm-6.

Overview of forested ravine to the southwest

Photo Log: Team B
Site Location: NMSW
Date: May 13

Nmsw-cc-3.

A non-wetland stand of *Merrilliodendron megacarpum*. In picture is view of ravine below twin 30-inch culverts located under the trail at the grotto. No sign of recent scouring flows or inundation; the basin is closed and well-drained through large gaps in limestone rock.

Nmsw-cc-4.

An ephemeral drainage with moss covered rocks and no evident scour marks. Channel is very rocky and densely overgrown with Areca, Pandanus, and Freycinetia.

Photo Log: Team B
Site Location: NMSW
Date: May 13

Nmsw-cc-5.

Narrow (ca. 20 inch) path of perennial seepage flow in an otherwise ephemeral drainage which has a wider scoured width in mineral soil. These dry season flows do not reach main channel. Like drainage cc-5 this drainage is densely overgrown but with Areca, Hibiscus, and Freycinetia.

Nmsw-cc-7.

Main channel is dry, deeply and steeply entrenched, and strewn with boulders, the largest of which create a 3 to 12 feet tall step-cascade-bedform.

Nmsw-cc-10.

The start of where the drainage has a step-pool bedform and perennial seepage flows fill the pools. Often there are series of pools, many which are inhabited by freshwater shrimp.

Photo point 3 - Overview to northeast of ravine forest on NMSW.

Photo Log: Team B
Site Location: NMSW
Date: May 13

Photo point 3 - Overview to south of ravine forest on NMSW.

Fin-cc-1.

Wetland evaluation plot near bottom of a large, forested sinkhole

Fin-cc-2.

Overview of large sinkhole dominated by sugar cane grass

Fin-cc-2.

Bright soils at bottom of sinkhole; soils thin with rock below several inches

Fin-cc-3.

Area of flat topography dominated by grasses.

Fin-cc-3.

Soil pit with brightly colored soils throughout the profile

Fin-gm-1.

Head of stormwater drainage with several pipes discharging to the area

Photo Log: Teams A and B
Site Location: Finegayan
Date: May 13, 2010

Fin-gm-1.
Soil pit along stormwater drainage within forested area; soils brightly colored throughout profile

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APPENDIX C
WETLAND DATA FORMS FOR 2010 FIELD STUDY AREAS

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Team A Forms

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DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Navy wetland - Apra-gm-13					Date: May 5, 10
Applicant/Owner:					State: Guam
Investigator(s): GM, SW					S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☑	Plot ID: Apra-GM-13
Is the area a potential Problem Area?	Yes	☐	No	☑	
Location Description: 20 m into Navy delin wetland just S. of tank farm					

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phrag kark	75%	H	Obl				
Spathodea camp	20%	T	Fac				
Leu leu	5%	T	FacU				

Percent of dominants OBL, FACW, & FAC: 67%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back): other spp.

Coccinia		Phrg kark w/ seeds
Passifla foet,		Spathcam w/ flws
Paspalum conjugatum		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: —

Depth to free water: —

Depth to saturated soil: —

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☑
- Sediment Deposits: Yes ☐ No ☑
- Drift Lines: Yes ☑ No ☐
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☑
- Local Soil Survey: Yes ☑ No ☐
- FAC Neutral: Yes ☐ No ☑
- Water-stained Leaves: Yes ☐ No ☑

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra - GM - 13	Date:

SOILS

Map Unit Name: (Series & Phase) Inarajan clay 0-4%	Drainage Class: Hydric
Taxonomy (subgroup): (hydric)	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe 1"

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
6-10	B	7.5YR 4/4	7.5YR 3/1	25-50% high	Sandy loam to clay loam
5	A	7.5 YR 3/1			silty clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Water stands on top clay & slowly evaporates?

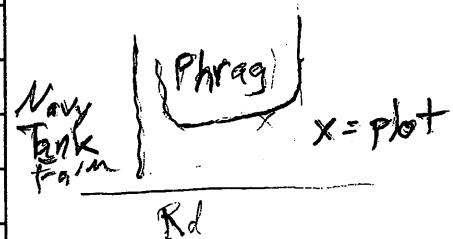
WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☑	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☑	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☑	No ☐	Unknown ☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

A few pig wallows noted



DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Apra-GM-14	Date: May 5
Applicant/Owner:	State: Guam
Investigator(s): GM, SW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: Apra-GM-14
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Just S of Sasa R. ~ 1000-1500' S of Tank farm	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Spath cam	90	T	Fac				
Neph bis	40	H	Fac				

Percent of dominants OBL, FACW, & FAC: 100 %

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back): other spp:

Poly punc	Antigonon	
Mikania	Cynosperma	
Leu leu	Arto alt.	
Poly sco		

HYDROLOGY

Is it the growing season? Yes ☐ No ☐

Based on:

Depth of Inundation: Dry

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

- Water Marks: Yes ☑ No ☐
- Sediment Deposits: Yes ☐ No ☑
- Drift Lines: Yes ☐ No ☑
- Drainage Patterns: Yes ☐ No ☑

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☑
- Local Soil Survey: Yes ☑ No ☐
- FAC Neutral: Yes ☐ No ☑
- Water-stained Leaves: Yes ☑ No ☐

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Obvious standing water at certain times. Distinct basin defined by top on all sides.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-GM-14	Date:

SOILS

Map Unit Name: (Series & Phase) Inarajan (hydric)	Drainage Class: Hydric
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
6-10	B	7.5YR 3/4	7.5YR 3/1	25% moderate	loam w/ sand
5"	A	7.5YR 3/1			silty clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

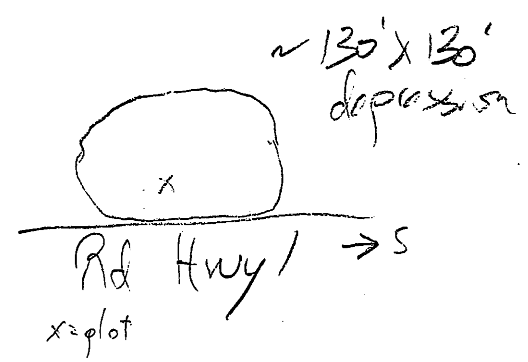
Rationale/Remarks: surface soil high clay - probably holds water & slowly drains

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance



DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Apra-gm-16N						Date: May 5, 10
Applicant/Owner:						State:
Investigator(s): GM, SW						S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐		Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☑		Plot ID: Apra-GM-16N
Is the area a potential Problem Area?	Yes	☐	No	☑		
Location Description: ~ 200' SE of large banyan, just N of Laguas R.						

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hib til	75	T	Fac				
Cocos nuc	10	T	FacU				
Phrag kark	10	H	Obl				
Neph bis	50	H	Fac				

Percent of dominants OBL, FACW, & FAC: 50% Tree, 100% H

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Mikania		
Poly punc		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	PRIMARY INDICATORS	
Based on:	Water Marks: Yes ☑ No ☐	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☑ No ☐
Depth to saturated soil: –		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Local ranch owner says river floods to hill near Hwy at banyan

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-GM-16N	Date:

SOILS

Map Unit Name: (Series & Phase) Inarajan (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil Probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10"	B	10YR 3/1	—		Clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

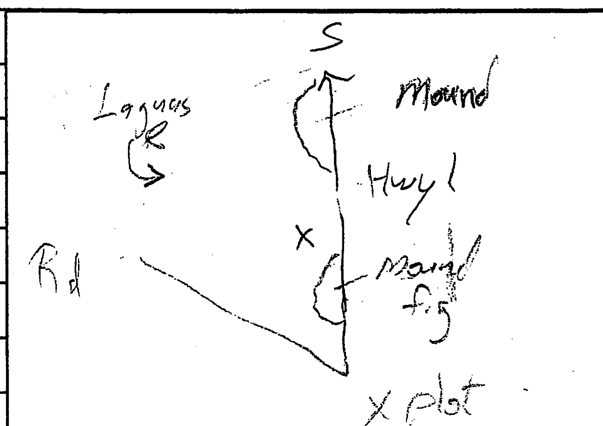
WETLAND SUMMARY

	Yes		No		Unknown	
Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Some rancho plantings on perimeter



DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Apra-gm-18		Date: May 5, 10
Applicant/Owner:		State:
Investigator(s): GM + SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Apra-GM-18
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: Just N of old Military Rd that angles SE		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hib til *	80%	T	Fac				
Mor cit	<5%	T	FacU	- not dominant			
Imperata con	<5%	H	Fac	- not dominant			

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Poly pun on tree trunks		
Poly sco		
Mikania scan		

HYDROLOGY

	PRIMARY INDICATORS	
Is it the growing season? Yes ☐ No ☐	Water Marks: Yes ☑ No ☐	Sediment Deposits: Yes ☐ No ☑
Based on:	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation:	SECONDARY INDICATORS (2 or more required)	
Depth to free water:	Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☑ No ☐
Depth to saturated soil:		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: crab holes

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-gm-18	Date:

SOILS

Map Unit Name: (Series & Phase) Inalajan (hydric)	Drainage Class: Hydric
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10"	B	7.5YR 3/1	7.5YR 4/3	~10% weak	Clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

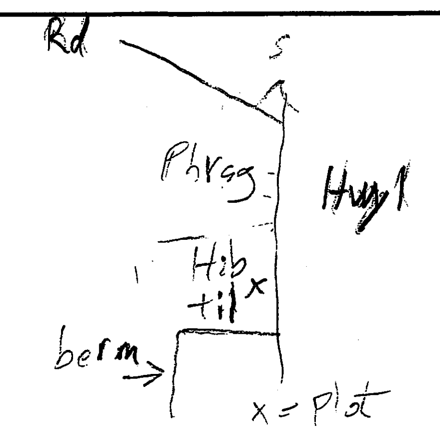
Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance



DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Apra-gm-19		Date: May 12, 10	
Applicant/Owner:		State:	
Investigator(s): GM, SW		S/T/R:	
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:	
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Apra-GM-19	
Is the area a potential Problem Area?	Yes ☐ No ☑		
Location Description: Near angel Rd Jesus — east side Hwy 1			

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hib til	90	T/S	Fac				
Pan tec	5	T/S	Fac				
Mikania sca	5	V	Fac				
Cocos nuc	5	S	Facu				
Poly pinc	5	H	–				

Percent of dominants OBL, FACW, & FAC: T/S 67% V 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back): Other spp:

Poly sco	Areca cat (abundant	
Flagellaria	in some areas of wetland)	
Davallia	Heritiera litt	
Hernandia		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: —	SECONDARY INDICATORS (2 or more required)	
Depth to free water: —	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil: —		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below:	Other:	
Stream, Lake or gage data: ☐		
Aerial photographs: ☐		

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Roots exposed from scour; crab holes

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-GM-19	Date:

SOILS

Map Unit Name: (Series & Phase) Inarajan (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: Soil Probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
2-12	B	7.5YR3/1	7.5YR3/4	20-30% strong	clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Topo defines on all sides

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Apra-gm-20	Date: May 12, 10
Applicant/Owner:	State:
Investigator(s): GM, SW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: Apra-GM-20
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Near N end of wetland w plot 19	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Senna ~~suff~~ +	50	S	Fac	+ = Cassia alata			
H. b t. l	20	S	Fac				
Pan tec	20	T	Fac				
Acrostichum	10	K	Obl				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back):

Mikania		
Panicum mut (patch	15X30' in one area)	

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☑ No ☐
	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☑ No ☐
Depth to saturated soil: –		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below:	Other:	
Stream, Lake or gage data: ☐		
Aerial photographs: ☐		

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Exposed roots

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-gm-20	Date:

SOILS

Map Unit Name: (Series & Phase) Inarajan (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: Shovel

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
2-12	B	7.5YR3/1	7.5YR3/4	10-25% moderate to strong	Clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Slope to east somewhat gradual.
Edge typically marked by
Cocos nuc

Several pig wallows noted

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Apra-gm-21					Date: May 12, 10
Applicant/Owner:					State: / /
Investigator(s): GM, SW					S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑	No ☐			Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐	No ☑			Plot ID: Apra-GM-21
Is the area a potential Problem Area?	Yes ☐	No ☑			
Location Description: Small Hib til dominated depression S. of Aguada R.					

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hib t.l	90	T/S	Fac				
Spathodea cam	10	T	Fac				
Flag indica	5	V	Fac				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Poly punc		
Blechum brownei		
Teramnus labialis		
Synedrella nodiflora		

HYDROLOGY

	PRIMARY INDICATORS	
Is it the growing season? Yes ☑ No ☐	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Based on:	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☑ No ☐
Depth to saturated soil: –		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Obvious depression – no outlet
Some roots exposed

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-gm-21	Date:

SOILS

Map Unit Name: (Series & Phase) Inarajan (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
2 - 12	B	10YR3/1	10YR4/6	25-50% strong	clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

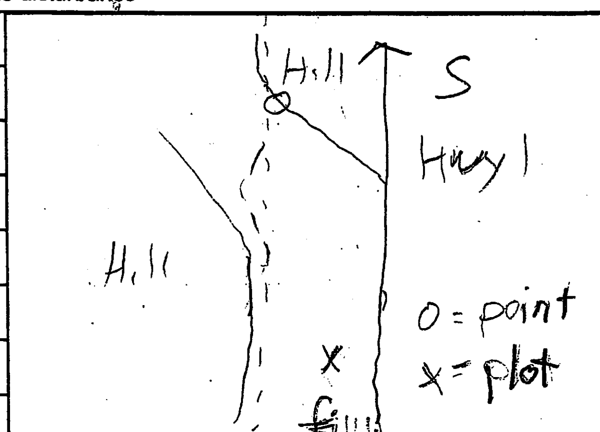
Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance



DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Fena-gm-7		Date: May 6, 10
Applicant/Owner:		State:
Investigator(s): GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Fena-gm-7
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: Imong floodplain near split w Sadog Gagu		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Cocos nuc*	75	T	FacU				
Curcuma	10	H	Fac				
Scleria	<5	H	Fac	- Not dom			
Neph hi?	<5	H	Fac	- Not dom			
Flay rei	5	V	Fac	- Not dom			

Percent of dominants OBL, FACW, & FAC: T 0% H

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☐ No ☑

Rationale/remarks; other plant species noted (continue on back):

Oplismenus		
Medinilla vine		
Pyrrosia lanc		

HYDROLOGY

Is it the growing season? Yes ☐ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☑ No ☐	Drainage Patterns: Yes ☐ No ☑
Depth of Inundation:	SECONDARY INDICATORS (2 or more required)	
Depth to free water:	Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil:		
	FAC Neutral: Yes ☐ No ☑	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: River floodplain.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Foragm-7	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10"	B	7.5YR3/3	—		Clay silt

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
Profile to 12" is bright-colored

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☐	No	☑	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☑	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Large Cpeo Palm flat forest
on N bank,
at former Veg transect

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Fena-gm-10	Date: May 6, 10
Applicant/Owner:	State:
Investigator(s): GM, SW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: Fena-GM-10
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Floodplain near stream, split	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pan dub	5	T	Fac	Vitex par	10	T	FacU
Areca cat	25	T	Fac	Neph hir	5	H	Fac
Cocos nuc	10	T	FacU				
Hib til	10	S	Fac				
Sac halum	40	H	Fac				

Percent of dominants OBL, FACW, & FAC: T = 50%, S = 100%, H = 100%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Curcuma	A few Cycad in the area	
Hiptis cap		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☑ No ☐	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☑ No ☐	Drainage Patterns: Yes ☐ No ☑
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil: ✓		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena-gm-10	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup): " "	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil Probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10"	B	7.5YR3/3	—		Sandy silt

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Bright soils 0-12"

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☑	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Substantial pig damage

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Fena-gm-12		Date: May 7
Applicant/Owner:		State: /
Investigator(s): GM SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Fena-GM-12
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description:		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Areca cat	50	T	Fac	Thelypteris spp.	5	-	
Hibtil	30	T	Fac				
Pantec	10	T	Fac				
Areca cat	25	S	Fac				
Freycineta	10	V	Fac				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Neph hir	Medinilla vine	
Belosia		
Vittaria inc		
Pyrrosia lonc		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☑ — Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑ — Drainage Patterns: Yes ☐ No ☑
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☐ No ☑ — Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil: –	
	FAC Neutral: Yes ☐ No ☑ — Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☐ No ☑

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena-gn-12	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10"	B	5YR 4/4	—		Silt

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Bright soils 0-12"

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☑	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☑	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Moderate pig disturbance.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland	Fena-gm-13	Date: May 7
Applicant/Owner:		State:
Investigator(s): GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Fena-GM-13
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description:		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pan tec	40	T	Fac	Neph bis	10	H	Fac
Hib t.l	10	T	Fac	Pan tec	95	S	Fac
Hyptis cap	25	H	Fac				
Vit par	10	T	Facu				
Scleria	15	H	Fac				

Percent of dominants OBL, FACW, & FAC: T = 67% H, S = 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Dendrobium guamen		
Lygodium		
Cycas mar		
Curcuma		

HYDROLOGY

	PRIMARY INDICATORS	
Is it the growing season? Yes ☐ No ☐	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Based on:	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☐ No ☑
Depth of Inundation:	SECONDARY INDICATORS (2 or more required)	
Depth to free water:	Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil:		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☐ No ☑

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Flra-gm-13	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10"	B	2.5Y 4/4	—		loam

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Bright Soils 0-12"

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☑	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☑	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Significant Pig Rooting

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Almag-gm-1		Date: May 11, 10
Applicant/Owner:		State:
Investigator(s): GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☐ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☐	Plot ID: Almag-gm-1
Is the area a potential Problem Area?	Yes ☐ No ☐	
Location Description: SW portion		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pan tec	15	T	Fac	Hyptis cap	10	H	Fac
Cocos nuc	25	T	FacU	Areca cat	10	S	Fac
Phrag Karka	40	H	Obl				
Thelyp mac	10	H	Fac				
Scleria poly	20	H	Fac				

Percent of dominants OBL, FACW, & FAC: T = 50% H, S = 100%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Stictocardia		
Mikania scan		

HYDROLOGY

Is it the growing season? Yes ☐ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☑
- Sediment Deposits: Yes ☐ No ☑
- Drift Lines: Yes ☐ No ☑
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☑ No ☐
- Local Soil Survey: Yes ☑ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves: Yes ☐ No ☑

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Near standing water w/ hummocks

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Alamag-gm-1	Date:

SOILS

Map Unit Name: (Series & Phase) Ylig clay (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
4-8	B	5YR4/2	5YR4/4	10% moderate	clay
Saprolite	below				

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

gleyed soils near by

Some pig damage

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Almag-gm-2	Date: May 11, 10
Applicant/Owner:	State:
Investigator(s): GM, SW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: Almag-gm-2
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Along SE corner	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hyptis cap	60	H	Fac	Phrag Ka-Ka	70	H	Obl
Scleria poly	20	H	Fac				
Pan tec	15	T	Fac				
Hib til	15	S	Fac				
Thelypt mano	5	H	Fac				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Lygodium

HYDROLOGY

Is it the growing season? Yes ☐ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☑ No ☐
FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☑

Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Hummocks

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Alamag-gm-2	Date:

SOILS

Map Unit Name: (Series & Phase) Ylig Clay (Hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
6-10	B	5YR3/2	5YR 4/4	10-20% Moderate	clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Alamag-gm-3	Date: May 11, 10
Applicant/Owner:	State:
Investigator(s): GM, SW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: Alamag-gm-3
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Bamboo grove	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Oplismenus com	50	H	Fac				
Bambusa vul	50	S	Fac				
Mikania scan	15	V	Fac				
Scleria poly	10	H	Fac				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: –	**SECONDARY INDICATORS (2 or more required)**	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☑ No ☐
Depth to saturated soil: –		
	FAC Neutral: Yes ☐ No ☑	Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below:	Other:	
Stream, Lake or gage data: ☐		
Aerial photographs: ☐		

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Standing water pools in area
Hummocky

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Alamag-gm-3	Date:

SOILS

Map Unit Name: (Series & Phase) Ylig Clay (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes [ ] No [ ]

Profile Description
Soil Profile Evaluated Yes [x] No [ ] Method: Probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
2+	strong gley				

Hydric Soil Indicators: (check all that apply)

- [ ] Histosol
- [ ] Histic Epipedon
- [ ] Sulfidic Odor
- [ ] Aquic Moisture Regime
- [ ] Reducing Conditions
- [x] Gleyed or Low-Chroma Colors
- [ ] Concretions
- [ ] High Organic Content in the Surface Layer of Sandy Soils
- [ ] Organic Streaking in Sandy Soils
- [x] Listed on Local Hydric Soils List
- [ ] Listed on National Hydric Soils List
- [ ] Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes [x]	No [ ]	Unknown [ ]
Wetland hydrology present?	Yes [x]	No [ ]	Unknown [ ]
Possible Hydric soil?	Yes [x]	No [ ]	Unknown [ ]

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Barrigada-gm-1	Date: May 10, 10
Applicant/Owner:	State: /
Investigator(s): GM GW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID: 1
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: Barrigada-gm-1
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pennisetum pdy	50	H	FacU				
Bidens alb	10	H	Fac				
Panicum max	15	H	FacU				
Panicum mut	10	H	Fac				
Pennis pdy	10	H	FacU				

Percent of dominants OBL, FACW, & FAC: 40%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☐ No ☑

Rationale/remarks; other plant species noted (continue on back): other spp.

Leu leu		
Phaseolus		

HYDROLOGY

Is it the growing season? Yes ☐ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☑ — Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑ — Drainage Patterns: Yes ☐ No ☑
Depth of Inundation:	SECONDARY INDICATORS (2 or more required)
Depth to free water:	Oxidized Root Channels < 12 In.: Yes ☐ No ☑ — Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil:	
	FAC Neutral: Yes ☐ No ☐ — Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☐ No ☑

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Barrigada gm-1	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil probe

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
2-12	B	7.5YR4/4	—		loam

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☐	No ☑	Unknown ☐
Wetland hydrology present?	Yes ☐	No ☑	Unknown ☐
Possible Hydric soil?	Yes ☐	No ☑	Unknown ☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam wetland Barrigada-gm-2		Date: May 10, 10
Applicant/Owner:		State:
Investigator(s): GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Barrigada-gm-2
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: East side near golf course fairway		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum maxi	85	H	Fac				
Commelina diffusa	10	H	Facw				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back): other spp:

Heliotropium indicum		
Cyrtosperma (at forest perimeter)		
Phaseolus		
Hib til @ boundary		

HYDROLOGY

	PRIMARY INDICATORS	
Is it the growing season? Yes ☑ No ☐	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Based on:	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☐ No ☑
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil: –		
	FAC Neutral: Yes ☐ No ☑	Water-stained Leaves Yes ☑ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Barrigada-gm-2	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
6-12	B	10YR 3/2	10YR 4/4	25% strong	silt loam

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland Barrigada-gm-3		Date: May 10, 10
Applicant/Owner:		State:
Investigator(s): GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: Barrigada-gm-3
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: West of Southernmost part of golf course		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Bambusa vulg	75	S	Fac				
Saccharum	10	H	Fac				
Fire makes it hard to tell	<						

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back): Other spp.

Sorghum hal?		
Hib til		
Panicum max		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)	
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☑ No ☐
Depth to saturated soil: –		
	FAC Neutral: Yes ☐ No ☑	Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Not known why there would be so much water draining here.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Barrigada gm-3	Date:

SOILS

Map Unit Name: (Series & Phase) Chach Clay (hydric)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: Soil pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
4-12	B	10YR 3/2	7.5YR 4/4	10-15 moderate	A few concretions? 10"
				more at < 10"	clay loam

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☑ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Recent fire
Hummocks around plants
Some pig wallows

Area extends outside NWI
boundary on S + E sides
boundary there is tangan, ferns,
flagging

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland - NMSW-gm-5		Date: May 18, 10
Applicant/Owner:		State:
Investigator(s): GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID: NMSW-gm-5
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: Western drainage ~ 75' downslope from trail		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pan tec	30	S	Fac	Oplismenus	20	H	Fac
Hib til	30	S	Fac				
Areca cat	20	S	Fac				
Miscan flor	10	H	Fac				
Freycinetia	10	V	Fac				

Percent of dominants OBL, FACW, & FAC: 100

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back): Other spp.

Mikania	Pteris quad	
Neph hir		
Hyptis cap		
Flag ind		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: —

Depth to free water: —

Depth to saturated soil: —

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☑
- Sediment Deposits: Yes ☐ No ☑
- Drift Lines: Yes ☐ No ☑
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☑
- Local Soil Survey: Yes ☐ No ☑
- FAC Neutral: Yes ☐ No ☑
- Water-stained Leaves Yes ☐ No ☑

Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: Exposed roots

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: NMSW-gm-5	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: shovel

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
1-4	A	7.5YR 3/1	—		
4-12	B	7.5YR 4/4	7.5YR 3/1	40% indistinct	Silty loam

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☑ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

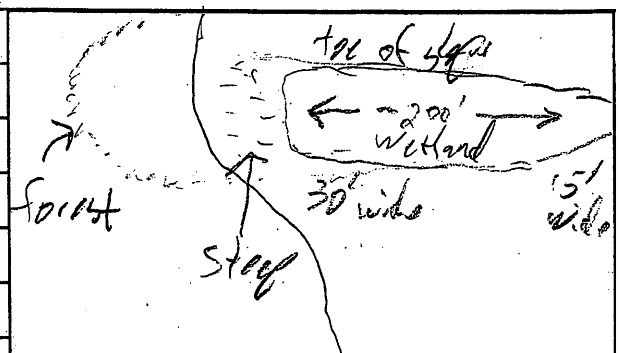
WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☑	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☑	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☑	No ☐	Unknown ☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Border of forested and savanna



DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Guam Wetland - FIN - gm - 1	Date: May 13, 10
Applicant/Owner:	State:
Investigator(s): GM	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID: fin-gm-1
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hib til	90	T/S	Fac				
Chromo odo	25	H	Fac				
Mikania	25	V	Fac				
Pteris Tri	5	H	FacU				

Percent of dominants OBL, FACW, & FAC: 75%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☑ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	PRIMARY INDICATORS Water Marks: Yes ☐ No ☑ — Sediment Deposits: Yes ☐ No ☑
Based on:	Drift Lines: Yes ☐ No ☑ — Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: –	SECONDARY INDICATORS (2 or more required)
Depth to free water: –	Oxidized Root Channels < 12 In.: Yes ☐ No ☑ — Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil: –	
	FAC Neutral: Yes ☐ No ☑ — Water-stained Leaves Yes ☐ No ☑
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: openings (small sinkholes) noted in the bedrock further downgradient from plot along drainage

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: fin-gm-1	Date:

SOILS

Map Unit Name: (Series & Phase) Not mapped Hydric	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: Shovel

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
2-12	A-B	2.5YR3/6	—		loam

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Soils in most areas thin 4-6" until mostly rock

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☑	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☑	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☐	No ☑	Unknown ☐

Rationale/Remarks: Water not present long enough to develop hydric soils

Sketch and Notes: Include rare species observations and level of site disturbance

Storm swale - wide 25-50'
Numerous small sinkholes along
swale and short channels (5-15')
typically leading into a sinkhole
Sinkholes often with Pteris tri fern
on edges or in
Swales often with Panic max
Some areas w/ Cocos nuc.

Team B Forms

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DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-4(a) Matgue River	Date: May 4, 2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Left bank facing downstream; Upstream of Marine Corp Drive (MCD)	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *	90	T	FAC	Areca catechu		T	FAC
Cocos nucifera		T	FACU	~~Centosteca lappacea~~ outside		H	FAC
Pandanus tectorius		T	FAC	Flagellaria indica		V	FAC
~~Colubrina asiatica outside~~		~~S/H~~	~~FAC~~				
Barringtonia asiatica		T	FACU				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☑
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☑
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Growth form of Hibiscus tiliaceus typical of wetland situations.

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

- Water Marks: Yes ☑ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☑
- Local Soil Survey: Yes ☐ No ☑
- FAC Neutral: Yes ☐ No ☑
- Water-stained Leaves: Yes ☐ No ☑

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other: Cracked, blocky ground in higher portions of floodplain wetland.

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

Within floodplain of Matgue River.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-4@ Matgue River	Date: Tues. May 4, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soil	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
10		dark low chroma matrix			blocky clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
Numerous crab holes, some with saturated gley-like soils
Dry Soil is silty, ~~and~~ alluvial with bits of limestone — dark low chroma soils observed but not completely described.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Positive indicators of vegetation, hydrology and soils are present on small patches of high floodplain along the right and left bank of the Matgue River.

Sketch and Notes: Include rare species observations and level of site disturbance

Large boulders demarcate edge of floodplain; Wetland ~~also~~ bench along bank on right and left side of river. Small floodplain wetlands. used as dump site for residential garbage.

Pics CC 1193 - 1230 downstream MCD
CC 1087-1171 upstream MCD

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra - CC - 46 Matgue River	Date: May 4, 2010 Tues.
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Narrow riverside wetland upstream of Road S-4 along the Matgue River	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Cyperus alternifolius *							

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

- Water Marks: Yes ☑ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☐
- Local Soil Survey: Yes ☐ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐
- Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:
Crab holes

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA-CC-4b	**Date:** May 4, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric soil	**Drainage Class:**
Taxonomy (subgroup):	**Field observations confirm mapped type?** Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☒ Method: shallow exploratory pit only

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

soil is dark almost black, clay

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: This thin sliver of wetland is above the OHWM of Matgue River and meets all 3 wetland criteria.

Sketch and Notes: Include rare species observations and level of site disturbance

Cyperus is only plant rooted on narrow bench adjacent Matgue River upstream of S-4 bridge. Hydrology is capillary action from stream. Very thin strip of "wetland" perhaps best treated as part of drainage apra-cc-3b.

cc 1136-1171

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-5 Near FishEye Observatory						Date: May 4, 2010 Tues.
Applicant/Owner:						State:
Investigator(s): RD, CC						S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐		Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☑		Plot ID:
Is the area a potential Problem Area?	Yes	☐	No	☑		
Location Description: Next to FishEye Parking Lot (Inland of Rt. 1)						

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka *	90+	H	OBL	Leucaina			
Mikania Scandens		V	FAC				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☑	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☒ No ☐ — Sediment Deposits: Yes ☐ No ☒
	Drift Lines: Yes ☐ No ☒ — Drainage Patterns: Yes ☐ No ☒
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)
Depth to free water: none	Oxidized Root Channels < 12 in.: Yes ☐ No ☒ — Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none?	
	FAC Neutral: Yes ☐ No ☒ — Water-stained Leaves Yes ☐ No ☒
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: Area confined by a berm along parking lot and by Rt. 1. Watemarks on lower stems of Phragmites

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra - cc - 5	Date: May 4, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clays + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☒ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: assumed hydric due to distinct boundry and dominance of obligate wetland species.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Strong wetland indicators present.

Sketch and Notes: Include rare species observations and level of site disturbance

Wetland bounded by MCD, and ditches associated w/ and active business on the east bound and abandoned residential on the west bound.

cc 1231 - 1252

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra cc-X-6b	Date: 4 May 2010 Tue
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☐ No ☑ Is the site significantly disturbed (atypical situation)? Yes ☑ No ☒ Is the area a potential Problem Area? Yes ☐ No ☑	Transect ID: Plot ID:
Location Description: Near taro patch; West end of Apra-cc-6.	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *		T	FAC				
Hymenocallis littoralis *		H	FAC				
Polypodium scolopendria *		H	FAC				
Cocos nucifera *		T	FACU				
Syngonium angustatum *		H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil:

PRIMARY INDICATORS

- Water Marks: Yes ☒ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 in.: Yes ☐ No ☐
- Local Soil Survey: Yes ☒ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves: Yes ☐ No ☐

Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: crab holes reveal relatively shallow water table even in the dry season.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-6b	Date: May 4, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay & clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☒ Method: crab holes show saturation, dark sandy soils

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
Wetland soils occur throughout area interrupted by concrete slabs, fencing, foundations etc...
Area is a mosaic of wetland/fastland with several exotic or cultivated spp. e.g. breadfruit, mango, Monstera, Syngonium, Cyrtosperma, etc...

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: Each of the 3 indicators are slightly inconsistent due to all the site disturbance. Subtle depressional topography was the key to defining wetland boundary.

Sketch and Notes: Include rare species observations and level of site disturbance

See disturbance remarks above.
Pago is most abundant native wetland species.
Claudine previously delineated eastern portion of wetland cc-6 (see Apra-cc-6a) and has data, if needed.

* Rich will use map to get location on private property. (driveway is landmark)

CC 1253-1272

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: ~~Orb~~ Apra CC-7	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD; CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: ~~along Rt.~~ Inland of Rt. 1 across Veterans Cemetery	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Wedelia trilobata *	70	H	FAC				
Panicum muticum *	25	H	FAC				
Spathodea campanulata		T	FACU				
Antigonon leptopus		V	FAC				
Nephrolepis hirsutula	5	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

~~Antigonon leptopus~~		
Delonix regia		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	PRIMARY INDICATORS
Based on:	Water Marks: Yes ☐ No ☐ / Sediment Deposits: Yes ☐ No ☐
	Drift Lines: Yes ☐ No ☐ / Drainage Patterns: Yes ☑ No ☐
Depth of Inundation:	SECONDARY INDICATORS (2 or more required)
Depth to free water:	Oxidized Root Channels < 12 In.: Yes ☐ No ☐ / Local Soil Survey: Yes ☐ No ☐
Depth to saturated soil:	
	FAC Neutral: Yes ☐ No ☐ / Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

Drainage patterns / hummucks

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-7	Date: 5 May 2010

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☑ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

	Yes		No		Unknown	
Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Herbaceous stand adjacent to forested wetland of Spathodea. Area was previously delineated and verified. Acquire boundarys from Duenas.

No pictures taken.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-8 a	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☐ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☐	
Location Description: Constructed wetland south of Rt. 18	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *	50	T					
Nephrolepis biserrata	25	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☐
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back):

Triphasia trifolia		
Pithecellobium dulce		
Polypodium scolopendria		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐
Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☐	Local Soil Survey: Yes ☐ No ☐
FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☑ No ☐

Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:

Depression impounded by berms and Rt. 1

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA – CC – 8a	Date: May 5, 2010

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☒ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: previously delineated boundary here

Sketch and Notes: Include rare species observations and level of site disturbance

Area is a forested pago-dominated wetland. Constructed wetland not investigated (lies further ~~inland~~ seaward). Wetland CC-8 is bounded by MCD, a pipeline row + old concrete slabs + disturbed ground to north (just south of Rd #18. Acquire boundaries from Duenas

See photos 1318-25 on CC camera

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-8c	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☐ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☐	
Location Description: Within Δ parcel, southern corner near Navy installation/pipeline along Rt. 1	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka	100	H	OBL				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back):

Spathodea campanulata		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐
Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☐	Local Soil Survey: Yes ☐ No ☐
FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☐

Check all that Apply & explain below:
Stream, Lake or gage data: ☐
Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:
Area lies in a depression impounded by pipeline berm and Rt. 1

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA-CC-8 c	Date: 5/5/2010 Wed

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☒ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Area abuts Bambusa vulgaris grove and Hibiscus tiliaceus Stand.

photos 1326 ~ 1328

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-9 A	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☐ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☐	
Location Description: South of road to Sasa Fuel Burning Pond, west of Rt. 1, at outer limit of 200 ft. Priority Area	

VEGETATION

Non-dom. spp.

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum muticum * Flower		H	FAC	Momordica Charantia Fruit		Vine	FAC
Ipomoea indica * Flower		V	FAC	Bidens alba Flower/Fruit		H	FAC
				Pennisetum purpureum		H	FAC

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐ — Sediment Deposits: Yes ☐ No ☐
Drift Lines: Yes ☐ No ☐ — Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☐ — Local Soil Survey: Yes ☐ No ☐
FAC Neutral: Yes ☐ No ☐ — Water-stained Leaves Yes ☐ No ☐

Check all that Apply & explain below:
Stream, Lake or gage data: ☐
Aerial photographs: ☐

Other: Thick matted grass (P. muticum) traps moisture, maintains saturated conditions in similar wetlands.

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:
Terrain is ~~no~~ fairly flat, level with adjacent coral paved road.

878-8497
Rex Hovey, AECOM

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-9A	Date: 5/5/2010 Wed

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
~6		dark ~/2	none	n/a	dry hard clay
6+		light ~/3 or/2		faint, few	"

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
possible hydric soil

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

possible disturbance from hazwaste clean-up
for Sasa Fuel Burning Pond
Area is adjacent to Leucaena/Panicum maximum
stand.

Photos cc 1329 ~1336
cc 1382-1387 of north end non-forested portion of wetland cc-9.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-9~~B~~~~Ø~~ e	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Inland of Rt. 1 South of Sasa Fuel Burning Pond	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Thelypteris interrupta * no sori	40	H	FACW				
Paspalum conjugatum * Flower	45	H	FAC				
~~#~~ Mikania scandens	5	V	FAC				
Spathodea campanulata Flower		T	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☐
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Morinda citrifolia Flower	Alocasia macrrhiza (1)	
Pithecellobium dulce	Axonopus compressus	
~~[illegible]~~ Mimosa pudica Fruit/Flower		
Nephrolepis biserrata no sori		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☐ / Sediment Deposits: Yes ☐ No ☐
	Drift Lines: Yes ☐ No ☐ / Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: none	**SECONDARY INDICATORS (2 or more required)**
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☐ No ☐ / Local Soil Survey: Yes ☐ No ☐
Depth to saturated soil: none	
	FAC Neutral: Yes ☐ No ☐ / Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:

Distinct drainage patterns and hummocks. At south-end wetland a 4 pipelines obstruct Sasa River channel immediately downstream of MCD bridge causing high flows to overbank into wetland CC-9.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: ~~APRA-CC-12~~ South of Sasa Bridge APRA-CC-9e	Date: May 5, 2010

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
Various shallow excavations revealed redox concentrations in a dark matrix close to surface in some locations and absent in others.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

North-South running pipeline row borders east side. To south Bambusa is invasive. The north boundary is a dirt road, a portion of which is in the wetland. The south boundary abuts a portion of the Sasa River bank or ends messily w/ in tailings and debris piles associated w/ the pipeline and/or MCD.

CC 1337 - 1343 CC-9e
CC 1344 - 1346 CC-10a SasaR
~~See #1341~1346 photos on GC camera~~

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-11a		Date: May 5, 2010
Applicant/Owner:		State:
Investigator(s): RD CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes [x] No [ ]	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes [ ] No [x]	Plot ID:
Is the area a potential Problem Area?	Yes [ ] No [x]	
Location Description: Inland of pipeline road to IRP site cleanup Sasa Fuel Burning Pond		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus		T	FAC				
Spathodea campanulata		T	FAC				
Nephrolepis biserrata		H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities [ ]
- Physiological or reproductive adaptations [ ]
- Technical Literature [ ]
- Wetland plant list (nat'l or regional) [ ]
- Morphological adaptations [ ]
- Wetland Plant Data Base [ ]
- Other: [ ]

Hydrophytic Vegetation Present? Yes [x] **No** [ ]

Rationale/remarks; other plant species noted (continue on back):

Thelypteris opulenta		

HYDROLOGY

Is it the growing season? Yes [x] No [ ]	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes [ ] No [ ] / Sediment Deposits: Yes [ ] No [ ]
	Drift Lines: Yes [ ] No [ ] / Drainage Patterns: Yes [ ] No [ ]
Depth of Inundation:	SECONDARY INDICATORS (2 or more required)
Depth to free water:	Oxidized Root Channels < 12 In.: within 5" Yes [x] No [ ] / Local Soil Survey: Yes [ ] No [ ]
Depth to saturated soil:	
	FAC Neutral: Yes [ ] No [ ] / Water-stained Leaves Yes [x] No [ ]
Check all that Apply & explain below: Stream, Lake or gage data: [ ] Aerial photographs: [ ]	Other:
Wetland hydrology Present?	Yes [x] No [ ]

Rationale/remarks:
Crab holes, some with gleyed soils.
Depression impounded by soil berm. Culvert through berm provides portion of hydrology.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA-CC-11a	Date: May 5, 2010

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
5		/2			Clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: strong redox near surface

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☑	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☑	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☑	No ☐	Unknown ☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Nearby Triphasia trifolia in fruit
Area appears to be part of previous delineation.
Old orange wetland flagging ~~observed~~ observed.
Natural topography defines the north boundary while an old berm and existing dirt road define the east + south boundary, respectively

CC 1391 - 1402

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-12 a	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka		H	OBL				
Spathodea campanulata		T	FAC				
Mikania scandens		V	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☐
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ **No** ☐

Rationale/remarks; other plant species noted (continue on back):

Leucaena leucocephala		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☐
- Local Soil Survey: Yes ☐ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:

Low linear Phragmites patch along Rt 1. Previously delineated.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-12A	Date: May 5, 2010

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
5		10YR 3/2	5YR 4/6		

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Long narrow strip along east edge of pipeline row + toe of MCD berm collects water to support phragmites and varying amount of Leucana. At wetland cc-12a Spathodea replaces Leucana as a dominant species

cc1403-1405

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-12B	Date: May 5, 2010
Applicant/Owner:	State:
Investigator(s):	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus		T	FAC	Spathodea Campanulata		T	FAC
Centosteca lappacea Flwr		H	FAC				
Pandanus tectorius		T	FAC				
Nephrolepis biserrata		H	FAC				
Morinda citrifolia		T	FACU				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☐ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☐ **No** ☐

Rationale/remarks; other plant species noted (continue on back):

~~Morinda citrifolia~~	~~Operculina~~ Phragmites karka	
Thelypteris parasitica	Polypodium punctatum	
Thelypteris opulenta		
~~Asplenium nidus~~		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐
Sediment Deposits: Yes ☐ No ☐
Drift Lines: Yes ☐ No ☐
Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☐
Local Soil Survey: Yes ☐ No ☐
FAC Neutral: Yes ☐ No ☐
Water-stained Leaves Yes ☐ No ☐

Other:

Check all that Apply & explain below:

Stream, Lake or gage data: ☐

Aerial photographs: ☐

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: CC-12B	Date: 5/5/10

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
5"		7.5YR 3/2	5YR 4/6		

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: abundant redox concentration near surface

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks:

Sketch and Notes: Include rare species observations and level of site disturbance

Previously delineated wetland. bounded to east by linear pipeline row that runs parallel to MCD.

CC 1407-1412

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-13 ~~B~~ A (	Date: May 5, 2010 Wed
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Rhizophora var. stylosa *		T	OBL				
Avecennia alba *		T	OBL				

Percent of dominants OBL, FACW, & FAC: 100%

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☐
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ **No** ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: not checked

Depth to saturated soil: surface

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

- Water Marks: Yes ☑ No ☐
- Sediment Deposits: Yes ☑ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☐ No ☐
- Local Soil Survey: Yes ☐ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐
- Other:

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

Tidal hydrology, crab holes

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-13~~8~~ a	Date: May 5, 2010

SOILS

Map Unit Name: (Series & Phase)	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☒ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☑ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☑ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: muddy ground present in dry season due primarily to tidal influence

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: Previous Navy wetland boundary was confirmed although small section of mangrove mudflat and Nypa fruticans fringe were added

Sketch and Notes: Include rare species observations and level of site disturbance

MCD bissects mangrove swamp with rip rap reinforced roadbed. Laguas River (CC-54) bissects mangrove west of MCD. although no real OHWM likely ever existed in the broad flat swamp → the Laguas River "channel" downstream of MCD bridge was likely excavated in past.

CC 1424-1447

/2010

DATA FORM
Wetland Assessment
(Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-14E	Date: May 7, 2010
Applicant/Owner:	State: ~~F~~ Friday
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: Aguada River downstream N of Rt. 1	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Barringtonia racemosa	10	T	FACW				
Hibiscus tiliaceus *	25	T	FAC				
~~Areca catechu~~	~~[illegible]~~	~~T~~	—				
Barr. racemosa *	5	H	FACW				
Areca catechu *	5	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☑ No ☐
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 in.: Yes ☐ No ☐
- Local Soil Survey: Yes ☒ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐

Other:

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:
several broad low drainage channels are overflow channels for the Aguada River

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-14 E	Date: May 7, 2010 FRI

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
<10		7.5YR 2.5/1	~~do~~ 10YR4/3	~~5%~~ 5%	~~clay~~ alluvial clay, dry, hard
			2.5YR 4/8	~~[illegible]~~ 10%	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks:
Area is broad drainage channel incised w/ several smaller channels.

Sketch and Notes: Include rare species observations and level of site disturbance

Road related development dictates south + east (MCD) bounds. North bound determines by small ranch and cultivated ground.

photos 1596-1599

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-15a		Date: May 7, 2010
Applicant/Owner:		State:
Investigator(s): RD, CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☐	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☐	
Location Description: west of MCD		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceous *	25	T	FAC				
Polypodium scolopendria *	5	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted:

Thelypteris opulenta		
Spathodea campanulata		
Polypodium punctatum		
Adiantum tenerum		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐	PRIMARY INDICATORS	
Based on:	Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐
	Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☒ No ☐
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☒ No ☐	Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below:	Other:	
Stream, Lake or gage data: ☐		
Aerial photographs: ☐		

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: few crab holes among broad network of drainage channels; ORCs are few but then so are roots in this sample.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-CC-15a	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ (→ weakly) No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-5		10YR 3/2	10YR 3/1	5	
5+		10YR 3.5/2		2	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: The 5% 3/1 in 0 to 5" depth is likely darkworm castings. Redox is very sparse in this transitional wetland sample → redox fades upon wetting, but is still bright compared to matrix. Marginal hydric soils possibly due to past ground disturbance. (see Notes below)

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☒	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☒	No ☐	Unknown ☐
Possible Hydric soil?	Yes ? ☒	No ☐	Unknown ☐

Rationale/Remarks: This low area is mapped as an extension of previous wetland mapping based mostly on topography and strong hydrologic + vegetation indicators.

Notes (e.g. species and habitats):

An old road bed spur extends into wetland from pipeline route along MCD. Various mounds and berms of old spoils also scattered w/in wetland among drainage channels. Large + small chunks of concrete present.

CC 1658 - 1665

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-15b	Date: May 7, 2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐ Is the site significantly disturbed (atypical situation)? Yes ☐ No ☐ Is the area a potential Problem Area? Yes ☐ No ☐	Transect ID: Plot ID:
Location Description: West of MCD	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceous *	30	T	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted:

Polypodium scolopendria		
Spathodea campanulata		
Morinda seedlings few		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐ Based on:	**PRIMARY INDICATORS** Water Marks: ? Yes ☒ No ☐ Drift Lines: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐ Drainage Patterns: Yes ☐ No ☐
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: none Depth to saturated soil: none	Oxidized Root Channels < 12 In.: Yes ☒ No ☐	Local Soil Survey: Yes ☒ No ☐
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: crab holes, subtle depression, few ORCs ; some older trees appear to have water marks

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-CC-15b	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-5		7.5YR 2.5/2			clay
5+		10YR 3/2	5YR 4/6	10%	clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surfece Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Sample was in previously mapped Navy wetland. The depression is subtle but positive indicators are present.

Notes (e.g. species and habitats):

No obvious disturbance although portion of wetland abuts MCD.

CC 1666-1673

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-17a		Date: May 7, 2010
Applicant/Owner:		State:
Investigator(s): RD, CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☒	
Location Description: Mangrove		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Rhizophora stylosa *	30	T	OBL				
Bruguiera gymnorhiza *	15	T	OBL				
Achrostichum aureum *	10	H	OBL				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted:

Pluchea indica		
Cocos nucifera		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐	**PRIMARY INDICATORS**	
	Water Marks: Yes ☒ No ☐	Sediment Deposits: Yes ☐ No ☐
Based on:	Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☐ No ☐
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☐ No ☐	Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:	

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: crab holes, cracked ground, water marks, some muddy ground

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra - cc - 17a	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☒ Method: shallow excavation

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: gley near surface

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Mangrove swamp previously mapped by Navy syncs with local topography

Notes (e.g. species and habitata):

Undisturbed mangrove. Many old "chlorox" bottles and various other garbage washed up to shoreline.

cc 1674, 1676, 1682, 1691-1699

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-18a	Date: May 7, 2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☐	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Rhizophora mucronata							
V. stylosa *	30	T	OBL				
Achrostichum aureum*	20	H	OBL				
Hibiscus tiliaceus *	15	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☒ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? **Yes** ☒ **No** ☐

Rationale/remarks; other plant species noted:

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: surface nearby

PRIMARY INDICATORS

Water Marks: Yes ☒ No ☐

Sediment Deposits: Yes ☐ No ☐

Drift Lines: Yes ☐ No ☐

Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☐

Local Soil Survey: Yes ☒ No ☐

FAC Neutral: Yes ☐ No ☐

Water-stained Leaves Yes ☐ No ☐

Check all that Apply & explain below:

Stream, Lake or gage data: ☐

Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: Crab holes, cracked ground, water marks

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-18a	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay and clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☒ Method: Shallow excavation

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: gleyed soils near surface

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☒	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☒	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☒	No ☐	Unknown ☐

Rationale/Remarks: Very dense vegetation on edge of Mangrove swamp

Notes (e.g. species and habitats):

No sign of disturbance.

rd 178-180

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra - CC - 18b	Date: May 7, 2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description:	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka *	90	H	OBL				
Hibiscus tiliaceus	10	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? **Yes** ☒ **No** ☐

Rationale/remarks; other plant species noted:

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐
Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☐	Local Soil Survey: Yes ☒ No ☐
FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☒ No ☐

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: obligate plants dominant - hydrology assumed

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-18b	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) Inargjan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☒ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☒ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Soils assumed given topography + obligate dominant vegetation

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: This portion of wetland CC-18 is dominated by obligate wetland plants

Notes (e.g. species and habitats):

No disturbance evident in dense veg.
– assumed disturbed in past given
close proximity to MCD.

rd 181 into dense phragmites from mangrove wetland (cc18a)

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-26a	Date: May 7, 2010
Applicant/Owner:	State: FRJ
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? possible Yes ☒ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: paso stand near Atantano River	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka *	30	H	OBL	Leucaena *	10%	T	FACU
Areca catechu *	5	T	FAC				
Hibiscus tiliaceus *	20	T	FAC				
Centosteca lappacea *	15	H	FAC				
Elephantopus mollis *	20	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Pand. tectorius
Thelypteris opulenta
Passiflora suberosa

HYDROLOGY

* closer to Rt. 1; Morinda, Phragmites, Leucaena, Brachiaria mutica
Photo 1744-1746

Is it the growing season? Yes ☒ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☐ — Sediment Deposits: Yes ☐ No ☐
	Drift Lines: Yes ☐ No ☐ — Drainage Patterns: Yes ☐ No ☐
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)
Depth to free water: none	Oxidized Root Channels < 12 in.: Yes ☒ No ☐ — Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none	FAC Neutral: Yes ☐ No ☐ — Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

crab holes, cracked surface soils

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra – CC – 26a	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-3		10YR 2/2			clay
3-6		10YR 3/2	10YR 3/3		clay
6-8		10YR 3/2	10YR 3/3	slightly higher depletion	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☒ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Evidence of ground disturbance i.e. fill spread on surface. Hydric soil indicators potentially not yet re-formed here due to past ground disturbance. Very few ORC – few roots also.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☐	Unknown	☒

Rationale/Remarks: Wetland bordered by MCD, shrine road, and high bank of Atantano River. Soils data inconclusive given evidence of past ground disturbance.

Sketch and Notes: Include rare species observations and level of site disturbance

Adjoint to asphalt rubble piles, may be disturbed. Isolated patch of pago wetland. Hydrology is assumed to be shallow groundwater. Ground is flat w/ lots of broken surface rock – soil data is inconclusive given apparent disturbance. Mapped wetland given topographic position, hydrophytic vegetation and hydrologic indicators.

photos 1738-1743

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-3Q 28c	Date: May 7, 2010
Applicant/Owner:	State: Friday
Investigator(s): RD CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: large privately owned wetland east of MCD	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *	30%	T	FAC	Mikania scandens	25	V	FAC
Phragmites Karka	5%	H	OBL				
Pandanus tectorius *	15%	T	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Polyp scolop.		
Polyp. punctatum		
Pass. suberosa		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☑ No ☐
- Local Soil Survey: Yes ☒ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐
- Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-~~3a~~ 28c	Date: May 7, 2010

SOILS

Map Unit Name: (Series & Phase) (close to boundary) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-4.5		10YR 2/1			clay
4.5+		10YR 3/1	2.5Y 5/4	15%	clay (depleted clay)
			5YR 4/6	5-10%	oxidized redox root channels

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☒ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
salt precipitate observed @ surface

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: paso w/ phragmites,

Sketch and Notes: Include rare species observations and level of site disturbance

Some spoils closer to MCD but otherwise no disturbance.

photos #1767 - 1772

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA South of Taco Bell	Date: Wed 5/12/10
Applicant/Owner: APRA-CC-30	State:
Investigator(s): RD, CL	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: @ Intersection Rt. 1 / Rt. 2A next to Taco Bell parking lot.	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phrag. karka	95	H	OBL				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Leucaena leucocephala Frt.	→ Edge sp. mostly against retaining wall	
Panicum max.	→ Edge sp.	
~~Passiflora suberosa~~ Trifoliate	vine	

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

- Water Marks: Yes ☒ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 in.: Yes ☐ No ☐
- Local Soil Survey: Yes ☐ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves: Yes ☐ No ☐

Other: Impounded by retaining Wall along Taco Bell parking lot and by Rt. 1

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: Could see a few water marked loower stems of phragmites.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA South of Taco Bell inland of Rt. 1	Date: Wed 5/12/2010

SOILS

Apra-CC-30

Map Unit Name: (Series & Phase) Non-hydric soil	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☒ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: wetland contains OBL sp. – hydric soils assumed.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: phragmites wetland neatly surrounded by Leucana & road banks.

Sketch and Notes: Include rare species observations and level of site disturbance

Photos 2054-2058

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: APRA CC-28a Inland of + south of Rt. 1		Date: Wed 5/12/2010
Applicant/Owner: just past ⊥ Shrine Rd / Rt. 1		State:
Investigator(s): RD, CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☒? No ☐	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☒	
Location Description:		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka *	90%	H	OBL				
Nephrolepis hirsutula	<1	H	FAC				
Hibiscus tiliaceus	10%	S	FAC				
Flagellaria indica	<1	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

outlying areas on pushed piles of fill/rubble : Leucaena, Neph. hirsutula, Flagellaria

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 in.: Yes ☐ No ☑
- Local Soil Survey: Yes ☒ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves: Yes ☐ No ☐
- Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-CC-28a	Date: Wed 5/17/2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay & clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-8.5		10YR 2/1.5	–	–	Coarse roots (pago), large rocks
					dry friable, gravelley

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ? ← ☐ Reducing Conditions
- ? ← ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Disturbed soils from earthmoving activities (push piles nearby) No moisture, Chunks of limestone rock. No mottles and just missed low chroma

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☒	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☒	No ☐	Unknown ☐
Possible Hydric soil?	Yes ? ☒	No ☐	Unknown ☐

Rationale/Remarks: Presence and abundance of Phragmite was primary means of determining wetland boundary; past ground disturbance makes soils data inconclusive

Sketch and Notes: Include rare species observations and level of site disturbance

Many areas w/ in priority 1 area along MCD have spoils or "push piles" spread over wetland soils.

photos: CC 2104 - 2108

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra - cc - 34	Date: May 12, 2010
Applicant/Owner:	State:
Investigator(s): RD CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☐ No ☒	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: small floodplain wetland at Atantano River	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceous *		T	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☐
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted:

Clerodendrum inerme		
Rhaphidophora aureus		
Syngonium angustatum		
Pandanus tectorius		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation:

Depth to free water:

Depth to saturated soil:

PRIMARY INDICATORS

- Water Marks: Yes ☐ ? No ☐
- Sediment Deposits: Yes ☐ No ☐
- Drift Lines: Yes ☐ No ☐
- Drainage Patterns: Yes ☐ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☒ No ☐
- Local Soil Survey: Yes ☒ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: shallow ORCs

Table Core UI
Parent Window

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-CC-34	Date: May 12, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: ORCs observed in top few inches of soil

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☒	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☒	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☒	No ☐	Unknown ☐

Rationale/Remarks: Small floodplain pago wetland above Atantano River OHWM but well below nearby wetland surfaces (CC-22, CC-26)

Notes (e.g. species and habitats):

Some garbage and cut woody vegetation from utility line clearing.

CC 1734
CC 2081-2089

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-35a Aguada R. upstream	Date: Wed 5/12/10
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Aguada River ("floodplain") restricted flow at MCD backs up water	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pandanus tect. *	80*	T	FAC				
Hibiscus tiliaceus	15*	T	FAC				
Cocos nucifera	10	T	FACU				
Areca catechu	15*	T	FAC				
Oplismenus	5	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Bambusa vulgare		
Morinda citrifolia		
Barringtonia racemosa		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☐ — Sediment Deposits: Yes ☑ No ☐
	Drift Lines: Yes ☑ No ☐ — Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☒ No ☐ — Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none	FAC Neutral: Yes ☐ No ☐ — Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other: cracked ground, crab holes

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: Aguada River channel is a mess; debris is racked everywhere. The main channel becomes narrow (hour glass) before it reaches the MCD bridge.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-cc-35a upstream Aguada R. floodplain	Date: 5/12/10 Wed

SOILS

Map Unit Name: (Series & Phase) Inajaran clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-0.5"		~~10YR 3/3~~ 10YR 3/3	5YR 4/6	5-10%	alluvial layer on surface
.5 – 6"		7.5YR 2.5/2	5YR 4/6	15%	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: redox is shallow and plentiful here and at cc-35h sample point.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: This wetland has variable topography and various modifications. Hydrology + soils seem consistent even if topography + vegetation is variable.

Sketch and Notes: Include rare species observations and level of site disturbance

This area east of MCD floods routinely during rainy season. MCD runoff enters river here through a pago-lined ditch. MCD defines much of west bounds. The northern 1/3 of wetland has been converted to agriculture and trampled by carabao. The Northeast boundary is bordered by cleared, compacted ground and slabs of concrete.

~~Photo #s 2127-2133~~

cc 2140-2148

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra CC-35H			Date: Wed 5/12/2010
Applicant/Owner:			State:
Investigator(s): RD CC			S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☐	No ☒	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☒	No ☐	Plot ID:
Is the area a potential Problem Area?	Yes ☐	No ☒	
Location Description: Hummocky Panicum muticum adjacent +(N) of Aguada R. upstream along Rt. 1 (visited w/ Ryan Winn US Corps of Eng.)			

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum muticum *	80	H	FAC				
Mimosa pudica	15	H	FAC				
Mikania Scandens	5	V	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Saccharum spontaneum		
Leucaena leucocephala		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	PRIMARY INDICATORS	
Based on:	Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐
	Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☑ No ☐
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☐ No ☐
Depth to saturated soil: none		
	FAC Neutral: Yes ☐ No ☐	Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other: Prominent drainage patterns (hummocks)	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks: cracked ground between hummocks highly compacted by carabao.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Apra-CC-35h	Date: May 12, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clay + clay loam	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-6"		7.5YR 2.5/1	5YR 5/8	2-5%	hard clay
			2.5YR 3/6	5%-7%	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☒ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: photo 2170 redox

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: This portion of CC-35 is or has converted to agriculture and is used for carabao grazing. However, there are still positive indicators for all 3 criteria

Sketch and Notes: Include rare species observations and level of site disturbance

Carabao droppings ~~and~~ and browsing observed
soil may be compacted by carabao during
wet season. area has been cleared
and possibly used to cultivate food
in addition to being grazed by
carabao

photos 2157-2161

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: POLARIS CC-1A	Date: Thurs, 5/13/2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: pago stand surrounding a man-made drainage w/debris	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus	80	T	FAC	Pand. tectorius	<5	T	FAC
Cocos nucifera	10	T	FAC	Morinda citrifolia	<5		FACU

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Colubrina asiatica		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☒ No ☐
Drift Lines: Yes ☒ No ☐	Drainage Patterns: Yes ☒ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 in.: Yes ☐ No ☑	Local Soil Survey: Yes ☒ No ☐
FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒

Other:

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: likely freshwater and brackish ground water and occasional tidal surge provide wetland hydrology.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Polaris - cc - 1	**Date:** May 13, 2010

SOILS

Map Unit Name: (Series & Phase) Inarajan clays	**Drainage Class:**
Taxonomy (subgroup):	**Field observations confirm mapped type?** Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ **Method:** pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-8"		10YR 2/1	–	–	gravel bits, greasy high
					organic content, roots
					moist soils

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☒ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
greasy soils and numerous crab holes w/ gleyed soils

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: this low-lying pago strand along Polaris Point has all 3 positive wetland indicators

Sketch and Notes: Include rare species observations and level of site disturbance

A dug out linear drainage or channel
intersects the low-lying pago strand
above Polaris Point beach → the low-lying
channel extends wetland to NE

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena - CC - 1	Date: May 6, 2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: Imong River	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Saccharum spontaneum*	90	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☒ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? **Yes** ☒ **No** ☐

Rationale/remarks; other plant species noted:

Hibiscus tiliaceus	} edges closest to hillslope	
Pandanus dubius		
Mikania scandens		
Panicum muticum		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐	PRIMARY INDICATORS	
Based on:	Water Marks: Yes ☐ No ☒	Sediment Deposits: Yes ☒ No ☐
	Drift Lines: Yes ☐ No ☒	Drainage Patterns: Yes ☐ No ☒
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: 5"	Oxidized Root Channels < 12 In.: Yes ☐ No ☒	Local Soil Survey: Yes ☐ No ☒
Depth to saturated soil: 3"		
	FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other: high river flows deposit sediment in lower portions of wetland.	
Wetland hydrology Present?	Yes ☒ No ☐	

Rationale/remarks: Water near surface in low-lying portions of wetland – hydrology tied to level of Imong River.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena - cc - 1	Date: May 6, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☒ Method: shallow excavation

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☒ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Soils gleyed + smelly (H_2S) in low areas; soils red alluvium in higher portions of wetland. Unclear if red parent material is masking redox - none was observed.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☒	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☒	No ☐	Unknown ☐
Possible Hydric soil?	Yes ? ☒	No ☐	Unknown ☐

Rationale/Remarks: Neatly defined emergent wetland situated above OHWM of Imong River.

Notes (e.g. species and habitats):

No man-made disturbances here.

rd 8
CC 1482 } taken from slope to NE (at fena-cc-3)

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena CC-3a		Date: May 6, 2010 Thurs
Applicant/Owner:		State:
Investigator(s): RD CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: Ravine wash/drainage channel (Fena-cc-2). Sample CC-3 (cc-6, cc-7) within sloped "wetland" mapped by Navy.		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pandanus dubius *	25	T	FAC	Nephrolepis hirsutula	10	H	FAC
Areca catechu	5	T	FAC	Hibiscus tiliaceus *	20	T	FAC
Scleria polycarpa	10	H	FAC				
Pandanus dubius *	10	S	FAC				
Hyptis capitata *	25	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Ficus tinctoria Fruit		
Chromolaena odorata		
Morinda citrifolia		
Cycas micronesica		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☒? No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☐ No ☒
FAC Neutral: Yes ☐ No ☒	Water-stained Leaves: Yes ☐ No ☒

Check all that Apply & explain below:

- Streem, Lake or gage data: ☐
- Aerial photographs: ☐

Other:

Wetland hydrology Present? Yes ☒? No ☒

Rationale/remarks: "drainage pattern" is in 15 square foot area, fully vegetated; possibly old erosion from deer traffic → not a clear primary indicator. Would be helpful to observe hydrologic conditions during wet season.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena-cc-3	Date: May 6, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0 to ~~8~~-6"		10YR 3/2	7.5YR 5/8	~~<2%~~ << 2%	clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: "mottle" is actually ORC's which are far too few to qualify for reducing conditions - non-hydric.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☑	No ☐	Unknown ☐
Wetland hydrology present? marginal	Yes ☑	No ☐	Unknown ☐
Possible Hydric soil? marginal	Yes ☑	No ☐	Unknown ☐

Rationale/Remarks: See also cc-6 + cc-7. Concluded that Navy's mapped wetland is mostly non-wetland; Wetland hydrology and soils mostly not present or inconsistent.

Sketch and Notes: Include rare species observations and level of site disturbance

photos 1469-1488

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena CC-4 a					Date: May 6, 2010 Thurs.
Applicant/Owner:					State:
Investigator(s): RD, CC					S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☐	Plot ID:
Is the area a potential Problem Area?	Yes	☐	No	☐	
Location Description: Saccharum patch old river bed					

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Saccharum spontaneum*	100	H	FAC				
Mikania scandens	15	V	FAC				
Teramnus labialis	5	V	FAC				

Percent of dominants OBL, FACW, & FAC: 100

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	PRIMARY INDICATORS		
Based on:	Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☑ No ☐	
	Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☐ No ☐	
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)		
Depth to free water: none *	Oxidized Root Channels < 12 In.: Yes ☐ No ☒	Local Soil Survey: Yes ☐ No ☒	
Depth to saturated soil: none			
	FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒	
Check all that Apply & explain below:	Other: within flood plain of Imong River		
Stream, Lake or gage data: ☐			
Aerial photographs: ☐			

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

appears to be former course of river now filled in + vegetated, standing water at toe of hillslope on west boundary mostly drains to river.

Source is likely a buried sidechannel of Imong River!

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena - cc-4	Date: May 6, 2010

SOILS

Map Unit Name: (Series & Phase) Nonhydric soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☒ Other (explain in remarks)

Rationale/Remarks: Alluvial w/ river rocks see photo #495. 2007 aerial suggest aggradation is recent and resulted in stable surface above OHWM - it is assumed that conditions are appropriate for creating reducing conditions in future based on stability of wetland Fena-cc-1.

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil? assumed	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Re-vegetated since 2007. Presumed alluvial deposition has built up surface; hydric soils not yet formed in alluvium; seep areas along west bounds has dark wetland soils.

Sketch and Notes: Include rare species observations and level of site disturbance

Photos cc 1489-1495
rd 88

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena CC-6					Date: May 6, 2010
Applicant/Owner:					State:
Investigator(s): RD, CC					S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☑	Plot ID:
Is the area a potential Problem Area?	Yes	☐	No	☑	
Location Description: slope wetland previously mapped					

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *	30	T	FAC	~~Scleria polycarpa~~ Carex fuirenoides *	20	H	FACU
Hyptis capitata *	30	H	FAC	Mikania scandens	5	V	FAC
Nephrolepis hirsutula *	20	H	FAC				
Pandanus dubius *	10	T	FAC				
Imperata conferta	5	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Cananga odorata Flwr		
Cycas micronesica		
Calophyllum inophyllum		
Freycinetia		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐	**PRIMARY INDICATORS**				
Based on:	Water Marks: Yes ☐ No ☒		Sediment Deposits: Yes ☐ No ☒		
	Drift Lines: Yes ☐ No ☒		Drainage Patterns: Yes ☐ No ☒		
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)				
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☐ No ☒		Local Soil Survey: Yes ☐ No ☒		
Depth to saturated soil: none					
	FAC Neutral: Yes ☐ No ☒		Water-stained Leaves Yes ☐ No ☒		
Check all that Apply & explain below:	Other:				
Stream, Lake or gage data: ☐					
Aerial photographs: ☐					

Wetland hydrology Present? Yes ☐ No ☒ slope, no obvious features

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena - cc - 6	Date: May 6, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
6"		7.5YR2.5/2	none	—	moist clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: no hydric soil characteristics

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☒	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☒	Unknown	☐

Rationale/Remarks: non-wetland; see cc-7 and cc-3 for additional data on sloped "wetland."

Sketch and Notes: Include rare species observations and level of site disturbance

photos CC 1505 – 1510

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fena CC-7	Date: May 6, 2010
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: overlooking river mouth dry river bed	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Scleria polycarpa fruits	15	H	FAC	~~Sp~~			
Neph. hirsutula *	30	H	FAC				
Hyptis capitata fruits	15	H	FAC				
Imperata conferta tall w/ flwrs.	20	H	FAC				
Hibiscus tiliaceus	5	T	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Cananga odorata		
Cycas micronesica		
Fragraea ramachii		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☒	Sediment Deposits: Yes ☐ No ☒
Drift Lines: Yes ☐ No ☒	Drainage Patterns: Yes ☐ No ☒

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 in.: Yes ☐ No ☒	Local Soil Survey: Yes ☐ No ☒
FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other: cracked soils @ elevation above data pt.

Wetland hydrology Present? Yes ☐ No ☒ questionable

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Fora CC-7	Date: 5/6/10

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☑ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-4		7.5YR 3/2	none	"	platy clay, dry
4+		2.5YR 3/4	"	"	silty clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: no hydric soil characteristics

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☒	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☒	Unknown	☐

Rationale/Remarks: non-wetland; see CC-3 + CC-6 for additional data on this sloped "wetland"

Sketch and Notes: Include rare species observations and level of site disturbance

CC 1516-1518

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: (West NMS) ALA CC-1a	Date: 5/11/10 Tues
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Western Finger of Navy Wetland along drainage channel (team splits up here into 2 smaller teams)	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Phragmites karka *	30	H	OBL	Mikania scandens	10	V	FAC
Hibiscus tiliaceus *	15	T	FAC	Oplismenus compositus	5	H	FAC
Hyptis capitata	10%	H	FAC	Thelypteris maemonensis	<5	H	FAC
Impatiens large	<5	H	FAC	Selenia polycarpa	<5	H	FAC
conferta				Areca catechu	15	T	FAC

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

Ceratopteris thalictroides (few)		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☑
	Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑
	Drainage Patterns: Yes ☑ No ☐
Depth of inundation: none	**SECONDARY INDICATORS (2 or more required)**
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☑ No ☐
Depth to saturated soil: Surface	Local Soil Survey: Yes ☒ No ☐
	FAC Neutral: Yes ☒ No ☐
	Water-stained Leaves Yes ☒ No ☐
Check all that Apply & explain below:	Other: stream channel runs nearby
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

Nearby areas along channel show inundation.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: ALA CC-1a	Date: 5/18/10 Tues.

SOILS

Map Unit Name: (Series & Phase) Ylig clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-4		4/5GY	7.5YR 5/8	large 20%	clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☒ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
see photo 1934

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: strong wetland indicators in this ravine wetland extension of the Alamagosa Basin.

Sketch and Notes: Include rare species observations and level of site disturbance

Coelogyne guamensis – 3 specimens observed along trail from CC-1 to CC-1C

photos 1934 – 1942

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: (west NMS) ALAMAGOSA ALA CC-#1C						Date: Tues 5/10/10
Applicant/Owner:						State:
Investigator(s): RD CC						S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐		Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☑		Plot ID:
Is the area a potential Problem Area?	Yes	☐	No	☑		
Location Description: Open field near topo break						

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Fimbristylis littralis *	20	H	OBL				
Hyptis capitata *	20	H	FAC				
Imperata tall *	20	H	FAC				
Thelypteris parasitica	5	H	FAC				
Stictocardia filiaefolia	10	V	FACU				
Percent of dominants OBL, FACW, & FAC:							

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

nearby Medinilla on old Cycas stumps w/ several fruits

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☒ — Sediment Deposits: Yes ☐ No ☒
	Drift Lines: Yes ☐ No ☒ — Drainage Patterns: Yes ☑ No ☒
Depth of Inundation: none	**SECONDARY INDICATORS (2 or more required)**
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☒ No ☐ — Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none	
	FAC Neutral: Yes ☒ No ☐ — Water-stained Leaves Yes ☐ No ☐
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Ala-cc-1c	Date: May 11, 2010

SOILS

Map Unit Name: (Series & Phase) Ylig clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-4		10YR 3/2	5YR 5/8	med 20%	clay
4+		10YR 5/6	-0-	-0-	clay red like on trail

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: good hydric characteristics in 0-4 inches; red soils below may be masking additional redox.

See photo # 1949 ~1951, 1956

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: gentle slope above main wetland depression has solid wetland indicators

Sketch and Notes: Include rare species observations and level of site disturbance

Boundary established by Navy may be a little generous and include 10-20 ft beyond topo break.

photos 1946-1956

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form -- Not for Jurisdictional Delineation) 04/2010

Project/Site: ALA CC-16		Date: Tues 5/10/2010
Applicant/Owner:		State:
Investigator(s): RD, CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description:		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Fimb littoralis	5	H	OBL	Stictocardia tiliaecus	5	V	FAC
Hyptis capitata *	95	H	FAC	Saccharum spontaneum *	30	H	FAC
Mikania scandens	5	V	FAC	Scleria polycarpa	5	H	FAC
Imperata tall *	15	H	FAC				
Phragmites karka	5	H	OBL				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Chromolaena odorata		
[illegible]		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**	
Based on:	Water Marks: Yes ☐ No ☒	Sediment Deposits: Yes ☐ No ☒
	Drift Lines: Yes ☐ No ☒	Drainage Patterns: Yes ☐ No ☒
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☑ No ☐	Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none		
	FAC Neutral: Yes ☒ No ☐	Water-stained Leaves Yes ☐ No ☒
Check all that Apply & explain below:	Other:	
Stream, Lake or gage data: ☐		
Aerial photographs: ☐		

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Ala-cc-19	Date: May 11, 2010

SOILS

Map Unit Name: (Series & Phase) Ylig clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-3"		10YR 3/2	10YR 5/8	10-15%	soft moist clay
3+		10YR 4/4	—	—	silty clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

photo #1972

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☒	No ☐	Unknown ☐
Wetland hydrology present?	Yes ☒	No ☐	Unknown ☐
Possible Hydric soil?	Yes ☒	No ☐	Unknown ☐

Rationale/Remarks: solid wetland indicators

Sketch and Notes: Include rare species observations and level of site disturbance

photos 1972 – 1977

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: ALA cc-1K		Date: Tues 5/10/10
Applicant/Owner:		State:
Investigator(s): RD, CC		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description:		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *	20	T	FAC	Oplismenus *	10	H	FAC
Areca catechu *	20	T	FAC	Mikania scandia	5	V	FAC
Pandanus tectorius	10	T	FAC	Stictocardia tiliacens	5	V	FACU
Microlepia speluncae *	10	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities ☐ Wetland plant list (nat'l or regional) ☒ Other: ☐
Physiological or reproductive adaptations ☐ Morphological adaptations ☐
Technical Literature ☐ Wetland Plant Data Base ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Axonopus compressus		
Cyrtococcum patens		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☐ — Sediment Deposits: Yes ☐ No ☐
	Drift Lines: Yes ☐ No ☐ — Drainage Patterns: Yes ☐ No ☐
Depth of Inundation: none	**SECONDARY INDICATORS (2 or more required)**
Depth to free water: none	Oxidized Root Channels < 12 In.: Few Yes ☑ No ☐ — Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none	
	FAC Neutral: Yes ☐ No ☒ — Water-stained Leaves: Yes ☐ No ☒
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: nearby pig wallow indicates saturated ground + inundation earlier in season → cracked soil in wallow

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Ala-cc-1k	Date: May 11, 2010

SOILS

Map Unit Name: (Series & Phase) Ylig clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐ ?

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-10		10YR 3.5/2	10YR 5/4	faint <5%	moist clay
			10YR 5/6	<5%	"

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: photo #1985

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐	
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐	
Possible Hydric soil?	Yes	☐	No	☑	Unknown	☐	no redox observed

Rationale/Remarks: Soils are weak here but subtle depressional topography along w/ positive indicators for hydrology + vegetation suggest this is at least a good transitional wetland → Leave Navy wetland as depicted.

Sketch and Notes: Include rare species observations and level of site disturbance

Pig wallow activities in this area
Antler scratches and browsing on
Pandanus tectorius (Photo 1990)

Photos 1985-1990

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: ALA CC-1P (West NMS)	Date: Tues 5/10/10
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: bottom of Alamagosa basin	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Hibiscus tiliaceus *	20	T	FAC	Thelypteris maemonensis	5	H	FAC
Acrostichum aureum *	15	H	OBL	Lygodium microphyllum	5	V	FAC
Phragmites karka *	20	H	OBL				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☑ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: 6"

Depth to saturated soil: surface

PRIMARY INDICATORS

- Water Marks: Yes ☒ No ☐
- Sediment Deposits: Yes ☐ No ☒
- Drift Lines: Yes ☐ No ☒
- Drainage Patterns: Yes ☒ No ☐

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes ☑ No ☐
- Local Soil Survey: Yes ☐ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves: Yes ☐ No ☐

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other: Hummocks photos 2004 - 2009
Inundation not @ pit site

Wetland hydrology Present? Yes ☐ No ☐

Rationale/remarks:
Area lies @ edge of topo break (toe of eastern ~~steep~~ slope) that drains into area.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Ala-cc-1p	Date: Tues 5/18/10

SOILS

Map Unit Name: (Series & Phase) Yliq clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-10		10YR3/2	–	–	sulfuric odor, roots/ ~~sapric~~ materials
					greasy

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☒ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

see photos 1997-1998
2002-2003

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: strong wetland indicators in Alamosa basin

Sketch and Notes: Include rare species observations and level of site disturbance

photos 1997-2009

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BARB CC-1a	Date: May 10, 2010
Applicant/Owner:	State: Monday
Investigator(s): RD CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes [ ] No [x]	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes [x] No [ ]	Plot ID:
Is the area a potential Problem Area? Yes [ ] No [ ]	
Location Description: Depression near tower	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Heliotropium indicum Flwr *	25	H	FACW	Ipomoea triloba Flower *	20	V	FAC
Panicum brulteum	10	H	FAC				
Stachy jamaicensis Flwr *	25	H	FAC				
Cyperus ligularis Flwr	5	H	FAC				
Alternanthera sessilis Flwr *	20	H	FACW				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities [ ]
- Physiological or reproductive adaptations [ ]
- Technical Literature [ ]
- Wetland plant list (nat'l or regional) [x]
- Morphological adaptations [ ]
- Wetland Plant Data Base [ ]
- Other: [ ]

Hydrophytic Vegetation Present? Yes [x] No [ ]

Rationale/remarks; other plant species noted (continue on back):

Physalis angulata	Fruiting	
Momordica charantia Flower		
Passiflora suberosa Flower		
Paspalum conjugatum Flower		

HYDROLOGY

Is it the growing season? Yes [x] No [ ]

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

- Stream, Lake or gage data: [ ]
- Aerial photographs: [ ]

PRIMARY INDICATORS

- Water Marks: Yes [ ] No [x]
- Sediment Deposits: Yes [ ] No [x]
- Drift Lines: Yes [ ] No [x]
- Drainage Patterns: Yes [ ] No [x]

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Yes [ ] No [x]
- Local Soil Survey: Yes [x] No [ ]
- FAC Neutral: Yes [x] No [ ]
- Water-stained Leaves Yes [ ] No [ ]

Other: Depression area that likely receives storm runoff.

Wetland hydrology Present? Yes [x] No [ ]

Rationale/remarks: ground is cracked w/in wetland but so is ground outside depression

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Bar-CC-1a	Date: May 10, 2010

SOILS

Map Unit Name: (Series & Phase) Chacha clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-4"		10YR 3.5/3	10YR 4/6	<1%	clay, dry
			7.5YR 5/8	<1%	clay, dry

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☒ Listed on Local Hydric Soils List
- ☒ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

cracked ground; reducing conditions are weak but present

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☑	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☑	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☑	No	☐	Unknown	☐

Rationale/Remarks: Wet depression is defined on 3 sides; east side is gradual slope, has subtle change in species composition which has burned recently → isolated wetland

Sketch and Notes: Include rare species observations and level of site disturbance

Area is a depression that contains charred remains of Saccharum. Wetland abuts charred Saccharum on one side and Leucaena thicket on other side. Wetland may be more extensive but burned condition may obscure wetland indicators in Saccharum field (center of depression)

photos # 1844-1871

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-2a	Date: May 10, 2010
Applicant/Owner:	State: Monday
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: Homogeneous Pan. mutium patch	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum mutium	100	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Colubrina asiatica		
surrounding veg: Sorghum	+ Leucaena	

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☒ — Sediment Deposits: Yes ☐ No ☒
	Drift Lines: Yes ☐ No ☒ — Drainage Patterns: Yes ☐ No ☒
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☐ No ☒ — Local Soil Survey: Yes ☒ No ☐
Depth to saturated soil: none	
	FAC Neutral: Yes ☐ No ☒ — Water-stained Leaves Yes ☐ No ☒
Check all that Apply & explain below:	Other:
Stream, Lake or gage data: ☐	Depression area near CC-1
Aerial photographs: ☐	

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: Berm on 1 side w/ lots of loose rocks, appears pushed or dumped. No positive hydrology indicators observed but grass is very dense.
Assumed sufficient wet season saturation.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BARR: CC-2a	Date: Mon May 10, 2010

SOILS

Map Unit Name: (Series & Phase) Chacha clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-10"		7.5YR 3.5/2	5YR4/6	5%	hard clay, "metal chunks"
					may cause red areas
					in some portions of profile.

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Wetland depression is subtle yet clearly defined - isolated wetland.

Sketch and Notes: Include rare species observations and level of site disturbance

Panicum patch north of CC-1; Old stable berm and newer spoils piles define south end of Panicum depression.

photos #1872-74

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-3a	Date: 5/10/10 Mon.
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☑ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☐	
Location Description: panicum patch near Tower	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Heliotropium procumbens *	~~15~~ 20		FACW				
Alternanthera pennsylvanica *	~~15~~ 20	-	FACW				
Mikania scandens	10		FAC				
Cassia occidentalis	5	Fruit/Flower		FAC			
Panicum maximum *	35		FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☐ No ☐

Rationale/remarks; other plant species noted (continue on back):

Cassia alata		
Momordica fruit		
Physalis fruit		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☒
- Sediment Deposits: Yes ☐ No ☒
- Drift Lines: Yes ☐ No ☒
- Drainage Patterns: Yes ☐ No ☒

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 in.: Yes ☐ No ☒
- Local Soil Survey: Yes ☒ No ☐
- FAC Neutral: Yes ☒ No ☐
- Water-stained Leaves: Yes ☐ No ☒

Other: cracked soils, drainage receives ~~storm~~ storm runoff

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-3a	Date: 5/10/10 Mon.

SOILS

Map Unit Name: (Series & Phase) Chacha clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-6		10YR3/3	5YR4/6	40%	dry clay

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: photo 1886

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Like CC-1 w/ portion of boundary burned. Strong wetland indicators are present → isolated wetland.

Sketch and Notes: Include rare species observations and level of site disturbance

Wetland lies along Leucaena tree line and a burned Saccharum field with one Pithecellobium tree. Burned conditions may obscure other wetland indicators.

Photos 1875-1888

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-4						Date: Mon 5/10/10
Applicant/Owner:						State:
Investigator(s): RD CC						S/T/R:
Do Normal Circumstances exist on the Site?	Yes	☑	No	☐		Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes	☐	No	☒		Plot ID:
Is the area a potential Problem Area?	Yes	☐	No	☒		
Location Description: Isolated wetland on southern Barrigada						

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum mutticum *	~~80~~ 95	H	FAC				
Heliotropium indicum	[illegible]	H	FACW				
	<1%						

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Cassia/Senna alata		
Psidium guajava		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐	PRIMARY INDICATORS		
Based on:	Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐	
	Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☑ No ☐	
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)		
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☒ No ☐	Local Soil Survey: Yes ☒ No ☐	
Depth to saturated soil: none			
	FAC Neutral: Yes ☒ No ☐	Water-stained Leaves Yes ☐ No ☐	
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other: Depression area		

Wetland hydrology Present? Yes ☑ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Bar - CC-4	Date: Mon 5/10/2010

SOILS

Map Unit Name: (Series & Phase) Chacha clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
~4"		10YR 3.5/3	5YR 4/6	25-30%	clay
			5YR 5/8	25-30%	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: photo 1893

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Strong wetland indicators are present → isolated wetland.

Sketch and Notes: Include rare species observations and level of site disturbance

Lots of guava trees along edge of wetland.
Homogenous Panicum muticum.

photos 1889-1899

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-5	Date: Monday 5/10/2010
Applicant/Owner:	State:
Investigator(s):	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☐ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☐	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☐	
Location Description: Panicum patch South of Navy boundary	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum maximum *	95	H	FAC				
Heliotropium indicum	2	H	FACW				
Momordica charantia	2	V	FAC				
Cassia alata	5	S	FAC				
Mikania scandens	5	V	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☐	Sediment Deposits: Yes ☐ No ☐
Drift Lines: Yes ☐ No ☐	Drainage Patterns: Yes ☑ No ☐

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 in.: Yes ☒ No ☐	Local Soil Survey: Yes ☒ No ☐
FAC Neutral: Yes ☒ No ☐	Water-stained Leaves Yes ☐ No ☐

Other: Depressional area

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Bar-cc-5	Date: May 10, 2010

SOILS

Map Unit Name: (Series & Phase) Chacha Clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description

Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-5"		10YR 4/3	5YR 4/6	} 40%	clay
			5YR 5/8		

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: photos 1900 – 1901

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Neatly defined depression w/ strong wetland indicators

Sketch and Notes: Include rare species observations and level of site disturbance

Tree nearby @ edge of wetland has wooden ladder (observation post? hunting perch / blind?)

photos 1900 – 1909

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-6	Date: 5/10/10 Monday
Applicant/Owner:	State:
Investigator(s): RD CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: Isolated wetland on southern Barrigada	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pan maximum *	95-100	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Pass. foetida		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☒	Sediment Deposits: Yes ☐ No ☒
Drift Lines: Yes ☐ No ☒	Drainage Patterns: Yes ☐ No ☒

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 in.: Yes ☐ No ☒	Local Soil Survey: Yes ☒ No ☐
FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒

Other:

Wetland hydrology Present? Yes ☒? No ☐

Rationale/remarks: No indicators although some may be obscured by dense grass thatch. Dry season - assumed depression is saturated during wet season

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-6	Date: 5/10/2010

SOILS

Map Unit Name: (Series & Phase) Chacha clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-8"		10YR 3/3	10YR 4/6	15-20%	clay w/redox near surface

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: depression boundaries are obscured by farm road and past cultivation on south side. Vegetation + soils indicators are strong and observed hydrology is weak → sufficient wet season saturation is assumed for this isolated wetland.

Sketch and Notes: Include rare species observations and level of site disturbance

Panicum miliaceum patch straddles jeep road/trail along edge of Sorghum field (photo 1910). Leucaena thicket forms another boundary.

photos 1910-1913

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-7a	Date: Mon 5/10/2010
Applicant/Owner:	State:
Investigator(s): RD CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: Panicum patch near farmed area	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Panicum muticum	97	H	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Ipomoea triloba		
Cassia alata		

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☐ No ☑

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☒ No ☐
FAC Neutral: Yes ☐ No ☑	Water-stained Leaves Yes ☐ No ☑

Other:

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks: Assume depression is saturated for sufficient length of time during wet season. Dense Panicum obscured ground.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: BAR CC-7	Date: 5/10/10

SOILS

Map Unit Name: (Series & Phase) Chacha clay	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☒ No ☐

Profile Description
Soil Profile Evaluated Yes ☑ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-4		10YR 4/3	7.5YR4/6 and 5YR 4/6	25-30%	loose clay
4-		10YR 3.5/3	5YR 5/8	10%-15%	platy clay, appears compacted

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: photo 1921, 1923

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: Vegetation + soils are strong yet hydrology is assumed (see notes) Previous cultivation edge abuts west boundary of wetland → likely represents the too-wet limit for cultivation.

Sketch and Notes: Include rare species observations and level of site disturbance

Heliotropium indicum area @ Ⓝ end of wetland. Wetland occupies portion of sorghum field that was previously a farmed area.

photos: 1914-1923

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site:	Mag CC-1a b				Date: Thurs. 5/13/2010
Applicant/Owner:					State:
Investigator(s):	RD, CC				S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☒	No ☐			Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐	No ☒			Plot ID:
Is the area a potential Problem Area?	Yes ☐	No ☒			
Location Description:	Magazine footprints across Alamagosa Springs Road				

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Pandanus tectorius	10	T	FAC				
Scleria polycarpa	15	H	FAC				
Imperata	20	H	FAC				
Hibiscus tiliaceus	10	T	FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Wedelia trilobata		
Discocalyx megacarpum		
Hyptis capitata		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐	PRIMARY INDICATORS	
Based on:	Water Marks: Yes ☐ No ☒	Sediment Deposits: Yes ☐ No ☒
	Drift Lines: Yes ☐ No ☒	Drainage Patterns: Yes ☐ No ☒
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)	
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☐ No ☒	Local Soil Survey: Yes ☐ No ☒
Depth to saturated soil: none		
	FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other: cracked soil surface	

Wetland hydrology Present? Yes ☐ No ☒

Rationale/remarks:

Area is on a slope and has no positive indicators of hydrology

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: Mas - cc - 16	Date: May 13, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-7		10YR 3.5/2	7.5YR 6/6	15% med	soft clay, coarse roots
7+		7.5YR 6/6	10YR 3.5/2	~~20%~~ med. 10-20%	soft clay
			5YR 5/8	10% med.-fine	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
Rainfall previous evening or this morning. Soils are moist. "Mottle" colors described are red soils + small soft rocks in soil profile starting at ca. 7 inches deep – they are not redox. features → non-hydric soils

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☒	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☒	Unknown	☐

Rationale/Remarks: Plot is on slope near the ridge crest and has no positive hydrologic and hydric soil indicators.

Sketch and Notes: Include rare species observations and level of site disturbance

cc 2202 - 2215

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: MAG CC-1 E	Date: Thurs. 5/13/10
Applicant/Owner:	State:
Investigator(s): RD, CC	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☑	
Location Description: well within mapped wetland, on flat topography	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Carex fuirenoides	15	H	FACU	Scleria polycarpa	20	H	FAC
Fimbristylis ovata	<5	H	FACW	Hibiscus tiliaceus	5	T	FAC
Eragrostis ciliaris	<5	H	FAC	Pandanus tectorius	5	T	FAC
Wedelia trilobata	10	H	FAC	Areca catechu	5	T	FAC
Hyptis capitata	5	H	FAC	Dichanthium bladhii (Bothriochloa)	10	H	FAC

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

Fimb. dichotoma	Medinilla medinilliana	
Psidium guajava	Glochidion marianum	
Vitex parviflora seedlings (?)	Penn. polystachion	
Clerodendrum inerme		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

PRIMARY INDICATORS

- Water Marks: Yes ☐ No ☒
- Sediment Deposits: Yes ☐ No ☒
- Drift Lines: Yes ☐ No ☒
- Drainage Patterns: Yes ☐ No ☒

SECONDARY INDICATORS (2 or more required)

- Oxidized Root Channels < 12 In.: Few Yes ☒ No ☐
- Local Soil Survey: Yes ☐ No ☐
- FAC Neutral: Yes ☐ No ☐
- Water-stained Leaves Yes ☐ No ☐

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

Other: Flat bench along slope

Wetland hydrology Present? Yes ☒ No ☐

Rationale/remarks:

subtle drainage patterns observed by vegetation, not prominent, no hummocks.

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: MAG - CC - 1e	Date: May 13 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-7		10YR 4/2	2.5YR 4/8,	5-10% med	bright red mottle, not redox.
7+		10YR 4/2	2.5YR 4/8	10-15% med	soft clay
~~0-7~~	~~also~~	~~10YR~~	7.5YR 5/6	5-10% med	"
0-7			10YR 2/1	5% med	gray mottle
			10YR 5/6	5% med	

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☒ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

photos # 2216, 2217

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☒	No	☐	Unknown	☐
Possible Hydric soil?	Yes	☒	No	☐	Unknown	☐

Rationale/Remarks: relatively flat topography with positive wetland indicators marks the upslope end of this ravine wetland.

Sketch and Notes: Include rare species observations and level of site disturbance

A paved road and a grass-covered road border the west + south side of the wetland, respectively.

CC 2216-2227

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: NCTS Finegayan (Sinkhole)		Date: Thurs. 5/13/10
Applicant/Owner: ~~AND-CC-1a~~ FIN-CC-1		State:
Investigator(s): RD, CC, GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☒	
Location Description:		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Guamia mariannae	10	S	FACU				
Neisosperma oppositifolia	15	T	FACU				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☐ No ☒

Rationale/remarks; other plant species noted (continue on back):

Piper guahamense		
Polyp. punctatum		
Pteris tripartita		

HYDROLOGY

Is it the growing season? Yes ☒ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

- Stream, Lake or gage data: ☐
- Aerial photographs: ☐

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☐ No ☑

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 In.: Yes ☐ No ☑	Local Soil Survey: Yes ☐ No ☒
FAC Neutral: Yes ☐ No ☑	Water-stained Leaves Yes ☐ No ☒

Other:

Wetland hydrology Present? Yes ☐ No ☒

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: FIN-CC-1	Date: May 13, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description

Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-3		2.5 YR 3/3	–	–	rocky, coarse roots
3+		2.5YR 3/2	–	–	rocks, loose soil no ped

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes ☐	No ☒	Unknown ☐
Wetland hydrology present?	Yes ☐	No ☒	Unknown ☐
Possible Hydric soil?	Yes ☐	No ☒	Unknown ☐

Rationale/Remarks: sinkhole had no positive wetland indicators

Sketch and Notes: Include rare species observations and level of site disturbance

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: ~~AND HCFS CC 2~~ FIN-CC-2	Date: May 13, 2010 Thurs.
Applicant/Owner:	State:
Investigator(s): RD, CC, GM, SW	S/T/R:
Do Normal Circumstances exist on the Site? Yes ☒ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)? Yes ☐ No ☒	Plot ID:
Is the area a potential Problem Area? Yes ☐ No ☒	
Location Description: Saccharum-dominated sinkhole	

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Saccharum spontaneum*	99	H	FAC				
Mikania scandens			FAC				

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

Regional Knowledge of plant communities	☐	Wetland plant list (nat'l or regional)	☒	Other:	☐
Physiological or reproductive adaptations	☐	Morphological adaptations	☐		
Technical Literature	☐	Wetland Plant Data Base	☐		

Hydrophytic Vegetation Present? Yes ☒ No ☐

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☑ No ☐

Based on:

Depth of Inundation: none

Depth to free water: none

Depth to saturated soil: none

Check all that Apply & explain below:

Stream, Lake or gage data: ☐

Aerial photographs: ☐

PRIMARY INDICATORS

Water Marks: Yes ☐ No ☑	Sediment Deposits: Yes ☐ No ☑
Drift Lines: Yes ☐ No ☑	Drainage Patterns: Yes ☐ No ☑

SECONDARY INDICATORS (2 or more required)

Oxidized Root Channels < 12 in.: Yes ☐ No ☑	Local Soil Survey: Yes ☐ No ☒
FAC Neutral: Yes ☐ No ☒	Water-stained Leaves Yes ☐ No ☒

Other: Depressional area.

Wetland hydrology Present? Yes ☐ No ☑

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: FIN-CC-2	Date: 5/13/10

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soil	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☒ No ☐ Method: pit

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-3+		2.5YR3/3			Loose soil, limestone rocks
					few fine roots

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks: Soils are friable + appear to be well-drained

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☒	No	☐	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☒	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☒	Unknown	☐

Rationale/Remarks: Despite hydrophytic vegetation and depression topography, the soils are well-drained and do not show evidence of inundation; non-wetland

Sketch and Notes: Include rare species observations and level of site disturbance

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form -- Not for Jurisdictional Delineation) 04/2010

Project/Site: ~~Andors CC 3 (NOTS Finegayan)~~		Date: 5/13/2010 Thurs
Applicant/Owner: FIN-CC-3		State:
Investigator(s): RD, CC, GM, SW		S/T/R:
Do Normal Circumstances exist on the Site?	Yes ☑ No ☐	Transect ID:
Is the site significantly disturbed (atypical situation)?	Yes ☐ No ☑	Plot ID:
Is the area a potential Problem Area?	Yes ☐ No ☑	
Location Description: Open field near antennas, radomes (N) Section		

VEGETATION

Dominant Plant Species (with *)	%Cov	Strat	Indic	Dominant Plant Species (with *)	%Cov	Strat	Indic
Bidens alba *	20		FACU				
Sporobolus ~~[illegible]~~ [illegible]	5						
Cyperus ligularis	2						
Pennisetum polystachion *	20		FACU				
Pan. maximum	5						

Percent of dominants OBL, FACW, & FAC:

Check all indicators that apply & explain below:

- Regional Knowledge of plant communities ☐
- Physiological or reproductive adaptations ☐
- Technical Literature ☐
- Wetland plant list (nat'l or regional) ☒
- Morphological adaptations ☐
- Wetland Plant Data Base ☐
- Other: ☐

Hydrophytic Vegetation Present? Yes ☐ No ☒

Rationale/remarks; other plant species noted (continue on back):

HYDROLOGY

Is it the growing season? Yes ☒ No ☐	**PRIMARY INDICATORS**
Based on:	Water Marks: Yes ☐ No ☑ — Sediment Deposits: Yes ☐ No ☑
	Drift Lines: Yes ☐ No ☑ — Drainage Patterns: Yes ☐ No ☑
Depth of Inundation: none	SECONDARY INDICATORS (2 or more required)
Depth to free water: none	Oxidized Root Channels < 12 In.: Yes ☐ No ☑ — Local Soil Survey: Yes ☐ No ☑
Depth to saturated soil: none	
	FAC Neutral: Yes ☐ No ☑ — Water-stained Leaves: Yes ☐ No ☑
Check all that Apply & explain below: Stream, Lake or gage data: ☐ Aerial photographs: ☐	Other:

Wetland hydrology Present? Yes ☐ No ☒

Rationale/remarks:

DATA FORM
Wetland Assessment
(TEC JV Modified 1987 Corps Wetland Delineation Manual Form – Not for Jurisdictional Delineation) 04/2010

Project/Site: FIN-CC-3	Date: May 13, 2010

SOILS

Map Unit Name: (Series & Phase) Non-hydric Soils	Drainage Class:
Taxonomy (subgroup):	Field observations confirm mapped type? Yes ☐ No ☐

Profile Description
Soil Profile Evaluated Yes ☐ No ☐ Method:

Depth (in.)	Horizon	Matrix Color (moist)	Mottle Color (moist)	Mottle abundance size & contrast	Texture, Concretions, Structure, etc.
0-8		2.5YR 3/3	–	–	Silty w/ limestone rocks

Hydric Soil Indicators: (check all that apply)

- ☐ Histosol
- ☐ Histic Epipedon
- ☐ Sulfidic Odor
- ☐ Aquic Moisture Regime
- ☐ Reducing Conditions
- ☐ Gleyed or Low-Chroma Colors
- ☐ Concretions
- ☐ High Organic Content in the Surface Layer of Sandy Soils
- ☐ Organic Streaking in Sandy Soils
- ☐ Listed on Local Hydric Soils List
- ☐ Listed on National Hydric Soils List
- ☐ Other (explain in remarks)

Rationale/Remarks:
Possible agricultural soils. Burned Limestone pieces found in pit.
No positive hydric soil indicators

WETLAND SUMMARY

Hydrophytic Vegetation present?	Yes	☐	No	☒	Unknown	☐
Wetland hydrology present?	Yes	☐	No	☒	Unknown	☐
Possible Hydric soil?	Yes	☐	No	☒	Unknown	☐

Rationale/Remarks: had no positive wetland indicators

Sketch and Notes: Include rare species observations and level of site disturbance

Photos:
~~Glenn Lee~~ 2242-2247

APPENDIX D
PLANT LIST FOR 2010 FIELD STUDY AREAS

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Guam 2010 Wetland Field Study
Plant List

Species	Family	Common Name (common/(	Common Name (from wetland tab)	Regional Indicator	Growth Form
Acrostichum aureum L. Langayao	POLYPODIACEAE		Giant swamp fern	OBL	H
Adiantum tenerum L.	POLYPODIACEAE			FACU	H
Alocasia macrorrhiza (L.) G.Don var. macrorrhiza	ARACEAE Jussieu	taro/papao-apaka, piga	Papao-apaka, Papao-atolong, Taro	FAC	H
Alternanthera sessilis (L.) R.Br. ex DC.	AMARANTHACEAE Juss.			FACW	H
Angiopteris evecta (Forst.f.) Hoffm.	MARATTIACEAE		Giant fern	FAC	H/S
Antigonon leptopus H.&A.	POLYGONACEAE A.L.Juss.	love-vine/cadena de amor	Cadena de amr, Chain of love	FACU	V
Antrophyum plantagineum (Cav.) Kaulf.	POLYPODIACEAE				
Areca catechu L.	ARECACEAE Schultz-Schul-tzenstein	betelnut/pugua	Betelnut, Pugua	FAC	T
Asplenium nidus L.	POLYPODIACEAE		Galak; Bird's nest fern	FACU	H
Asystasia gangetica (L.) Anders.	ACANTHACEAE Jussieu			FACU	H
Avicennia marina var. alba (Bl.) Bakh.	VERBENACEAE St.-Hiliare		White mangrove	OBL	T
Axonopus compressus (Sw.) Beauv.	POACEAE Barnhart			FAC	H
Bambusa vulgaris Schrad. ex Wendl.	POACEAE Barnhart	pi'ao palao'an	Piao palaoan; Common bamboo	FAC	T
Barringtonia asiatica (L.) Kurz	LECYTHIDACEAE Poiteau	puting	Putting, Fish-kill Tree	FACU	T
Barringtonia racemosa (L.) Spreng	LECYTHIDACEAE Poiteau	langasat		FACW	S,T
Belvisia spicata (L.f.) Mirb. ex Copel	POLYPODIACEAE				
Bidens alba (L.) DC.	ASTERACEAE Dumortier		Daisy, Beggar's tick, Spanish needles	FAC	H
Blechum brownei f. puberulum Leonard	POLYPODIACEAE			FAC	H
Bruguiera gymnorhiza (L.) Lam.	RHIZOPHORACEAE R.Br.		Mangle lahi	OBL	T
Buddleja asiatica Lour.	LOGANIACEAE C.v.Martius				
Calanthe triplicata (Willem.) Ames	ORCHIDACEAE A.L.Jussieu			FAC	H
Calophyllum inophyllum L.	CLUSIACEAE Lindley	da'ok	Da'ok, Palomaria	FAC	T
Cananga odorata (Lam.) Hook. f. & Thoms.	ANNONACEAE A.L.Jussieu	Ilangilang	Ilangilang	FC	T
Carex fuirenoides Gaud.	CYPERACEAE Juss.			FACU	H
Carica papaya L.	CARICACEAE Dumortier		Papaya, Pawpaw	FAC	H,T
Cassia alata L.	FABACEAE Lindley / CAESALPINIOIDEAE	take-biha	Take biha, Candlebush	FAC	S
Cassia occidentalis L.	FABACEAE Lindley / CAESALPINIOIDEAE	mumutun-sable	Mumutun-sable, coffee senna	FAC	S
Casuarina equisetifolia L.	CASUARINACEAE R.Br.	gago	Gago, Ironwood	FAC	T
Centotheca lappacea (L.) Desv.	POACEAE Barnhart			FAC	H
Ceratopteris gaudichaudii Brongn.	PARKERIACEAE	guafak-uhong, umog-sensor	Guafak-uhong, Water fern	OBL	H
Chromolaena odorata (L.) King 7 Rob.	ASTERACEAE Dumortier		Masigsig	FAC	H
Clerodendrum inerme var. oceanicum A.Gray	VERBENACEAE St.-Hiliare	lodugao	Lodugao	FAC	S
Cocos nucifera L.	ARECACEAE Schultz-Schul-tzenstein		Niyog; Coconut	FACU	T
Coix lacryma-jobi L. Bilen	POACEAE Barnhart		Bilen; Job's tears	OBL	H
Colubrina asiatica (L.) Brongn.	RHAMNACEAE A.L.Jussieu	gasusu, gasoso		**FAC**	
Curcuma australasica Hook. f.	ZINGIBERACEAE Lindl.			FAC	H
Cycas circinalis L. (C. micronesica K.D.Hill 1994)	CYCADACEAE C.Pers.	cycad/fadang	Fadang, Frederico	FAC	T
Cyperus alternifolius ssp. Flabelliformis (Rottb.)Kuk.	CYPERACEAE Juss.			OBL	H
Cyperus ligularis L.	CYPERACEAE Juss.		Rocket sedge	FAC	H
Cyrtococcum patens (L.) Camus	POACEAE Barnhart				
Dalbergia candenatensiEl (Dennst) Frain	FABACEAE Lindl. - MIMOSIOIDEAE			FACW	V
Delonix regia (Boj.) Raf.	FABACEAE Lindley / CAESALPINIOIDEAE	flame tree, arbol-del-fuego	Tronkon albot, Flame tree	FACU	T
Discocalyx megacarpa Merr.	MYRSINACEAE R. Brown	otot	Otot, Otug	FAC	S
Elephantopus mollis HBK.	ASTERACEAE Dumortier	papago vaca, papago halom	Papago vaca, Papago halomtano	FAC	H
Ficus tinctoria var neo-ebudarum (Summerh.)Fosb.	MORACEAE Link	hoda	Hoda, Tagete, Dyers' fig	FACU	T
Fimbristylis cymosa R.Br.	CYPERACEAE Juss.			FAC	H
Fimbristylis dichotoma (L.) Vahl	CYPERACEAE Juss.			FAC	H
Fimbristylis littoralis Gaud.	CYPERACEAE Juss.			OBL	H
Fimbristylis tristachya R.Br. Fuirena Rottb.	CYPERACEAE Juss.			FAC	H
Flagellaria indica L. Bejuco halom-tano	FLAGELLARIACEAE Dumortier		False rattan	FAC	V
Freycinetia reineckei Warb.	PANDANACEAE R.Br.		Fianti; Vine Pandanus	FAC	V
Glochidion marianum Muell.-Arg.	EUPHORBIACEAE Jussieu	chosga, abas duendes	Chosga, Abas duendes	FACU	S
Heliotropium indicum L.	BORAGINACEAE Jussieu		Berbena	FACW	H
Heliotropium procumbens var. depressum (Cham.) Fosb. & Sachet	BORAGINACEAE Jussieu		Hunig-tasi	FAC	H

Note: Regional indicator source:
UoG undated list supplied by L. Raulerson

Guam 2010 Wetland Field Study
Plant List

Species	Family	Common Name (common/(	Common Name (from wetland tab)	Regional Indicator	Growth Form
Heterospathe elata Scheff.	ARECACEAE Schultz-Schul-tzenstein	palma brava	Palma brava	FAC	T
Hibiscus tiliaceus L.	MALVACEAE A.L.Jussieu	sea hibiscus/pago	Pago, Sea Hibiscus	FAC	S,T
Hymenocallis littoralis (Jacq.) Salisb. Lirio	LILIACEAE A.L.Jussieu		Spider lily	FAC	H
Hyptis capitata Jacq.	LAMIACEAE J.Lindley	button weed/batones	Botones	FAC	H
Imperata conferta (J.S.Presl) Ohwi	POACEAE Barnhart			FAC	H
Ipomoea aquatica Forst.	CONVOLVULACEAE Juss.	Kangkun	Kangkun, Swamp cabbage	OBL	V
Ipomoea indica (Burm.)Merr. var. indica	CONVOLVULACEAE Juss.	Fofgu, Asa-gao	Fofgu, Asa-gao, Japanese Morning-glory	FAC	V
Ipomoea pes-caprae ssp. brasiliensis (L.) v.Ooststr.	CONVOLVULACEAE Juss.	Alalag-tasi	Alalag-tasi, Beach morning-glory	FASU	V
Ipomoea triloba L.	CONVOLVULACEAE Juss.	fofgu-sabana	Fofgu sabana	FAC	V
Isachne miliacea var. minutula (Gaud.) Fosb.& Sachet	POACEAE Barnhart			FACW	H
Leucaena leucocephala (Lam.) deWit	FABACEAE Lindl. - MIMOSIOIDEAE	tangantangan		FACU	T
Lumnitzera littorea (Jack) Voigt	COMBRETACEAE R.Br.		Nana, Bacawaine	OBL	T
Lygodium microphyllum (Cav.) R.Br.	SCHIZAEACEAE		Vining fern	FAC	Nd
Medinilla medinilliana (Gaud.) Fosb. & Sachet	MELASTOMATACEAE Juss.	gafus	Gafus	FAC	VS
Melastoma malabathricum var. mariannum (Naudin) Fosb. & Sachet	MELASTOMATACEAE Juss.	gafao? (UOG website)		FAC	S
Merrilliodendron megacarpum (Hemsl.) Sleumer	ICACINACEAE Miers		Faniok	FACW	T
Microlepia speluncae (L.) T. Moore	POLYPODIACEAE			FAC	H
Mikania scandens (L.) Willd.	ASTERACEAE Dumortier		Mile-a-minute	FAC	V
Mimosa pudica L.	FABACEAE Lindl. - MIMOSIOIDEAE	sleeping grass	Sleeping grass, sensitive plant	FAC	H/V
Momordica charantia L.	CUCURBITACEAE Jussieu	Atmagoso	Bittermelon	FACU	V
Morinda citrifolia L. var. citrifolia	RUBIACEAE A.L.Jussieu	lada	Lada	FACU	S,T
Nephrolepis biserrata (Sw.) Schott var. Schott	POLYPODIACEAE			FAC	H
Nephrolepis hirsutula (Forst.f.) Presl	POLYPODIACEAE			FAC	H
Oplismenus compositus L.	POACEAE Barnhart			FAC	H
Pandanus dubius Spreng. var. dubius	PANDANACEAE R.Br.	pahong	Pahong; Screw pine	FAC	T
Pandanus tectorius Park.	PANDANACEAE R.Br.	kafu	Kafu; Screw pine	FAC	T
Panicum maximum Jacq.	POACEAE Barnhart		Guinea grass	FACU	H
Panicum muticum Forsk. (Brachiara mutica (Forsk) Stapf)	POACEAE Barnhart	para grass		FAC	H
Paspalum conjugatum Berg.	POACEAE Barnhart		Hilo grass	FAC	H
Passiflora foetida var. hispida (DC.) Killip	PASSIFLORACEAE Juss. ex Kunth	love-in-a-mist	Love-in-a-mist	FACU	V
Passiflora suberosa L.	PASSIFLORACEAE Juss. ex Kunth	wild passion flower		FAC	V
Pennisetum polystachion (L.) Schult. f. polystachion	POACEAE Barnhart		Mission grass, foxtail	FACU	H
Pennisetum purpureum Schumach.	POACEAE Barnhart	elephant grass, napier grass	Elephant or Napier Grass	FAC	H
Phragmites karka (Retz.) Trin. ex Steud.	POACEAE Barnhart	reed, karisso	Karriso; Reed	OBL	H
Physalis angulata L. var. angulata	SOLANACEAE A.L.Jussieu		Tomates chaca	FACU	H
Piper guahamense C.DC. f. guahamense	PIPERACEAE C.Agardh	wild piper/pupulu-n-aniti	Pupulu-n-aniti	FAC	H
Pipturus argenteus (Forst.f.) Wedd. var. argenteus	URTICACEAE A.L.Jussieu	amahadyan	Amahadyan	FACU	S/T
Pithecellobium dulce (Roxb.) Benth.	FABACEAE Lindl. - MIMOSIOIDEAE	kamachile	Kamachile	FAC	T
Pityrogramma calomelanos (L.) Link	POLYPODIACEAE			FAC	H
Pluchea indica (L.) Less.	ASTERACEAE Dumortier			FACW	S
Polypodium cyathoides Sw.	POLYPODIACEAE	strapleaf fern			
Polypodium punctatum (L.) Sw.	POLYPODIACEAE	dwarf elkhorn fern		?	
Polypodium scolopendria Burm.f.	POLYPODIACEAE			FAC	H
Premna obtusifolia R.Br. (P. serratifolia)	VERBENACEAE St.-Hiliare	ahgao	Ahgao	FACU	T
Psidium guajava L.	MYRTACEAE A.L.Jussieu	guava/abas	Abas, guava	FAC	T
Psilotum nudum (L.)Beauv.	PSILOTACEAE		whisk fern	FAC	H
Pteris ensiformis Burm.f.	POLYPODIACEAE			FAC	H
Pteris quadriaurita Retz. s.l.	POLYPODIACEAE			FAC	H
Pteris vittata L.	POLYPODIACEAE			FAC	H
Rhaphidophora aureus	ARACEAE Jussieu				
Rhizophora mucronata Lam. var. mucronata	RHIZOPHORACEAE R.Br.		Mangle	OBL	T
Rhizophora mucronata var. stylosa (Griff.) Schimper	RHIZOPHORACEAE R.Br.			OBL	T
Rhynchospora corymbosa (L.) Britt.	CYPERACEAE Juss.			FACW	H
Saccharum spontaneum L.	POACEAE Barnhart		Wild cane	FAC	H
Scaevola taccada (Gaertn.) Roxb.	GOODENIACEAE R.Brown	half-flower/nanaso	Nanasu, Half-flower	FAC	S
Scirpus littoralis var. capensis (Boeck.) Koyama	CYPERACEAE Juss.		Bullrush	OBL	H
Scleria polycarpa Boeck.	CYPERACEAE Juss.			FAC	H
Sorghum halepense (L.) Pers.	POACEAE Barnhart		Johnson grass	FACU	H

Note: Regional indicator source:
UoG undated list supplied by L. Raulerson

Guam 2010 Wetland Field Study
Plant List

Species	Family	Common Name (common/(	Common Name (from wetland tab)	Regional Indicator	Growth Form
Spathodea campanulata Beauv.	BIGNONIACEAE Jussieu		African tulip tree	FAC	T
Spathoglottis sp(p).	ORCHIDACEAE A.L.Jussieu				
Sporobolus virginicus (L.) Kunth	POACEAE Barnhart		Beach-dropseed, salt grass	FACW	H
Stachytarpheta jamaicensis (L.) Vahl	VERBENACEAE St.-Hiliare	false verbena		FAC	H
Stachytarpheta urticifolia Sims	VERBENACEAE St.-Hiliare			FAC	H
Stictocardia tiliaefolia (Desr.) Hall.f.	CONVOLVULACEAE Juss.	abubo	Abubo	FACU	V
Synedrella nodiflora (L.) Gaertn.	ASTERACEAE Dumortier		saigon	FAC	H
Syngonium angustatum Schott	ARACEAE Jussieu			FAC	H
Tectaria crenata Cav.	POLYPODIACEAE		Polka Dot fern	FAC	H
Teramnus labialis (L.f.) Spreng.	FABACEAE Lindley / PAPILLIONIOIDEAE	chaguan cacaguates		FAC	V
Terminalia catappa L.	COMBRETACEAE R.Br.	talisai	Tahitian almond	FAC	T
Thelypteris interrupta (Willd.) Iwats.	POLYPODIACEAE			FACW	H
Thelypteris maemonensis (Wagner & Grether) Stone	POLYPODIACEAE			FAC	H
Thelypteris opulenta (Kaulf.) Fosb.	POLYPODIACEAE			FAC	H
Thelypteris parasitica (L.) Tard.	POLYPODIACEAE			FAC	H
Thelypteris subpubescens (Bl.) Iwats.	POLYPODIACEAE			FACW	H
Thelypteris torresiana (Gaud.) Alston	POLYPODIACEAE			FAC	H
Thelypteris unita (L.) Morton	POLYPODIACEAE			FACW	H
Thespesia populnea (L.) Sol. ex Correa	MALVACEAE A.L.Jussieu	banalo	Banalo, Kilulu	FACU	T
Triphasia trifolia (Burm.f.) P.Wils.	RUTACEAE A.L.Jussieu	lemonchina	Limon-di-china, Limonchina	FAC	S
Vitex parviflora Juss.	VERBENACEAE St.-Hiliare			FACU	T
Wedelia trilobata (L.) Hitchc.	ASTERACEAE Dumortier			FAC	H

Note: Regional indicator source:
UoG undated list supplied by L. Raulerson

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APPENDIX E
REMOTE SENSING AND MAPPING REPORT

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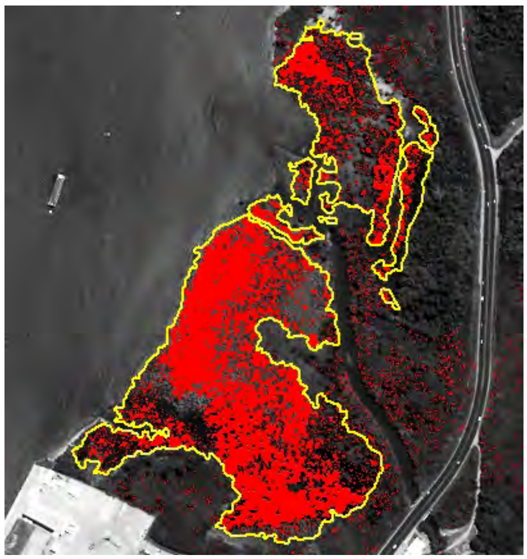
Report: Wetlands Identification and Analysis over the Island of Guam Using Remote Sensing



For:

TEC

2696 Old Ivy Road

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Submitted by:

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9390 Gateway Drive, Suite 100

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1.0 INTRODUCTION

Under the current Purchase Order Subcontract 8846-25580 to provide professional ENGINEERING CONSULTING SERVICES in support of the GUAM REMOTE SENSING WETLAND STUDY to TEC of Charlottesville, VA by SpecTIR LLC, the firm is submitting this report, “Wetland Identification and Analysis over the Island of Guam Using Satellite Remote Sensing.”

Initially, the satellite remote sensing data were provided to SpecTIR by the US Navy to perform an assessment of the imagery for suitability of wetland characterizations on Guam. GeoEye[1] imagery of Guam was selected for the best cloud free days with nadir daylight looks of the island. High priority areas for wetlands analysis were provided by TEC for SpecTIR to examine in the imagery and to guide ground truthing efforts for the identification of potential wetlands. Additional areas on the island were analyzed followed the initial assessments.

Multiple and varied attempts to produce reasonably accurate wetland delineations were made and assessed based on previously documented environmental characterizations of the island, *a priori* knowledge, and concurrent visits from biologists in the field.

2.0 TECHNICAL APPROACH

ENVI image processing software was used to analyze the GeoEye data in an attempt to identify and map boundaries of potential wetlands and associated wetland and upland plant communities. GIS shape files from previously delineated jurisdictional wetland areas on Navy lands in Guam were used to identify reference wetland signatures to begin preparation of a draft wetland map for follow-up field verification. Additional ancillary data layers were provided, including previous Navy wetland delineations, soil maps, hydrology, NWI delineations, LiDAR, high resolution aerial photography, and topographic data. A TEC Inc. biological field scientist having wetland delineation expertise provided technical assistance and guidance during the course of the project.

3.0 PRELIMINARY ASSESSMENT OF GEOEYE-1 DATA

Satellite image products provided by GeoEye, Inc. included:

- 0.5 meter panchromatic (tiled) TIFF files, with JPEG “quicklook” images;
- 0.5 meter (pan-sharpened) tiled, true color composite files in TIFF format, Mr. SID format, and JPEG quicklooks;
- 2.0 meter, 4-band multispectral imagery (un-tiled) in multiple-file, TIFF format;
- Related documentation, metadata, and ancillary files.

[1] Attachment 1 – GeoEye-1 Sensor Specifications

All spatial data had been geocorrected and georeferenced to Universal Transverse Mercator (UTM) projection, Zone 55, WGS84 horizontal datum, units = meters.

Because wetlands identification and delineation were the primary goal of this study, the 2-meter multispectral data set was considered of greatest value. The four spectral bands were delivered as four separate 1-band TIFF files. Since most post-processing procedures would require that the bands reside within a single file, the individual bands were merged or "stacked" into a single 4-band composite file. Of concern, however, was the fact that the GeoEye data were delivered as 8-bit digital numbers, limiting the dynamic range to 256 digital numbers. GeoEye-1 is capable of collecting and storing 11-bit data, providing a much larger dynamic range of 2048. Therefore, a request to GeoEye for 11-bit TIFF files was made and fulfilled shortly thereafter.

Overall image quality of the multispectral data appeared good visually in terms of noise and atmospherics. Tropical/maritime climates are notoriously troublesome in terms of acquiring cloud-free imagery. Ordinarily, image segments from multiple overpasses are pieced together to produce a relatively “cloud-free” mosaic image. However, potential problems arise from combining scenes acquired at different periods. For example, over the course of time, there are typically changes in scene composition and conditions, changes due to seasonality, differences in sun/view angle conditions (BRDF), and variations in the atmosphere. These variations all lead to alterations in the spectral character of the scene. The spectral continuity across an area is often compromised, which can have a negative impact on post-processing efforts, including image classification. The entire GeoEye mosaic of Guam appears to have been constructed of segments from up to 12 different satellite scenes (see Figure 1).

Cloud cover/shadow impairment within the initial priority study areas was estimated at 8 percent, which is generally considered acceptable for this geographic region.

An earlier preliminary unsupervised classification, performed prior to receiving ancillary data, suggested that certain areas suspected of being “wetlands” may be spectrally distinct and, thus, separable. However, because of the highly seasonal rainfall and well-drained soil characteristics of the island, many potential “wetlands” are not perennial, resulting in either errors of omission or errors of commission, depending upon conditions on the ground at the time of data capture. Therefore, a more robust classification approach relying, at least in part, on the identification of indicator species of plants may be needed to achieve better classification accuracy. Such a classification may, however, require data of higher spectral, spatial, and radiometric resolution to discriminate the various vegetation types. Therefore, future efforts may consider the advantages of using airborne hyperspectral data. In addition to offering higher resolution, airborne collection affords greater flexibility in collection scheduling compared to satellite systems, resulting in imagery with fewer atmospheric artifacts such as haze and clouds.

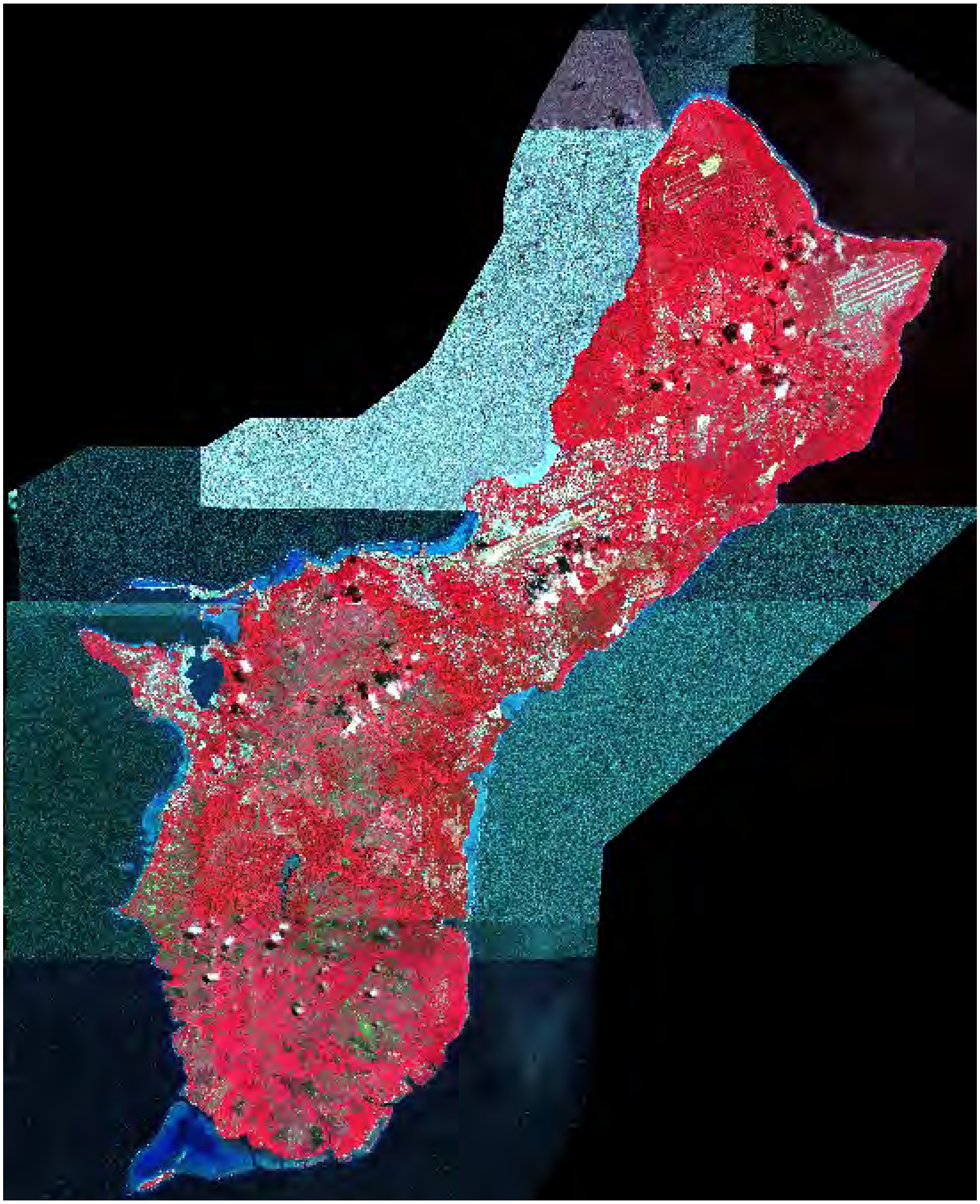


Figure 1. False color composite image (R = infrared, G = red, B = green) of the GeoEye-1 scene of Guam. The multiple segments from different satellite scenes mosaicked together to form a relatively "cloud-free" dataset are quite evident.

4.0 WETLAND IDENTIFICATION AND DELINEATION METHODS

4.1 Data Preparation and Preliminary Classification

Preliminary wetlands classification efforts for the island of Guam focused on select locations designated as “priority areas.” These areas were selected to serve the purpose of guiding subsequent ground truthing campaigns in the field. The field work validated conditions on the ground, specifically with regard to a general wetland verses non-wetland designation. This spatial information was used to help “train” the computer to identify/classify wetland areas.

A priori information in the form of ancillary data provided by the contractor served as reference sources and provided initial input for base classifications attempts. Early computer classifications were based entirely on GeoEye-1 spectral bands alone. GeoEye multispectral data consists of four rather wide spectral channels positioned in the visible and near infrared portions of the electromagnetic spectrum – blue, green, red, and near infrared.

Preliminary classifications were performed using unsupervised clustering algorithms (Isodata and K-means methods) prior to the collection of field data. Wetland maps compiled for the Navy by AECOS in 2009 were available and were considered accurate in the vicinity of Apra Harbor; therefore, areas identified therein as “wetland” were used as surrogate training sites. All non-wetland areas were masked from subsequent analyses, so that only “wetland” areas were included in the unsupervised classification routines. This strategy was adopted in an effort to segregate areas previously designated as “wetland” into spectrally distinct classes. The spectral signatures of these classes could then be used as input for the identification of similar wetland types across other areas of the island using supervised classification techniques.

A pixel purity process for the collection of end member pixels within the image was also attempted, though with little success. The algorithm routinely overlooked what was considered “pure” wetland end members signatures. And, without an exhaustive characterization of virtually every end member comprising the wetland areas, such an approach is simply not viable.

After several rounds of unsupervised classifications to generate distinct wetland categories, approximately 20 “wetland” classes were used as training data for extrapolating the classification to other areas (see Figure 2). Several supervised classification techniques were employed in an attempt to achieve optimal results – Parallelepiped, Minimum Distance, Mahalanobis Minimum Distance, Maximum Likelihood, and Spectral Angle Mapper. Statistical probability maps (or “rule” images) were also generated and used post-classification to refine results using a Rule Classifier.

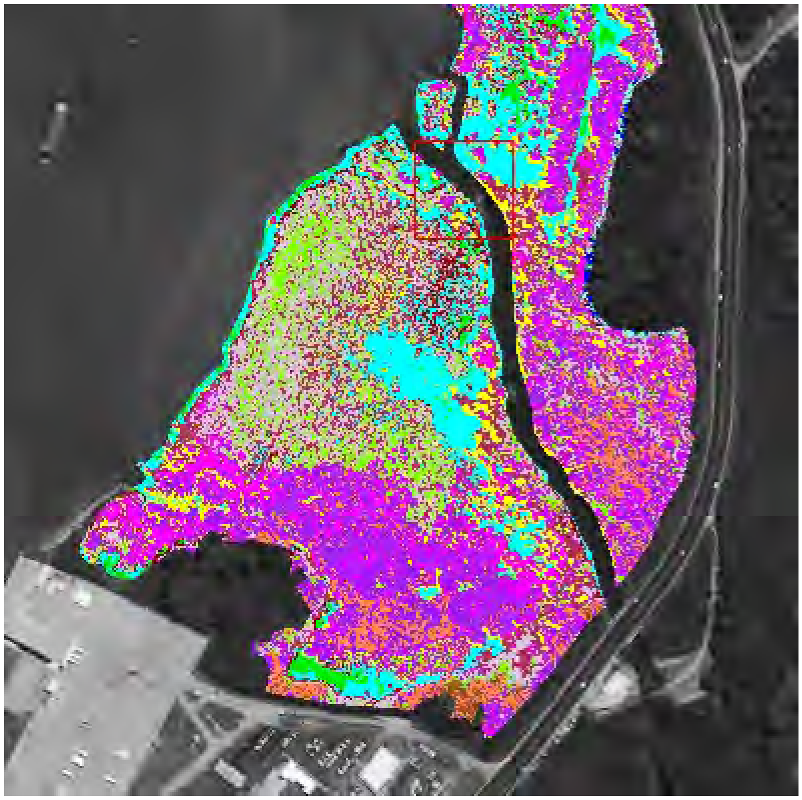


Figure 2. Results of an unsupervised classification (or clustering algorithm) performed within the confines of previously designated "wetland" areas. Potentially, the different classes indicate spectrally distinct groups of pixels.

The resulting classified maps exhibited what appeared to be extensive errors of commission. Areas presumably non-wetland (upland) were being categorized as wetland. Examination of spectral response patterns among wetland and upland areas showed a high degree of similarity, resulting in the inability of the classifier to adequately separate the two.

In an attempt to maximize variability within the dataset, and thereby increasing class separability, a canonical form of Principal Component Analysis (PCA) was performed. Typically, PCA is used in image processing to reduce an overwhelming amount of redundancy in multi and/or hyperspectral data sets, yielding a relatively small set of spectral bands that collectively contain over 99% of the information content of all the original bands. With only four spectral channels in the GeoEye dataset, data redundancy was not an issue, however, performing a Principal Component Analysis based on statistics derived from target vegetated areas on the image would hopefully produce new PC channels with increased variance among targeted areas, resulting in greater separability.

In addition to Principal Component Analysis, an examination of spectral signatures from various wetland and non-wetland areas suggested a slight difference in the spectral curve from the green "peak" to the near infrared "shoulder" of the spectrum, sometimes called the "red well." The dip, notable in the red wavelengths of vegetated spectra, generally appeared shallower in vegetated areas believed to be wetland compared to non-wetland. Mathematical manipulation of three spectral channels – green, red, and infrared – produced a synthetic channel characterizing this “red well” which was included in subsequent analyses.

Available elevation data was also integrated into the analyses since topography was believed to be correlated with wetlands. Five-foot digital contours provided by the contractor were used to generate a raster digital elevation model (DEM), which was then used to create a “slope” map (see Figure 3). Most wetlands were observed to be in areas of less than 6 degrees slope.

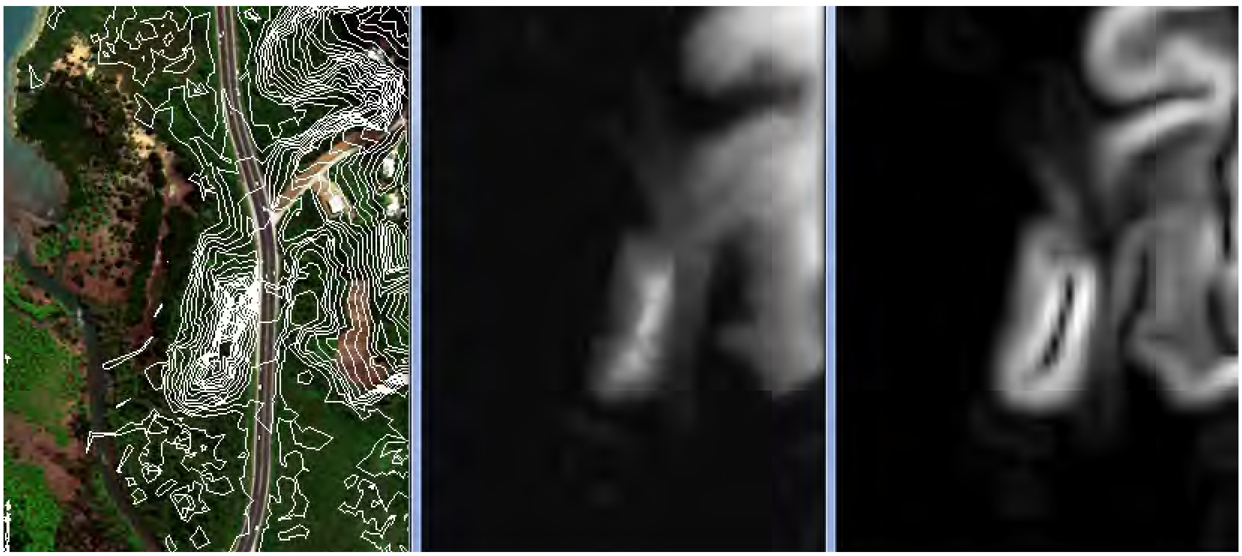


Figure 3. Five-foot digital contours provided by the contractor (left) were converted to a digital elevation model (center), which was then processed into a topographic slope map (right). This information was used to constrain the classification of wetlands to low, flat areas.

A new enhanced data set consisting of 10 channels – the four original GeoEye spectral bands, the four Principal Component bands, the “red well” band, and the “slope” channel – was used as input for subsequent classification attempts. Data values for the latter six channels were scaled for the purpose of matching the general dynamic range of the four original spectral channels and to eliminate negative pixel values. While overall results seemed to improve, separability between classes was still not sufficient to clearly distinguish all wetland from non-wetland areas. The greatest confusion appeared to exist between forested communities where underlying substrate is not visible to the sensor – i.e. the signal is predominantly canopy reflectance. Open wetland areas (non-vegetated, herbaceous, and macrophytic wetlands) appeared to be more accurately identified; although, certain open wetland areas had spectral signatures very similar to cultural features, such as paved surfaces, resulting in classification errors.

4.2 Targeted Supervised Classifications - Phragmites

Multiple attempts to improve classification accuracy were made using various combinations of spectral and non-spectral image channels, and by trying several different classification techniques. Because a considerable level of confusion between wetlands and non-wetlands plagued basically all classification attempts, the decision was made to focus on individual plant species that could potentially serve as indicators of wetland conditions. Phragmites is one such species. However, Guam also contains sugarcane, which tends to be found in non-wetland areas, but has a spectral signature very similar to that of phragmites (see Figure 4). In fact, the two species are nearly indistinguishable as viewed on high resolution aerial photography. Although some success was achieved in identifying areas of phragmites, the spectral similarity with sugarcane was problematic and the classification results, therefore, somewhat unreliable (see Figure 5).

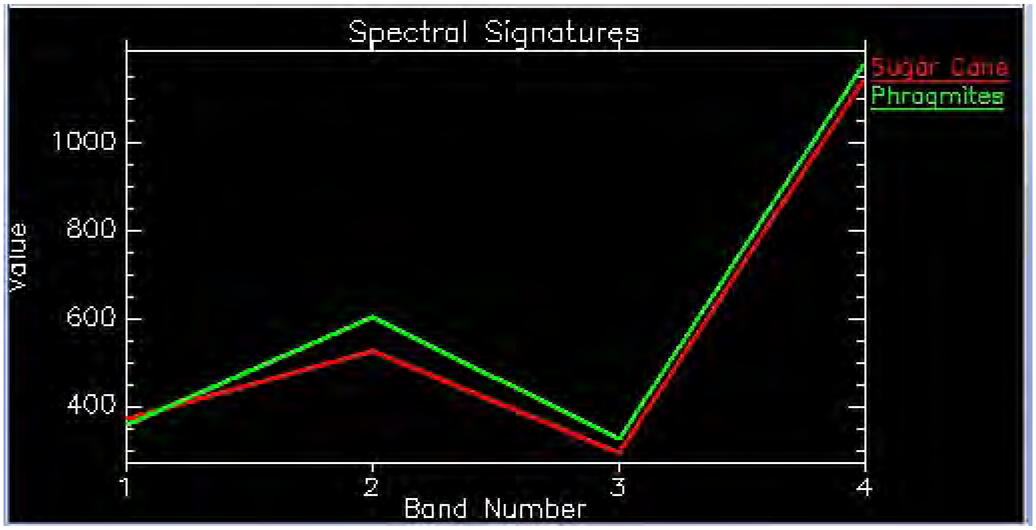


Figure 4. Spectral response patterns (signatures) of two different plant genera – sugarcane and phragmites. Variations in such spectral signatures naturally occur according to variations in areas/conditions. The similarity shown here illustrates the difficulty encountered in trying to separate the two on the imagery.

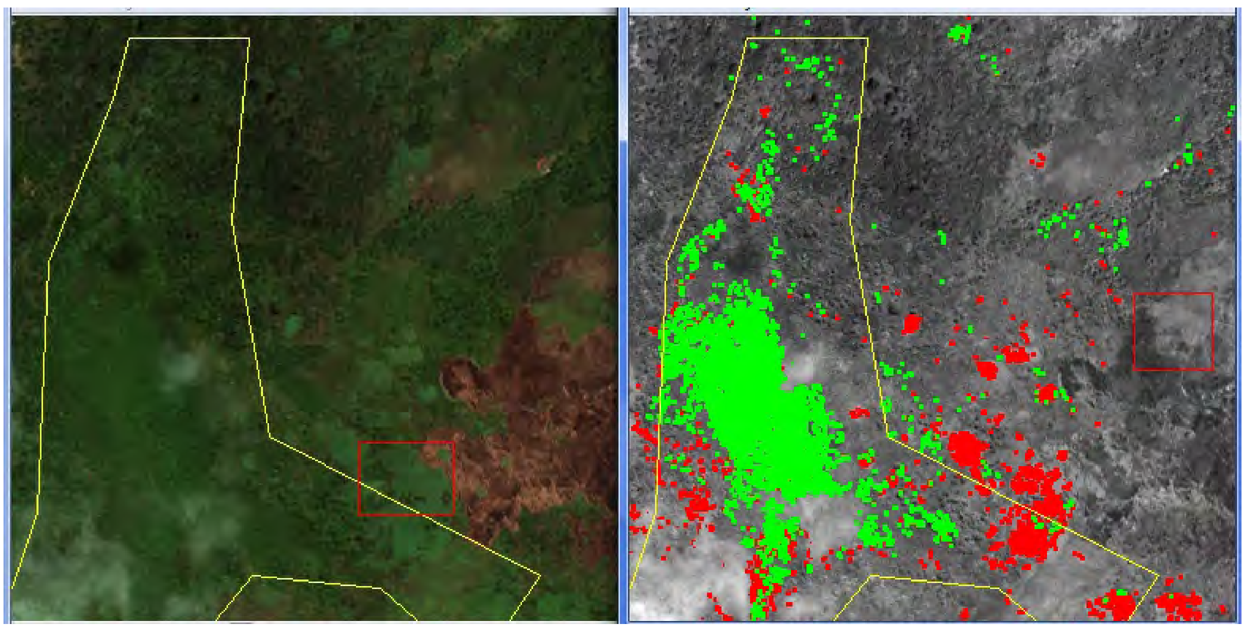


Figure 5. Some success was achieved in delineating phragmites and sugarcane, which are quite similar spectrally. The area in southern Guam has a mix of both in close proximity – phragmites shown in green and sugarcane in red.

4.3 Targeted Supervised Classifications – Open Water

Open water areas located in the northern half of Guam were extracted using the four GeoEye spectral channels. Again, reflectance characteristics between water bodies and other natural and man-made surfaces on the island were quite similar given the four rather broad spectral channels. In particular, water bodies were often confused with asphalt surfaces, certain roofing materials, and various shadowed surfaces. To compound the confusion, spectral response patterns of water bodies were inconsistent due to variations in sediment load, algae content, depth, and solar glint. Conventional statistically based classification routines alone proved insufficient at extracting open water areas. Instead, a "decision tree" algorithm was developed to move the spectral data through a series of binary rule-based criteria to eliminate non-open water features in a stepwise fashion. In this case, six criteria were used to produce an open water class. The criteria included overall visual-near infrared (VNIR) brightness, infrared (IR) brightness, existence of a green spectral "peak," existence of a negative red "elbow," magnitude of the green peak, and blue maximum. With the exception of "sun glint" resulting from the specular reflectance of sunlight off the surface of the water, directly into the sensor, the classification of open water areas was deemed successful.

4.4 Targeted Supervised Classifications - Mangrove

Mangroves in the Apra Harbor region were considered to be good indicators of wetland conditions and were therefore targeted for identification. Several types of mangrove exist on Guam; some more spectrally distinct than others. Avicennia, which has notably light green foliage, appears to be one of the few plants on the island that is spectrally distinct using the four broad spectral bands of GeoEye. However, mangroves exhibiting darker foliage, such as Rhizophora, have a spectral signature much like that of several other plant species on the island, resulting in errors of commission. In an attempt to accentuate the slight spectral differences that exist between mangrove and other plant species, the ten channel data set used previously was subjected to derivative analysis. This procedure characterizes the band-to-band changes in the signature, essentially emphasizing spectral signature shape. The ten derivative channels improved overall classification of mangrove, but did not reduce errors of commission to an acceptable level. However, the classification did highlight general areas of mangrove rather well; thus, facilitating subsequent mapping efforts (see Figure 6). High resolution scanned color photography was used in conjunction with the mangrove classification to successfully digitize mangrove-dominant wetlands. In fact, a comparison of the digitized mangrove polygons with previously mapped mangrove areas from the AECOS Navy wetland delineations shows a rather large discrepancy, suggesting a higher level of accuracy associated with the delineations derived herein (see Figure 7).

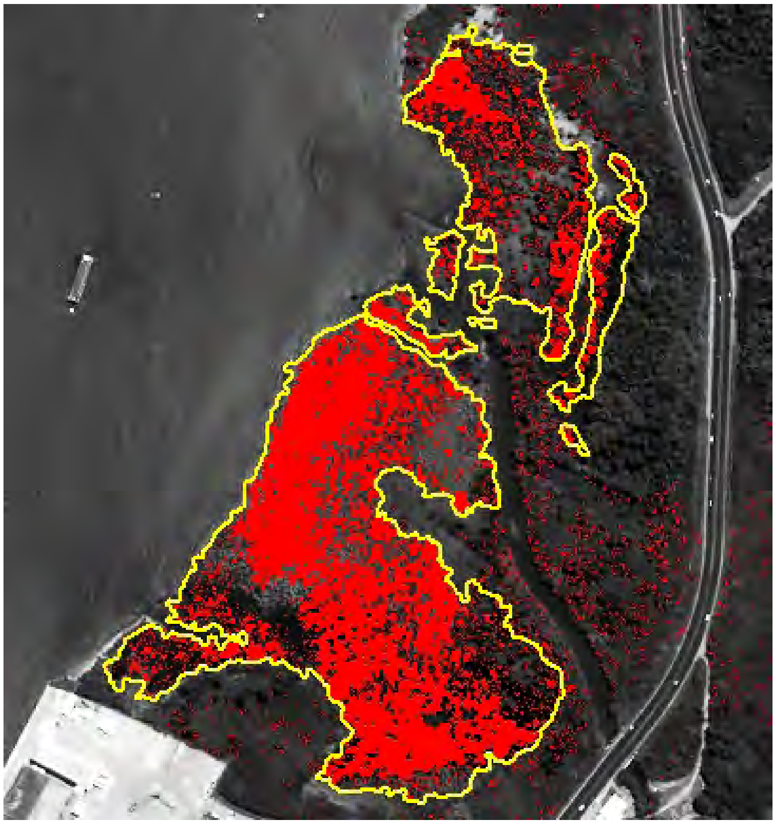
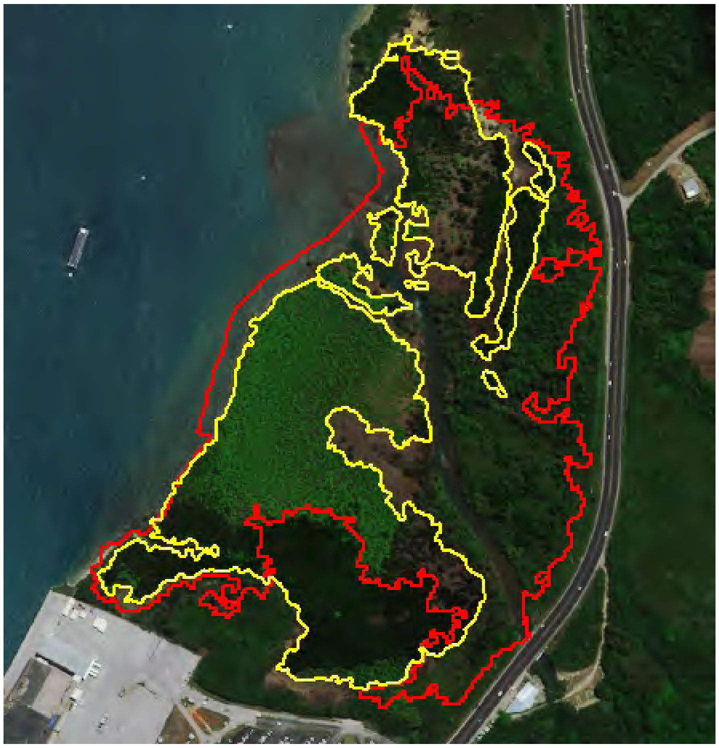


Figure 6. The mangrove classification (red) of the GeoEye data was used to facilitate the delineation of mangrove-dominant wetlands (yellow polygons).

Figure 6. The Mangrove wetland delineations compiled from a combination of the GeoEye classification and the high resolution color aerial photography (yellow polygons) was deemed more accurate than earlier AECOS Navy wetland delineations (red polygons).



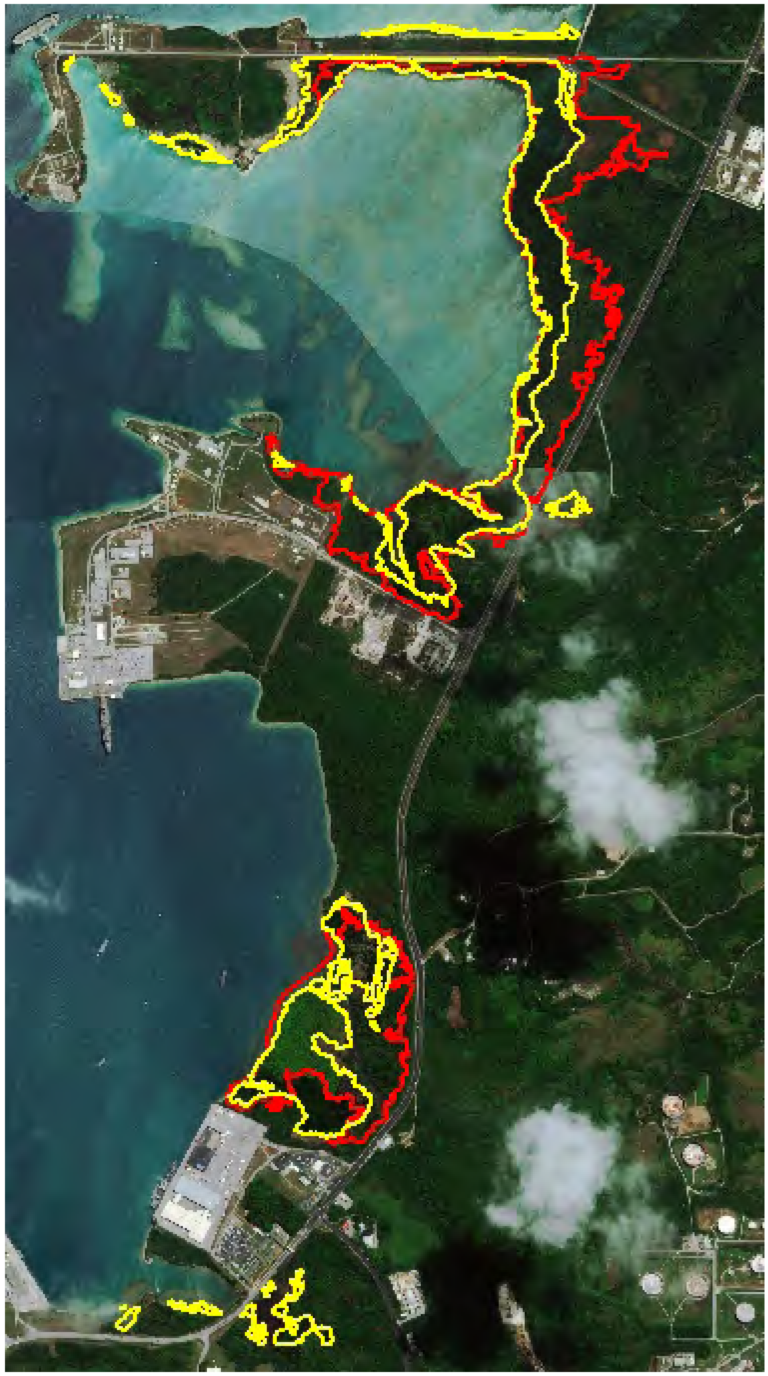


Figure 7. Comparison of mangrove wetland delineations compiled during this study (yellow polygons) with the earlier AECOS Navy wetland delineations (red polygons) in the Apra Harbor area of Guam. Several areas of mangrove were missed entirely by the AECOS Navy map.

5.0 Conclusions

Without question, remote sensing has been shown to be an invaluable tool in mapping environmental phenomena, including wetland conditions. In this particular study, wetland classification/mapping accuracy proved to be a formidable task for a variety of reasons. Dense canopy frequently obscured underlying substrate, making wetland determination difficult. Given the distinct wet/dry seasons characteristic of Guam, along with moderately to highly permeable soils across much of the island, timing of data acquisition would seem pertinent – the optimal time for capturing data being soon after a major rain event. Unfortunately, the periodicity of satellite coverage and frequent cloud cover over the tropics severely limit opportunities for data collection. The GeoEye-1 coverage of the island consisted of several separate sub-scenes mosaicked together. Conditions at the time of these collections are unclear, were most likely varied, and perhaps not optimal.

In general, it is believed that the inability to produce acceptable classification results using GeoEye-1 satellite data is attributable primarily to limitations of the data. In terms of spatial resolution, radiometric resolution and, especially, spectral resolution, GeoEye may simply not be the best tool for the job. The four rather broad spectral bands seemingly provided little discriminatory capability for wetland/non-wetland communities and features found on the island of Guam.

Attachment 1

1.0 GeoEye-1 Satellite Specifications

1.1 GeoEye-1 Satellite Imagery / Sensor Specifications[2]

Satellite Imaging Corporation acquires and processes imagery from the groundbreaking GeoEye-1 satellite sensor. The satellite sensor launched on September 6, 2008

1.2 GeoEye-1: Satellite Sensor Characteristics

The following specifications are courtesy of GeoEye, and are subject to change.

IMAGING & COLLECTION SPECIFICATIONS

Launch Date	September 6, 2008 11:50:57 to 11:52:21 AM PST
Camera Modes	• Simultaneous panchromatic and multispectral (pan-sharpened) • Panchromatic only • Multispectral only
Resolution	0.41 m / 1.34 ft*[3] panchromatic (nominal at Nadir 1.65 m / 5.41 ft* multispectral (nominal at Nadir
Metric Accuracy/Geolocation	CE stereo: 2 m / 6.6 ft LE stereo: 3 m / 9.84 ft CE mono: 2.5 m / 8.20 ft These are specified as 90% CE (circular error) for the horizontal and 90% LE (linear error) for the vertical with no ground control points (GCP's)

[2] Satellite Imaging Corporation GeoEye -1

[3] Data reflects ground sample distance resolution at Nadir for exclusive use by the U.S. government and any foreign government that the U.S. government may designate. Imagery sold to commercial customers will be resampled to 0.5-meter resolution. GeoEye's current operating license with NOAA does not permit the commercial sale of imagery below 0.5-meter resolution

Swath Widths & Representative Area Sizes	• Nominal swath width - 15.2 km / 9.44 mi at Nadir • Single-point scene - 225 sq km (15x15 km) • Contiguous large area - 15,000 sq km (300x50 km) • Contiguous 1° cell size areas - 10,000 sq km (100x100 km) • Contiguous stereo area - 6,270 sq km (224x28 km) (Area assumes pan mode at highest line rate)
Imaging Angle	Capable of imaging in any direction

Revisit Frequency at 684 km Altitude (40° Latitude Target)	**Max Pan GSD (m)**	**Off Nadir Look Angle (deg)**	**Average Revisit (days)**
	0.42	10	8.3
	0.50	28	2.8
	0.59	35	2.1

Daily Monoscopic Area Collection Capacity	Up to 700,000 sq km/day (270,271 sq mi/day) of pan area (about the size of Texas). Up to 350,000 sq km/day (135,135 sq mi/day) of pan-sharpened multispectral area (about the size of New Mexico)

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TECHNICAL INFORMATION

Launch Vehicle	Delta II
Launch Vehicle Manufacturer	Boeing Corporation
Launch Location	Vandenberg Air Force Base, California
Satellite Weight	1955 kg / 4310 lbs
Satellite Storage and Downlink	1 Terabit recorder; X-band downlink (at 740 mb/sec or 150 mb/sec)

Operational Life	Fully redundant 7+ year design life; fuel for 15 years
Satellite Modes of Operation	• Store and forward • Real-time image and downlink • Direct uplink with real-time downlink
Orbital Altitude	684 kilometers / 425 miles
Orbital Velocity	About 7.5 km/sec or 17,000 mi/hr
Inclination/Equator Crossing Time	98 degrees / 10:30am
Orbit type/period	Sun-synchronous / 98 minutes

MITIGATION SITE SURVEYS AND EVALUATIONS
WATERSHEDS OF SOUTHWESTERN GUAM AND APRA HARBOR
ASSESSMENT OF CORAL REEF RESOURCES

PRELIMINARY REPORT

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June 2010

EXECUTIVE SUMMARY

One of the components of the Guam and CNMI Military Relocation EIS is an examination of the environmental consequences of proposed construction of berthing and operational facilities for Nuclear Aircraft Carriers (CVN) in Apra Harbor, Guam. These actions are expected to result in impacts to reef coral communities. In order to compensate for these impacts, appropriate mitigation will be required. Prior to developing appropriate mitigation, site assessments of the potential target areas are required to establish existing conditions and provide an initial assessment of potential effectiveness of the proposed mitigation.

This report presents results of field surveys conducted in May 2010 to assess and document the existing conditions of near-shore marine resources offshore of watersheds on the southwestern coastal area of Guam from Fouha to Bile Bays, as well as the entirety of Apra Harbor west of the proposed CVN turning basin. Surveys included all reef areas extending from the shoreline to a depth limit of 60 feet. This report is considered a “quick-look” consisting of a preliminary review of results provided approximately 10 days following completion of fieldwork. A more detailed report of findings will be provided at a later date.

Surveys were conducted by collecting a total of 780 “calibration/validation” points, each of which consisted of five digital photographs comprising 3.3 m^2 of the benthic surface (294 sites were within the southwestern watersheds; 486 sites were in Apra Harbor). Preliminary results

of these surveys based on visual interpretation of benthic composition were used to develop an initial assessment of the overall reef community structure.

The overall physiographic structure of each of the four bays that receive drainage from the southwestern watersheds is similar, consisting of U-shaped bays bisected by sand-filled paleostream channels. On either side of the channels shallow reef flats extend from the shoreline to steeply sloping reef edges that extend to the sandy channel floors. The reef flats are colonized by a variety of small corals and in many cases abundant algae. The reef slopes generally consist of large colonies of *Porites* spp. Terrigenous mud from river drainage is apparent on the inner reefs of all of the bays, although in greatly varying amounts, with a north-south gradient of decreasing occurrence. The effects of mud to reef community structure are most apparent in Fouha Bay, where impacts are substantial throughout nearly the entire embayment. In Toguan and Bile Bays, the effects of sediment are restricted to the areas close to the points of river discharge, with the remainders of these bays showing virtually no effects of sediment. The reefs between the embayments consist of gently sloping platforms that extend from the shoreline to offshore sand flats. At the time of the surveys in May 2010, benthic cover of the between-bay areas was dominated by two species of algae (*Padina* sp. and *Chrysocystis fragilis*) which are known to be seasonal in occurrence and will likely disappear during the winter. Based on collected field data, there is a total of 53 acres of coral within the survey area of the southwestern watershed reefs, a total of 342 acres of frondose and turf algae, and 34 acres of mud covered bottom.

Reef structure within Apra Harbor consists generally of a shallow reef flat that extends from the shoreline to a steeply sloping reef face that terminates at the sandy floor of the Harbor. The sloping reef faces throughout the Harbor are generally fully colonized and largely dominated by a single species of coral (*Porites rus*). Several pinnacles with flat tops at depths less than 60 feet occur throughout the Harbor, with the tops and sides often completely covered with coral. Two large patch reefs (Jade Shoals and Western Shoals) at the eastern end of the Outer Harbor bound the CVN turning area. The outer (western and northern) regions of these patch reefs, examined in this survey, are colonized by extensive and diverse coral assemblages. While there is abundant calcareous sands and mud within the Harbor, there were no observations of red terrigenous sediment that occurred on the reefs within the embayments receiving input from the southwestern watersheds. Based on collected field data, there are a total of about 129 acres of coral within the Apra Harbor survey areas, and about 79 acres of algae and algal turf.

Results of these assessments will be used by the Navy to evaluate the potential for effective mitigation in the form of conducting improvements to the watershed sites and potential artificial reef sites within Apra Harbor.

INTRODUCTION and PURPOSE

Significant impacts to coral resulting from the construction of a CVN transient pier and supporting navigational channel are anticipated. Prior to developing appropriate mitigation, a site assessment is needed to establish existing conditions and to evaluate the potential of those sites for mitigating impacts to coral resources.

This report presents results of surveys conducted in May 2010 to assess and document the existing conditions of near-shore marine resources offshore of watersheds on the southwestern coastal area of Guam. In addition, as Apra Harbor is under consideration for mitigation actions, surveys of the entirety of the Harbor were also conducted. This report is considered a “quick-look” consisting of a preliminary review of results provided approximately 10 days following completion of fieldwork. A more detailed report of findings will be provided at a later date.

METHODS

The U.S. Navy has requested quantitative evaluations of the composition of benthic habitats at several nearshore areas of the Island of Guam that may serve as potential mitigation sites for dredging projects. These habitats include: 1) reef areas potentially affected by terrigenous sediment emanating from stream flow generated from upland watersheds which may be affected by anthropogenic factors, and 2) western Outer Apra Harbor. These targeted regions cover a nominal area of approximately 27,000 acres (~11 km^2). To best complete this task with the limited available resources a uniform set of field data was collected that quantitatively describes benthic community structure. The resulting data set provides input data for application of remote sensing techniques designed to generate habitat maps of the subject reef areas. Thus a standard remote sensing mapping project, supported by field operations, provided the necessary calibration/validation (cal/val) data to construct the best maps possible.

Collection of Field Cal/Val Data

Field operations consisted of assessing 780 cal/val sites placed strategically throughout the survey areas (294 sites off the southwestern watersheds; 486 sites in Apra Harbor). Sites were located within the 60-foot depth contour. Locations of cal/val sites were determined in the field based on investigator knowledge and visual interpretation of existing satellite “true-color” imagery with the intent of maximizing coverage of all reef areas within the survey areas. Exact site locations were defined during the course of field work using a GPS with a presumed accuracy of <1 m.

At each geo-located site, cal/val data was obtained by digitally recording the composition of the benthic surface using an underwater camera. To ensure uniformity of the area of data collection, the camera is mounted on a platform centered over a PVC frame by four legs similar to a tripod. The frame, or quadrat has dimensions of 1 m x 0.66 m, which is the same proportion as a photographic frame. Each cal/val site consists of five photo-quadrats arranged in a “cross” pattern ~5 m in diagonal, resulting in total reef surface area of 3.33 m^2, which encompasses an area of approximately four pixels of remote sensing imagery.

Photo-quadrats were “pre-analyzed” during field operations using a rapid visual interpretive method in order to obtain a preliminary data set. The rapid visual interpretation consisted of investigators examining digital images of each of the 3,900 photo-quadrats and estimating percentage cover of all benthos. The resulting data set provided the input for preliminary benthic cover maps included in the present document.

Inherent in the collection of cal/val photo-quadrat data in the southwestern coastal locations was characterization of the effects of sediment discharge from upland streams on coral communities. This characterization was conducted by swimming a water-proofed GPS over the reef surface and locating cal/val sites in areas with recognizable effects of sediment discharge (either sediment deposition *per se*, or visible evidence of damage to coral tissue from time-integrated sediment deposition). These data will be incorporated into preliminary map products to provide an estimate of the magnitude and extent of sediment effects on the surveyed reefs.

Preliminary Data Analysis

For the “quick-look” data analysis, the survey areas were broken into multiple zones. These zones encompassed all reef hardbottom area in the depth range 0–60 feet. Quick-look photo-analysis results were averaged across all sites within a given zone, providing values for mean percent cover of each general bottom-type in that zone. Zonal area coverage for each bottom-type was estimated as the percent cover of that bottom-type multiplied by the area of the zone. In total, there were nineteen zones in Apra Harbor and nine zones in the southern watershed survey area (Figures 58, 59). Table 1 shows the percent cover and area of each benthic category type within each zone of the southern watersheds, while Table 2 shows percent cover and area of each zone in Harbor.

RESULTS

Descriptions of the Survey Areas

<u>Southwestern Watersheds</u>

Figure 1 shows a map of southwestern Guam along with the boundaries of the four watersheds that are under consideration for potential coral mitigation (Umatac, Ugum, Toguan and Geus). The drainage for Geus is into the Cocos Lagoon channel and was not considered as a site for potential mitigation. The other three watersheds drain to rivers that discharge into Fouha, Umatac, Toguan, and Bile Bays. The contiguous region containing these four Bays comprised the survey area.

In general, the physiographic structure of all four bays is similar. Each bay consists of a semi-enclosed indentation in the coastline with at least one river mouth at the most landward point of the bay. The center of each bay consists of a sand-filled paleostream channel. The sides of the bays consist of shallow reef flats that extend from the shoreline and terminate in steep-sided walls that terminate on the sandy floor of the central channels. The reef flats are separated on the north and south sides of the bays by the river channel. The reef flats and central river channels through the reef are clearly visible in aerial photographs of the four bays (Figure 2 and 3). The reef areas between bays consist of rocky shorelines that extend to gently sloping fringing reef platforms that terminate to offshore sand plains.

The other dominant feature of the embayments is that each contains an inner region that is characterized by terrigenous sediment deposited by river discharge. While the general physical structure of the four bays is similar, the major difference between bays is the area extent of sediment deposition and the associated effects to reef community structure. The influence of sediment decreases in a north to south gradient with Fouha Bay exhibiting the highest effects, and Toguan and Bile Bays the least. Each of the four areas is discussed below.

Fouha Bay

The distinguishing feature of Fouha Bay is the visible effects of sediment throughout the boundaries of the embayment. While the outer shallow reef flats bordering the bay are not covered with sediment, they are relatively barren compared to similar locations at other sites (Figure 4). The inner reef flats are carpeted with a thick layer of terrigenous sediment (Figure 4). The reef slope at the margin of the central channel cut is colonized by corals, predominantly of the species *Porites rus* and *Porites lutea*, although there is substantial sediment deposition between living portions of colonies (Figures 5 and 6).

A consistent observation on the outer reef platforms at all of the survey areas in southwestern Guam was the dominance of benthic cover by two species of algae. According to researchers at the University of Guam, both of these species of algae are seasonal. One species is the “golden algae” *Chrysocystis fragilis*, which covers the bottom as weakly attached wispy fronds that are easily broken from the bottom and suspended in the water column by only the slightest of water motion (Figures 7). *Chrysocystis fragilis* occurs in Hawaii during the summer season on deep reefs that are not subject to wave action, and disappears each winter with wave energy associated with winter swell. It is likely the same pattern occurs on the southwestern reefs of Guam. This alga often attaches to the bases of living coral and may overgrow healthy coral tissue (Figure 8). While *Chrysocystis fragilis* was abundant on all the outer reefs of the southwestern watershed study sites, it was not noted within Apra Harbor.

The other extremely abundant alga throughout southwestern Guam, as well as within Apra Harbor is the brown alga *Padina* sp. (Figure 9). *Padina* occurs on the reef as clusters of cup-shaped flat blades that are lightly calcified. Throughout the areas investigated, vast meadows of these plants colonized deep reef substratum not covered by corals (Figure 9).

Umatac Bay

Umatac Bay is the largest of the survey bays. The outer reef flat on the northern side of the bay is dominated by a mixture of algae including *Padina, Turbinaria*, and *Sargassum* interspersed with small corals (Figures 10 and 11). The inner reef flat consists of large coral structures, predominantly of the species *Porites lutea*. Many of these corals area partially covered by sediment, but many large colonies are apparently healthy and able to withstand the high sediment loading of the area (Figures 12-14). The outer regions of the channel walls are colonized by nearly solid cover of corals (Figure 15). Beyond the boundaries of the bay, the offshore reef platforms are dominated by algae, although corals occur sporadically (Figure 16).

Toguan Bay

The effects of sediment input to reef communities at Toguan Bay were far less pronounced than at either Fouha or Umatac. The reef flats on the outer margins of the Bay were populated by a variety of corals and algae, with little apparent effects of sediment (Figure 17). The central channel slopes were colonized by extensive growth of *Porites rus* that extended to the channel floor (Figure 18). Directly off the mouth of Toguan stream in the center of the Bay, the reef flat was devoid of coral and consisted of a barren sediment-covered bench (Figure 18). The deep reef platforms beyond the boundaries of Toguan Bay were similar to other Bays with mixed communities of coral and algae sloping to sand plains (Figure 19).

Bile Bay

Bile Bay was somewhat unique in structure compared to the other Bays as two rivers discharge into the area (Figure 3). As at Toguan Bay, the reef flats rimming the Bay are colonized by a diverse population of small corals, except directly in front of the points of stream discharge where the reef flat is covered by a layer of terrigenous sediment (Figure 20). The reef platform between the stream discharges is populated by large colonies of *Porites rus* (Figure 21).

<u>Apra Harbor</u>

Data was collected in Outer Apra Harbor extending from Western and Jade Shoals to near the Harbor entrance (Figure 22). Several structural components comprise the Apra reefs. These structures consist of: 1) steep sloping walls along both the north (Glass Breakwater) and south (Gab Gab to Orote) margins of the Outer Harbor that terminate in the sand channel floor; 2) pinnacles that arise from the Harbor floor; and 3) shallow-topped reefs that slope to the channel floor (e.g., Western and Jade Shoals). Below are descriptions of these various zones by sector throughout Apra Harbor.

Reef structure in the northeastern sector of Apra Harbor is composed primarily of a fine-grained sandy bottom populated by a variety of corals, sponges and algae (Figures 23 and 24). Moving to the west, a shallow spur, sometimes known as “Dog-leg Reef” extends to the southeast from the northern shoreline of the Harbor. The top of Dog-leg reef is populated by a diverse variety of hard and soft corals which cover virtually the entire surface of the platform (Figures 25 and 26). Moving west from Dog-leg reef, the length of Glass Breakwater consists of a steeply sloping face that extends from the edge of the breakwater to the sand flats of the channel floor. The entire surface of the slope consists of assemblages of coral, primarily large amalgamated colonies of *Porites* rus (Figures 27 and 28). Near the western end of Glass Breakwater the bottom is littered with numerous discarded metal objects, including pipes and a bulldozer (Figures 29 and 30).

Throughout the central portion of the channel, numerous flat-topped pinnacles extent from the sand channel upward to a depth of 45-50 feet. Many of these pinnacles are completely covered with dense growth of coral than extends from the tops along the sloping sides to the channel floor (Figures 31-33). Several of the pinnacles, however, were not covered with coral, but rather consisted of rubble, along with algae and sponges (Figure 32).

Along the southern shoreline of Apra Harbor, reef structure consists of shallow reef flats that extend from the shoreline to a shallow reef crest. At the western end of the Harbor, between Kilo Wharf and Orote Point, the reef flats consist primarily of bare limestone surfaces populated by small corals (Figure 34). East of Kilo Wharf, and particularly off of Gab Gab Beach, the reef flat contains a high percent cover of algae, primarily *Padina* sp.

Seaward of the reef crest along the southern shoreline from Kilo Wharf to San Luis Beach, the reef slopes steeply, terminating at the sand channel floor. The length of the reef slope consists uniformly of solid cover of *Porites rus*, primarily dome-shaped growing in overlapping plating colonies (Figures 35 and 36).

At the present time, construction is underway to length the Kilo Wharf, located near the western end of the southern shoreline of Apra Harbor. Dredging required for the expansion has produced a cut into the reef platform (Figure 37). To the west of Kilo Wharf, the effects of dredging are evident in increased sediment bound in algal turf. Communities of *Porites rus* adjacent to the dredging site appear relatively unaffected by the construction activities (Figure 38). However, communities of *Porites lutea* located west of the dredging show distinct effects of recent sediment deposition, with many colonies at least partially dead and covered by sediment (Figure 39).

The final major reef biotope within Apra Harbor consists of large flat-topped patch reefs that rim the proposed CVN turning basin. Jade Shoals lays to the north of the turning basin and Western Shoals forms the western boundary of the basin. Western Shoals consists of three separate reefs separated by deep channels with the southernmost reef just to the north of the Big Blue Dry Dock (Figure 22). The western side of these patch reef contain some of the most varied coral communities within the Harbor, including large thickets of interconnected finely branching *Acropora formosa* (Figure 40), and dense mixed species assemblages of branching, foliose and plating forms (Figure 41).

Evaluations of Benthic Composition

Locations of calibration/validation (cal/val) sites for all of Apra Harbor are shown in Figure 42 and for the entire southwestern shoreline area are shown in Figure 43. In each of these figures, circles representing cal/val sites are scaled by color to represent percent cover of coral, with white representing no coral, and deep red representing total coral cover. For easier viewing of details of the reef, each survey area is broken up into smaller units: Apra Harbor is divided into 14 units shown in Figures 44-50, while the southwestern watersheds are shown as individual embayments in Figures 51-53.

Figure 54 shows a similar overview of the southwestern watershed bays with cal/val points scaled by color to represent percent cover of mud. Again, white represents no mud, while dark brown indicates complete mud cover of the reef. Figures 55-57 show detailed images of the bays with cal/val points color-scaled to mud content. It is evident from these figures that the highest mud content is within Fouha and Umatac Bays, while Toguan and Bile Bays contain far less muddy sediment.

In order to gain some quantitative estimates of categories of benthic cover within the survey areas, each of the survey areas were divided into zones based on reef structure (Figures 58 and 59). Percent coverage of each bottom type contained within the photo-quadrats of the cal/val sites for each zone are shown in Table 1 for the southwestern watersheds and Table 2 for Apra Harbor. The product of the benthic area of each zone and the percent cover produces estimates of cover of each bottom type (Tables 1 and 2).

Of the 401 acres of survey area within the southwestern watershed embayments, approximately 53 acres (13%) consists of coral, while about 270 acres (67%) consisted of combined algae and algal turf. Within the survey areas of the watershed embayments, approximately 31 acres, or about 8% is covered with mud.

Within the survey areas of Apra Harbor, about 129 acres of bottom cover (41%) consists of live coral, with about 25% cover (79 acres) of combined algae and algal turf. Sand and mud comprised about 14% of the bottom. It must be noted, however, that the survey sites selected did not include the sandy bottom of the Harbor, which comprises the majority of the embayment below a depth of 60 feet.

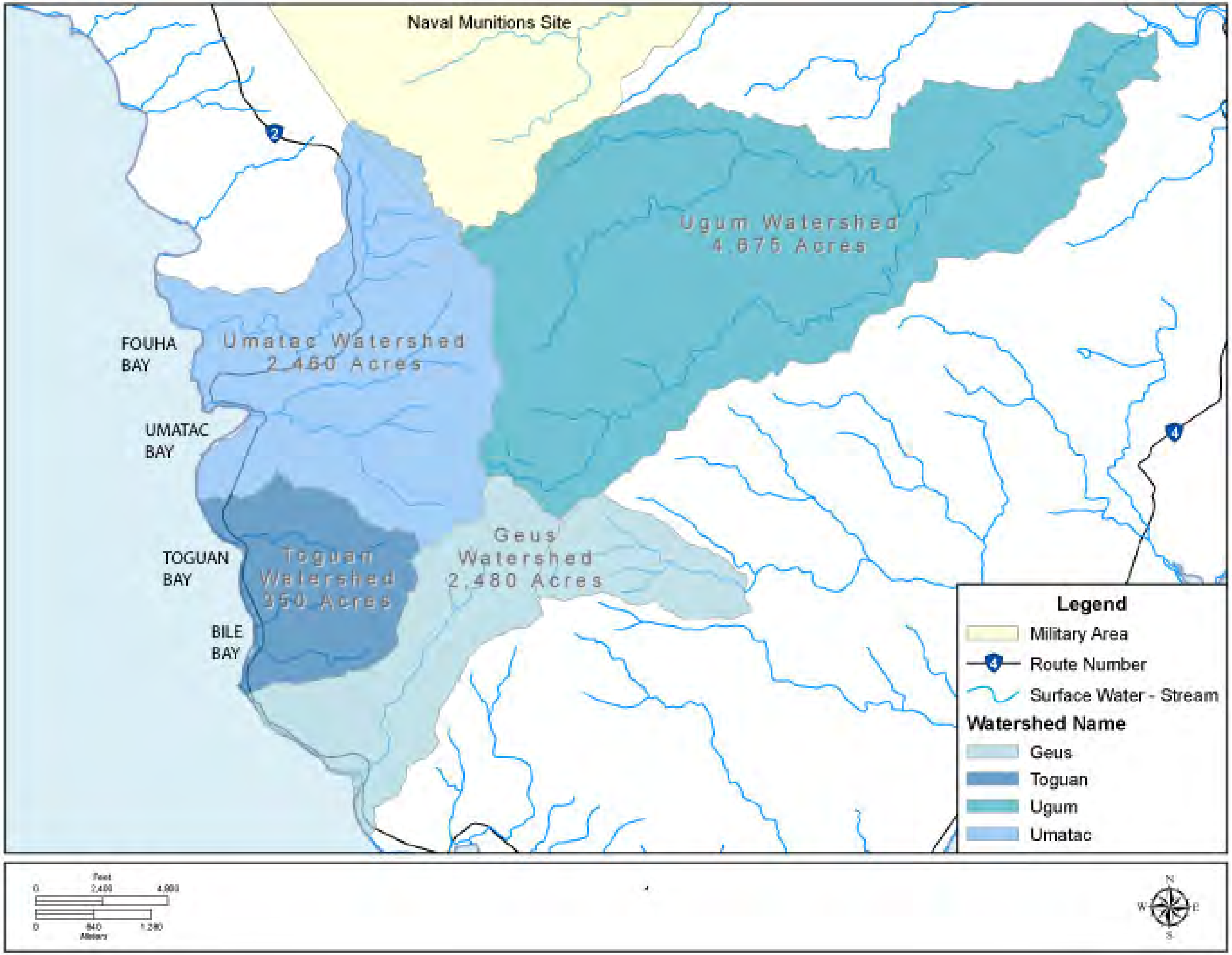


FIGURE 1. Map of southwestern Guam showing watersheds under consideration for potential mitigation actions. The four Bays shown offshore of the watersheds comprised the study area for the benthic assessments.

FIGURE 2. Ikonos satellite image of southwestern Guam showing reef structure and river channels in Fouha and Umatac Bays.

FIGURE 3. Ikonos satellite image of southwestern Guam showing reef structure and river channels in Toguan and Bile Bays.

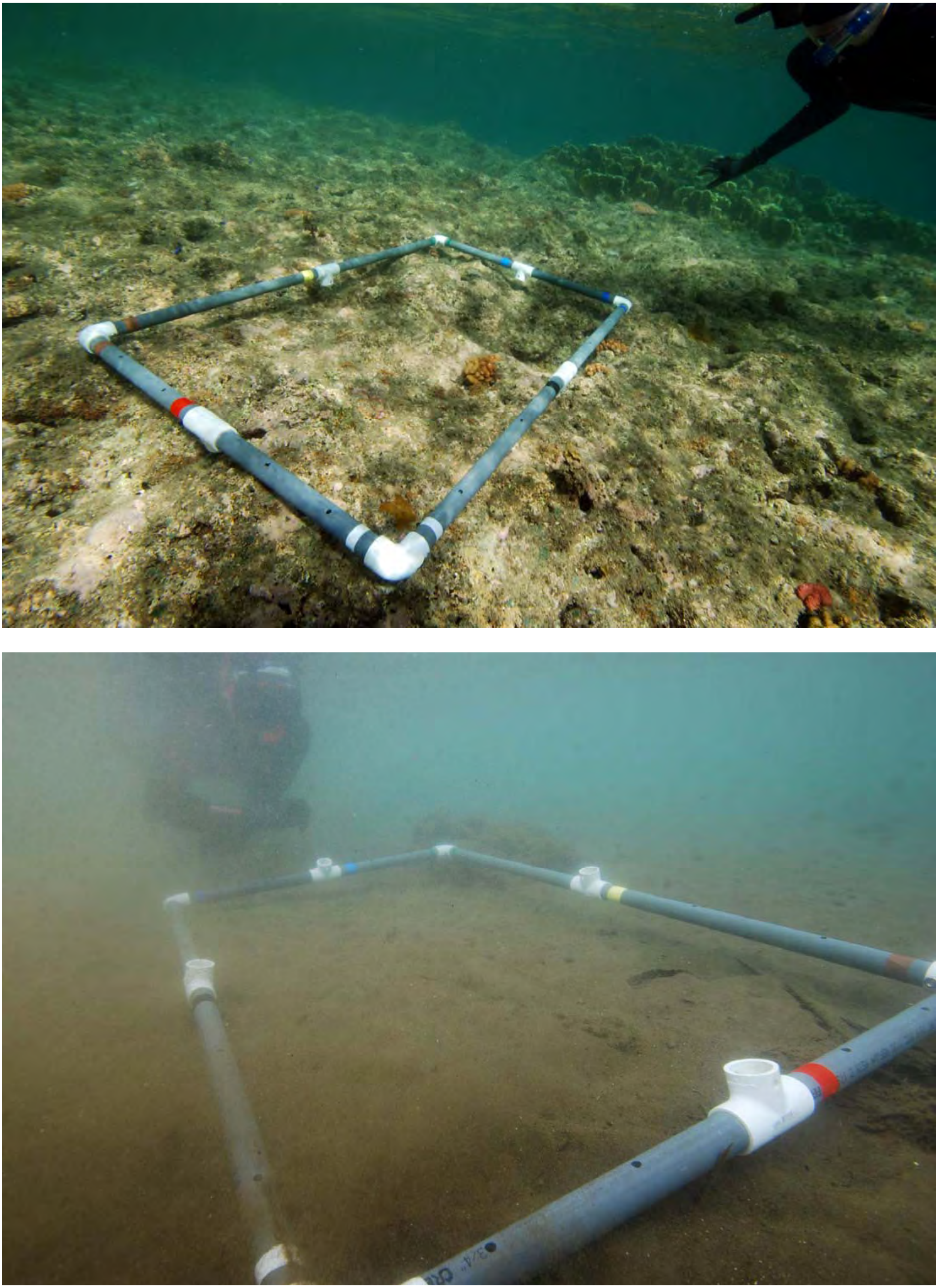


FIGURE 4. Outer (top) and inner (bottom) reef flat at Fouha Bay, southwestern Guam.

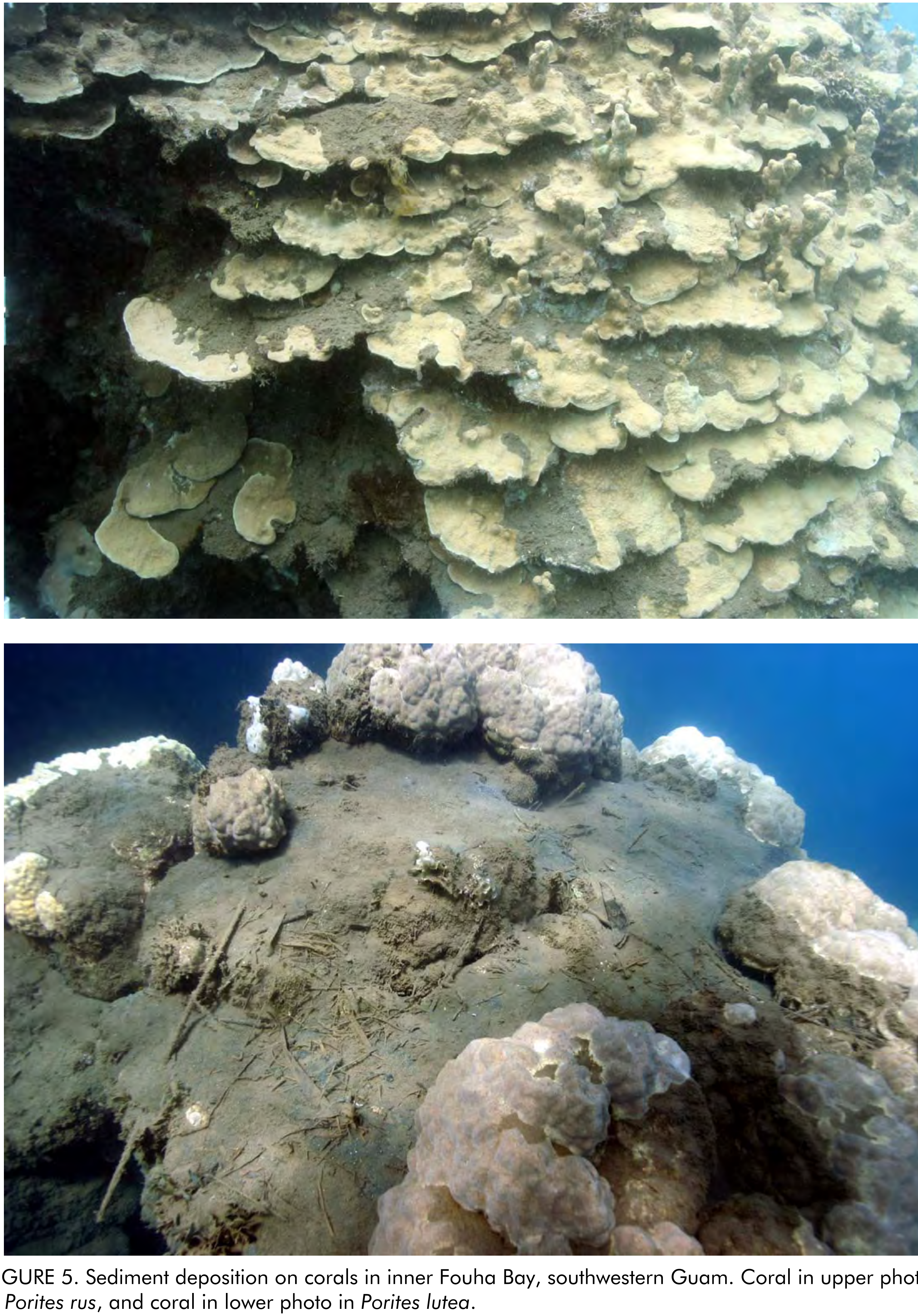


FIGURE 5. Sediment deposition on corals in inner Fouha Bay, southwestern Guam. Coral in upper photo is *Porites rus*, and coral in lower photo in *Porites lutea*.

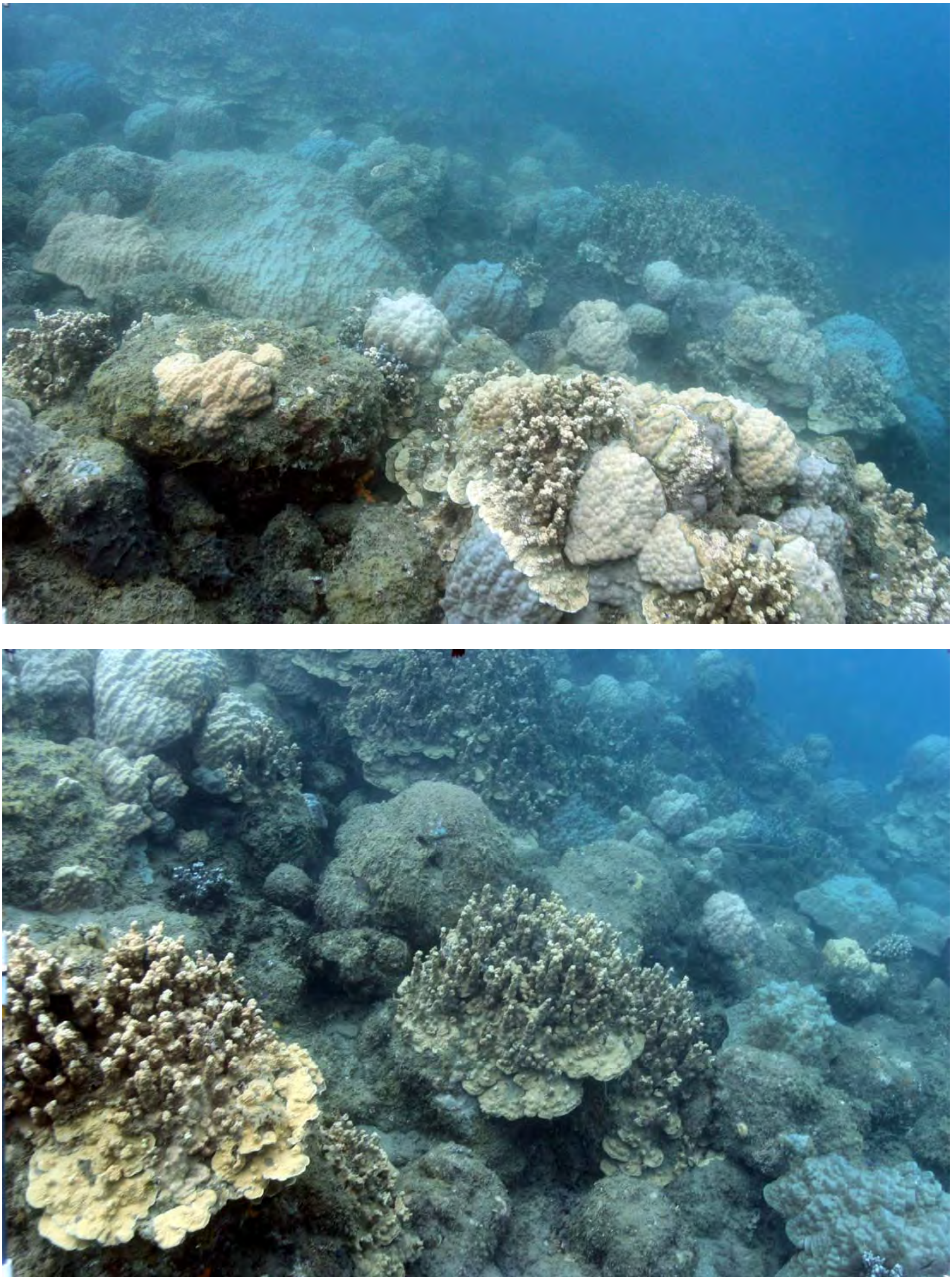


FIGURE 6. Outer channel coral communities, Fouha Bay, southwestern Guam.

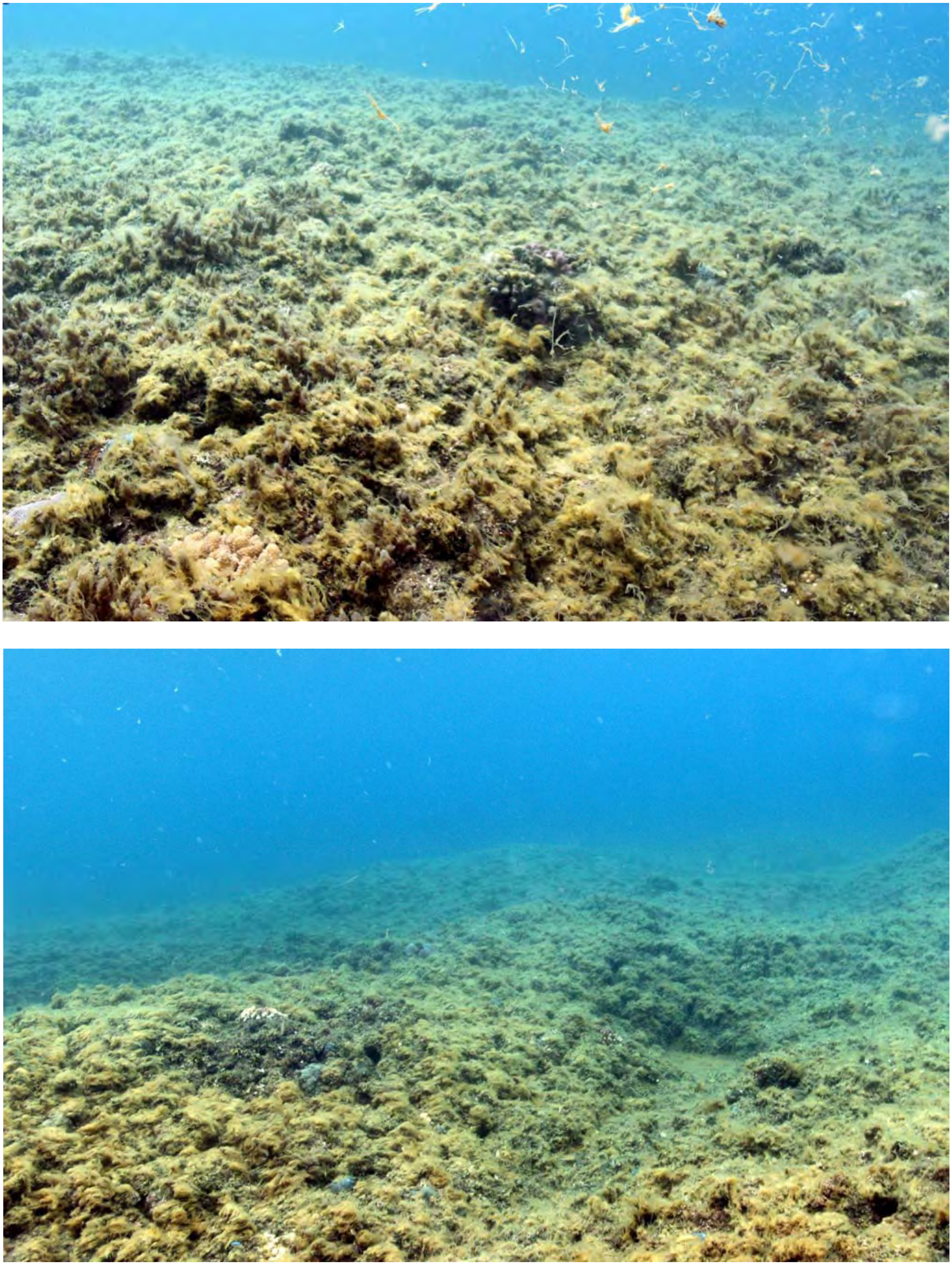


FIGURE 7. Outer reef flat (top) and reef platform (bottom) at Fouha Bay, southwestern Guam. In both areas, bottom cover is dominated by the alga *Chrysocystis fragilis*.

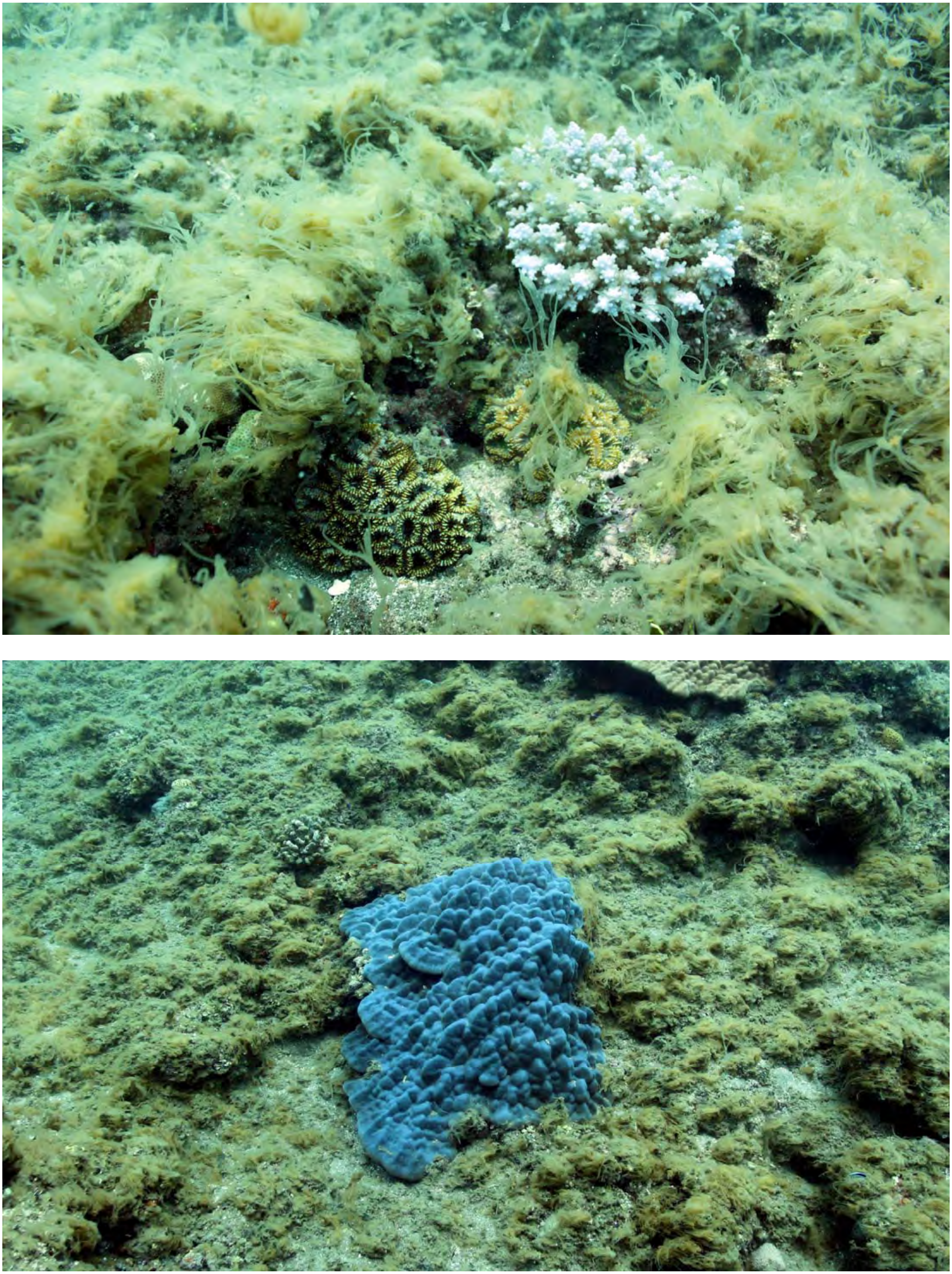


FIGURE 8. Golden alga *Chrysocystis fragilis* growing in over coral on outer reef platform in Umatec Bay, southwestern Guam.

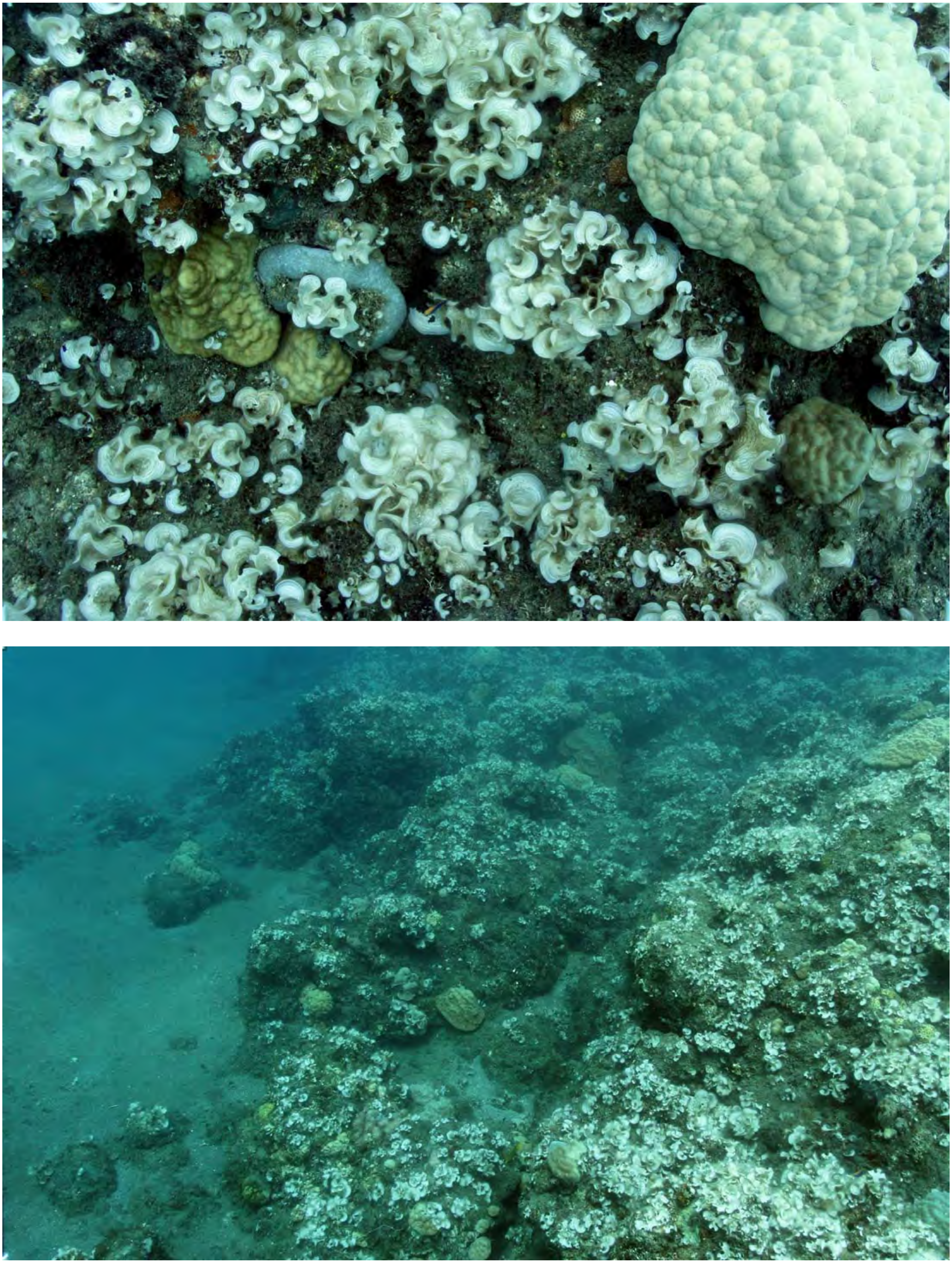


FIGURE 9. *Padina* sp. covering outer reef platform in Umatec Bay, southwestern Guam.

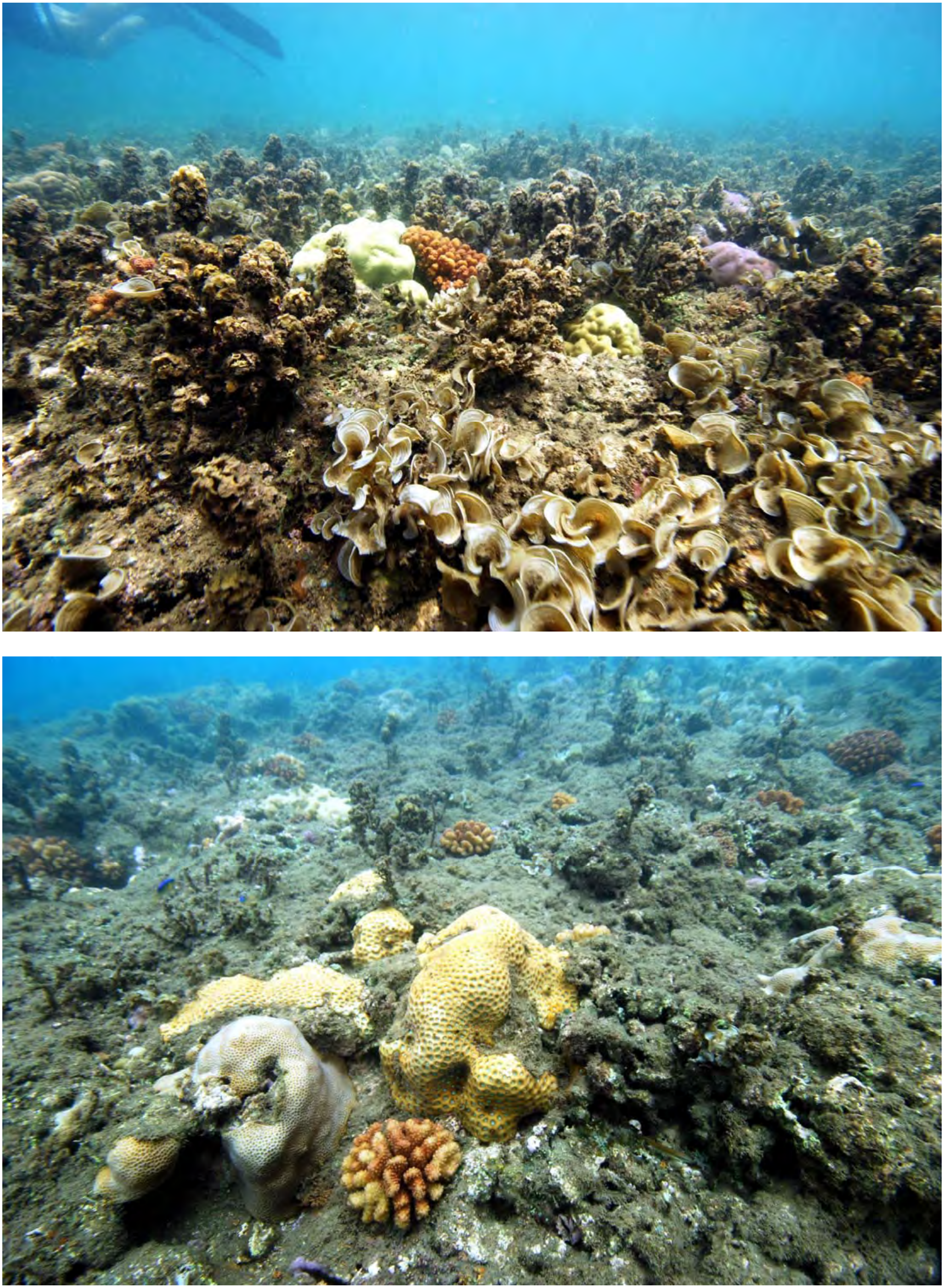


FIGURE 10. Inner reef flat off of north side of Umatec Bay, southwestern Guam.

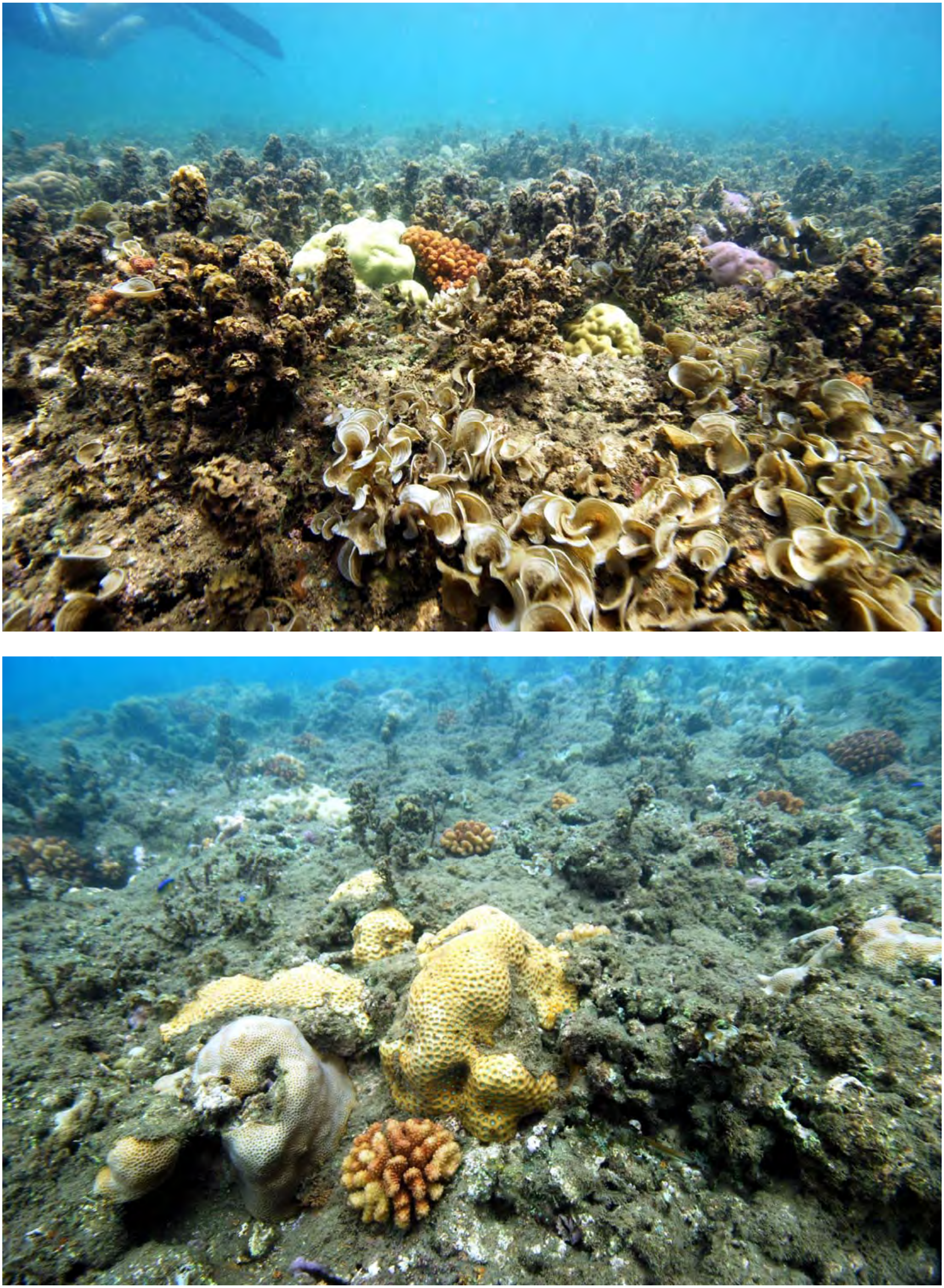


FIGURE 10. Inner reef flat off of north side of Umatec Bay, southwestern Guam.

FIGURE 11. Reef flat off of north side of Umatec Bay, southwestern Guam.

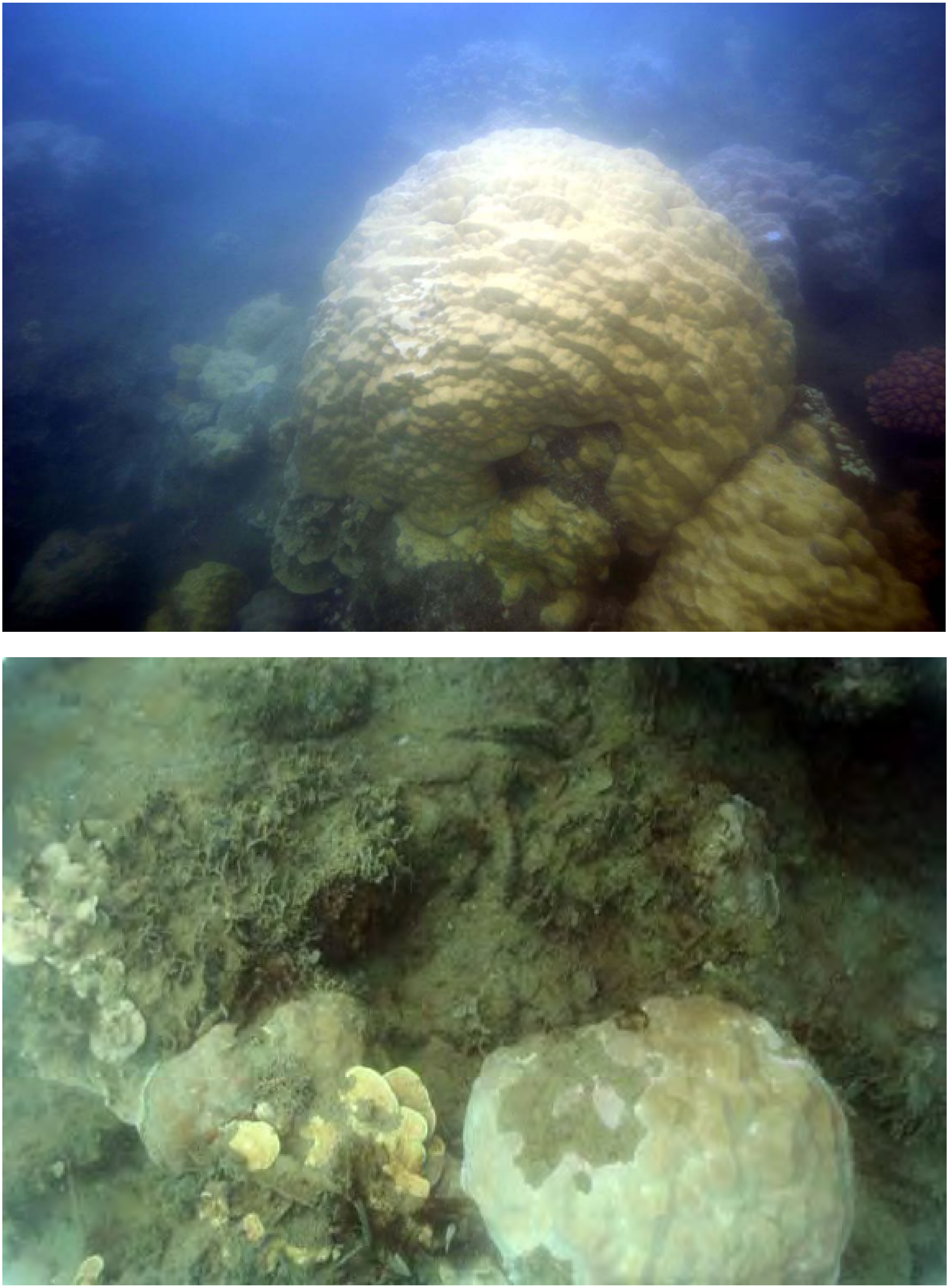


FIGURE 12. Coral colonies on inner reef at Umatec Bay, southwestern Guam.

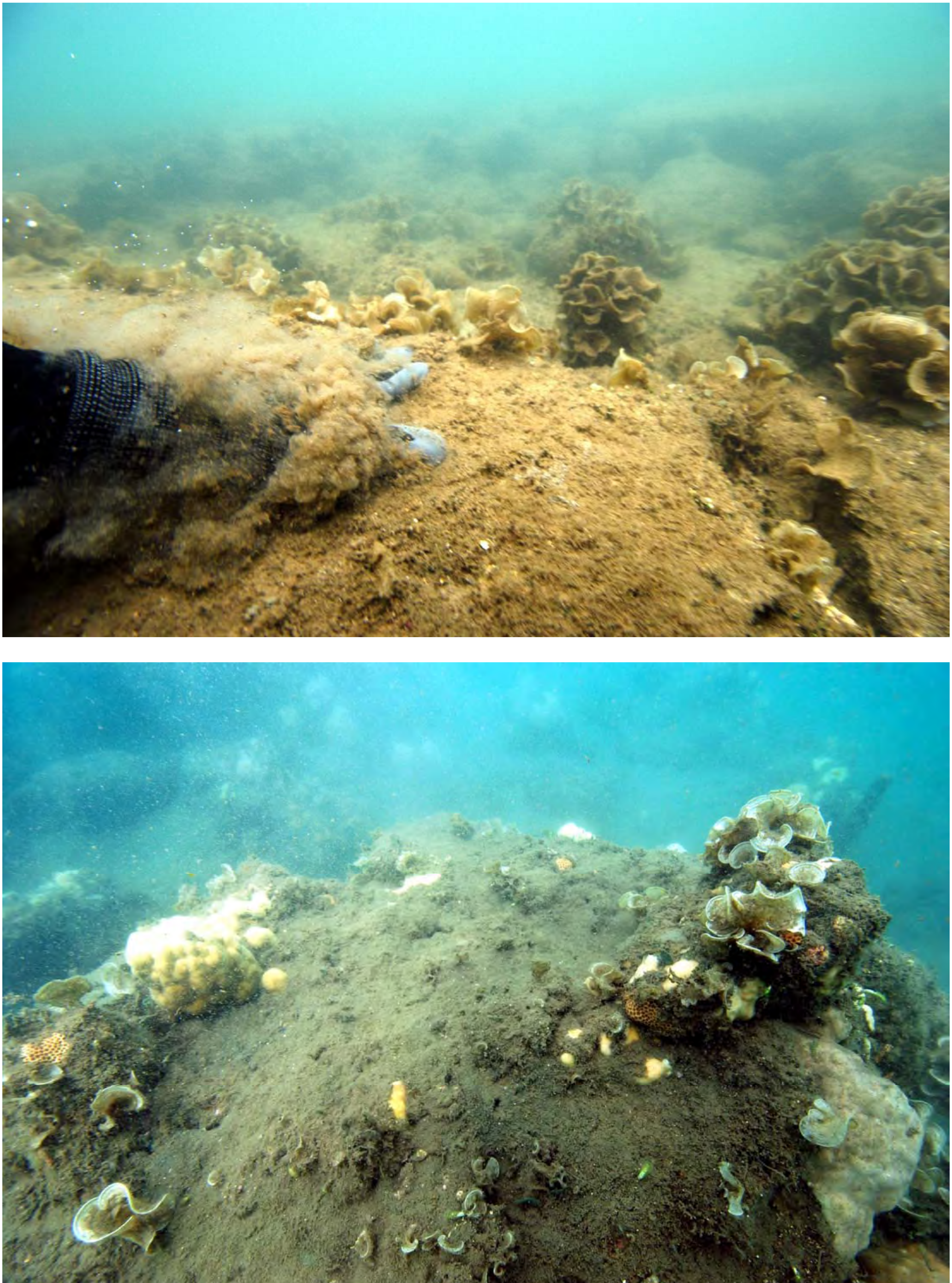


FIGURE 13. Inner reef flat off of north side of Umatec Bay, southwestern Guam. Top photo shows layer of easily resuspended sediment on reef surface.

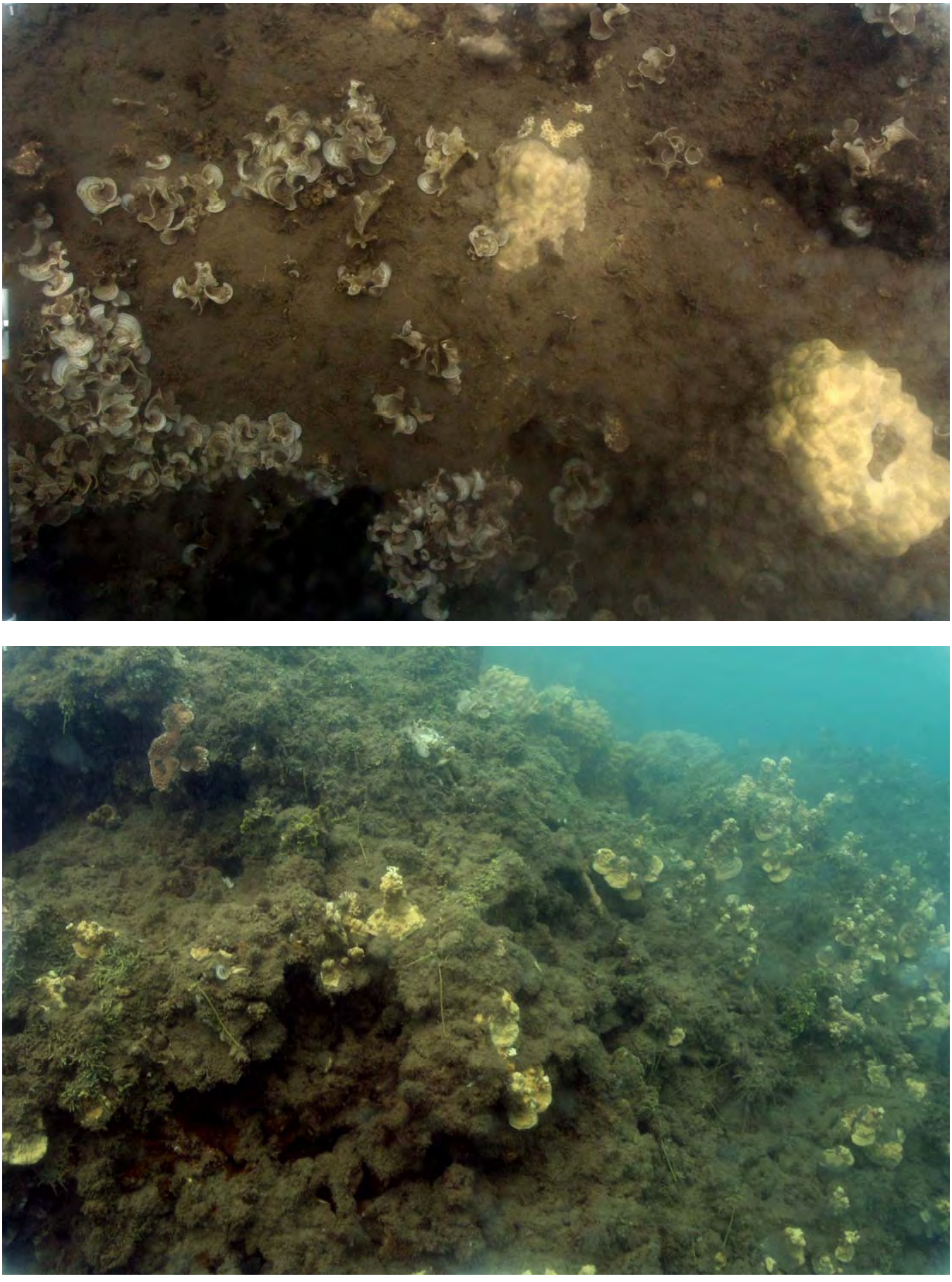


FIGURE 14. Sediment cover on inner reef at Umatec Bay, southwestern Guam.

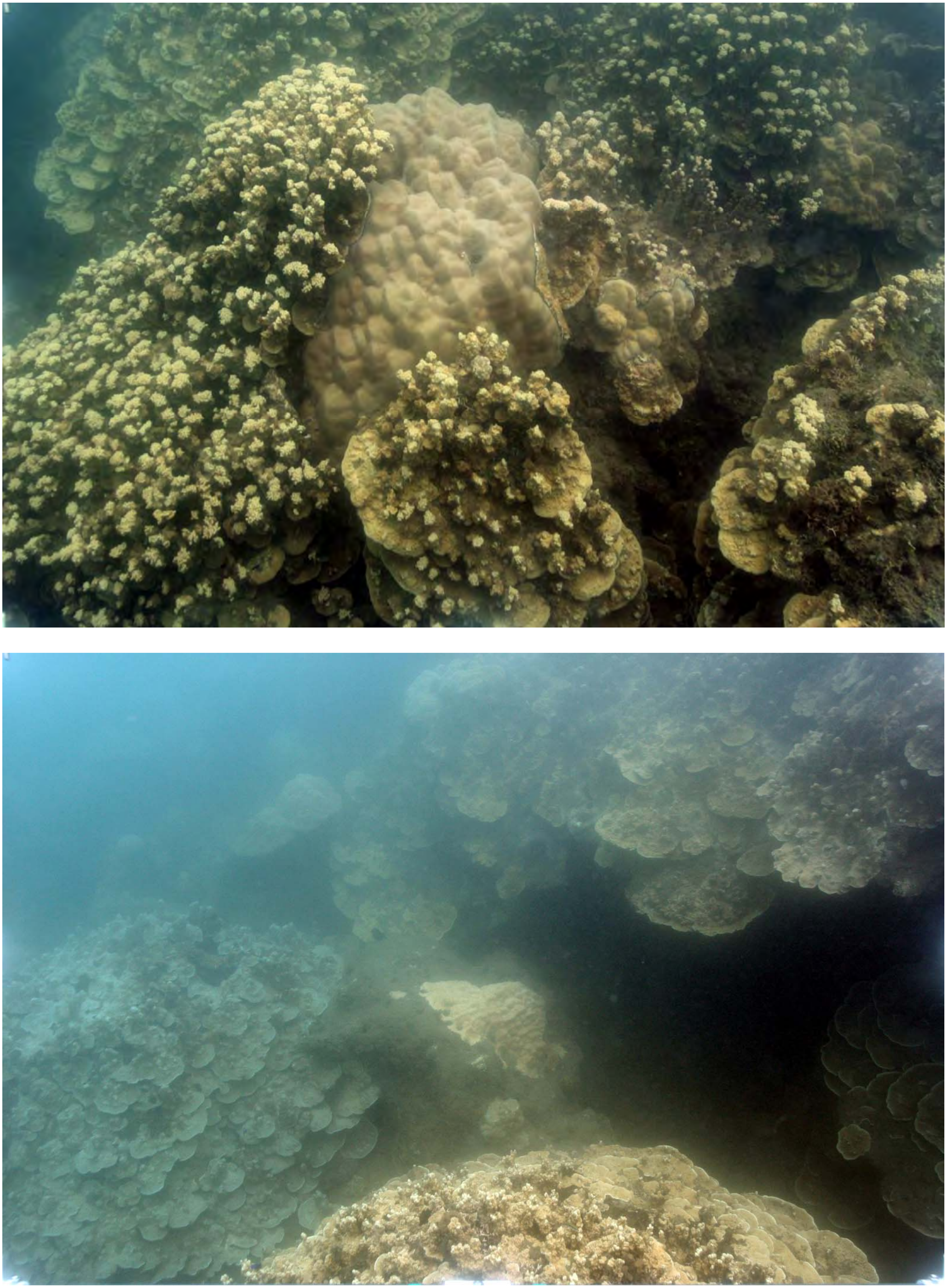


FIGURE 15. Coral communities consisting of *Porites rus* and *Porites lutea* on outer channel walls of Umatec Bay.

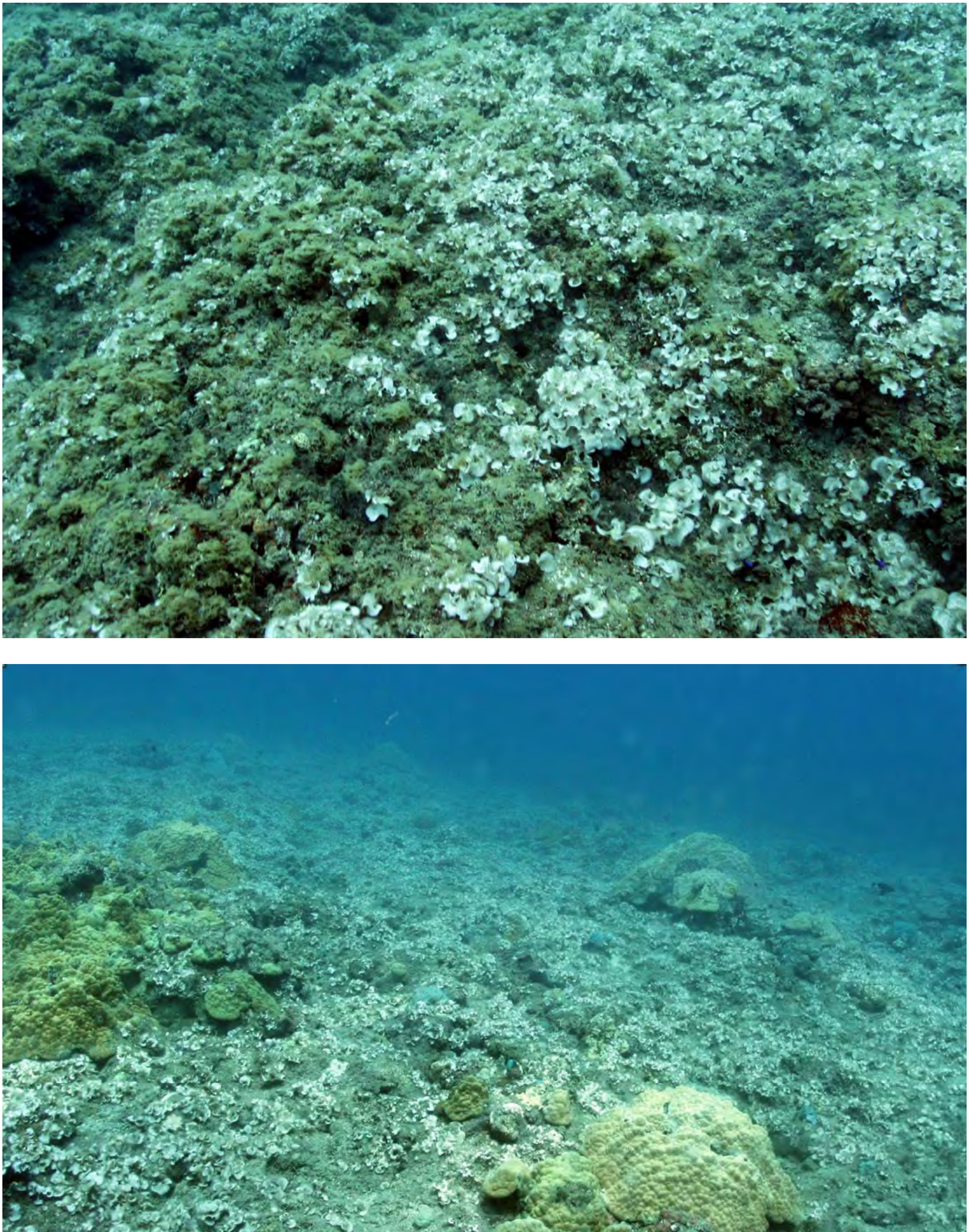


FIGURE 16. Mixed fields of *Padina* sp. and *Chrysocystis fragilis* covering outer reef platform in Umatec Bay (top), and *Padina* amid colonies of *Porites lutea* on outer reef slope of Umatac Bay, southwestern Guam (bottom).

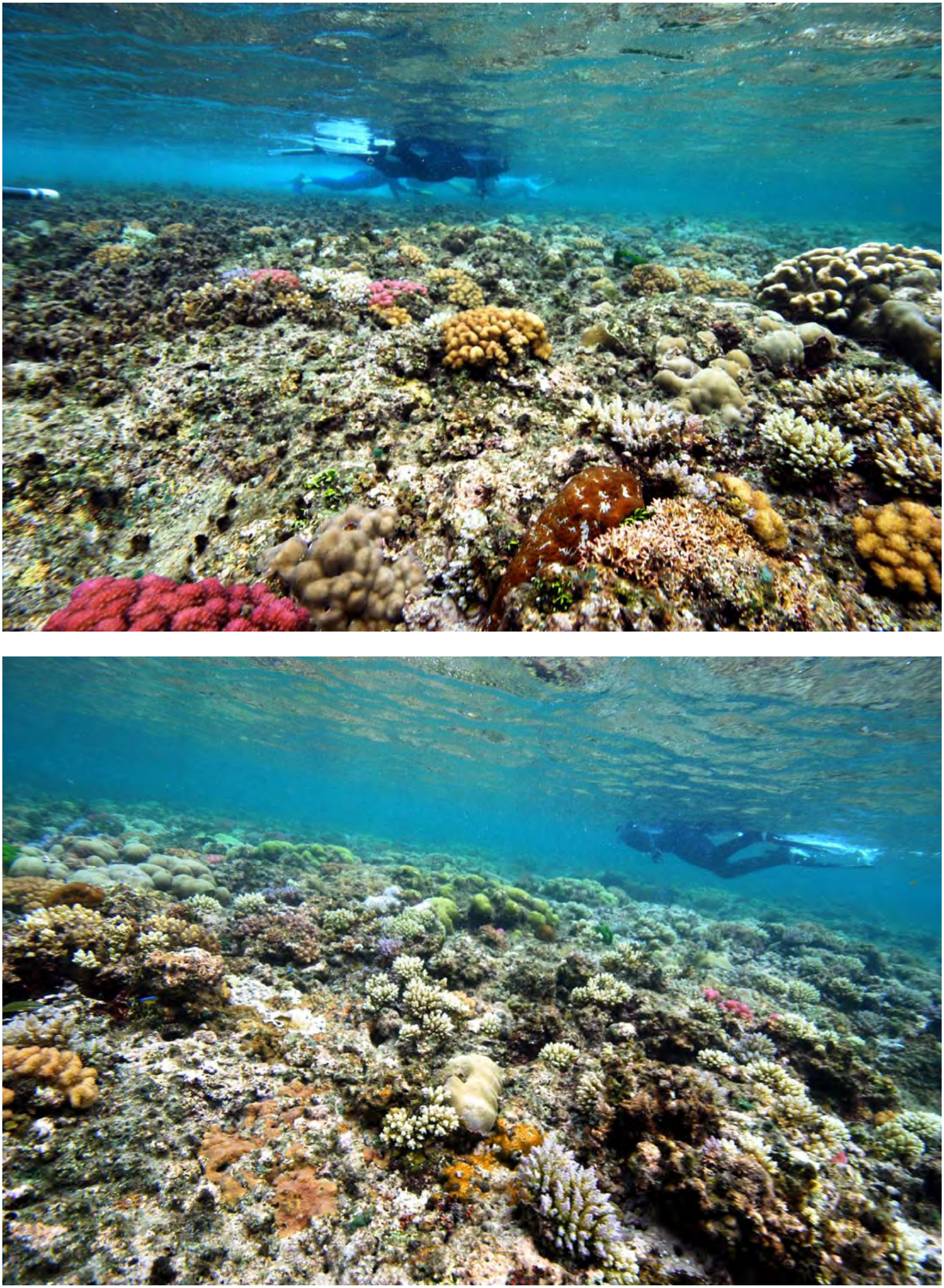


FIGURE 17. Reef front off of north side of Togoan Bay, southwestern Guam.

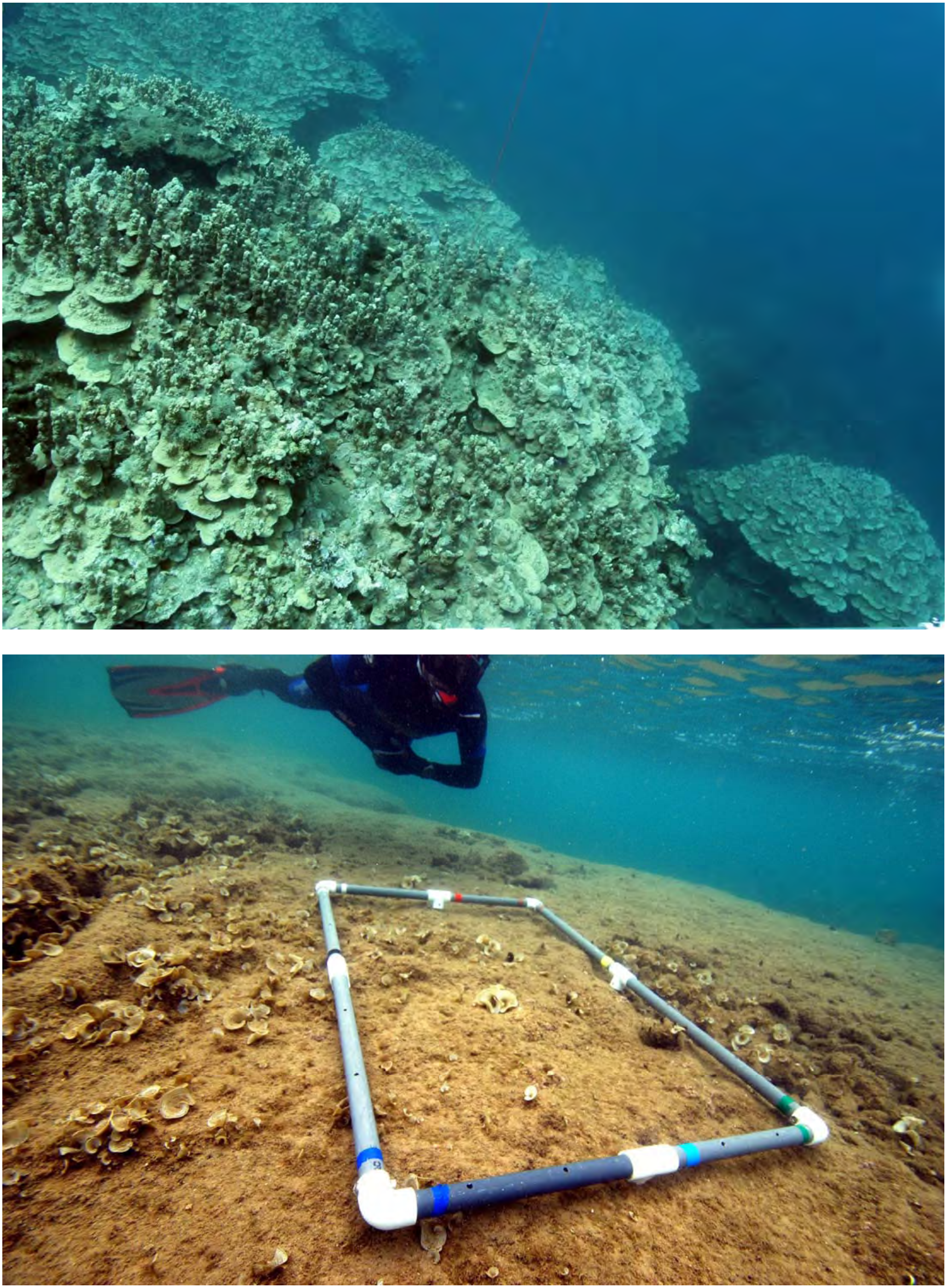


FIGURE 18. Corals on outer reef channel of Togoan Bay, southwestern Guam (top). Inner reef flat off mouth of Togoan Stream (bottom).

FIGURE 19. Outer reef front off of north side of Togoan Bay, southwestern Guam.

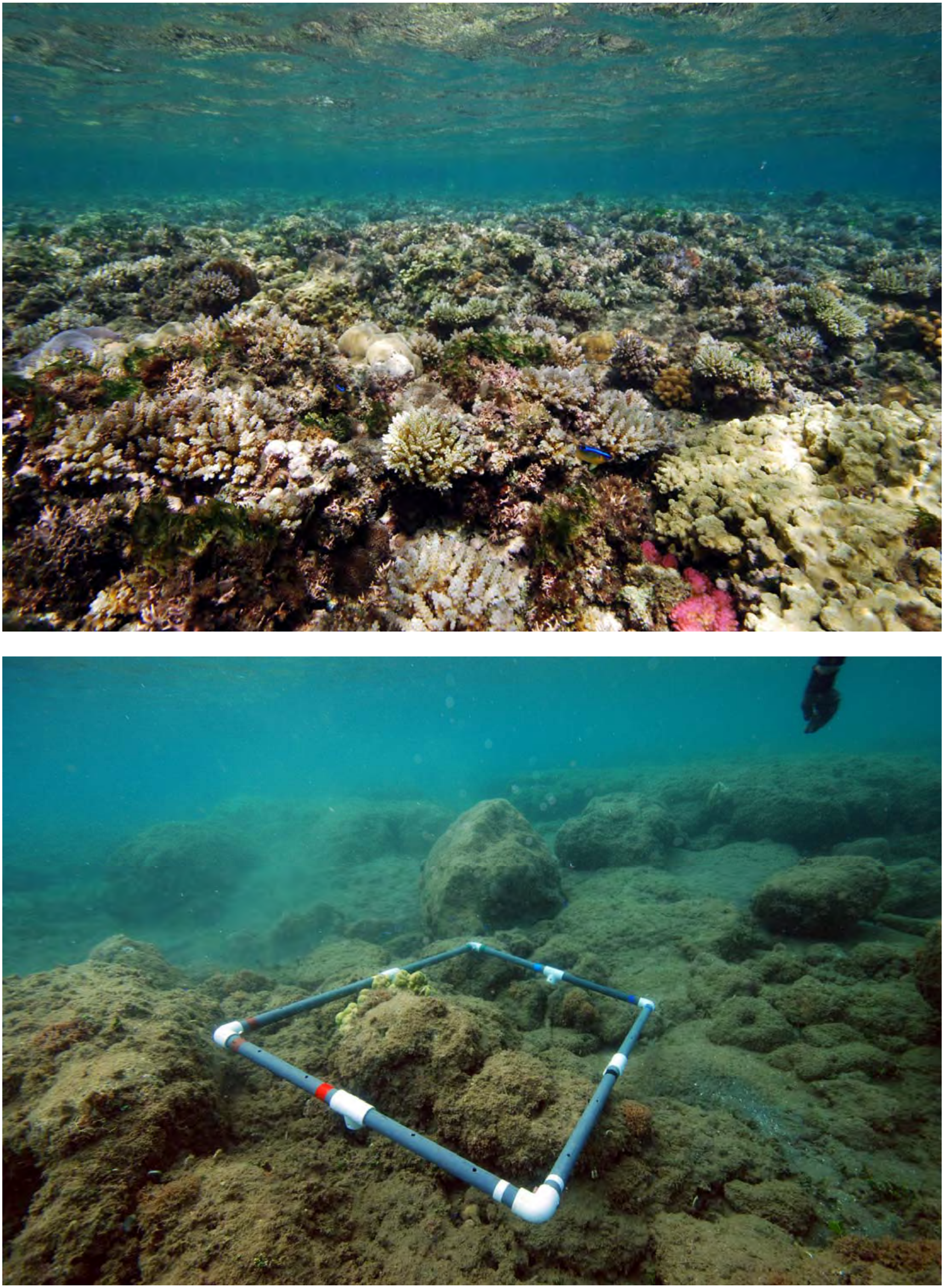


FIGURE 20. Outer (top) and inner (bottom) reef flat at Bile Bay, southwestern Guam.

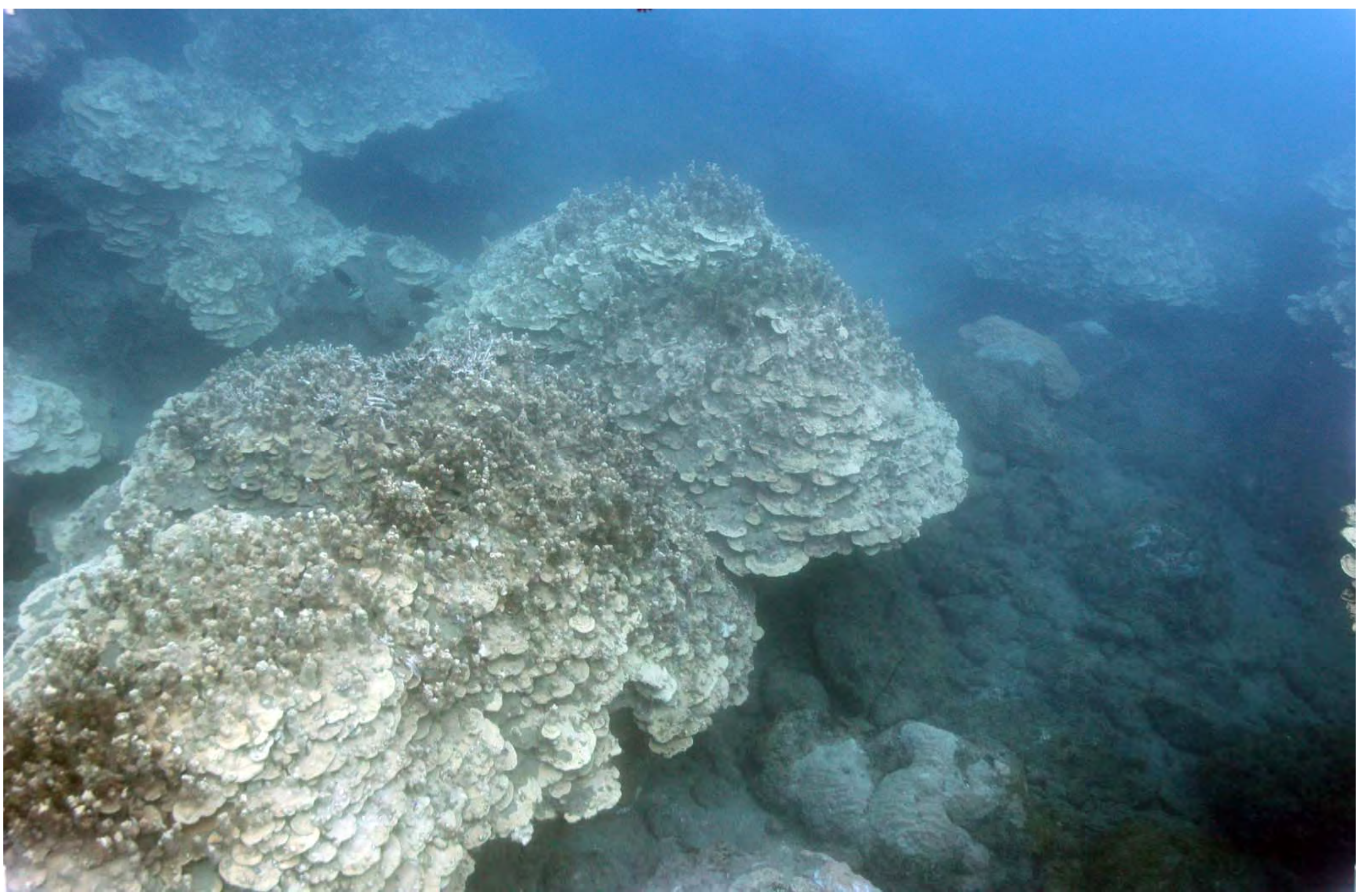



FIGURE 21. Outer reef platform at Bile Bay, southwestern Guam. Most of the large coral colonies in both photographs are *Porites rus*.

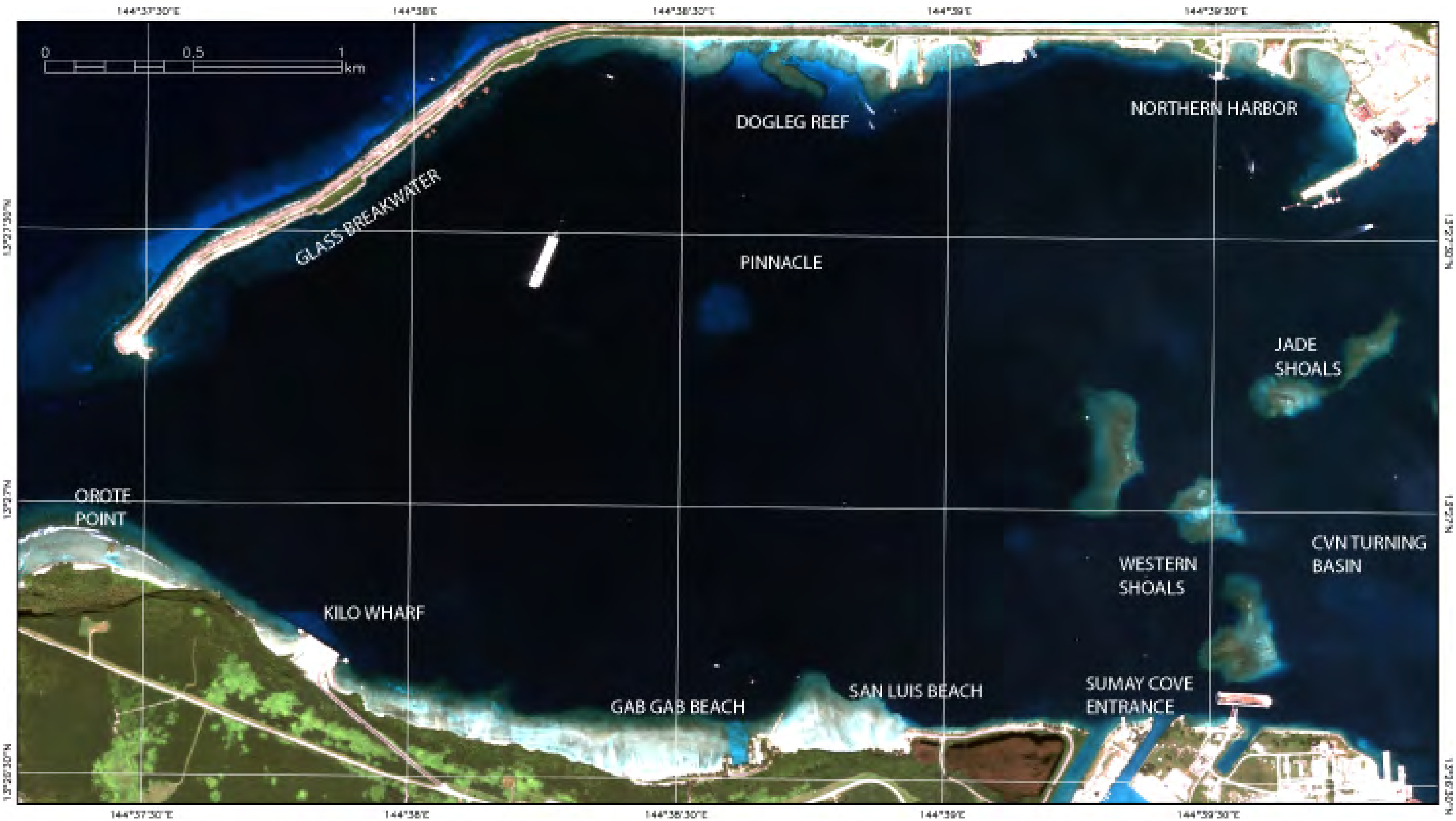


FIGURE 22 Satellite image of Apra Harbor Guam, showing landmark locations within mitigation site survey area.

FIGURE 23. Reef off of Seaplane ramp in northeastern sector of Apra Harbor, Guam.

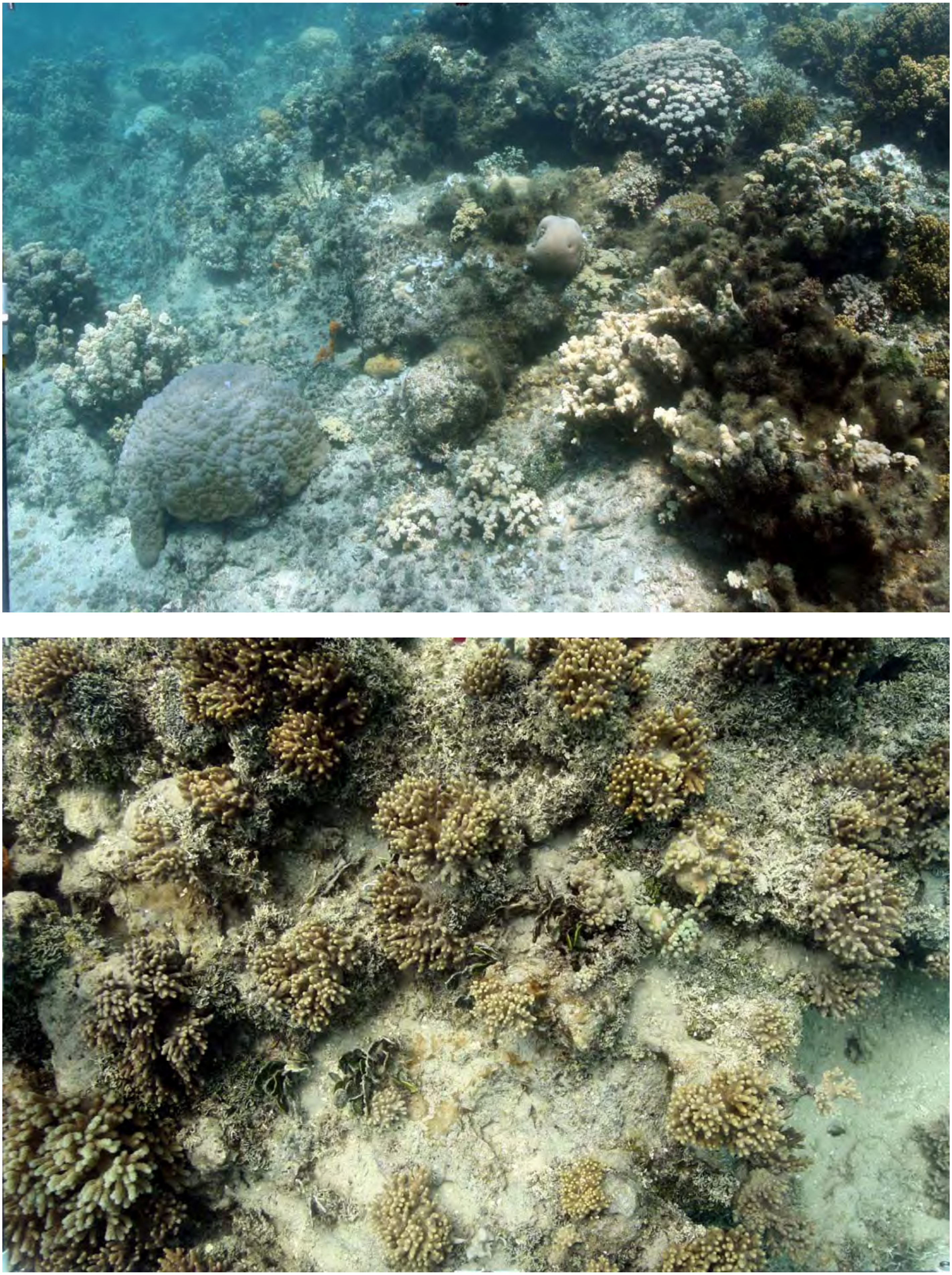


FIGURE 24. Reef off of Seaplane ramp in northeastern sector of Apra Harbor, Guam.

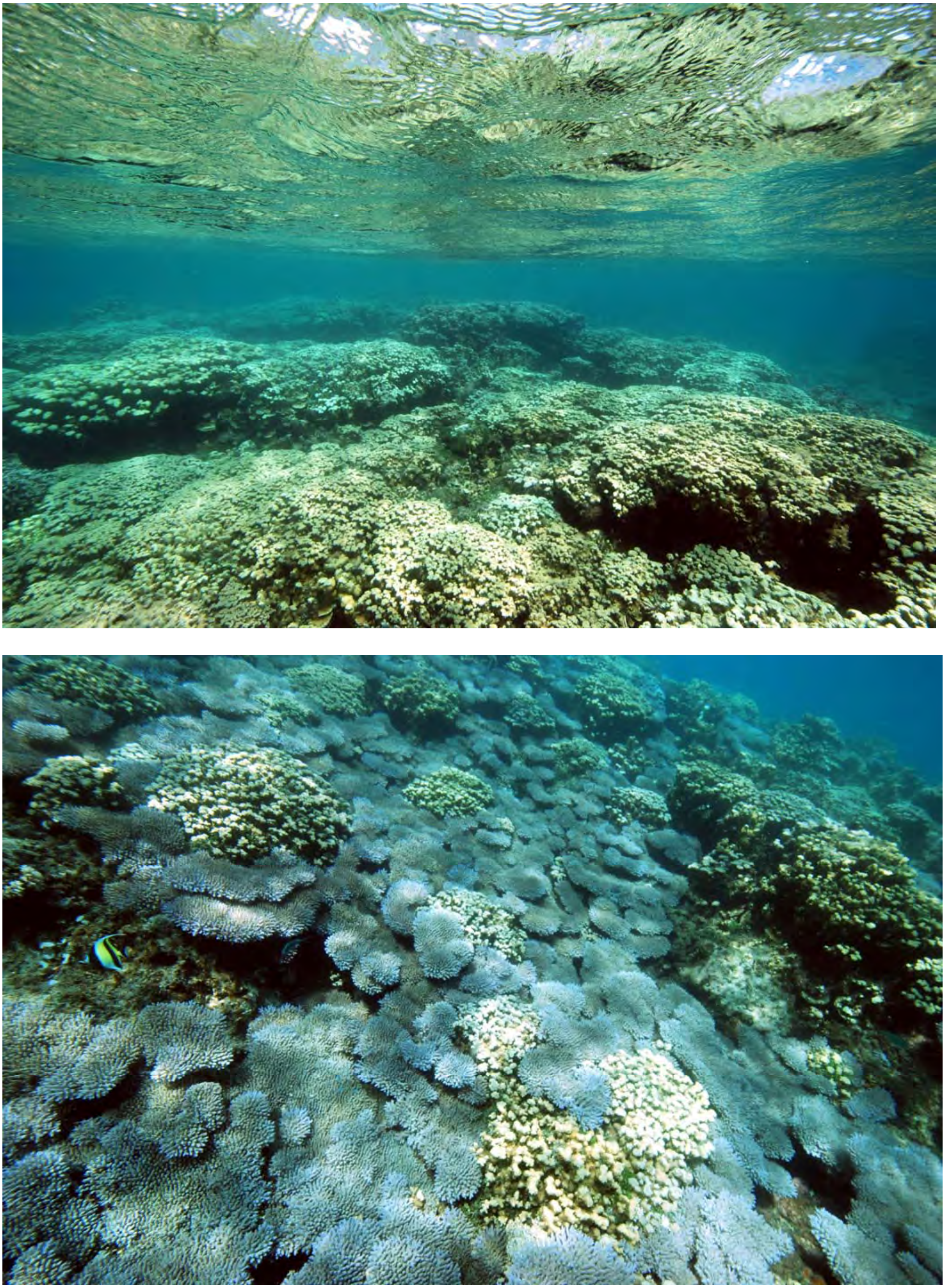


FIGURE 25. Top of "Dog-leg" reef in northeastern sector of Apra Harbor, Guam.

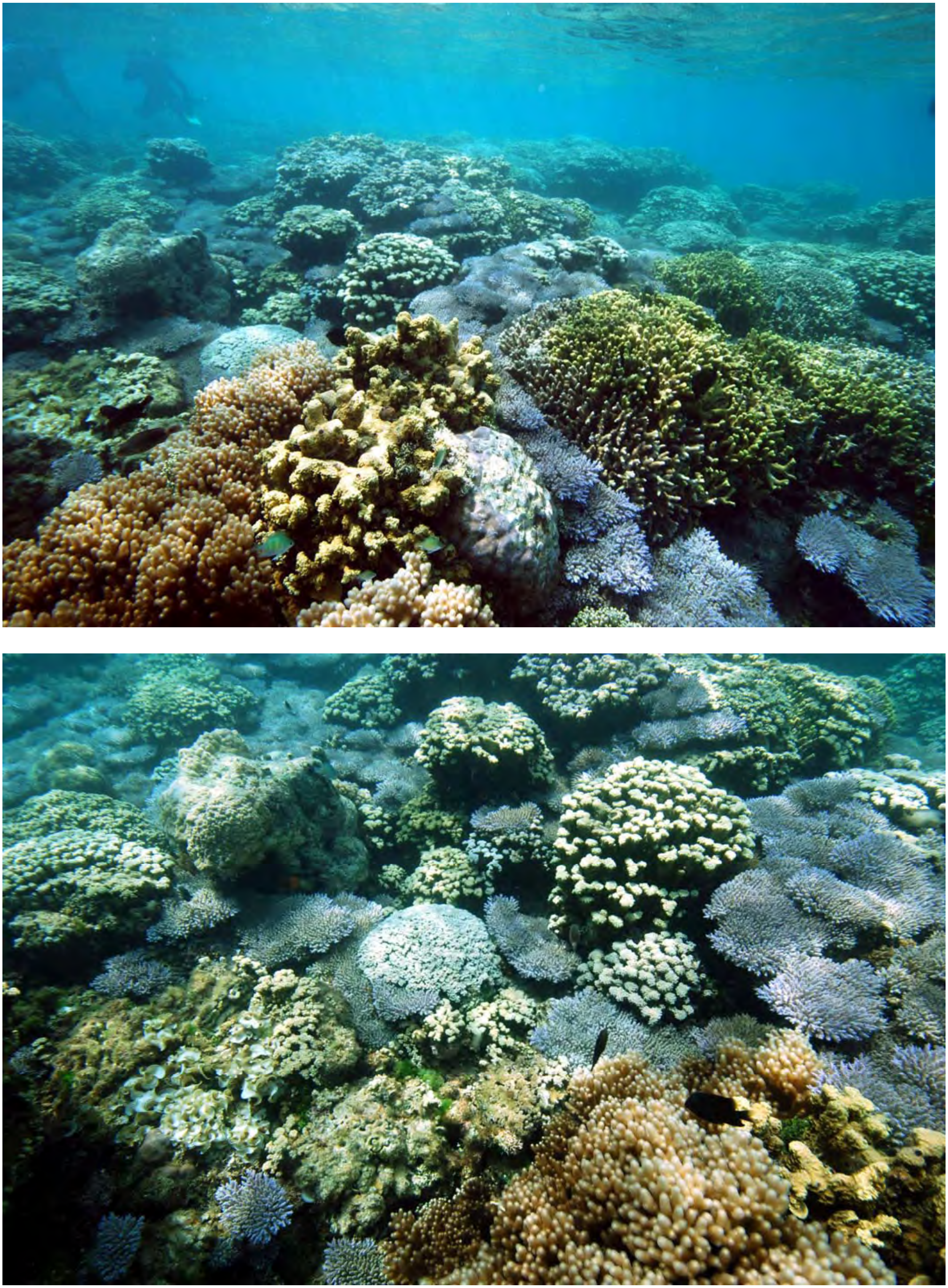


FIGURE 26. Top of “Dog-leg” reef in northeastern sector of Apra Harbor, Guam.

FIGURE 27. Reef slope off central portion of Glass Breakwater in northern sector of Apra Harbor, Guam. Top photo shows near vertical wall of *Porites rus* that extends from the base of the Breakwater to the channel floor; bottom photo shows several elephant ear sponges (*Ianthella basta*) growing at the base of the reef slope.

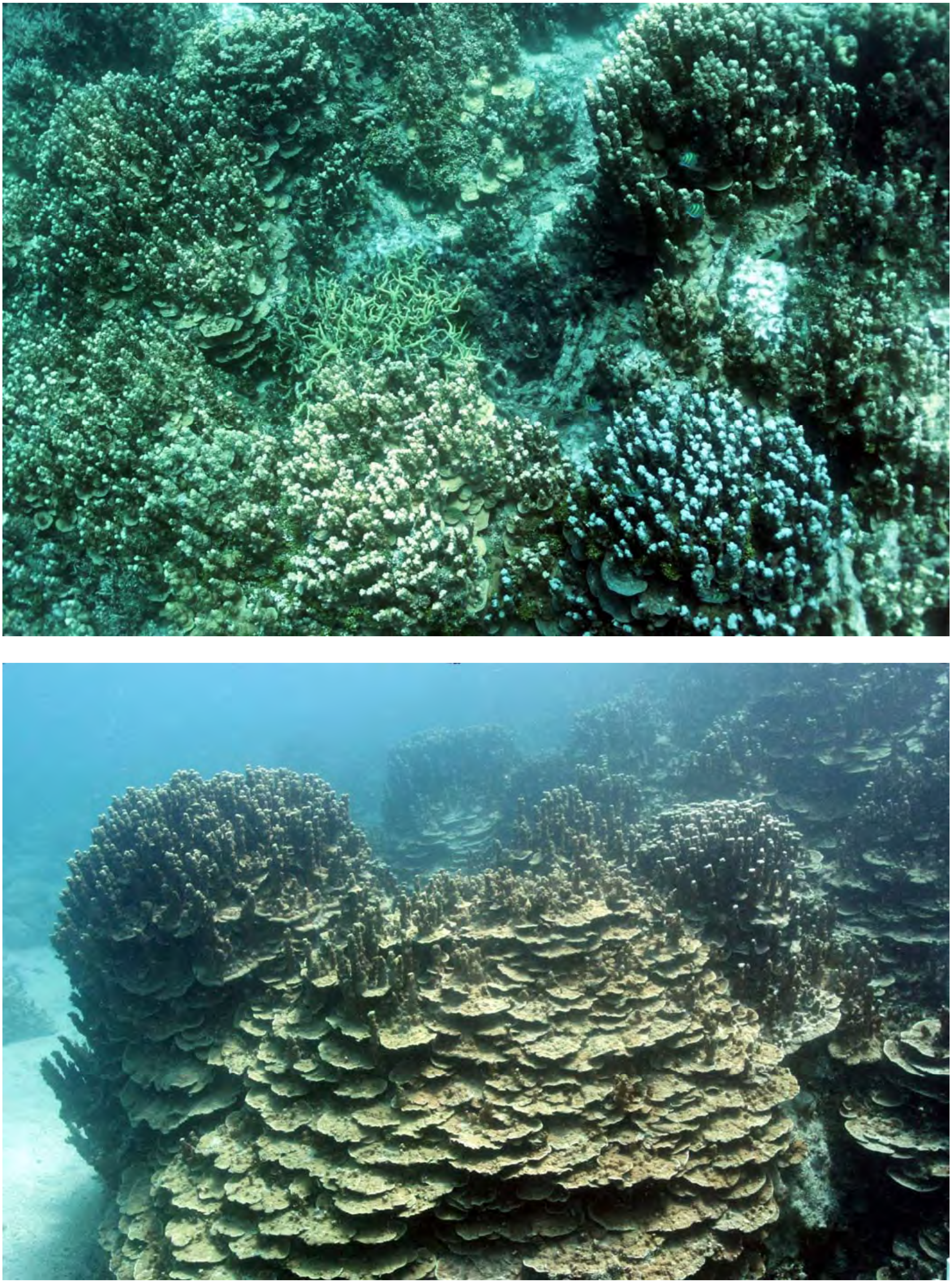


FIGURE 28. Colonies of *Porites rus* growing at base of reef slope off central portion of Glass Breakwater in northern sector of Apra Harbor, Guam.

FIGURE 29. Discarded materials on floor of Apra Harbor, Guam off western portion of Glass Breakwater in area known as "Seebee Junkyard."

FIGURE 30. Discarded materials on floor of Apra Harbor, Guam off western portion of Glass Breakwater in area known as "Seebee Junkyard."

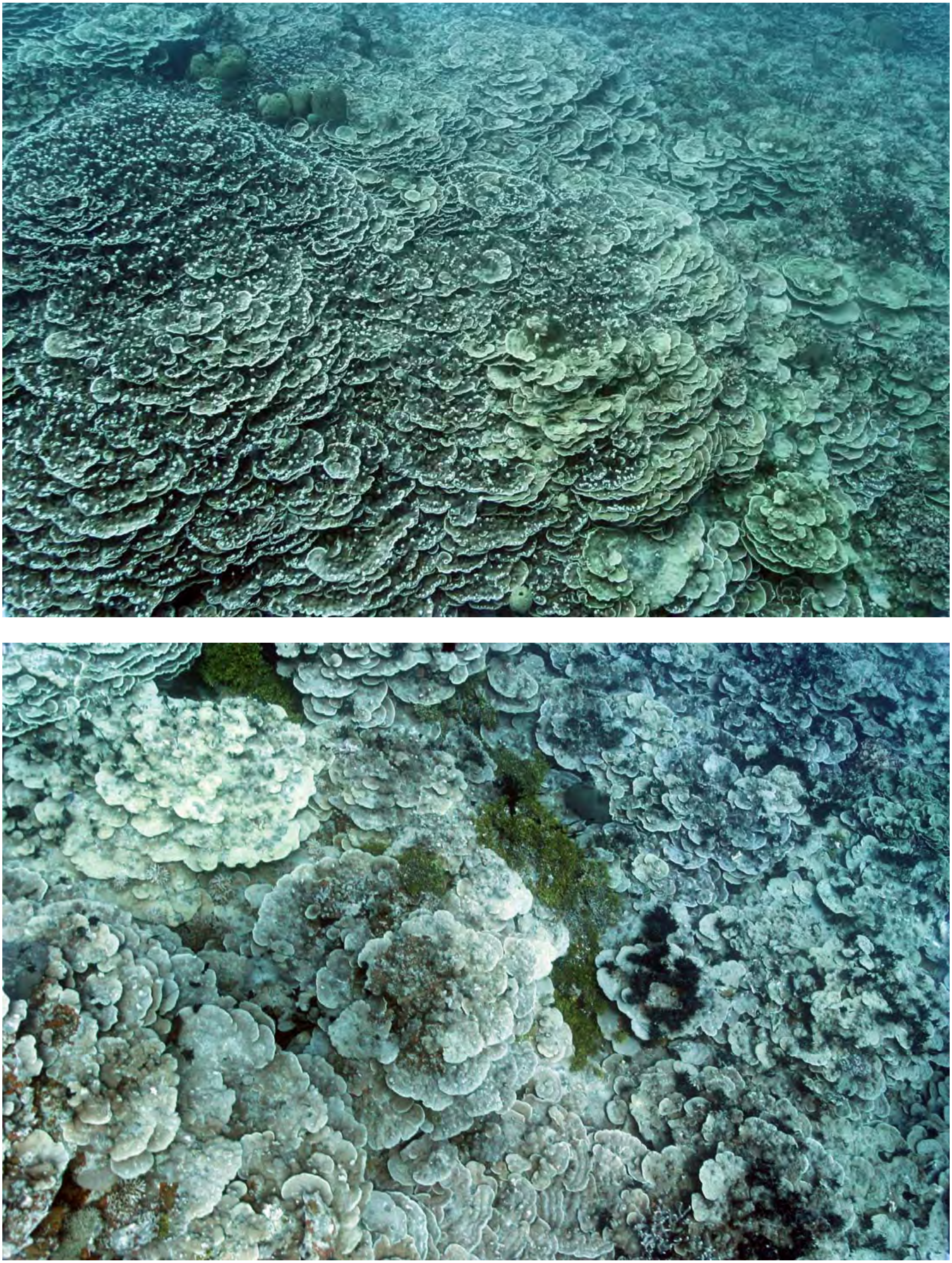


FIGURE 31. Top and edges of pinnacles in central Apra Harbor, Guam .

FIGURE 32. Reef surface of pinnacles in southeastern sector of, Apra Harbor, Guam .

FIGURE 33. Top of "Hidden Reef" pinnacle located to the east of Kilo Wharf, southwestern sector of Apra Harbor, Guam.

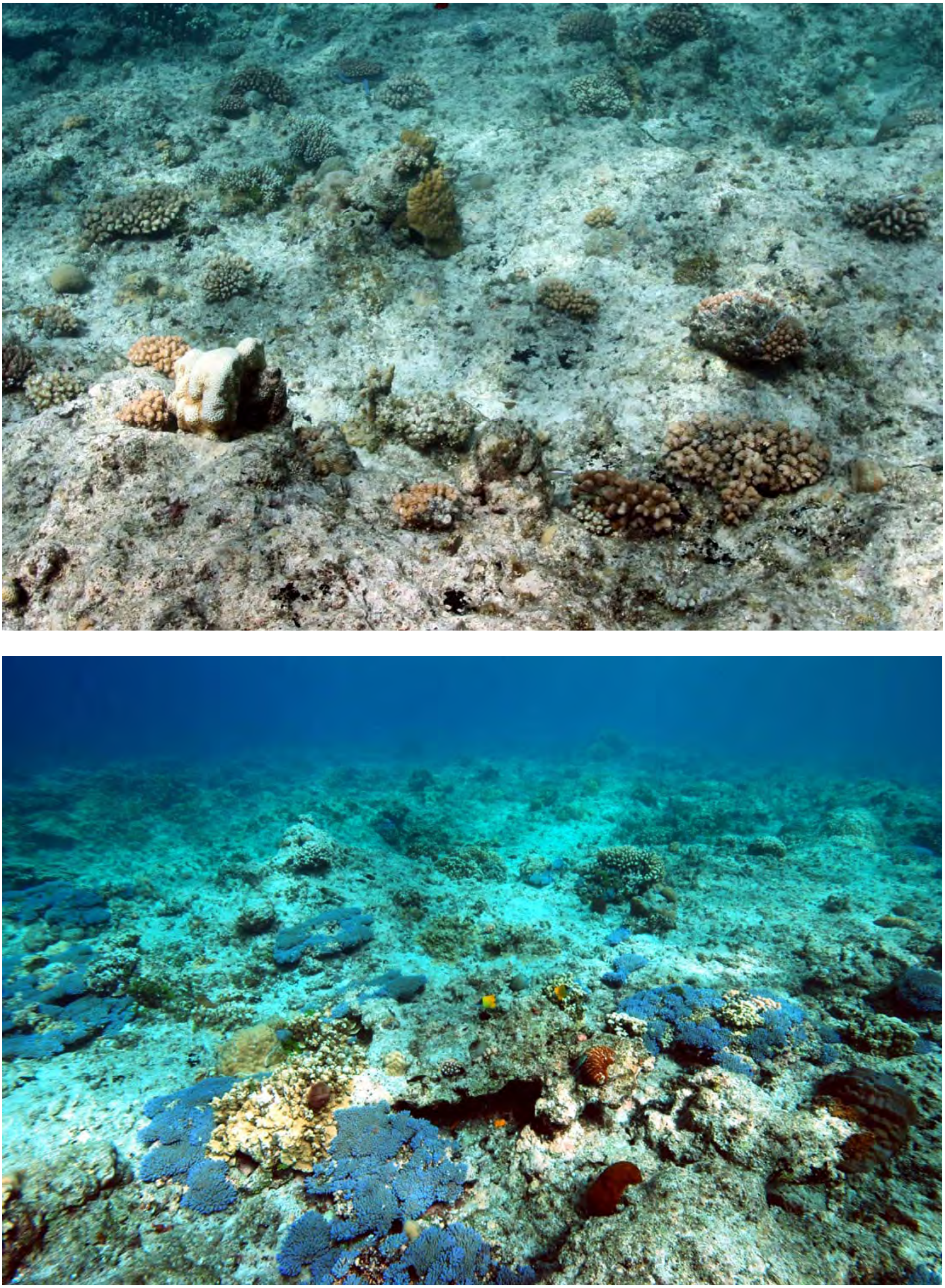


FIGURE 34. Reef flats off at between Kilo Wharf and Orote Point (top) in Apra Harbor, Guam .

FIGURE 35. Reef edge off Gab Gab Beach in southern sector of Apra Harbor, Guam composed primarily of overlapping plates of *Porites rus*.

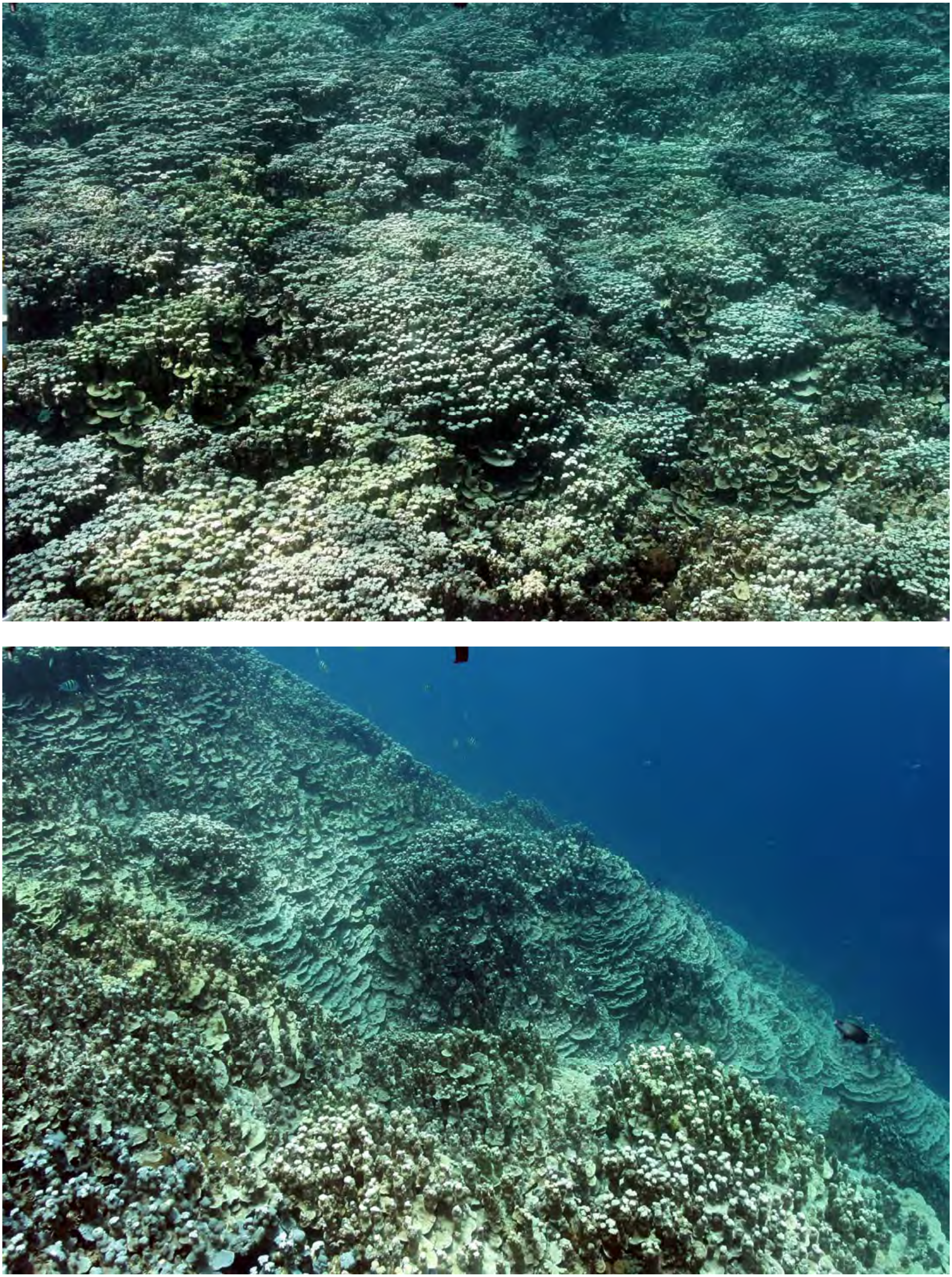


FIGURE 36. Reef edge (top) and reef slope (bottom) off Gab Gab Beach in southern sector of Apra Harbor, Guam composed primarily of overlapping plates of *Porites rus*.

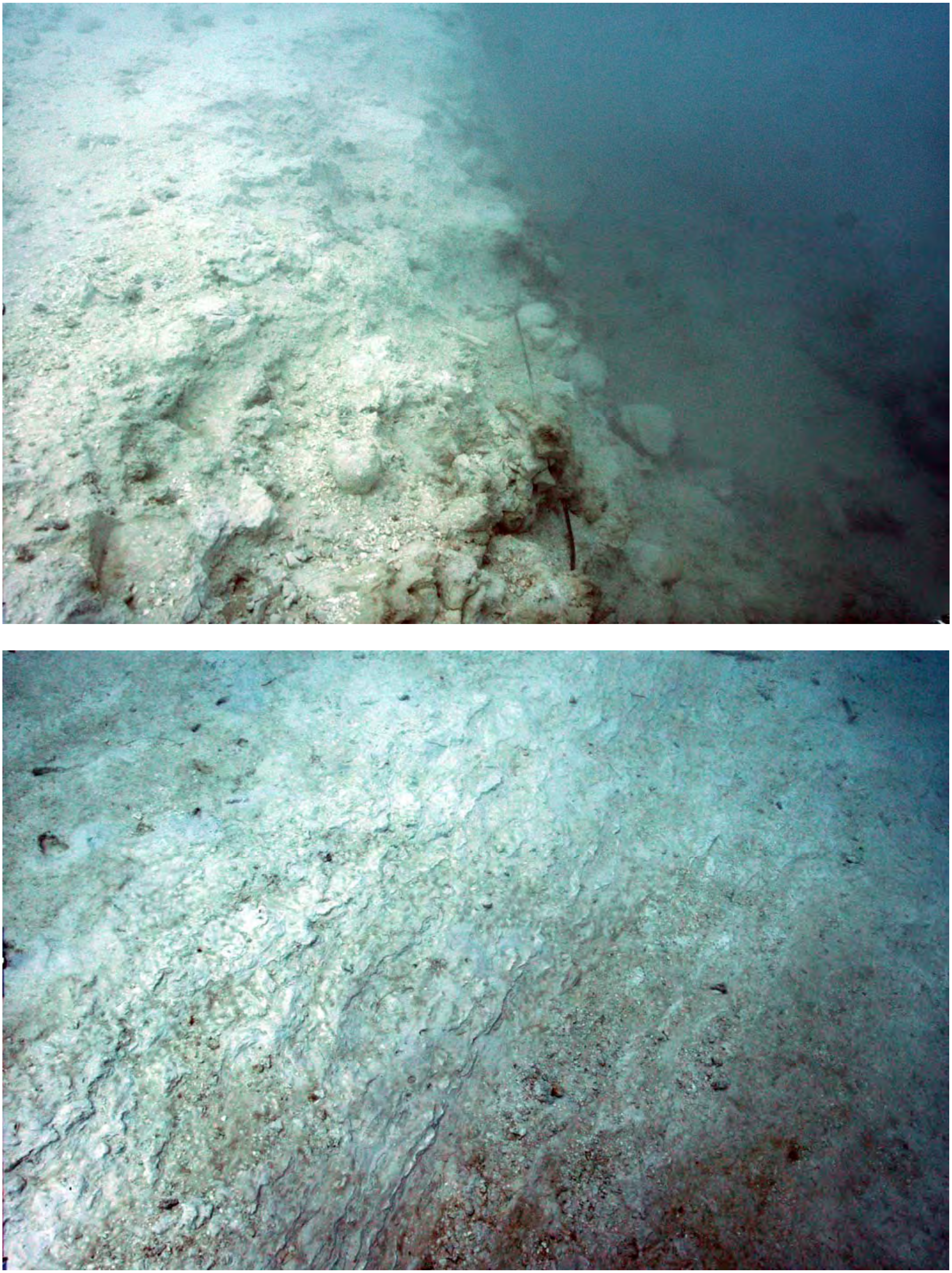
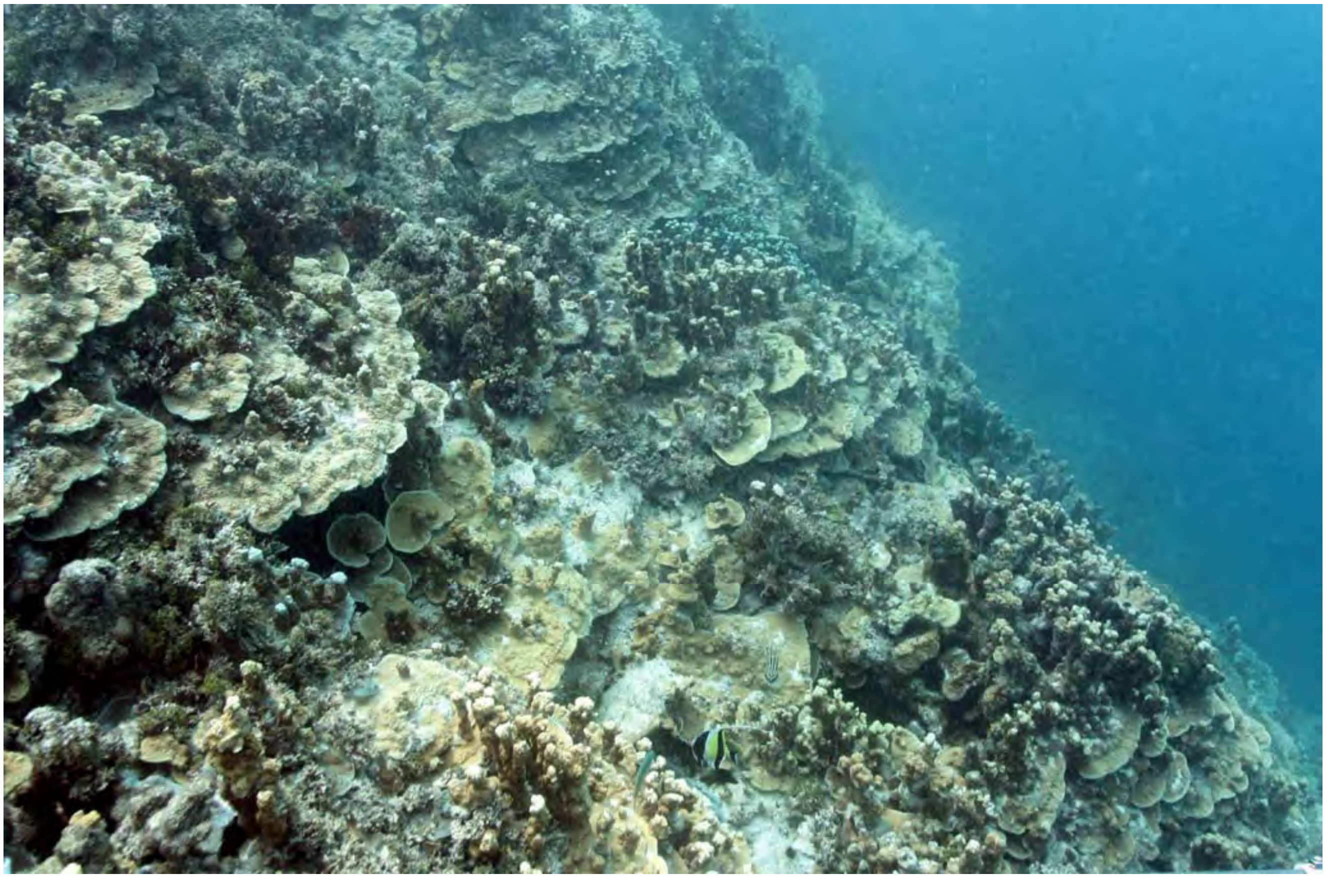


FIGURE 37. Edge of dredge cut off of Kilo Wharf, southwestern sector of Apra Harbor, Guam.



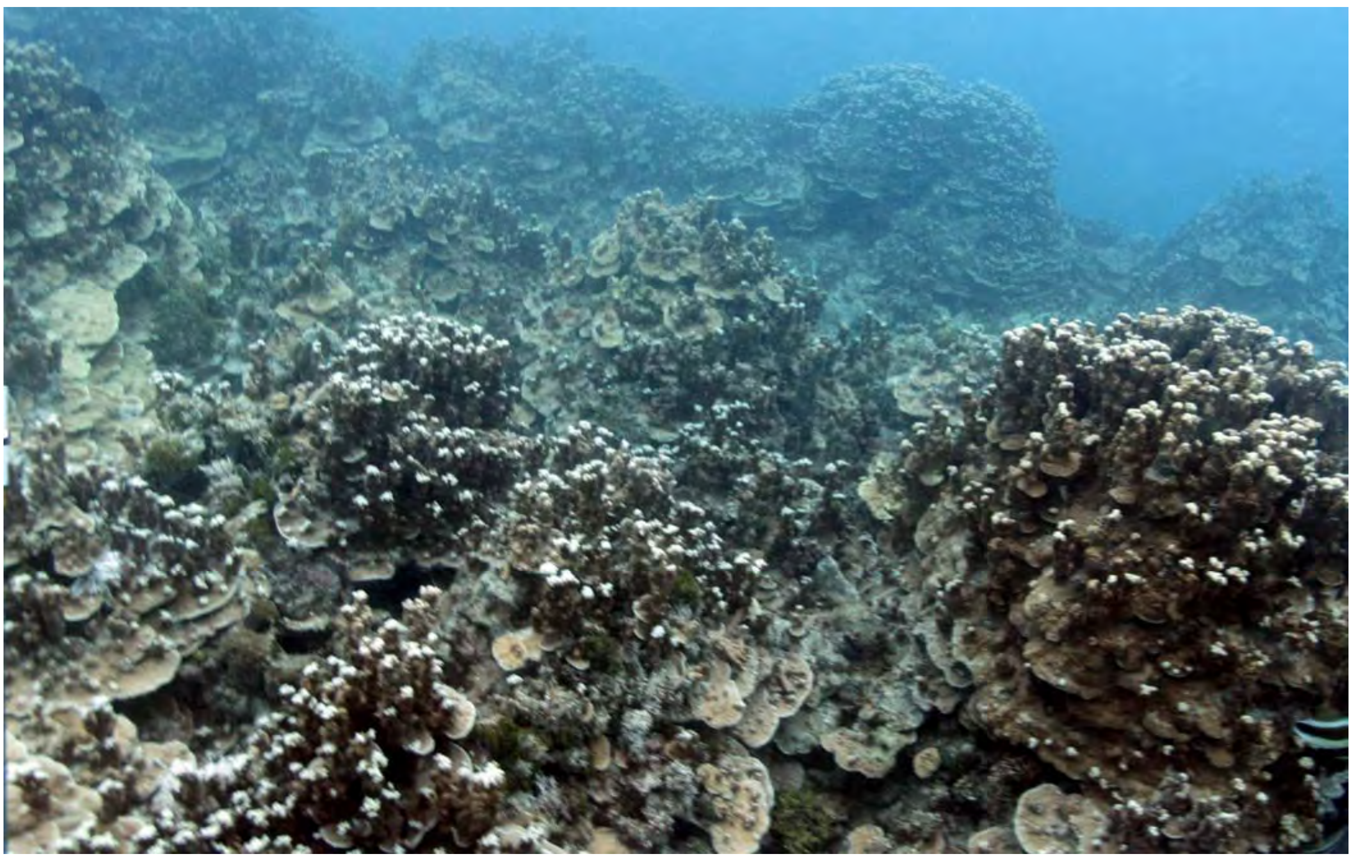


FIGURE 38. Edge of reef directly west of Kilo Wharf, southwestern sector of Apra Harbor, Guam. Most colonies of *Porites rus* show little indication of impact from construction activities associated with expansion of Kilo Wharf.

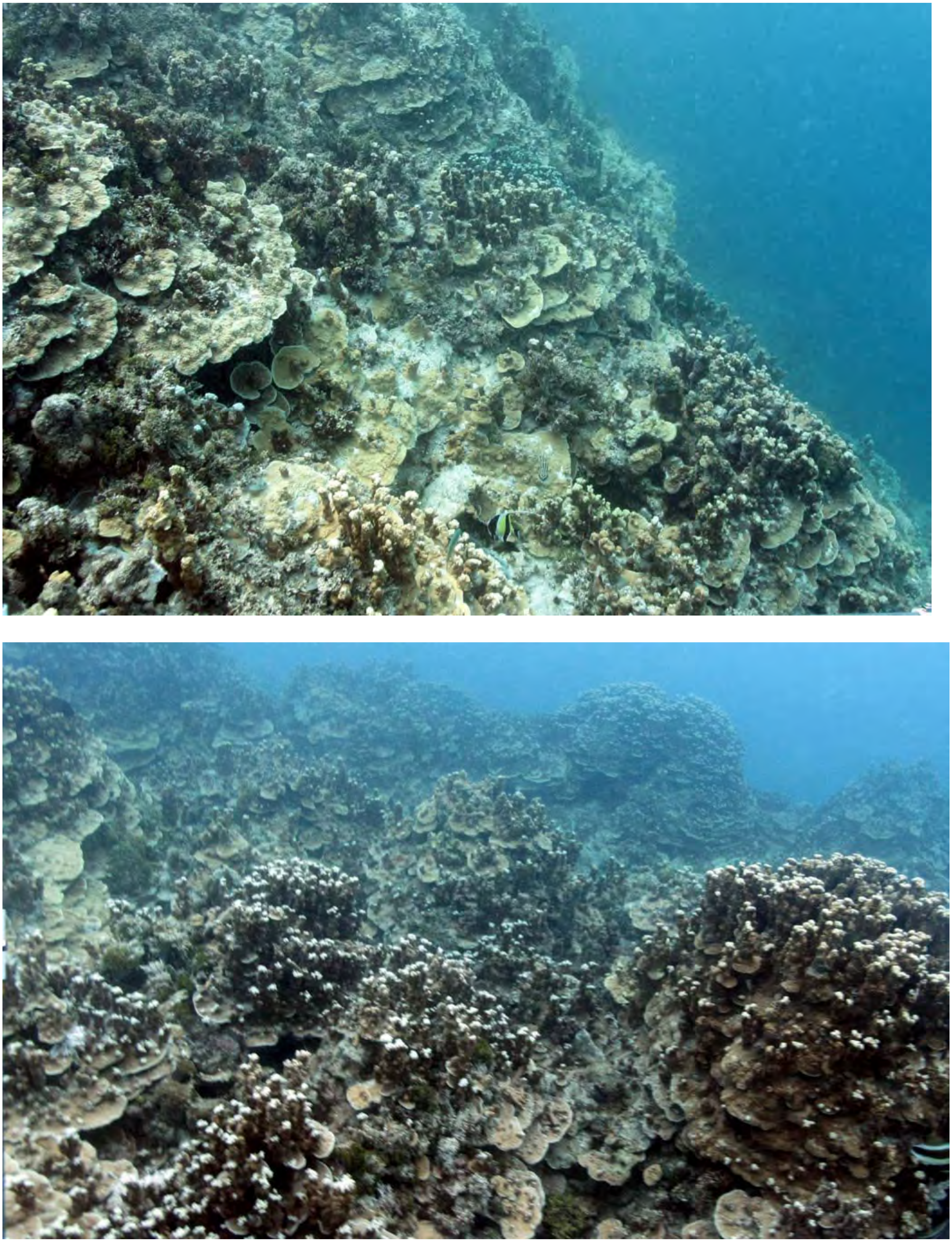


FIGURE 38. Edge of reef directly west of Kilo Wharf, southwestern sector of Apra Harbor, Guam. Most colonies of *Porites rus* show little indication of impact from construction activities associated with expansion of Kilo Wharf.

FIGURE 39. Edge of reef directly west of Kilo Wharf, southwestern sector of Apra Harbor, Guam showing effects of sediment to massive colonies of *Porites lutea*.

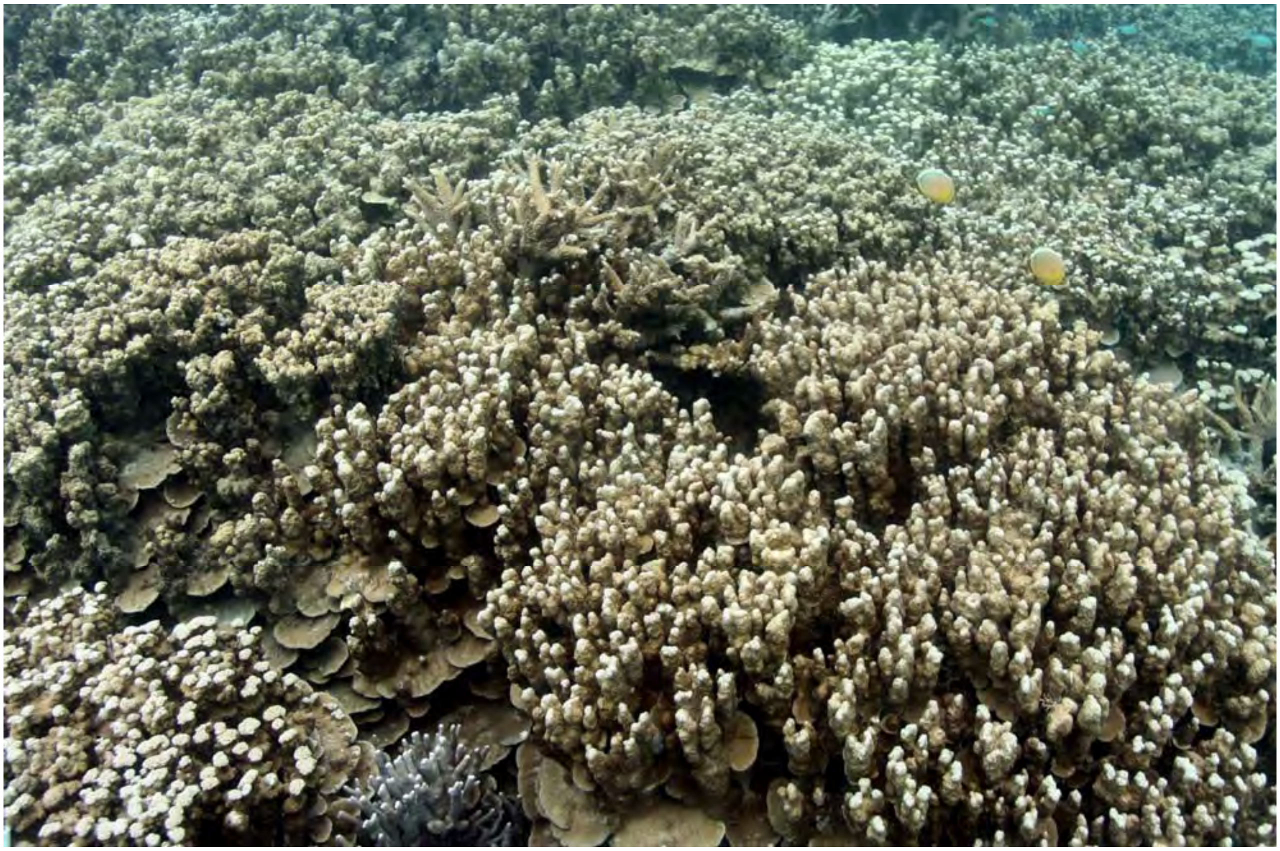


FIGURE 40. Coral thickets on top of Western Shoals adjacent to Big Blue Dry Dock, southeastern Apra Harbor, Guam. Coral in photo is predominantly *Porites rus*; coral in bottom photo is *Acropora formosa*.

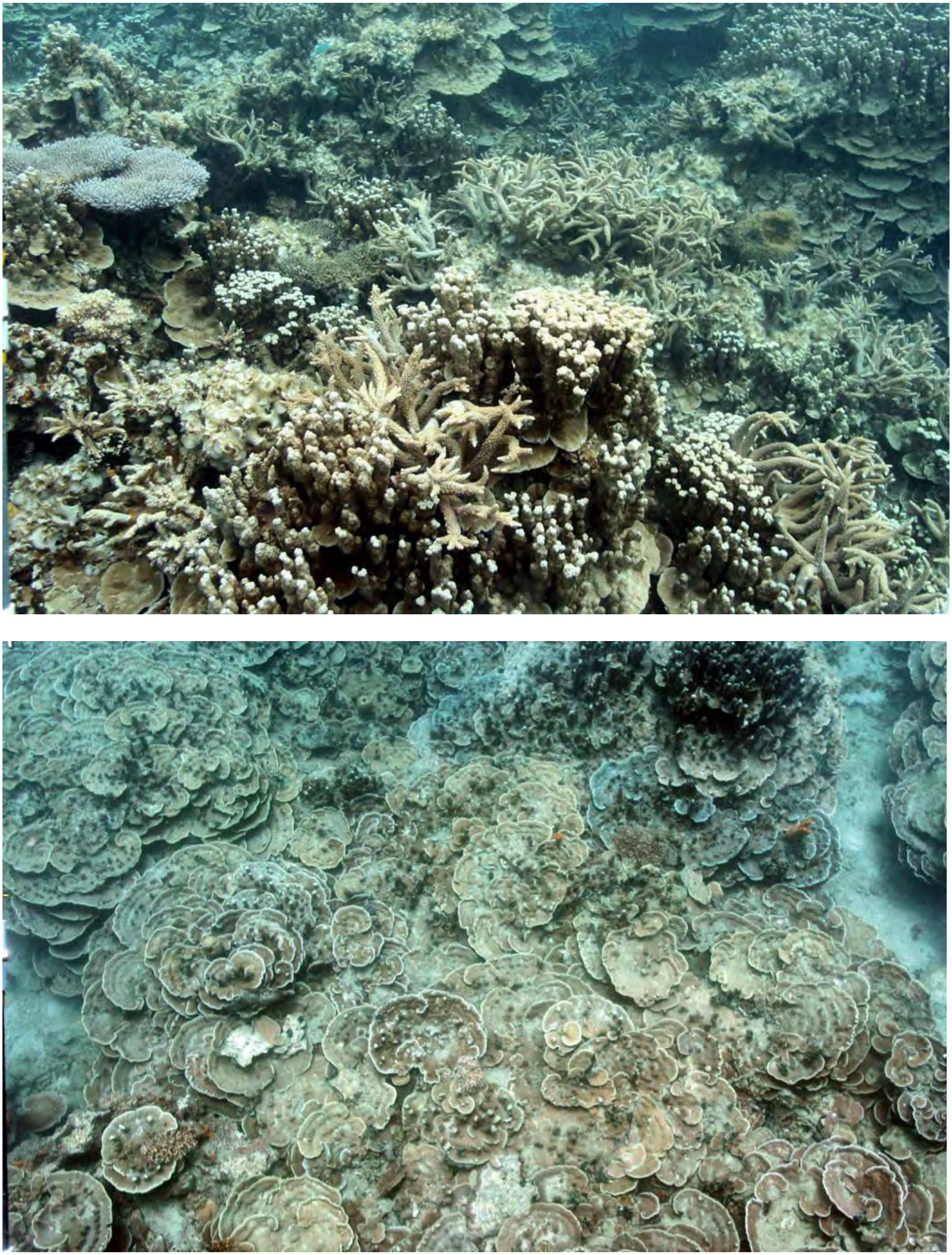


FIGURE 41. Base of reef slope of Western Shoals adjacent to Big Blue Dry Dock, southeastern Apra Harbor, Guam.

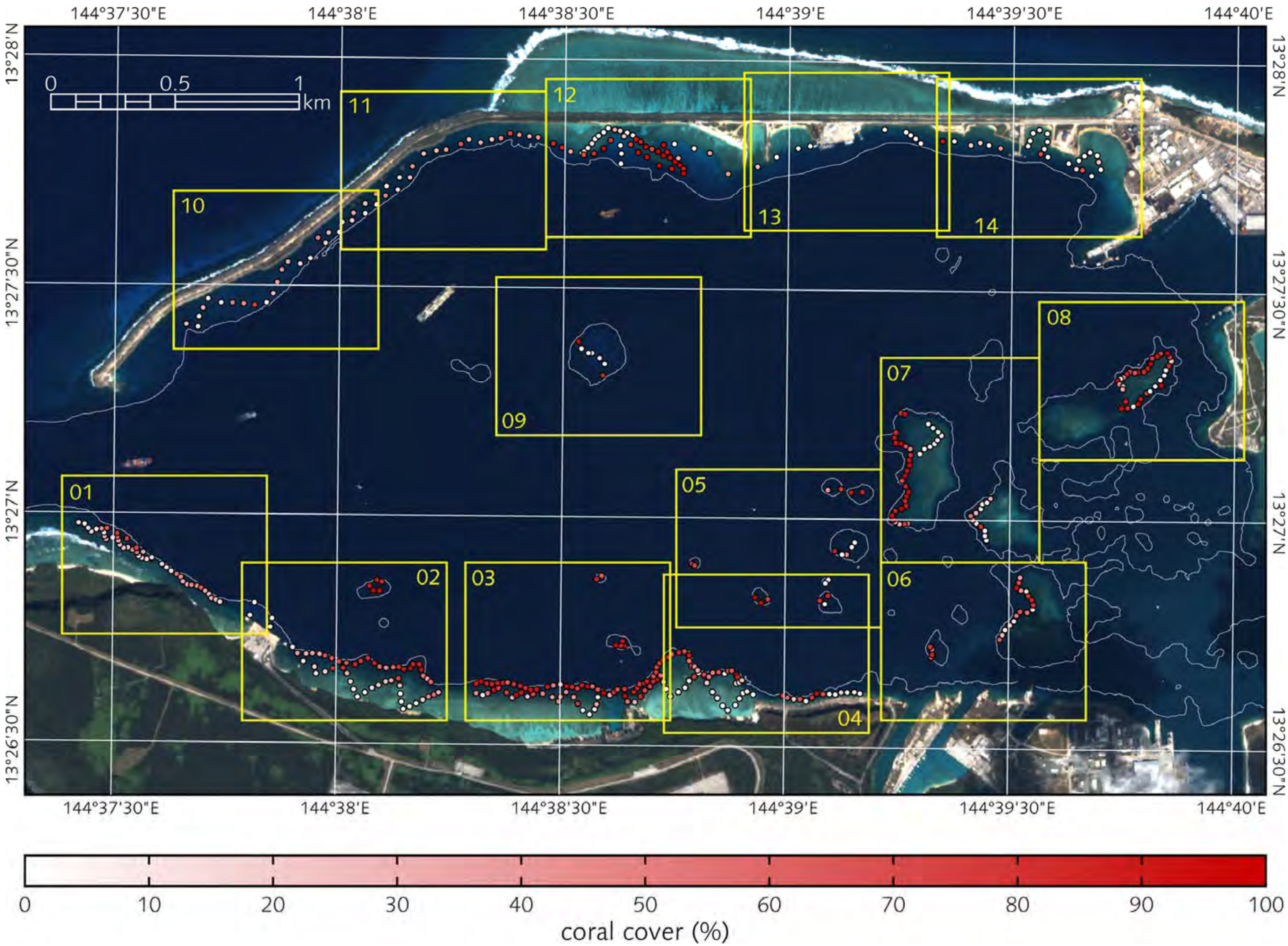


FIGURE 42. Overview of Apra Harbor study area. Circles represent locations of calibration/validation (cal/val) sites surveyed. Scale at right shows gradient of coral cover within cal/val site. Yellow boxes represent sectors of overview shown in following figures.

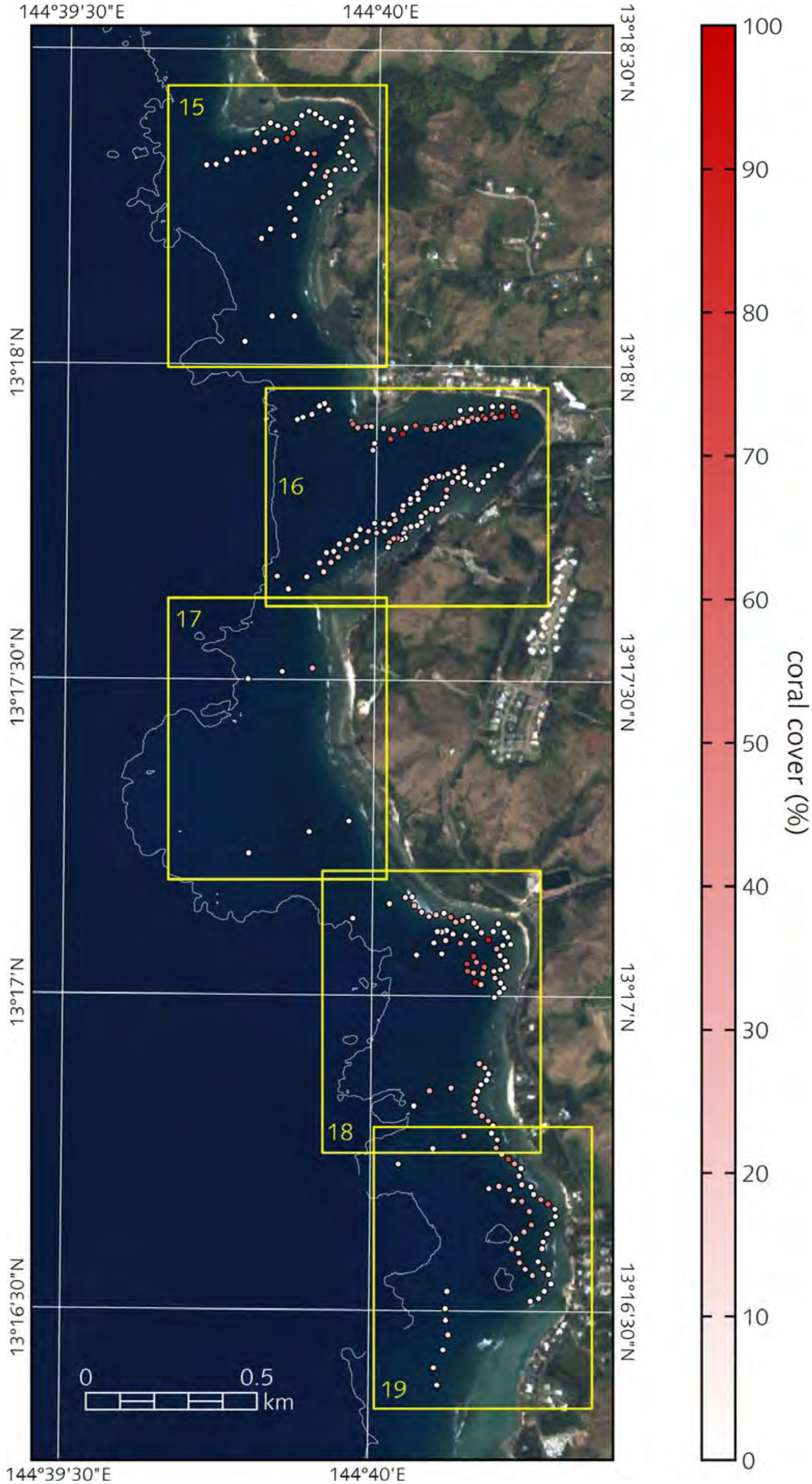


FIGURE 43. Overview of southwestern Guam watershed study area. Circles represent locations of calibration/validation (cal/val) sites surveyed. Scale at right shows gradient of coral cover within cal/val site. Yellow boxes represent sectors of overview shown in following figures.

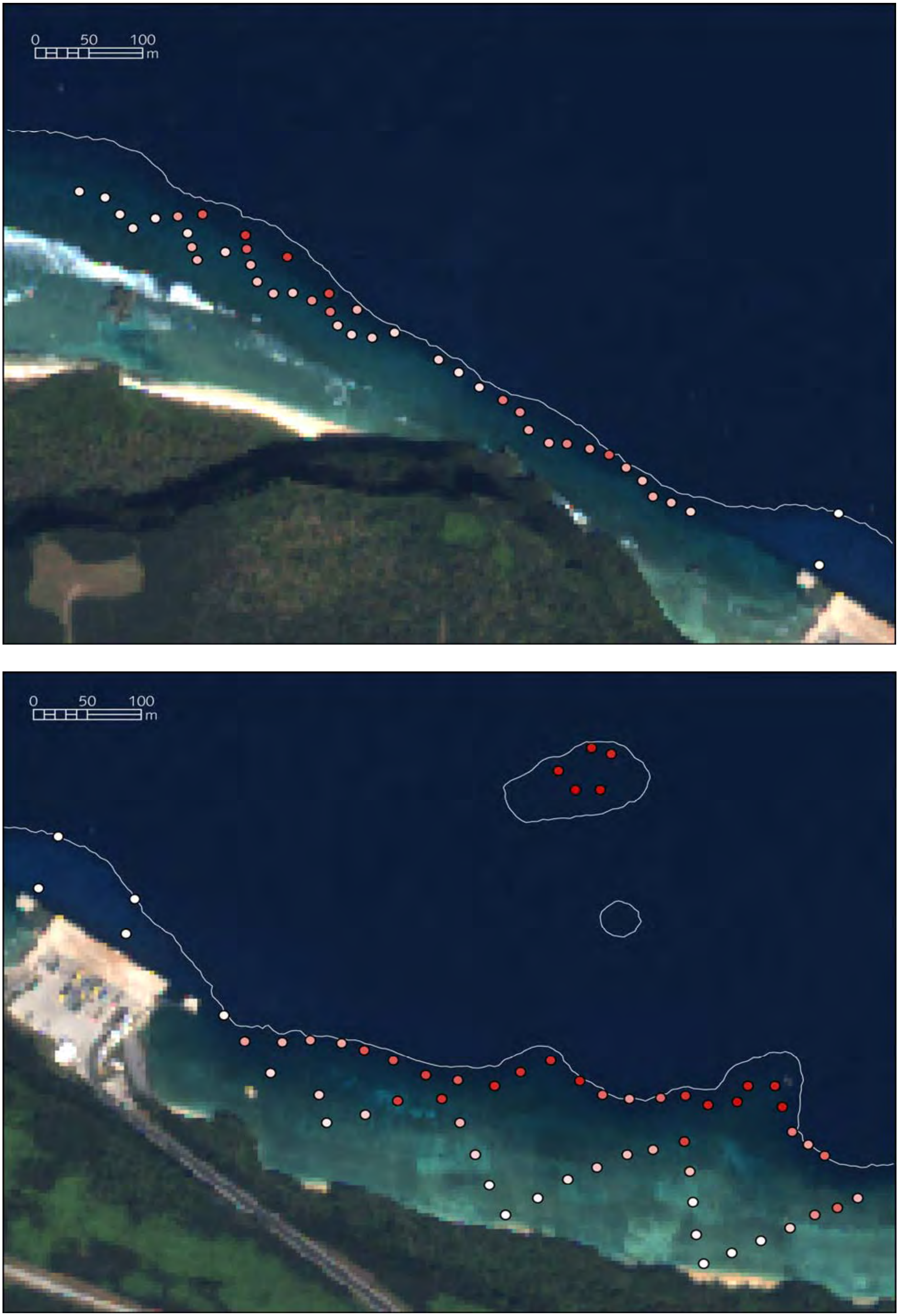


FIGURE 44. Sectors 1 and 2 of Apra Harbor study area from Orote Point to east of Kilo Wharf showing locations of cal/val sites color coded for coral abundance (see Figure 42 for coral abundance scale).

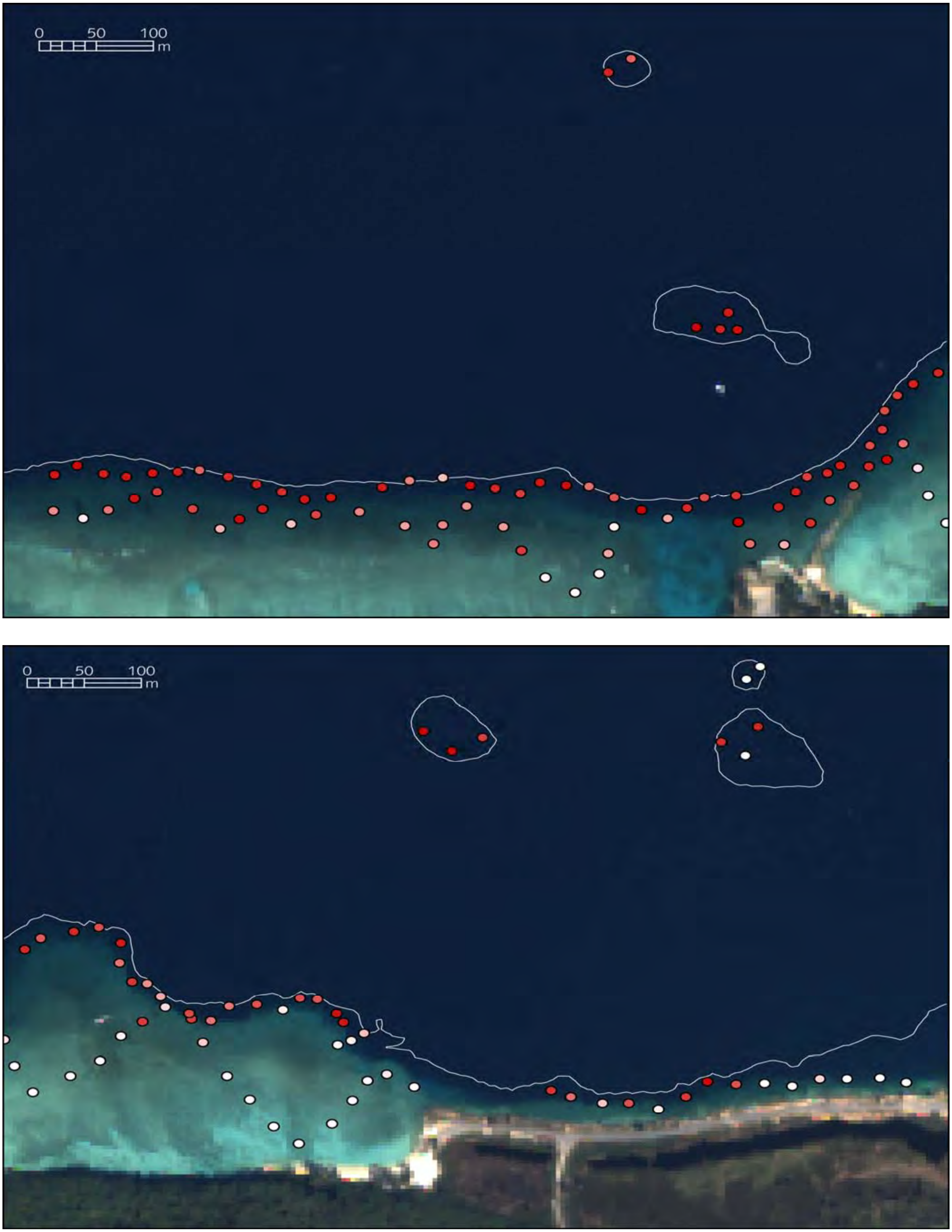


FIGURE 45. Sectors 3 (top) and 4 (bottom) of Apra Harbor study area from Gab Gab Beach to San Luis Beach, as well as mid-Harbor pinnacles showing locations of cal/val sites color coded for coral abundance (see Figure 42 for coral abundance scale).

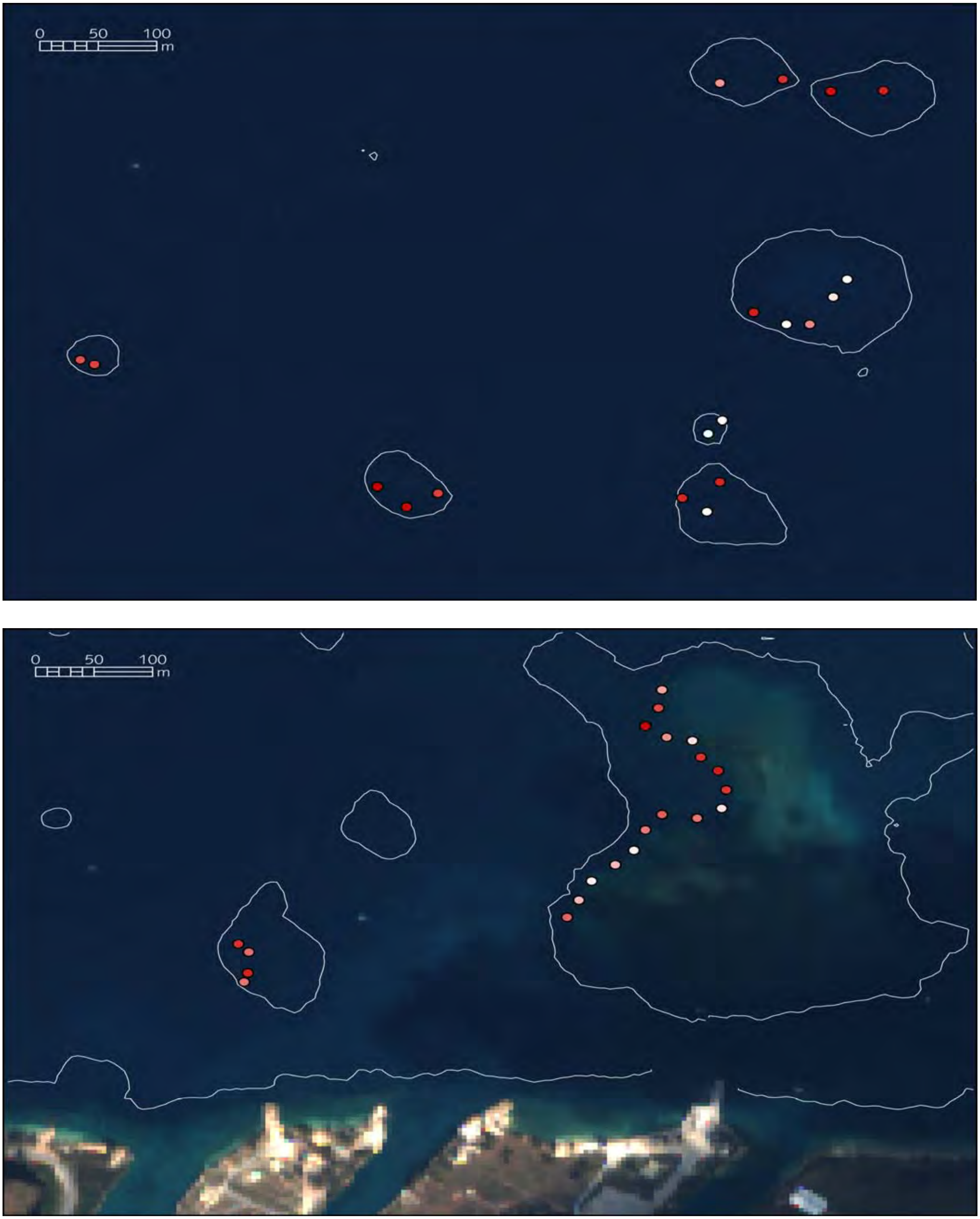


FIGURE 46. Sectors 5 (top) and 6 (bottom) of Apra Harbor study area showing mid-Harbor pinnacles and western side of the southernmost patch reef of Western Shoals showing locations of cal/val sites color coded for coral abundance (see Figure 42 for coral abundance scale).

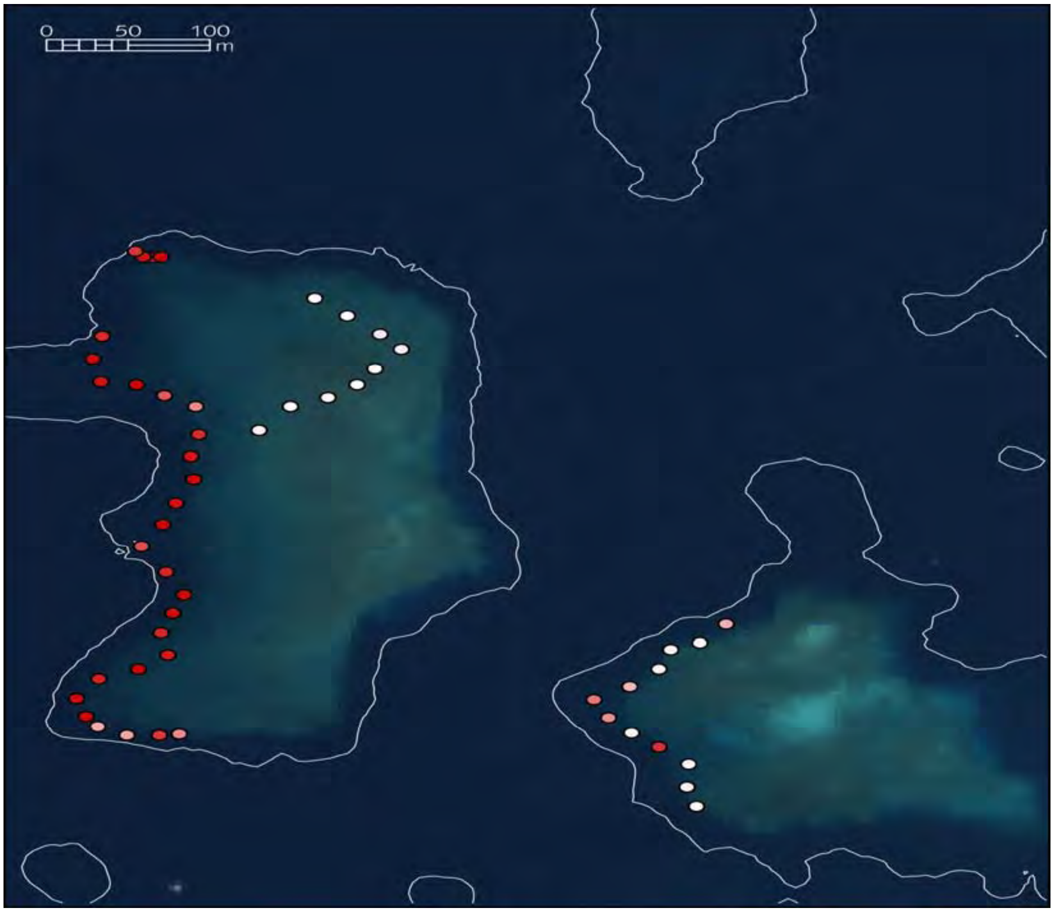
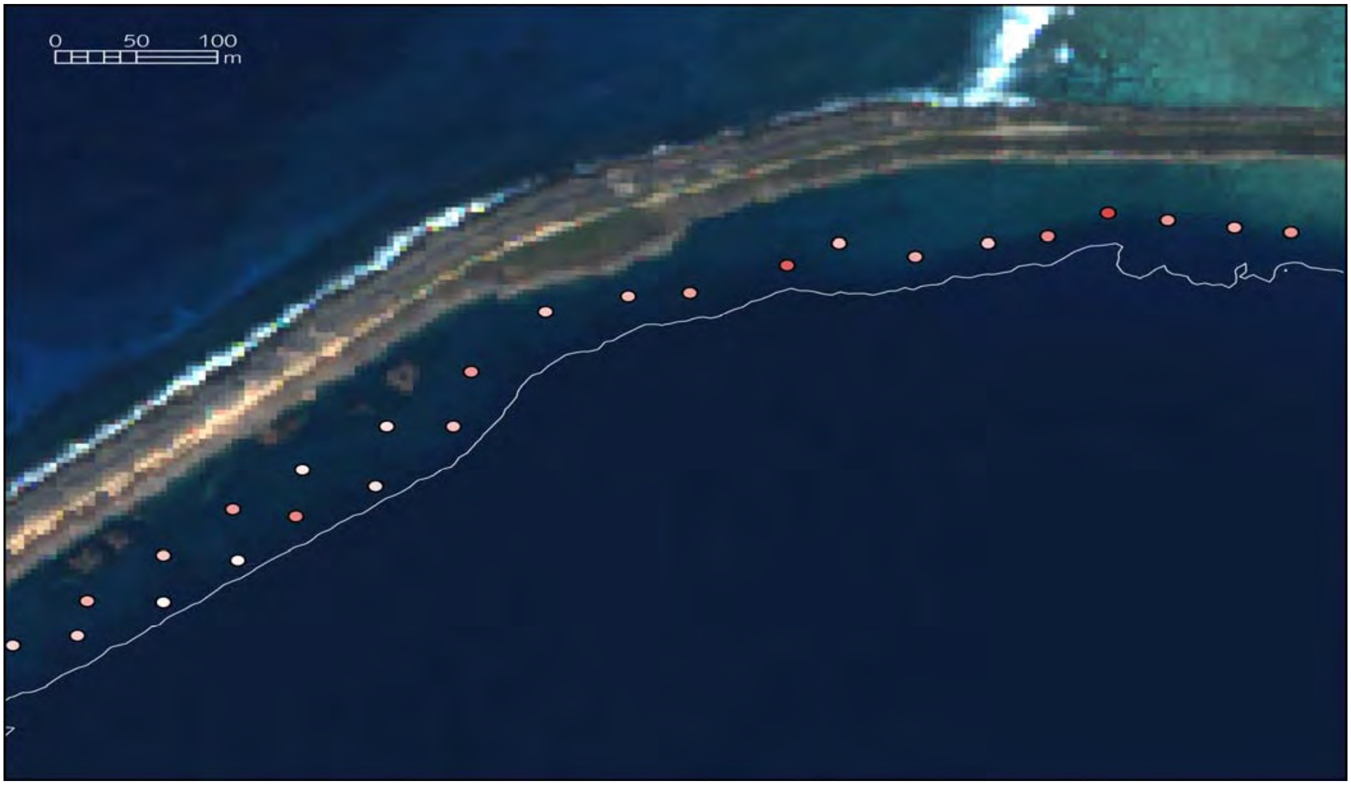


FIGURE 47. Sector 7 (top) of Apra Harbor study area showing central and northern patch reefs of Western Shoals, and Sector 8 (bottom) showing Jade Shoals. Cal/val points are shown as circles color coded for coral abundance (see Figure 42 for coral abundance scale).

FIGURE 48. Sector 9 (top) of Apra Harbor study showing area large flat-topped pinnacle in center of Harbor, and Sector 10 (bottom) showing western end of inner Glass Breakwater. Cal/val points are shown as circles color coded for coral abundance (see Figure 42 for coral abundance scale).



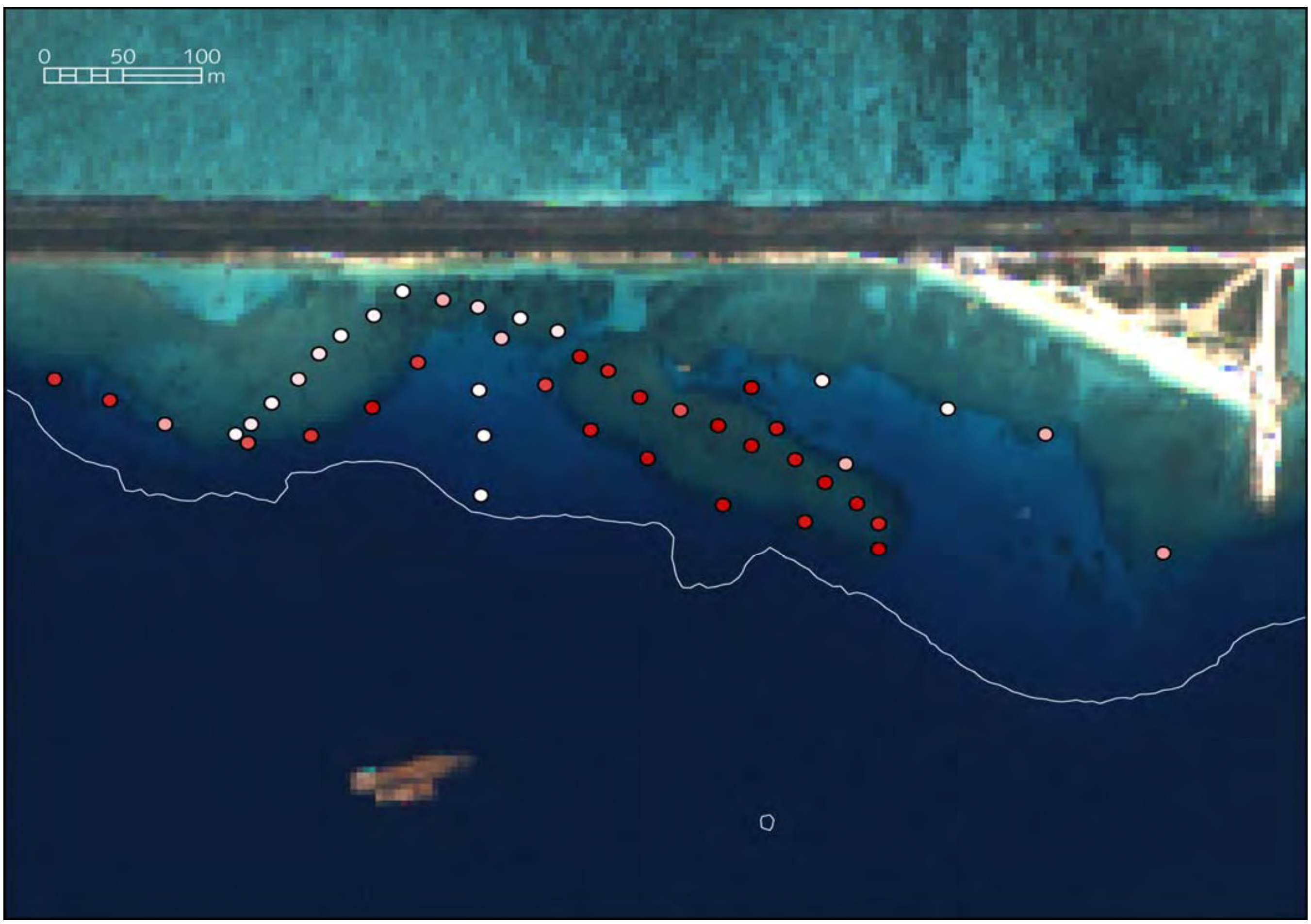


FIGURE 49. Sector 11 (top) of Apra Harbor study area showing central portion of inner Glass Breakwater, and Sector 12 (bottom) showing “Dog-Leg Reef”. Cal/val points are shown as circles color coded for coral abundance (see Figure 42 for coral abundance scale).

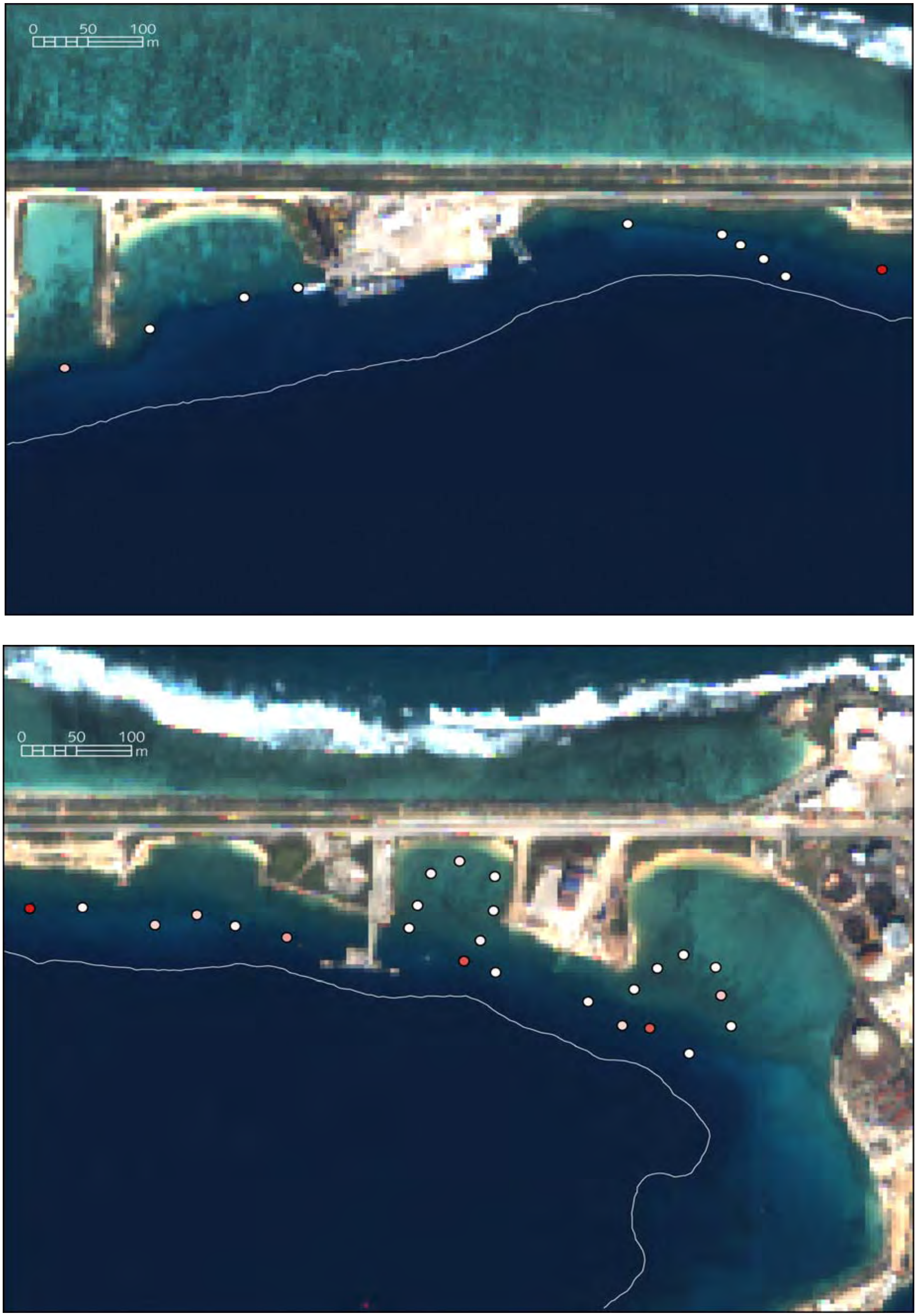


FIGURE 50. Sectors 13 (top) and 14 (bottom) of northern Apra Harbor study area. Cal/val points are shown as circles color coded for coral abundance (see Figure 42 for coral abundance scale).

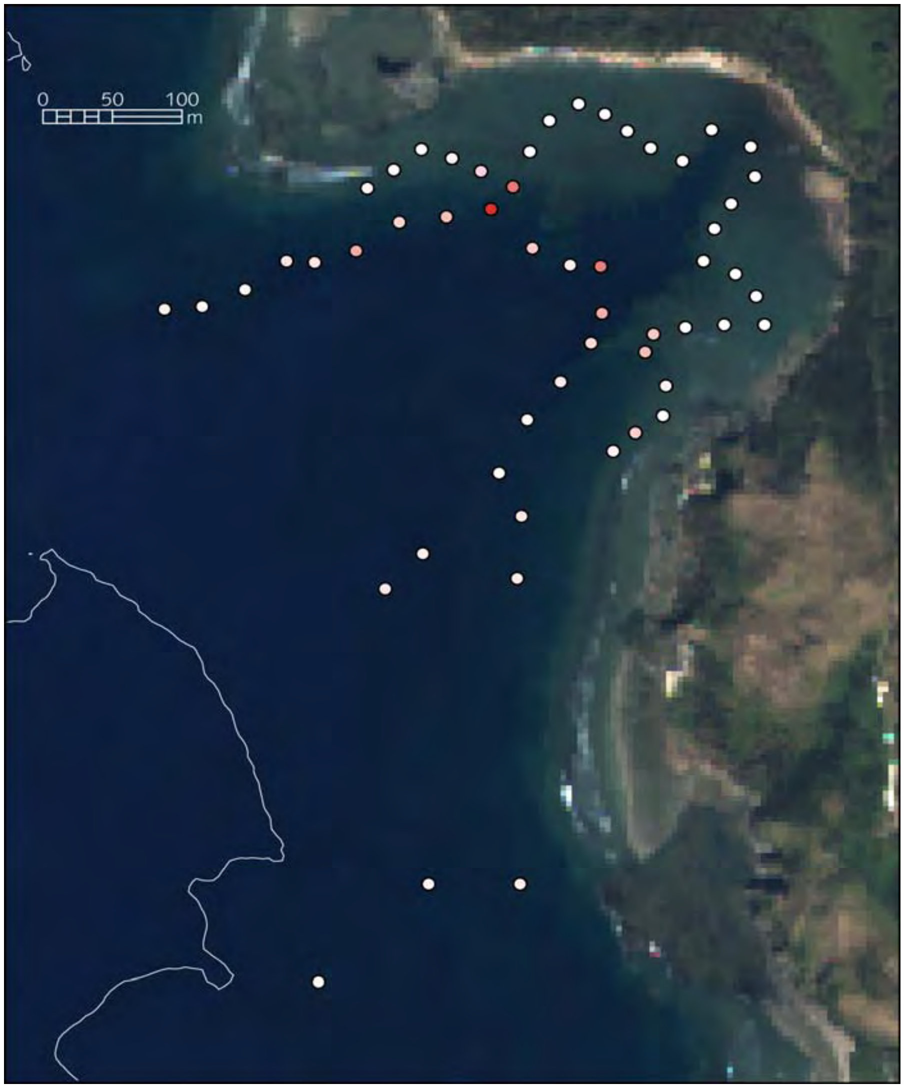


FIGURE 51. Sector 15 (top) showing study area of Fouha Bay and Sector16 (bottom) showing Umatac Bay study area. Cal/val points are shown as circles color coded for coral abundance (see Figure 43 for coral abundance scale).

FIGURE 52. Sector 17 (top) showing headland between Umatac and Togoan Bays, and Sector18 (bottom) showing Togoan Bay study area. Cal/val points are shown as circles color coded for coral abundance (see Figure 43 for coral abundance scale).

FIGURE 53. Sector 19 showing Bile Bay study area. Cal/val points are shown as circles color coded for coral abundance (see Figure 43 for coral abundance scale).

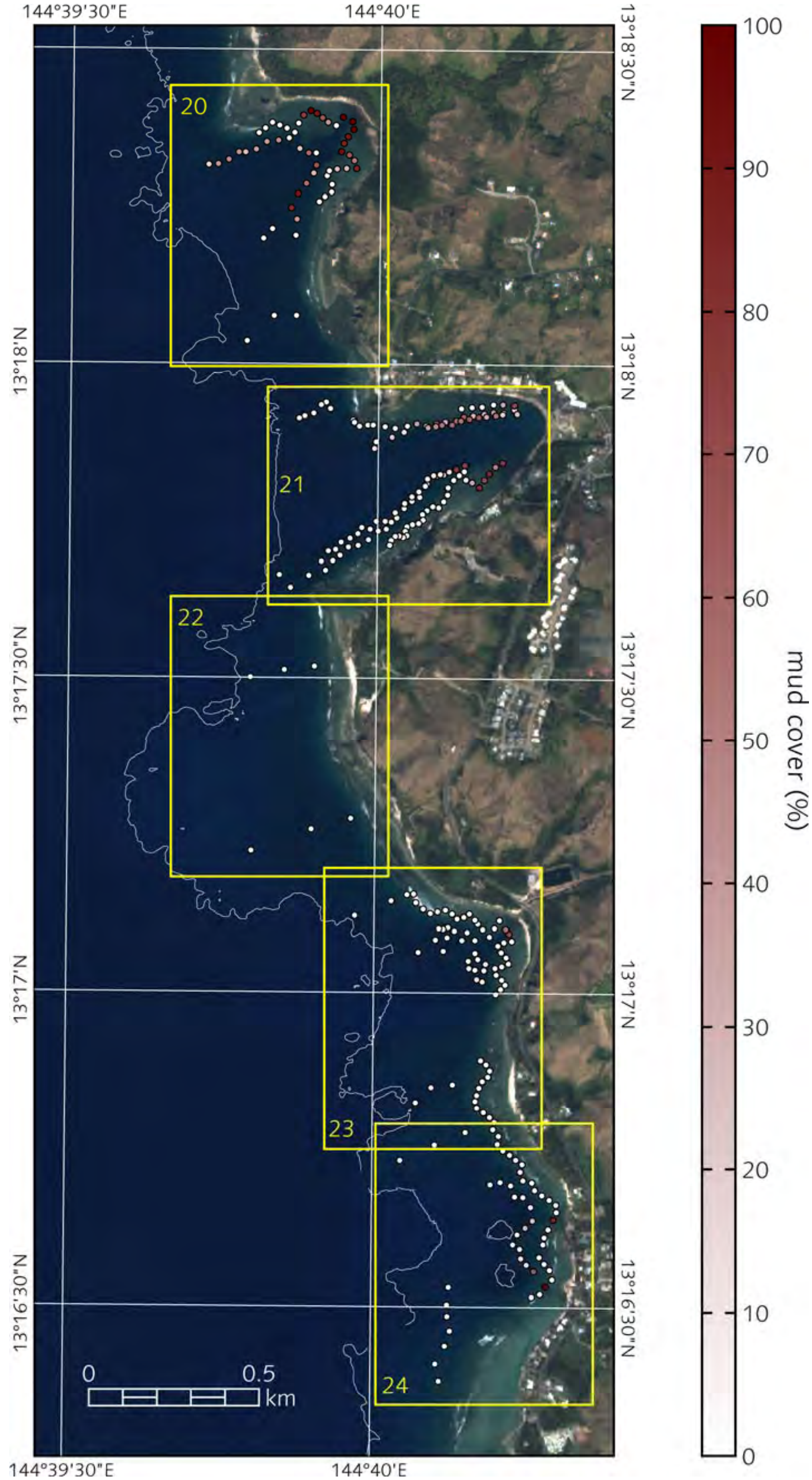


FIGURE 54. Overview satellite image of southwestern Guam watershed study area by bay sector. Cal/val points are shown as circles color coded for occurrence of mud on the reef. Color scale for percentage cover of reef by mud is shown at right.

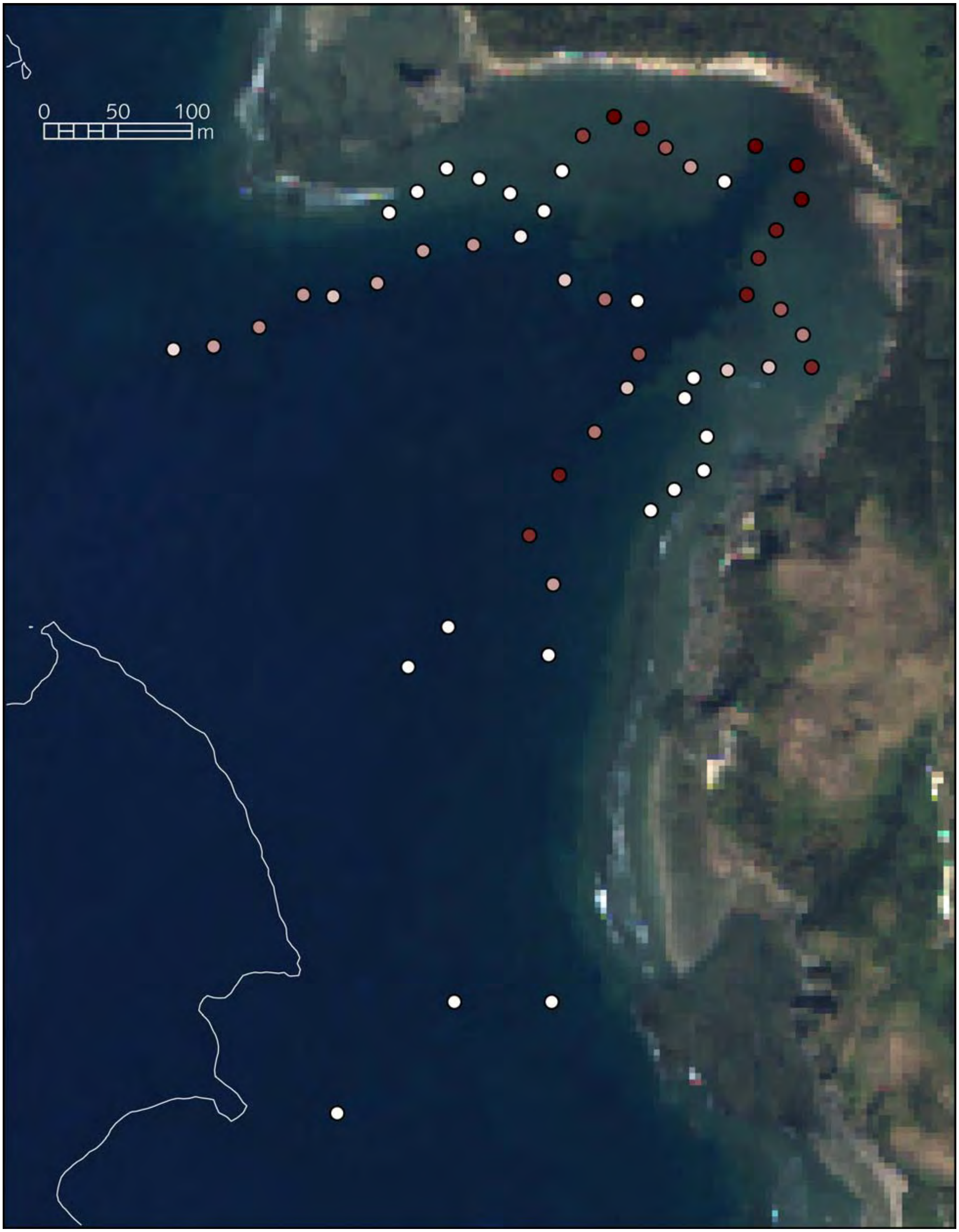


FIGURE 55. Sector 20 showing Fouha Bay study area. Cal/val points are shown as circles color coded for mud abundance (see Figure 54 for mud abundance scale).

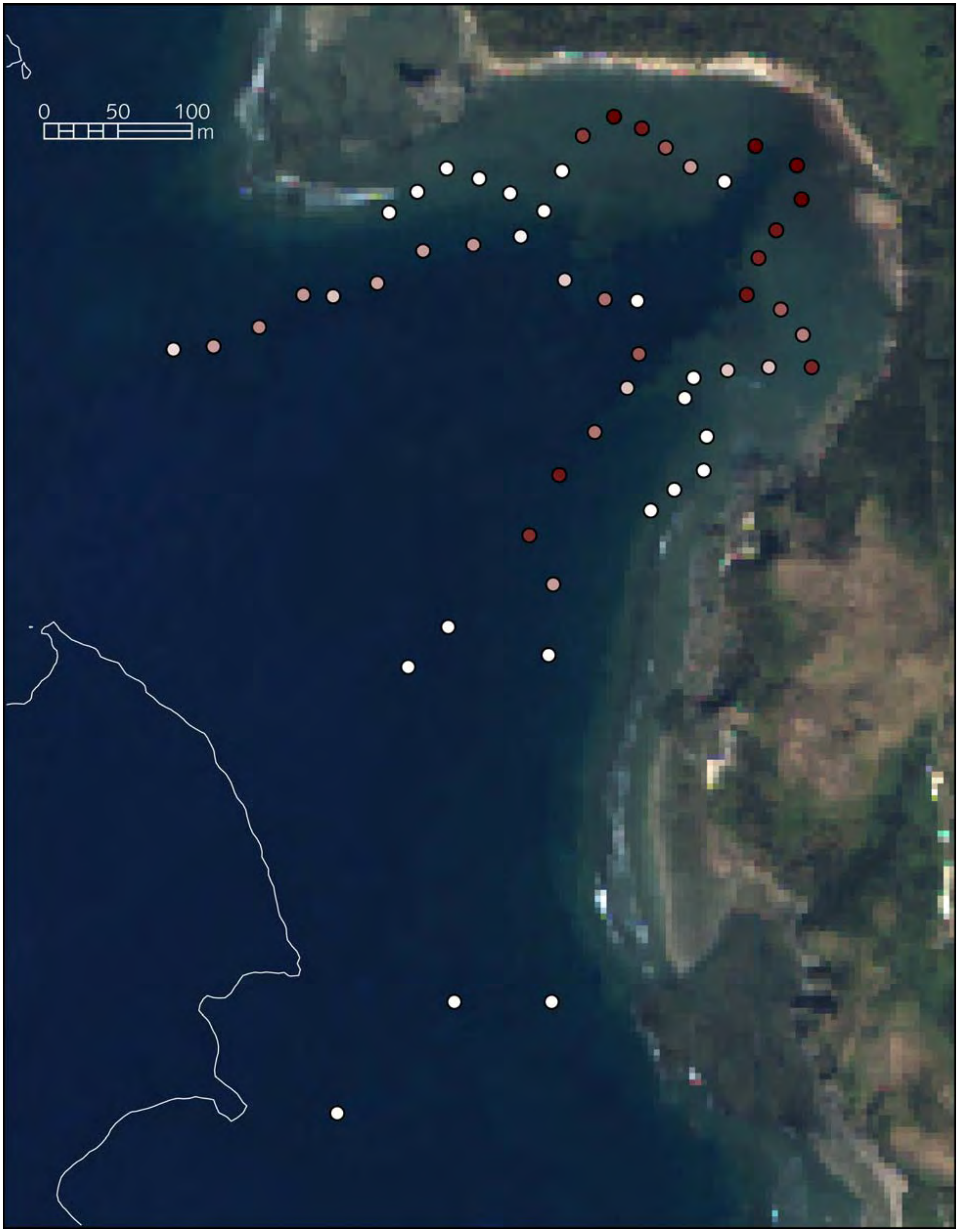


FIGURE 55. Sector 20 showing Fouha Bay study area. Cal/val points are shown as circles color coded for mud abundance (see Figure 54 for mud abundance scale).

FIGURE 56. Sectors 21(top) showing Umatec Bay and 23 (bottom) showing Toguan Bay study areas. Cal/val points are shown as circles color coded for mud abundance (see Figure 54 for mud abundance scale).

FIGURE 57. Sectors 24 showing Bile Bay study areas. Cal/val points are shown as circles color coded for mud abundance (see Figure 54 for mud abundance scale).

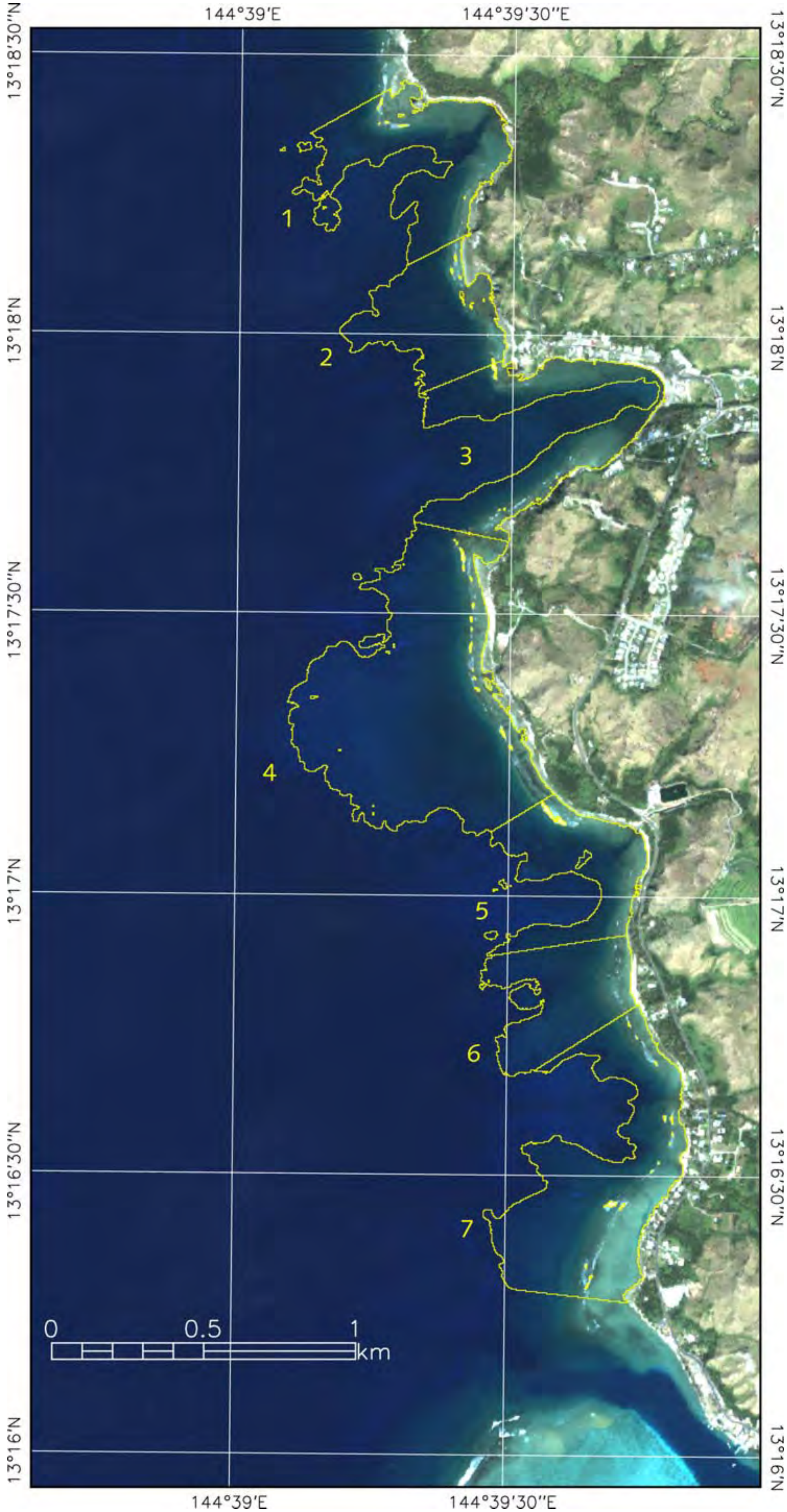


FIGURE 58. Image of southwestern Guam Watersheds showing zones (marked by yellow dashed lines) used to calculate percentage benthic reef cover (see Table 2).

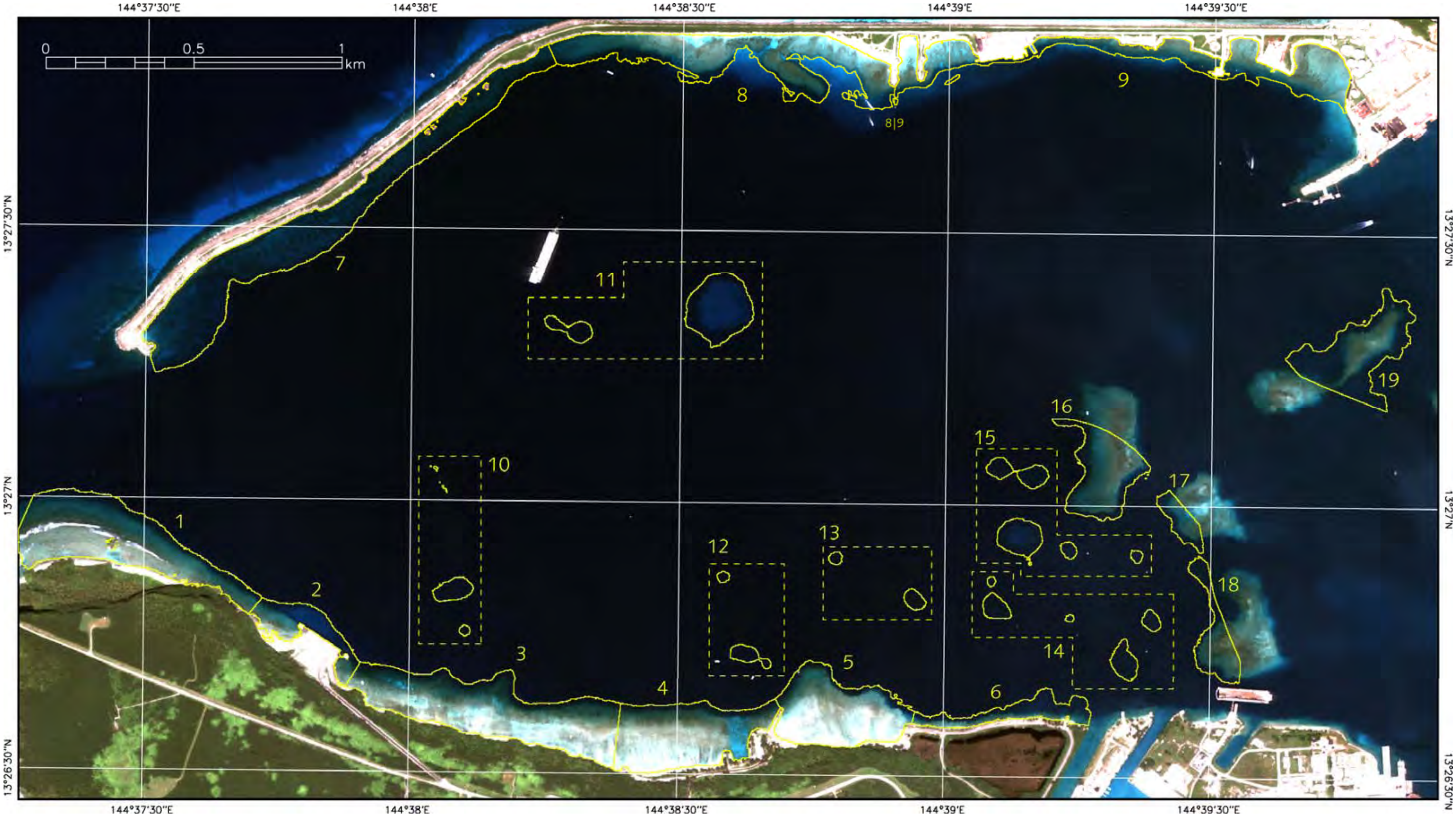


FIGURE 59. Image of Apra Harbor showing zones (marked by yellow dashed lines) used to calculate percentage benthic reef cover (see Table 2).

TABLE 1. Percentage (A), Area (square meters) (B) and acres (C) of each bottom type from calibration/validation points collected in watersheds of southwestern Guam from Fouha Bay to Bile Bay. See Figure 58 for locations of zones. Abbreviations for bottom types are: LS= limestone; Dead co = dead coral; CCA = crustose calcareous algae; mud/tbs = mud and turf-bound sediment.

(A) Mean Cover (%)

ZONE	CORAL	ALGAE	TURF	SPONGE	SAND	LS	DEAD CO	CCA	RUBBLE	MUD/TBS	OTHER
Watershed 1	10.2	29.8	9.3	1.4	2.5	7.7	0.2	1.2	0.5	37.3	0.0
Watershed 2	4.9	66.3	14.6	6.0	8.1	0.0	0.1	0.0	0.0	0.0	0.0
Watershed 3	19.9	27.6	25.5	0.7	2.6	6.4	0.1	1.4	0.0	15.6	0.1
Watershed 4	10.1	22.1	57.6	0.2	1.1	7.5	0.1	1.1	0.1	0.0	0.0
Watershed 5	20.1	26.4	33.0	0.4	1.9	12.6	0.1	1.4	0.3	3.6	0.1
Watershed 6	14.5	39.5	33.0	0.6	3.0	8.3	0.0	0.7	0.0	0.4	0.1
Watershed 7	16.8	23.9	42.8	1.6	1.5	4.8	0.0	0.8	0.1	7.6	0.0
AVERAGE	13.8	33.7	30.8	1.6	3.0	6.8	0.1	0.9	0.1	9.2	0.0

Areas (m^2)

ZONE	CORAL	ALGAE	TURF	SPONGE	SAND	LS	DEAD CO	CCA	RUBBLE	MUD/TBS	OTHER	TOTAL
Watershed 1	19761	55660	18359	2635	4979	15333	389	2295	1011	74058	0	194480
Watershed 2	7001	95547	21004	8649	11737	0	206	0	0	0	0	144144
Watershed 3	34454	50864	47854	1357	4999	12094	206	2638	0	27507	124	182096
Watershed 4	51130	112307	293041	1272	5851	38156	636	5724	636	0	0	508752
Watershed 5	27557	36209	37810	595	2634	17271	105	1983	395	12264	137	136961
Watershed 6	20650	56318	47082	826	4280	11789	0	1051	0	601	75	142672
Watershed 7	52873	75052	134731	5062	4788	15116	68	2462	410	23940	137	314640
TOTAL	213425	481957	599880	20396	39268	109760	1611	16153	2453	138370	473	1623745

Area (acres)

ZONE	CORAL	ALGAE	TURF	SPONGE	SAND	LS	DEAD CO	CCA	RUBBLE	MUD/TBS	OTHER	TOTAL
Watershed 1	5	14	5	1	1	4	0	1	0	18	0	48
Watershed 2	2	24	5	2	3	0	0	0	0	0	0	36
Watershed 3	9	13	12	0	1	3	0	1	0	7	0	45
Watershed 4	13	28	72	0	1	9	0	1	0	0	0	126
Watershed 5	7	9	9	0	1	4	0	0	0	3	0	34
Watershed 6	5	14	12	0	1	3	0	0	0	0	0	35
Watershed 7	13	19	33	1	1	4	0	1	0	6	0	78
TOTAL	53	119	148	5	10	27	0	4	1	34	0	401

TABLE 2. Percentage (A), Area (square meters) (B) and acres (C) of each bottom type from calibration/validation points collected in Apra Harbor Guam. See Figure 59 for locations of zones. Abbreviations for bottom types are: LS= limestone; Dead co = dead coral; CCA = crustose calcareous algae; mud/tbs = mud and turf-bound sediment.

(A) Mean Cover (%)

ZONE	CORAL	ALGAE	TURF	SPONGE	SAND	LS	DEAD CO	CCA	RUBBLE	MUD/TBS	OTHER
Apra 1	32.3	16.7	6.2	1.9	2.5	39.0	0.5	0.3	0.4	0.0	0.0
Apra 2	15.6	28.2	26.0	1.4	27.4	0.0	0.6	0.0	0.8	0.0	0.0
Apra 3	49.0	14.4	6.5	0.9	7.0	22.1	0.0	0.0	0.1	0.0	0.0
Apra 4	62.4	7.3	0.0	2.4	5.0	20.6	0.8	0.0	1.0	0.0	0.4
Apra 5	43.3	25.3	0.3	4.8	9.9	13.0	0.0	0.0	3.2	0.0	0.1
Apra 6	35.1	22.1	10.7	6.2	5.7	8.9	0.3	0.0	9.7	1.3	0.0
Apra 7	23.9	20.7	9.4	6.0	30.5	3.1	0.7	0.2	5.5	0.0	0.0
Apra 8	50.1	18.9	7.5	1.3	13.8	1.8	0.2	0.2	0.5	0.4	5.3
Apra 9	12.1	31.3	10.6	1.2	37.2	4.4	0.1	0.4	0.8	1.8	0.0
Apra 10	91.2	7.2	0.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apra 11	25.7	2.4	0.0	3.2	61.1	4.5	0.0	0.0	3.0	0.0	0.1
Apra 12	85.7	8.0	0.5	4.1	0.0	0.2	1.5	0.0	0.0	0.0	0.0
Apra 13	82.2	9.4	0.0	3.0	0.8	1.0	3.0	0.0	0.6	0.0	0.0
Apra 14	55.4	14.8	1.6	11.5	0.0	0.1	0.0	0.0	16.4	0.0	0.2
Apra 15	49.1	16.0	0.0	10.0	4.0	0.0	0.0	0.0	20.9	0.0	0.0
Apra 16	81.2	7.3	0.7	4.0	0.5	1.4	1.7	0.1	2.9	0.0	0.3
Apra 17	27.9	23.0	30.8	4.5	8.3	0.0	0.0	0.0	4.9	0.2	0.2
Apra 18	29.9	22.6	28.6	6.1	0.7	0.3	0.0	10.0	1.8	0.0	0.0
Apra 19	60.6	9.7	2.3	0.4	1.6	3.2	0.0	0.5	21.8	0.0	0.0
AVERAGE	48.0	16.1	7.5	3.9	11.4	6.5	0.5	0.6	5.0	0.2	0.3

Areas (m^2)

ZONE	CORAL	ALGAE	TURF	SPONGE	SAND	LS	DEAD CO	CCA	RUBBLE	MUD/TBS	OTHER	TOTAL
Apra 1	42572	22022	8218	2497	3301	51312	716	426	581	0	0	131645
Apra 2	5483	9912	9138	492	9648	0	211	0	264	0	0	35148
Apra 3	74401	21868	9861	1361	10646	33456	0	0	108	0	0	151701
Apra 4	61609	7250	0	2417	4938	20379	780	0	988	0	390	98750
Apra 5	39147	22908	302	4390	8950	11758	0	0	2926	0	126	90507
Apra 6	11165	7045	3412	1962	1820	2832	91	0	3093	423	0	31841
Apra 7	46394	40097	18138	11572	59095	6028	1399	377	10657	0	0	193755
Apra 8	69558	27842	11156	1854	12739	2603	243	323	512	0	7902	134732
Apra 9	14608	39612	13371	1160	33721	5172	77	500	1076	2126	0	111421
Apra 10	8095	639	18	124	0	0	0	0	0	0	0	8876
Apra 11	12145	1113	0	1535	28851	2120	0	0	1400	0	68	47232
Apra 12	5583	523	33	267	0	11	98	0	0	0	0	6515
Apra 13	4219	480	0	156	41	51	154	0	31	0	0	5132
Apra 14	10191	2715	299	2116	0	23	0	0	3014	0	46	18403
Apra 15	14387	4687	0	2930	1172	0	0	0	6120	0	0	29295
Apra 16	45761	4104	371	2279	289	801	934	30	1639	0	148	56356
Apra 17	4007	3307	4429	642	1194	0	0	0	709	36	36	14360
Apra 18	8895	6724	8510	1824	199	99	0	2977	546	0	0	29773
Apra 19	44607	7148	1696	290	1160	2382	0	335	16023	0	0	73642
TOTAL	522827	229997	88950	39868	177763	139026	4702	4967	49684	2585	8715	1269084

Area (acres)

ZONE	CORAL	ALGAE	TURF	SPONGE	SAND	LS	DEAD CO	CCA	RUBBLE	MUD/TBS	OTHER	TOTAL
Apra 1	11	5	2	1	1	13	0	0	0	0	0	33
Apra 2	1	2	2	0	2	0	0	0	0	0	0	9
Apra 3	18	5	2	0	3	8	0	0	0	0	0	37
Apra 4	15	2	0	1	1	5	0	0	0	0	0	24
Apra 5	10	6	0	1	2	3	0	0	1	0	0	22
Apra 6	3	2	1	0	0	1	0	0	1	0	0	8
Apra 7	11	10	4	3	15	1	0	0	3	0	0	48
Apra 8	17	7	3	0	3	1	0	0	0	0	2	33
Apra 9	4	10	3	0	8	1	0	0	0	1	0	28
Apra 10	2	0	0	0	0	0	0	0	0	0	0	2
Apra 11	3	0	0	0	7	1	0	0	0	0	0	12
Apra 12	1	0	0	0	0	0	0	0	0	0	0	2
Apra 13	1	0	0	0	0	0	0	0	0	0	0	1
Apra 14	3	1	0	1	0	0	0	0	1	0	0	5
Apra 15	4	1	0	1	0	0	0	0	2	0	0	7
Apra 16	11	1	0	1	0	0	0	0	0	0	0	14
Apra 17	1	1	1	0	0	0	0	0	0	0	0	4
Apra 18	2	2	2	0	0	0	0	1	0	0	0	7
Apra 19	11	2	0	0	0	1	0	0	4	0	0	18
TOTAL	129	57	22	10	44	34	1	1	12	1	2	314

FINAL

WATERSHED ASSESSMENT FOR POTENTIAL CORAL MITIGATION PROJECTS

Umatac, Toguan, Geus and Ugum Watersheds, Guam

June 28, 2010

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, HI 96860-3134

Naval Facilities Engineering Command
NAVFAC PACIFIC

AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives Contract Number N62742-06-D-1870, TO 0047 (Amend 53)

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Appendix A Watershed Modeling Factors

List of Acronyms and Abbreviations

4WD	Four-wheel Drive
ac	Acres
ARS	Agriculture Research Service
BCA	Bolanos Conservation Area
BSP	Bureau of Statistics and Plans
CVN	Carrier Vessel Nuclear
DGO	Geographic Data Overview
EIS	Environmental Impact Statement
ft	Feet
GEPA	Guam Environmental Protection Agency
GIS	Geographic Information System
GDAWR	Government of Guam Department of Agricultural and Wildlife Resources
GWA	Guam Water Authority
ha	Hectares
km	Kilometers
Km/h	Kilometers per Hour
m	Meter
mi	Miles
mph	Miles per hour
NAVFAC	Naval Facilities Engineering Command
NAVFACMAR	Naval Facilities Engineering Command Marianas
NRCS	Natural Resource Conservation Service
N-SPECT	Non-Source Pollution and Erosion Comparison Tool
RUSLE	Revised Unified Soil Loss Equation
sq ft	square feet
sq m	square meters
TO	Task Order
TSS	Total Suspended Solids
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USLE	Unified Soil Loss Equation
WERI	Water and Environment Research Institute
WP	Way Point

EXECUTIVE SUMMARY

This Watershed Assessment was initiated by NAVFAC to collect the necessary data to support the Environmental Impact Statement (EIS) by providing coral mitigation options to the CVN berthing in Apra Harbor.

This Watershed Assessment for the Umatac, Toguan, Geus and Ugum Watersheds on Guam has been prepared to evaluate soil erosion and sediment discharge into the coastal areas of southern Guam as part of the potential mitigation for loss of coral resulting from the proposed CVN berthing in Apra Harbor.

This assessment has accomplished the objectives of the study to briefly assess and document the existing conditions of the watersheds and provide a GIS based model of soil erosion in each watershed. This initial study will be used by the Navy to assist in assessing the potential of conducting improvements to the watershed sites to mitigate anticipated effects to coral caused by the proposed action.

This report presents the overall approach taken during implementation of the Umatac, Toguan, Geus and Ugum Watershed Assessments including: 1) a limited verification of the watersheds GIS coverages, 2) modeling of sediment discharge from sheet and rill, gully, stream, and mass-wasting sources using N-SPECT and RUSLE2, 3) an estimation of sediment transport and deposition in the watershed drainage system, 4) identification and discussion of factors that affect soil erosion and sediment deposition, including urban development and 5) proposals for specific conservation practices to reduce erosion and sedimentation.

There report describes the study areas in detail based on available GIS coverages and from the field verification effort. The assessment then provides preliminary estimates for erosion and sediment yield. The lack of site specific data on flow and TSS levels in each river limits the reliability of the modeling results. The results of this modeling effort should be used as an upper bound estimate for planning purposes.

The sediment yield evaluation was modeled using to methodologies:

- An ArcGIS based model - The long-term average annual soil loss will be calculated using the USLE in the manner described in the University of Guam (UOG) Water and Environmental Research Institute (WERI) Technical Publication (TP) # 117 *Developing a GIS-based Soil Erosion Potential Model of the Ugum Watershed.*

- NOAA’s N-SPECT - NOAA's Coastal Services Center a tool to calculate the Nonpoint Source Pollution and Erosion.

Total TSS loads for each watershed were calculated for the Umatac at 997 tonnes/yr (1,099 tons/yr); for the Toguan 405.5 tonnes/yr (447 tons/yr); for the Geus at 312.1 tonnes/year (344 tons/yr); and for the Ugum 1,322.7 tonnes/yr (1,458 tons/yr).

Limited total suspended solids data is available for the rivers in the four watersheds. For the La Sa Fua River the average TSS yield for the period 2005 through 2009 is 1,640.1 tonnes/yr (1,808 tons/yr). The baseline model TSS yield for the La Sa Fua River is 484.4 tonnes/yr (534 tons/yr), indicating the TSS yields from the model may be biased low.

Finally, this assessment describes potential conservation alternatives that are feasible within each watershed and calculates the reduction in TSS load to the coastal marine environment. The alternatives include replanting of bare/badlands and savanna areas on Government of Guam Lands, controlling the burn cycle, and control of ungulate damage. Due to lack of potential future development in these watersheds implementing new road designs and implementing construction best management practices is not proposed although should be implemented if necessary at some future time frame. In addition, due to the private land ownership along the rivers and the coast the construction of sediment basins, construction of mangrove areas along the coast or wetland enhancement is not proposed.

1 INTRODUCTION

The TEC JV received Task Order (TO) 0047 (Amend 53) for Watershed Assessment Surveys on Guam in support of a Marine Corps Relocation Initiative to Various Locations on Guam under a NAVFAC contract for AE Services for Environmental Planning to Support Strategic Forward Basing Initiatives. The basis for this assignment was to provide the necessary data to support the Environmental Impact Statement (EIS) for the Joint Guam Program Office actions relating to the relocation of the Marines by providing coral mitigation options to the CVN berthing in Apra Harbor.

This Watershed Assessment for the Umatac, Toguan, Geus, and Ugum Watersheds on Guam has been prepared to evaluate soil erosion and sediment discharge into the coastal areas of southern Guam and to develop potential conservation projects.

This report presents the overall approach taken during implementation of the Umatac, Toguan, Geus, and Ugum Watershed Resource Assessments, including: 1) a limited verification of the watersheds GIS coverages, 2) modeling of sediment discharge from sheet and rill, gully, stream, and mass-wasting sources using N-SPECT and RUSLE2, 3) an estimation of sediment transport and deposition in the watershed drainage system, 4) identification and discussion of factors that affect soil erosion and sediment deposition, including urban development, and 5) proposals for specific conservation practices to reduce erosion and sedimentation.

The report is comprised of seven sections and one appendix, as listed below:

Section 1 (this section) is the introduction.
Section 2 describes the study area.
Section 3 presents a summary of the Rapid Watershed Assessment.
Section 4 presents an identification of the methodologies for developing and monitoring conservation projects.
Section 5 presents the potential monitoring.
Section 6 contains report conclusions.
Section 7 contains the references used to develop this report.

2 STUDY AREA

Guam lies between 13.2°N and 13.7 °N and between 144.6°E and 145.0°E and is an unincorporated territory of the United States. Guam is the largest and southernmost island of the Mariana Island chain (Figure 1). Guam is approximately 48 kilometers (km) (30 miles [mi]) long and 17.6 km (11 mi) wide at its widest point. Total land area is approximately at 212 square miles. The Mariana Islands border the Pacific Ocean on their east coast and the Philippine Sea on their west. Guam ranges from 0 meters (m) (0 feet [ft]) in elevation to 406 m (1,332 ft) at its highest elevation near Mount Lamlam. The project watersheds are located in southern Guam (Figure 2).

The watersheds investigated comprise Umatac (991.4 hectares (ha) [2,450 acres (ac)]), Toguan (364.2 ha [900 ac]), Geus 448.7 ha (1,109 acres), and 562.5 ha (1,390 ac) of the Bolanos Conservation Area (BCA) of the Ugum Watershed. The watersheds contain some of the largest rivers on Guam as well as other minor drainages into the Philippine Sea and the southern Pacific Ocean (Figure 2). Topography in all four watersheds is moderately sloping to steep or flat along the coastal fringe.

2.1 Climate

Guam's climate is considered tropical marine resulting in a climate, which is hot and humid with average temperatures between 70°F and 90°F. Rainfall averages on Guam are between 219.9 and 292.1 centimeters (cm) (85 and 115 inches [in] per year). Rainfall derives from rainstorms of intense but short duration with irregular distribution across the island. There is a two season (rainy and dry) hydrological cycle. Rainfall averages vary from a few inches per month in February to April to more than ten inches during September and October. The rainy season typically starts in late June and continues through November. In addition, Guam is located along the major typhoon track for the western Pacific. An average of three tropical storms and one typhoon pass Guam annually. Based on annual rainfall averages, southern Guam receives more rainfall than northern Guam.

The trade winds are from the east or northeast direction. During the dry season, the trade winds of 25.6 to 40 kph (16 to 25 mph) are the norm. Thunderstorms may be accompanied by severe downbursts of wind that may cause localized damage. Damaging winds exceeding 100 km/h (62 mph) associated with storm events occur infrequently.

Figure 1 Guam and the Northern Mariana Islands

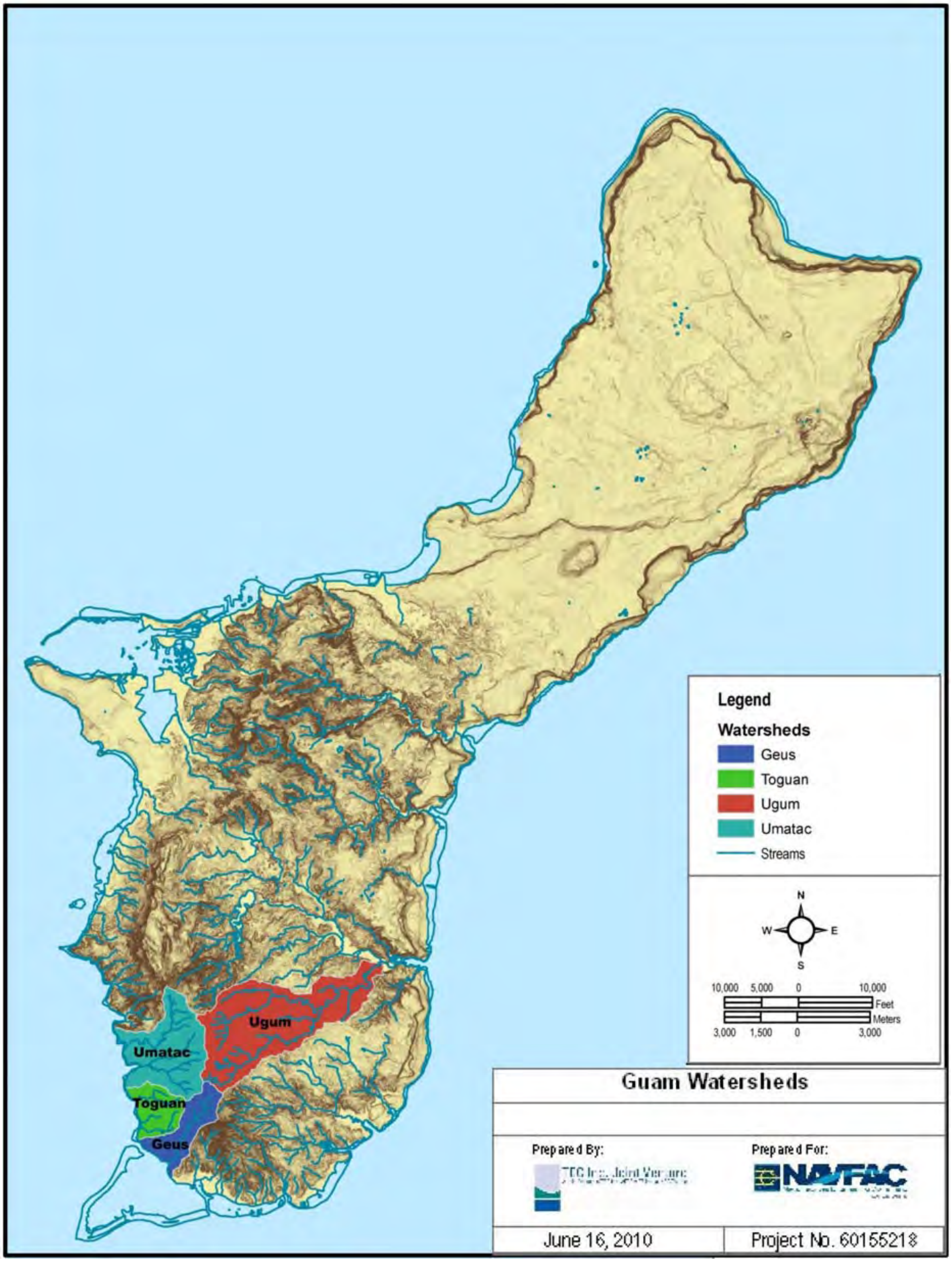


Figure 2 Umatac, Toguan, Geus, and Ugum Watersheds

3 WATERSHED ASSESSMENT

A Watershed Assessment (WA) was conducted by the TEC JV for of the Umatac, Toguan, Geus, and Ugum watersheds (Figure 2) to assist the Navy in the selection of upland mitigation sites and strategies in southern Guam. The purpose of the upland mitigation is to reduce sediment deposition into the near-shore marine environments of southern Guam, which directly impact coastal coral reefs. Within the Ugum Watershed, only lands in the BCA were investigated and are proposed for conservation activities. The BCA is a 1,153-ha (2,850-acre) parcel managed by Government of Guam, Division of Aquatic and Wildlife Resources (GDAWR) for hunting and outdoor recreation.

3.1 Geographic Data Overview

Using established procedures developed by the Agriculture Research Service (ARS) and the NRCS, the TEC JV developed a map book (Geographic Data Overview [DGO], TEC JV 2010). Coverages include in the DGO include vegetation communities, soils, surface geology, hydrological features (e.g., rivers, drainages), topography (e.g., contours, elevation models, and slope coverages), administrative boundaries, developed/improved areas, aerial photographs, and marine habitats. These coverages we field verified and used in developing this report.

3.2 Field Verification and Data Collection

3.2.1 Field Verification

Prior to developing appropriate conservation projects, existing data from resource agencies and GIS-based resource mapping was reviewed for each watershed. Next, a brief field survey was conducted over a two-week period in May, 2010. The field surveys focused on accomplishing three action items::

1. Confirm, and when necessary correct, the existing resource mapping.
2. Identify potential logistical constraints to restoration activities.
3. Select sites for restoration based on feasibility.

Within this subchapter, the existing conditions of the watersheds are described based on the available agency data and GIS coverages. Following this description, the results of the field investigations are provided.

3.2.1.1 Vegetation

The GIS vegetation coverage is derived from the Guam 2005 high resolution land cover data, which was downloaded from the NOAA Coastal Change Analysis Program web site. The vegetation types are shown in Figure 3 for the Umatac, Toguan, and Geus Watersheds, and in Figure 4 for the Ugum Watershed. The maps depict the following cover types; bare land, cultivated land, deciduous forest, evergreen grassland [savanna complex], impervious surface, open water, scrub/shrub wetlands [estuarine and palustrine], unconsolidated shoreline, urban/built-up, or barren cover type

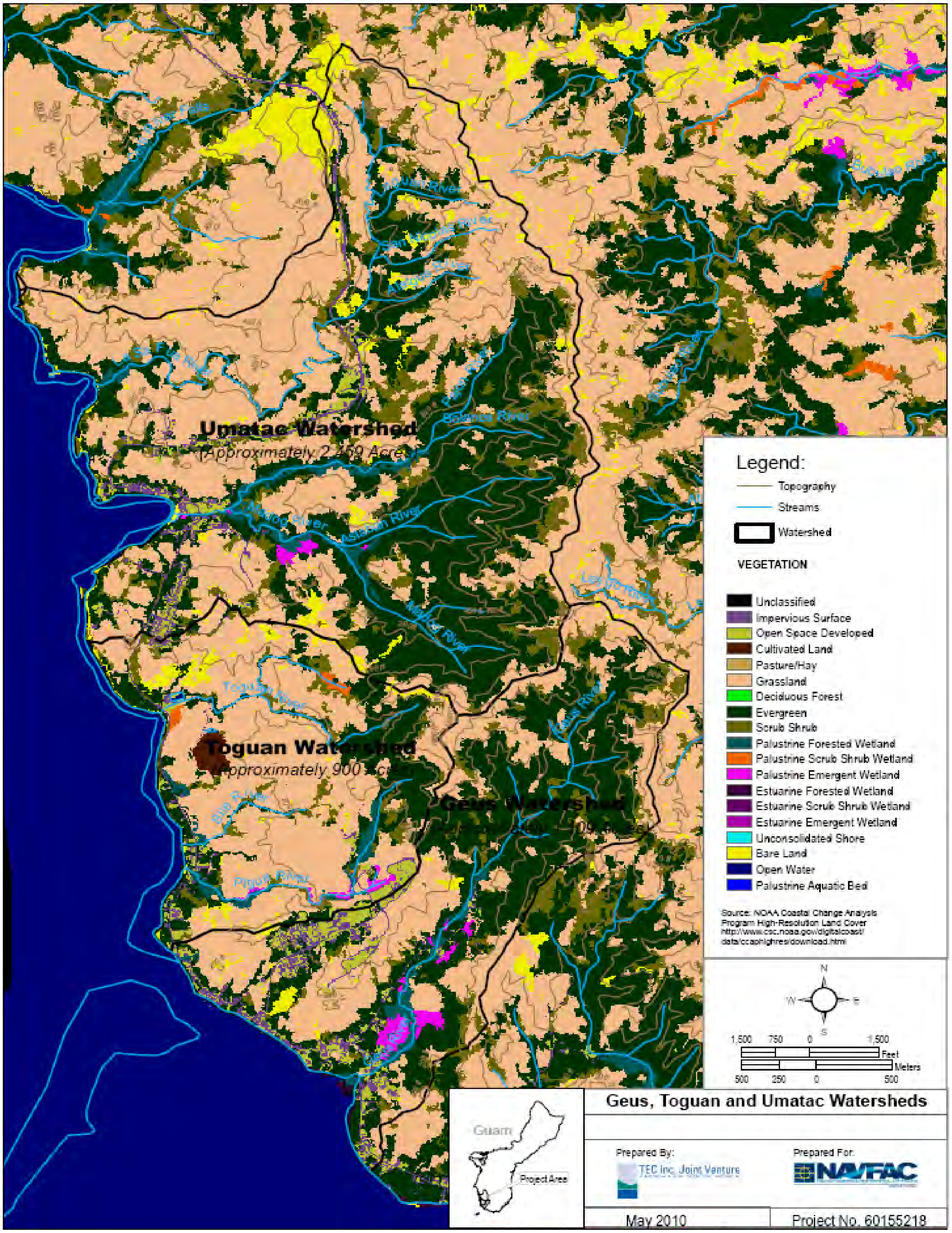


Figure 3 Vegetation Types - Umatac, Toguan, and Geus Watersheds

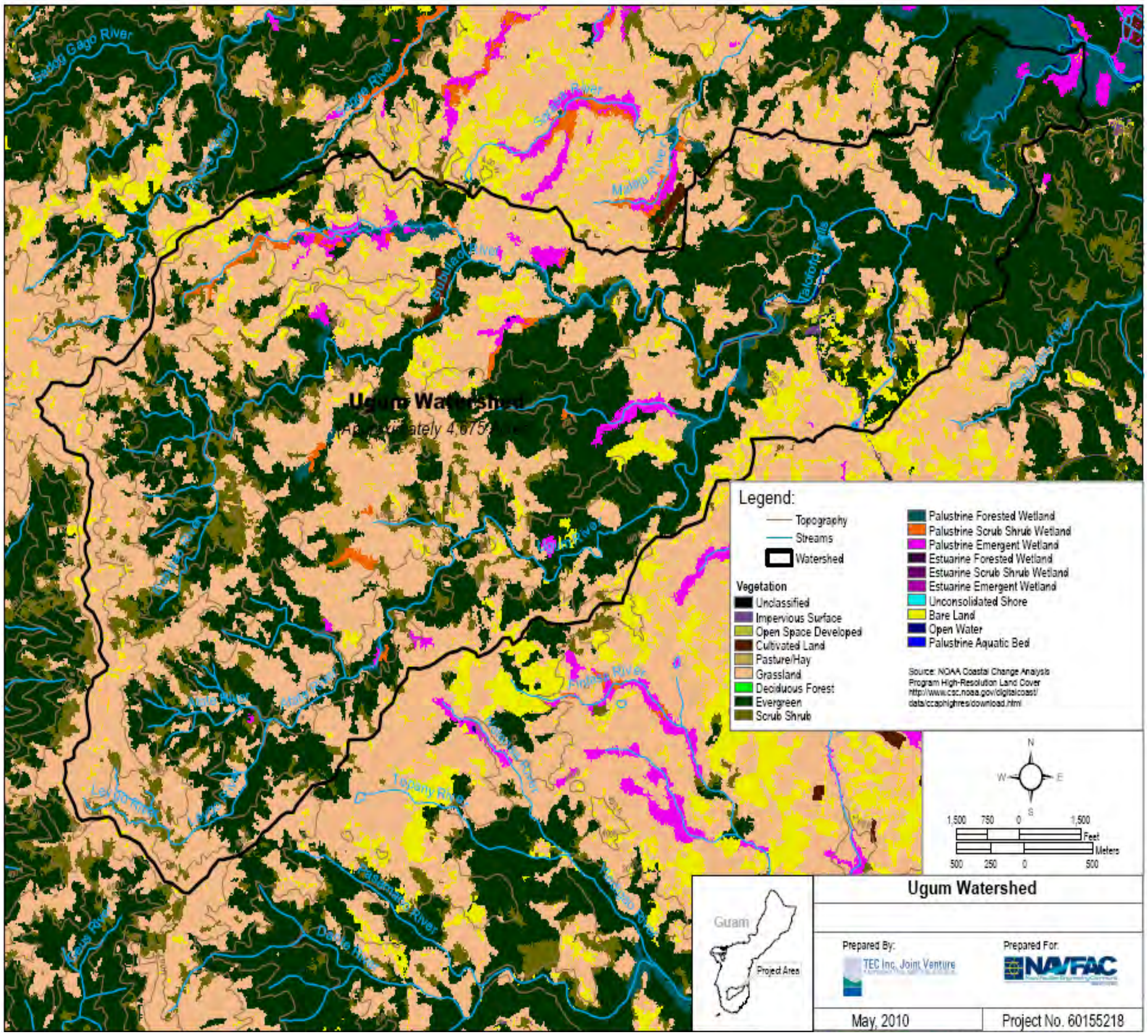


Figure 4 Vegetation Types - Ugum Watershed

Field investigations confirmed that the cover types depicted in the field match the existing conditions within all three watersheds. cover types were confirmed by scientists traversing through each watershed, identifying their geographical position, and then confirming or augmenting the vegetation cover type map. For parcels that could not be accessed due to the need to cross private property or due to safety concerns (i.e., need to either cross steep slopes, areas on fire or recently burned areas, etc.), the scientists selected positions of high elevation and visually scanned the watershed to confirm and/or augment the cover type mapping. Binoculars and a camera's zoom feature assisted in the exercise.

- **Umatac Watershed**

Based on the GIS coverage, the 995.1 ha (2,459 ac) in the Umatac watershed it is comprised of 2.4 ha (6 ac) of badland/barren habitat, 12.1 ha (30 ac) of coconut plantation, 25.4 ha (63 acres) of tangantangan (*Leucaena leucocephala*) stand, 304.7 ha (753 ac) of ravine forest, 573.4 ha (1,417 ac) of savanna complex, 54.2 ha (134 ac) of scrub forest, 14.6 ha (36 ac) of urban build-up, and 5.2 ha (13 ac) of urban cultivated.

- **Toguan Watershed**

Based on the GIS coverage, the 364.2 ha (900 ac) in the Ugum watershed is comprised of 5.2 ha (13 ac) of agricultural field, 1.2 ha (3 ac) of badland habitat and 1.2 ha (3 ac) of barren habitat, 1.2 ha (3 ac) of tangantangan, 27.5 ha (68 ac) of ravine forest, 245.2 ha (606 ac) of savanna complex, 69.2 ha (171 ac) of scrub forest, 5.6 ha (14 ac) of urban build-up, 6.1 ha (15 ac) of urban cultivated, one acre of open water, and 0.8 ha (2 ac) of unclassified land.

- **Geus Watershed**

The cover types within the Geus watershed are identified in Figure 3. Ravine forests were common along the river and within lower elevations of the watershed. Species commonly observed included coconut (*Cocos nucifera*); betel nut, (*Areca catechu*); Pago (*Hibiscus tiliaceus*), and screwpine (*Pananus tectorius*). Forested areas typically had over 90 percent canopy cover. Vegetation types within the slopes and ridge tops consisted of savanna and badlands dominated by swordgrass (*Miscanthus floridulus*) and a few isolated shrubs. The percent of grass coverage and composition of the savanna fluctuates on a yearly basis due to fire activity.. Generally most areas had approximately 50 percent vegetative cover. During the investigations fires were observed within the watershed, in fact, one fire burned approximately 100 acres in a 24-hour period (Photos 1 and 2). Conversations with Navy personnel on Guam indicated that if ironwoods (*Casuarina equiestifolia*), are not present, it is likely that the area burned within the last five years a ironwoods are a pioneer species that is very susceptible to fire, if the species is (personal communication, Robert Wescom NAVFACMAR, May 2010). No ironwoods were observed in Geus' savanna.

Based on the GIS coverage for the watershed, of the 448.7 ha (1,109 ac) in the watershed it is comprised of 21 ha (51 ac) of badland habitat, 2.4 ha (6 ac) of tangantangan stand, 176.8 ha (437 ac) of ravine forest, 144.1 ha (356 ac) of savanna complex, 69.2 (171 ac) of scrub forest, 21 ha (52 ac) of urban build-up, 13.4 ha (33 ac) of urban cultivated land, 0.4 ha (1 ac) of wetland and 1.2 ha (3 ac) of unclassified land.

PHOTO 1 LOOKING EAST AT A WILDFIRE IN THE GEUS WATERSHED.

PHOTO 2 LOOKING WEST AT A RECENTLY BURNED AREA IN THE GEUS WATERSHED.

- **Ugum Watershed**

Figure 4 identifies the cover types within the Ugum Watershed. The vegetative cover is nearly identical to that of the Geus Watershed. Bottomlands around streams consist of dense ravine forests. Slopes and ridge tops consist of savanna and badlands, the composition of which varies annually due to fires and erosion. Despite evidence of recent burning, the grasses in the Ugum watershed tended to be more dense and taller. This may be a result of increased rainfall in the watershed.

Based on the GIS coverage, the 1,891.4 ha (4,675 ac) Ugum watershed is comprised of 4.9 ha (12 ac) of *Acacia* plantation, 0.4 ha (1 ac) of agricultural field, 45.7 ha (113 ac) of badland, 12.1 ha (30 ac) of barren habitat, 755.1 ha (1,866 ac) of ravine forest, 927.1 ha (2,291 ac) of savanna complex, 136.4 ha (337 ac) of scrub forest, 1.2 ha (3 ac) of urban build-up, 8.1 ha (20 ac) of urban cultivated, and 0.8 ha (2 ac) of open water.

3.2.1.2 Aquatic Resources

A mountain chain, that runs predominately north-south along the southwest coast of the island serves as the hydrologic divide between the Umatac, Toguan and Geus Watersheds and the Ugum Watershed. Numerous drainage ways are observed within the mountains and valleys. Often the lower portions of the streams are perennial and the headwaters of the streams are ephemeral and are often situated on steep slopes. Figure 5 identifies the surface water features in the Umatac, Toguan, and Geus Watersheds. Figure 6 identifies surface water features in the Ugum Watershed.

As part of the field effort, scientists observed stream conditions and noted the presence of erosional features along the bank as well as the level of vegetation along the bank. The scientists confirmed the benthic cover type mapping within 100 m (328.1 ft) of the rivers' mouths. For all four watersheds, the coverage data for the benthic mapping was obtained from the University of Guam's Marine Laboratory Coastal Atlas Website (UOG, 2010).

- **Umatac Watershed**

The main rivers in the Umatac Watershed are the La Sa Fua River, Madog River, Laelae River, and the Umatac River. The rivers all flow from east to west and their headwaters consist of the numerous drainages within the mountains.

The Laelae and Madog River join to form the Umatac River, approximately 0.5 km (0.3 mi) from Umatac's confluence with the ocean. The Umatac and its major headwaters have approximately 6.4 km (4 miles) of linear drainage. Riffles were observed periodically along the lengths of the rivers. Figure 7 identifies the coastal aquatic habitats in the Umatac Watershed. Snorkel surveys were conducted near the mouths of the rivers in Fouha and Umatac Bay. On Figure 7, GPS readings (Way point [WP]#) identify the locations of habitats which are further described in the text.

The La Su Fua River empties into Fouha Bay. Snorkel surveys indicate that a large sediment tongue is present (WP 21). Seaward from the sediment tongue, a reef flat and fringing reef's fore reef area are present (WP 28). Although there was a notable sediment deposit at the river's mouth, field investigations in upstream areas indicated that the river's walls were well defined. It is likely the sediment is a result of deposition originating from upstream sources (i.e., savanna, bare areas, etc.).

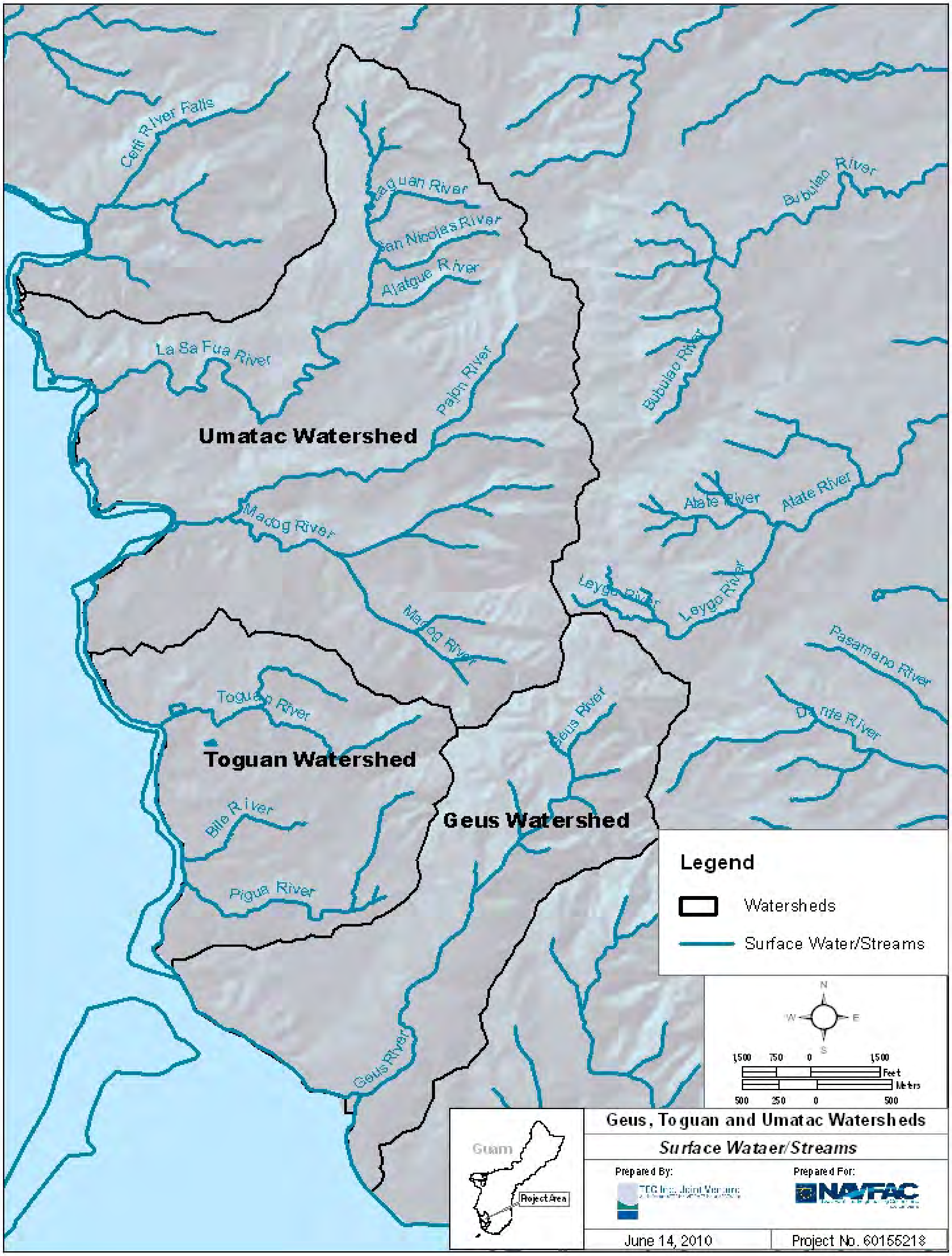


Figure 5 Surface Waters - Umatac, Toguan and Geus Watersheds

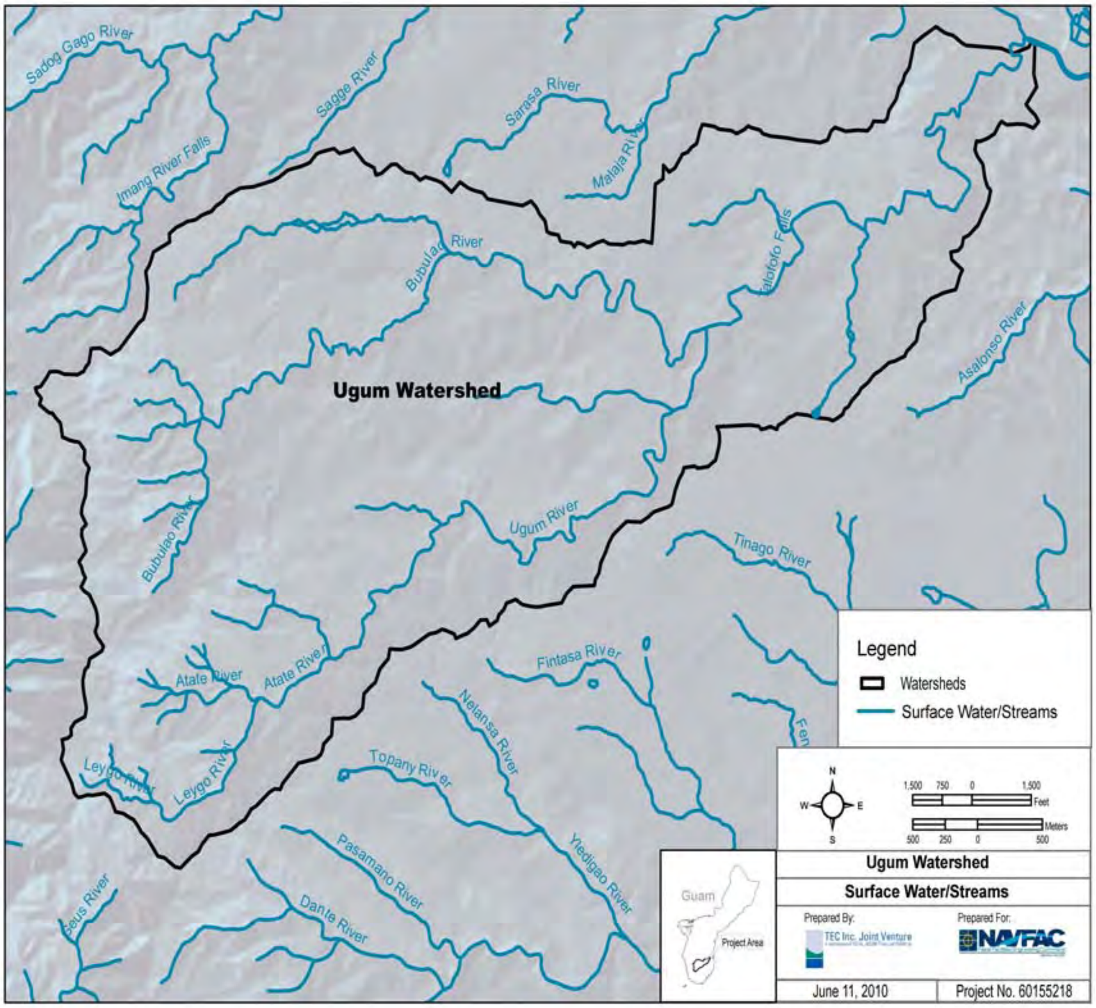
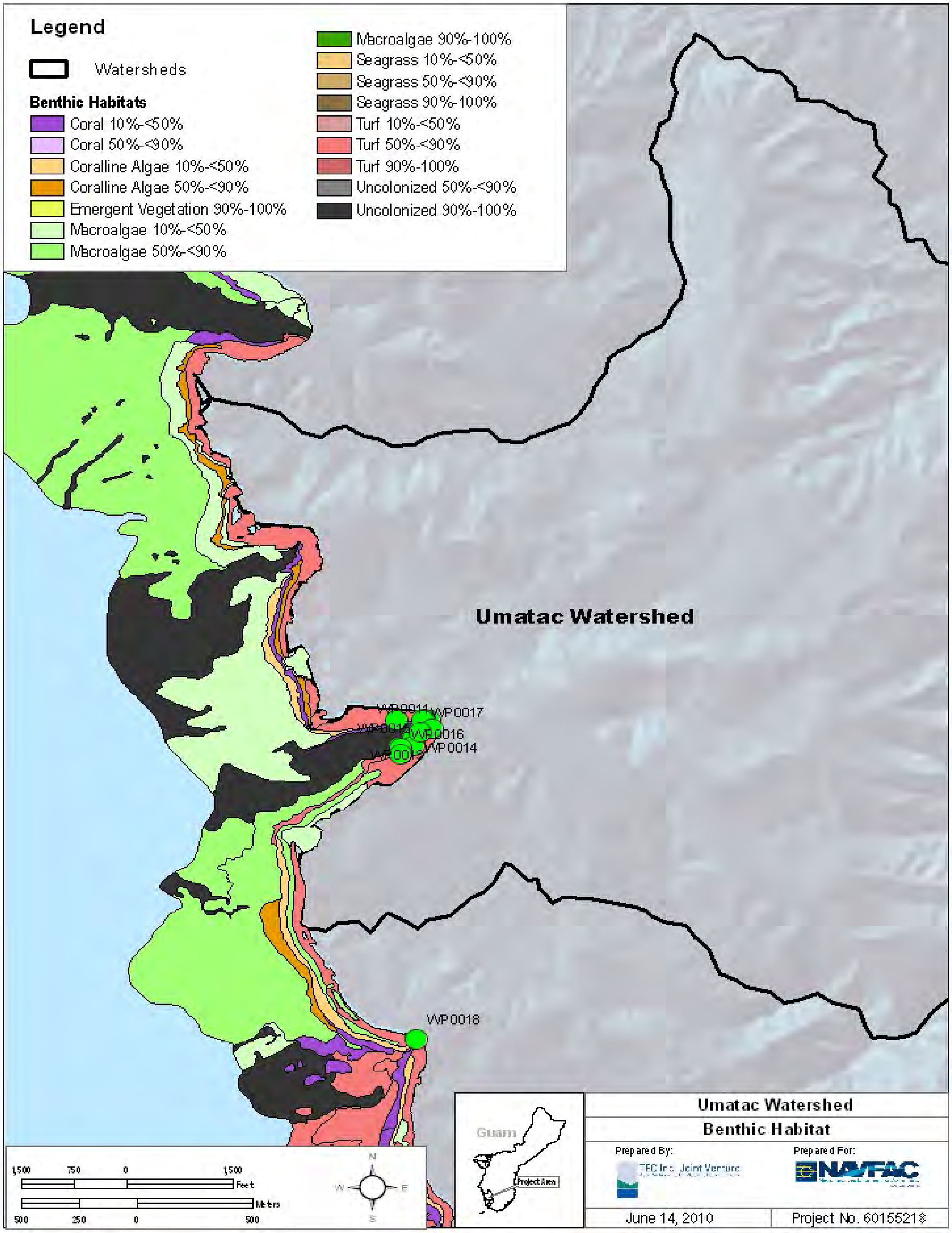


Figure 6 Surface Waters - Ugum Watershed



From the Guam Coastal Atlas, http://www.guammarinelab.com/coastal.atlas/htm/Maps.htm

Figure 7 Benthic Habitat - Umatac Watershed

The mouth of the Umatac River empties into the south side of Umatac Bay (WP 11). Near the mouth, the benthic communities consist of poorly sorted gravel and fine silts. On larger boulders approximately 30.5 m (100 ft) from the mouth, several small isolated corals were observed (WP 12). On the north side of the bay, coral heads with over 50 percent cover are present in water approximately 3 m (9.8 ft) deep.

- **Toguan Watershed**

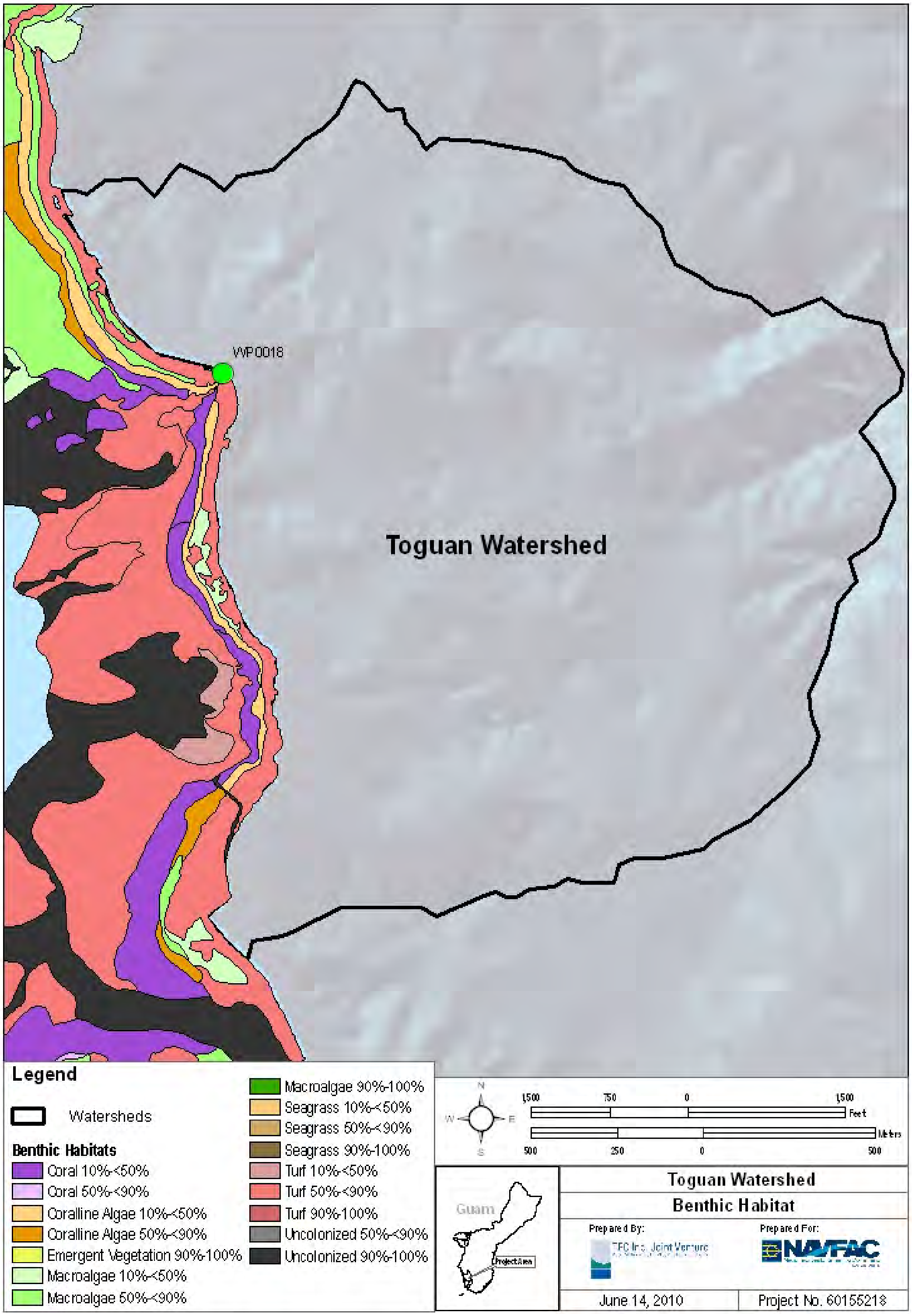
The main surface water in the Toguan Watershed is the Toguan River. Other rivers in the watershed include the Bile River and the Pigua River. All rivers in the watershed flow from east to west. The bed of the Toguan River is generally about 4. m (13 ft) wide, with well-defined vegetated banks, approximately 1.5 m (5 ft) in height; although, in some areas erosional features are present and the bank consists of a 4.6 m- (15 ft-) high bare soil wall with signs of undercutting. Much of the river bed is exposed rock with deposits of coarse sediments. Figure 8 identifies the coastal aquatic habitats in the Toguan Watershed. Snorkel surveys were not performed at the mouth of the Toguan due to restrictions on swimming caused by the water treatment plant-related construction activities. The mouth of the Toguan River empties into Philippine Sea. Visible observations from shore of the shallow-water portions of the mouth (WP 18) identified a cobble substrate extending approximately 15.2 m (50 ft) from the mouth. The rocks appeared to have limited fine sediment deposits on them.

Portions of the Bile and Pigua River that were able to be accessed were similar in geomorphology to the Toguan. During late May, 2010, the period when the field surveys were conducted, the Bile had a sediment berm across its mouth. It is anticipated the berm occurs during the dry season when low flows do not permit the dislodging of sediments. It is likely that during the rainy season and periods of higher hydrology, this berm dissipates. Snorkel surveys were not possible due to access issues and the need to cross private property.

- **Geus Watershed**

The only surface waterbody in the watershed is the east to west flowing Geus River. At the time of the investigation, the river was less than 0.32 m (0.98 ft) deep; however, sediment marks and drift lines and other evidence of hydrology indicates that the river can be more than 2 m (6.6 ft) deep during the rainy season. Also, a conversation with a homeowner indicated that in recent years, the Geus often overtops its banks during the rainy season. The banks of the river are generally vegetated with herbaceous vegetation and the tops of the banks are vegetated with woody species. The banks varied between near vertical structures with some undercutting to slopes of 45 degrees. It is likely that during periods of higher flow, active scour and deposition occurs along the river.

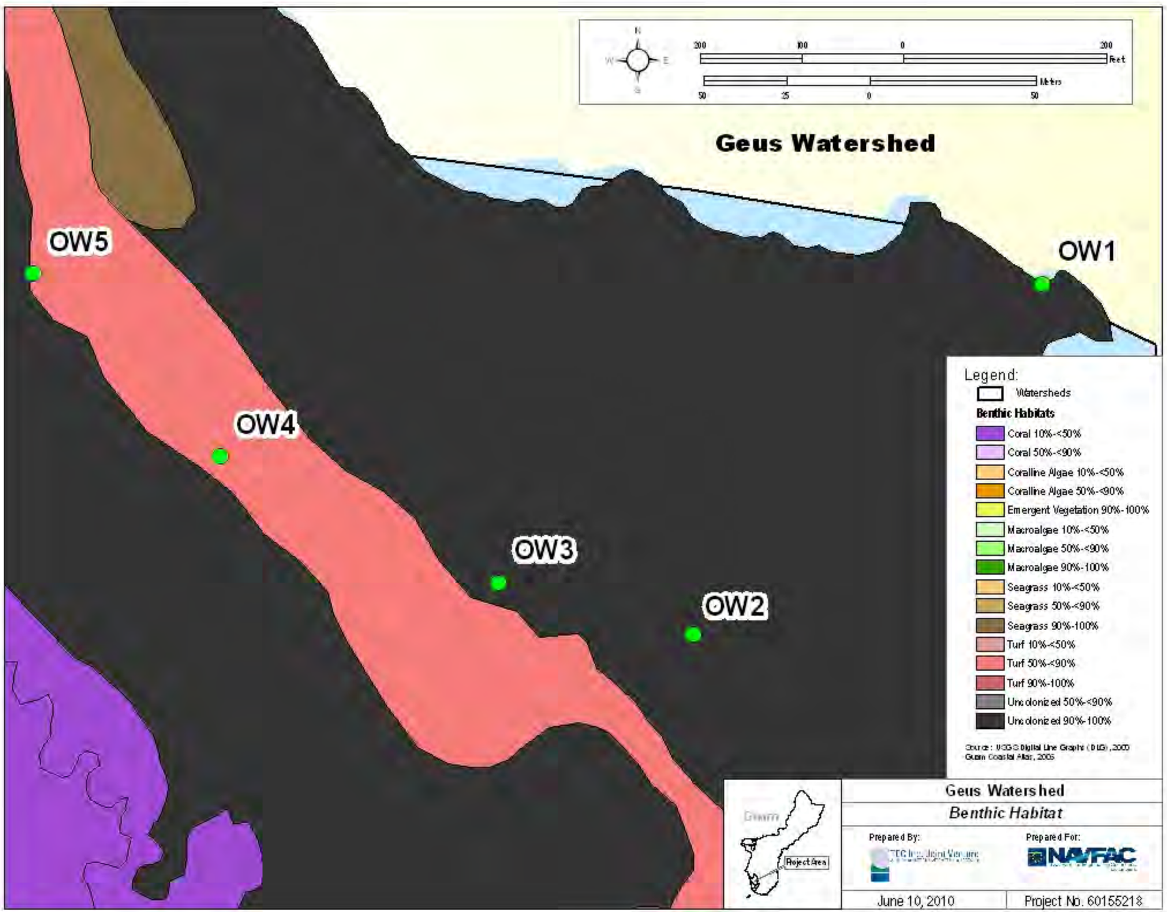
The head waters consist of ephemeral rivulets that are located within the mountainous region in the eastern portion of the watershed. These rivulets were often vegetated with swordgrass or consist of small, unvegetated channels. The channels often measured no more that 0.5 m (1.6 ft) deep and 0.5 m (1.6 ft) wide. Due to the high-clay content soils, it is likely there is also substantial sheetflow during periods of higher hydrology.



From the Guam Coastal Atlas, http://www.guammarinelab.com/coastal.atlas/htm/Maps.htm

Figure 8 Benthic Habitat - Toguan Watershed

Figure 9 identifies the coastal aquatic habitats in the Geus Watershed. The mapped benthic environments near the mouth of the Geus River were confirmed by snorkel surveys. As per Figure 9, snorkel surveys confirmed that within 100 m (328.1 ft) of the river mouth, the benthic habitat is uncolonized. The mouth of the Geus River and shoreline are dominated by large mangrove areas (Photo 3). The benthic composition near the river mouth is flat and rocky for approximately 60 m (196.9 ft), seaward. Then, the benthic environment becomes an area of soft sediment deposition. This soft, silty material extends approximately 150 m (492.1 ft) to the channel shelf. The sediment is over 0.6 m (1.9 ft) in depth (Photo 4).



From the Guam Coastal Atlas, http://www.guammarinelab.com/coastal.atlas/htm/Maps.htm

Figure 9 Benthic Habitat - Geus Watershed

Coral and other benthic habitats that require clear water conditions are not present with the river's mouth. Within the figure, six observation locations OW1 (Photo 3), OW2 (Photo 4), OW3 (Photo 5), OW 4 (Photo 6), and OW 5 (Photo 7) are identified. As can be seen in the photos, the health and density of the corals improves as distances increase from the river mouth.

PHOTO 3 LOCATION OW1. LOOKING NORTH AT THE MOUTH OF THE GEUS RIVER. NOTE THE MANGROVES ON THE LEFT AND RIGHT SIDES OF THE PHOTOGRAPH.

PHOTO 4 LOCATION OW2. SOFT SEDIMENT DEPOSITS LOCATED NEAR THE MOUTH OF THE GEUS RIVER.

PHOTO 5 LOCATION OW3. STRESSED CORAL, LIKELY DUE TO SEDIMENTATION.

PHOTO 6 LOCATION OW4. CORALS IN THIS LOCATION EXHIBIT SIGNS OF STRESS; HOWEVER, THE PERCENT OF HARD CORAL HAS INCREASED AS COMPARED TO LOCATION OW3.

PHOTO 7 LOCATION OW5, DENSE STAND OF CORAL. WATER CLARITY AT THIS LOCATION WAS MARKEDLY IMPROVED.

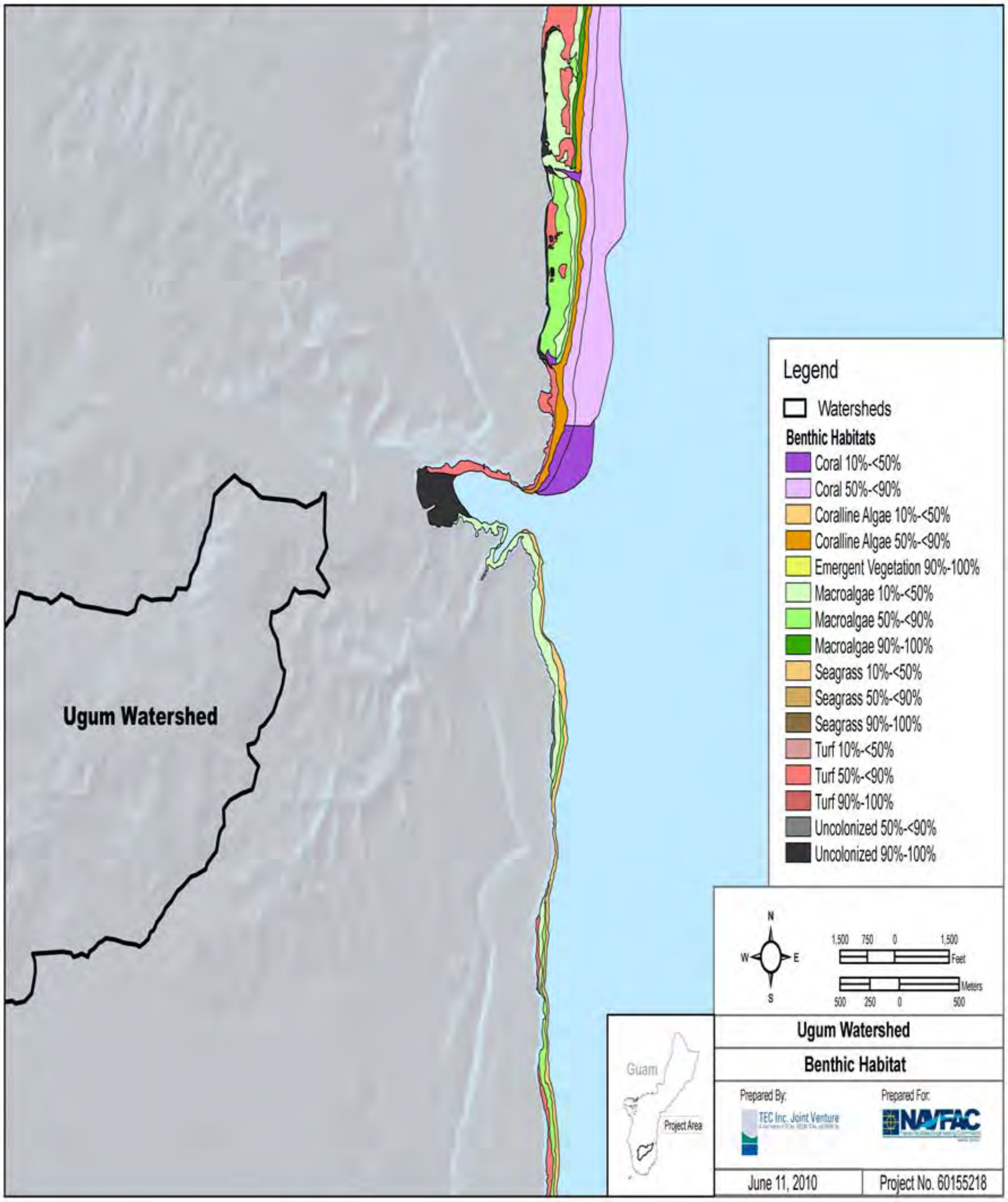
- **Ugum Watershed**

The headwaters of the Bubulao and Atate River occur within the BCA of the Ugum Watershed. The tops of the river banks were often heavily vegetated (Photo 8) with swordgrass or tall reed (*Phragmites karka*). The sides of the banks were generally near vertical and up to 2 m (6.6 ft) in height. During the wet season, high flows and scouring of the riverbanks occur. Generally, the Atate and Bubulao's headwaters were small rivulets that drain the mountains in the BCA's eastern region.

At the mouth of the Talofofo River there are large deposits of soft sediments (Photo 9). Coral reefs are not present at the mouth, but are mapped as occurring approximately 400 m (1,312.3 ft) away. Due to a ban on swimming because of contamination in the bay, snorkel surveys were not conducted. Figure 10 identifies the previously mapped aquatic habitats in the Ugum Watershed.

PHOTO 8 VEGETATED BANKS OF THE BUBULAO RIVER IN THE UGUM WATERSHED.

PHOTO 9 LARGE SEDIMENT DEPOSITS AT THE MOUTH OF THE TALOFOFO RIVER.



From the Guam Coastal Atlas, http://www.guammarinelab.com/coastal.atlas/htm/Maps.htm

Figure 10 Benthic Habitat - Ugum Watersheds

3.2.1.3 Geology and Soils, Erosion Features and Sedimentation

- **Geology**

Guam is the southernmost and largest island of the Mariana Islands chain. The island is comprised of two geologically distinct districts. The northern half of the island is an uplifted limestone plateau, while the southern half is the eroded remnant of a Miocene volcano. The northern limestone plateau has low relief, is highly permeable, and supports no permanent streams. In contrast, the southern landscape is dissected with numerous stream systems starting at the steep headwaters and radiating to the coastline (WERI, 2010).

Most of the southern Guam is covered by volcanic rocks that form the island's foundation. These rocks are locally overlain by limestone. The oldest exposed rocks on the island are of Eocene and Oligocene age and comprise the Facpi and Alutom Formations. They outcrop in the highlands from central to southern Guam and underlie all other exposed rock units (Tracey et al., 1964; Reagan and Meijer, 1984). They contain a series of pillow basalts and pyroclastic rocks of volcanic origin, and range from tuffaceous shale to coarse boulder conglomerate and breccias (WERI, 2010). Finally, there are minor reef limestone, beach deposits, and alluvium of Holocene age. The beach deposits are composed of poorly consolidated calcareous sand and gravel or volcanic sand. Alluvial deposits fill stream valleys and cover parts of the coastal lowlands.

Review of the Guam geologic map (Figure 11) shows that in the Umatac, Toguan, Geus, and Ugum Watersheds, the geology of the watersheds is comprised of Umatac Formation members and alluvium. The mapped members are the following:

- Qal - Alluvium
- Tub - Umatac Formation Bolanos Pyroclastic Member
- Tud - Umatac Formation Dandan Flow Member
- Tuf - Umatac Formation Facpi Volcanic Member
- Tum - Umatac Formation Maemong Limestone Member

The Umatac Formation of Oligocene - late Miocene age (Tracey et al., 1964) is separated from the underlying Alutom Formation by a structural unconformity. The Umatac Formation crops out over about 15 percent of the land surface, principally in the south-central highlands and plateaus. The unit thickens to the south away from the Alutom Formation and is at least 320 m (1,050 ft) thick along the southwest side of the island (Tracey et al., 1964). Here, the Umatac Formation is composed (from oldest to youngest) of about 76.2 m (250 ft) of reef and forereef limestone (Maemong Limestone Member), about 228.6 m (750 ft) of tuff breccia and volcanic conglomerate (Bolanos Pyroclastic Member, Schroeder Flow Member), and about 15.3 m (50 ft) of basalt flows (Dandan Flow Member) (Meijer et al., 1983; Reagan and Meijer, 1984). The permeability of the formation is considered low (Ward et al., 1965; USGS, 2010).

Minor reef beach deposits, reef limestone, and alluvium are of Holocene age. These deposits cover about 7 percent of the surface of Guam, and may be as much as 61 m (200 ft) thick at the mouths of some rivers. The beach deposits are composed of poorly consolidated sediments, mostly calcareous sand and gravel thrown onto beaches by waves but some deposits of volcanic sand can be found where streams drain volcanic uplands (Tracey and others, 1964).

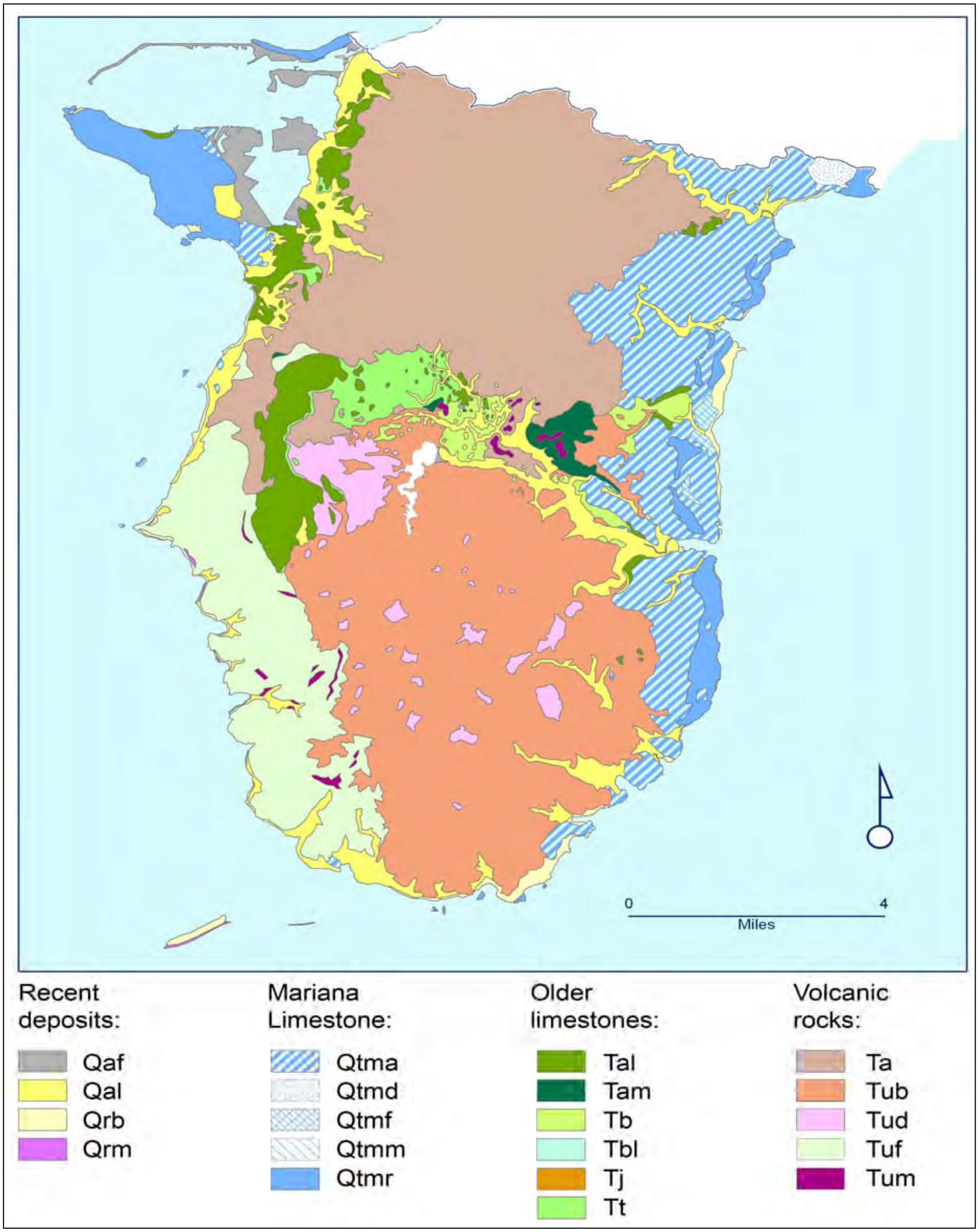


Figure 11 Geologic Map of Southern Guam

PHOTO 10 EXPOSED BEDROCK. OBSERVED BEDROCK IN THE WATERSHEDS OFTEN TOOK THE FORM OF BRECCIAS AND WEATHERED PILLOW BASALTS. NOTE THE CLINOMETER IN THE PHOTO FOR SCALE.

The Merizo Limestone is reef limestone up to 3.7 m (12 ft) thick. Deposits of alluvial clay fill stream valleys and cover the inner parts of coastal lowlands. The overall permeability of alluvial deposits may be moderate but hydrologic information is limited (Ayers and Clayshulte, 1983; USGS, 2010).

- **Topography**

The geologic volcanic and uplifting activities of the past have resulted in a varied topography within the watersheds. Slopes within the Umatac, Toguan, and Geus Watersheds are described in the following sections. Severe soil erosion has exposed the underlying bedrock in the watersheds (Photo 10)

- **Umatac Watershed**

The topography of the Umatac Watershed is depicted in Figure 12. The western area of the watershed contains low elevations and the main stem of the Umatac (Photo 11) and the La Sa Fua Rivers. The Umatac River has its headwaters in the eastern portion of the watershed with its tributaries, the, Pajon, Bolanos, Astaban, and Madog Rivers. The headwaters of the La Sa Fua River (Photo 12) are also in the eastern ridges with its tributaries LaGuan, San Nicolas and Alatgue Rivers.

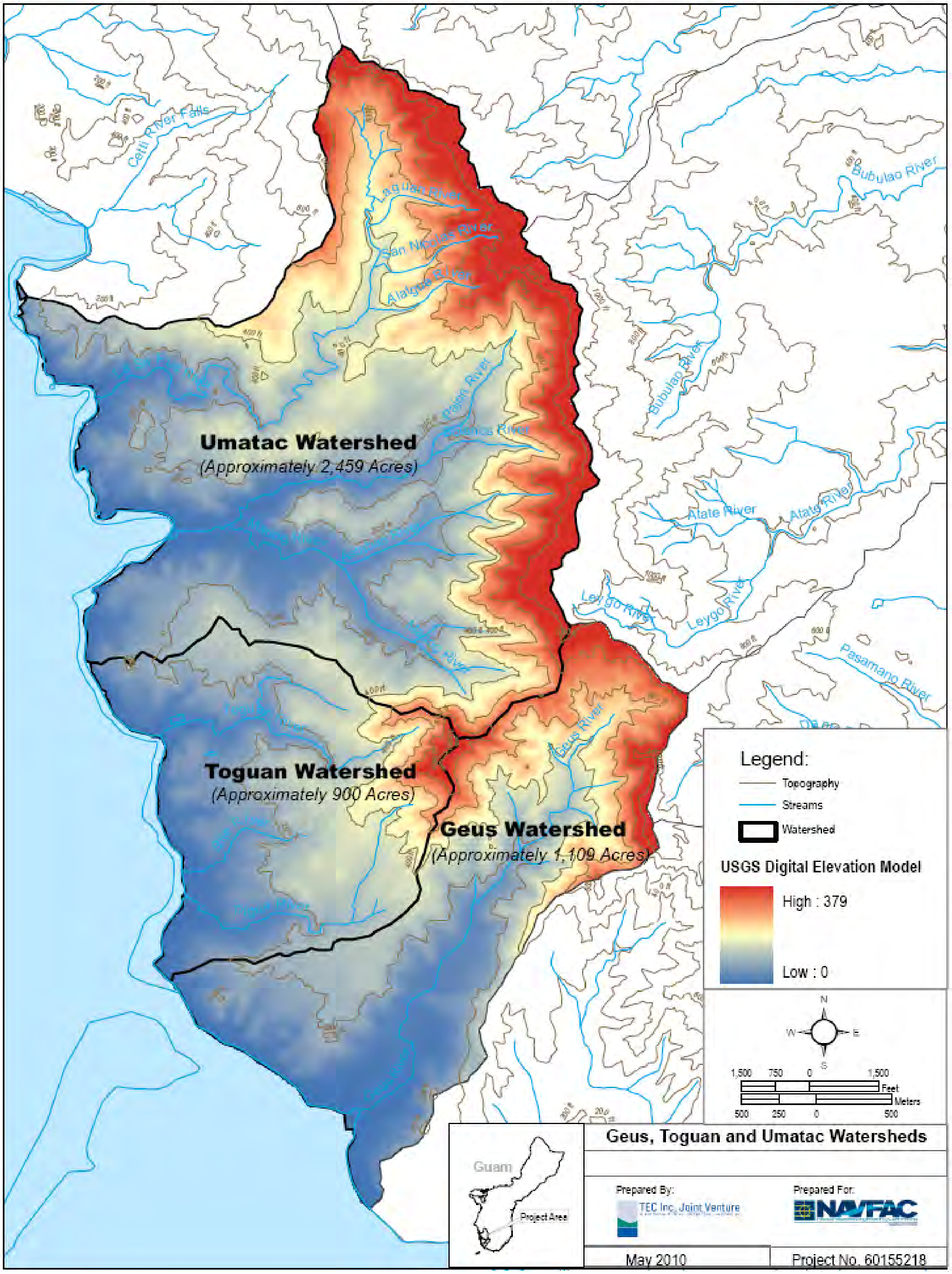


Figure 12 Digital Elevation Model of the Umatac, Toguan, and Geus Watersheds

PHOTO 11 LOOKING SOUTHEAST ALONG UMATAC RIVER

PHOTO 12 LOOKING WEST ALONG THE LA SA FUA RIVER

The watershed at its widest point is 5,000 m (16,404.2 ft) wide (north to south), comprising approximately 995 ha (2,459 ac) and conveys the Umatac and La Sa Fua Rivers to the Philippine Sea. The river valley is bounded by ridges to the east approximately 305 m (1,000.6 ft) in elevation, with moderate slopes of less than 50 percent. Photos of each river are provided in Photos 11 and 12.

Mount Jumullong Manglo 420 m (1,280 ft) is located in the northeastern corner of the La Sa Fua sub-watershed and Mount Bolanos 407.5 m (1,242 ft) and Mount Ilicho 399.3 m (1,217 ft) are both located in the eastern edge of the Umatac sub-watershed. During field investigations, slopes were measured using clinometers. Within the watershed, the visual observations generally conformed to the mapped slopes. However, small scale erosional features often had steep slopes greater than 50% that were not represented by the mapped slopes.

- **Toguan Watershed**

The Toguan Watershed consists primarily of a western area containing low elevations and the main stem of the Toguan, Bile and Pigua Rivers and an eastern half that is dominated by mountains and the rivers headwaters (Figure 12). The watershed at its widest point is 2,493.4 m (7,600 ft) wide (north to south) comprising approximately 364.2 ha (900 ac) and conveys the Toguan, Bile and Pigua Rivers to the Philippine Sea. The valley is bounded by ridges to the east approximately 328.1 m (1,000ft) in elevation, with moderate slopes of less than 50 percent.

During field investigations, slopes were measured using clinometers. Within the watershed, the visual observations generally conformed to the mapped slopes. However, small scale erosional features often had steep slopes greater than 50% that were not represented by the mapped slopes.

The topography of the Toguan Watershed is depicted in Figure 12. The Toguan Watershed has steeply-sloped (>30%) mountains in the very east corner of the watershed and more moderately-sloped (0 to 20%) hills in the central and western portions of the watershed. The Toguan Watershed consists of three main sub-watersheds that have separate outlets to the ocean: the Toguan sub-watershed to the north, the Bile sub-watershed in the central portion, and the Pigua sub-watershed to the south. The Toguan River (Photo 13) flows through a narrow valley in the western portion of the Toguan sub-watershed that drains into Toguan Bay (Photo 13). The mouths of the Bile River and Pigua River are approximately 300 feet apart and both drain into Bile Bay. The Toguan River and its one major tributary drain the moderately-sloped (0 to 20%) central portion of the sub-watershed while only the main stem of the river drains the steeply-sloped (>30%) mountain headwaters located in the eastern portion of the watershed. The Bile River has no major tributaries and drains the moderately-sloped (0 to 20%) hills in the central portion of the watershed. The Pigua River has a single small tributary and drains mostly moderately-sloped (0 to 20%) areas with minor contribution from the steeply-sloped (>30%) mountain headwaters located in the eastern portion of the watershed. Mount Schroeder (346.8 m [1,057 ft]) is located in the eastern corner of the watershed.

PHOTO 13 LOOKING WEST ALONG THE TOGUAN RIVER

- **Geus Watershed**

The topography of the Geus Watershed is depicted in Figure 12. The western half of the Geus Watershed contains low elevations and the main stem of the Geus River. The eastern half of the watershed is dominated by mountains and the river's headwaters (Photo 14).

The western half of the watershed is a narrow, east-west running river valley. The valley is approximately 0.8 km wide and conveys the Geus River to the Cocos Lagoon. The valley is bounded by two ridges approximately 66-100 m (216.5 – 328 ft) in elevation, with moderate slopes; although, during the field investigation the slopes were observed to be impacted by increased erosion. All urban development and infrastructure are located within the western half of the watershed.

The eastern half of the watershed contains the headwaters of the Geus River (Photo 14). The topography in this portion of the watershed is striking; the eastern half of the watershed is bowl-shaped and ringed by steeply-sloped mountains (Mt Sasalagulan, elevation 362 m [1,103 ft]; Mt Schroeder, elevation 347 m, [1,058 ft] etc.). The topography in the eastern half of the watershed precludes any substantial development. The headwaters converge to form the Geus River at approximately 40 m in elevation. The main stem of the river flows for approximately 1,800 m (5,486 ft) before emptying into Cocos Lagoon.

PHOTO 14 LOOKING WEST DOWN THE GEUS RIVER VALLEY.

During the field investigations, slopes were measured using clinometers. Within the watershed, the visual observations generally conformed to the mapped slopes of 40 percent or less. However, in the field, two differences were observed from the mapped slopes:

- Slopes greater than 40 percent were often underestimated by the mapping; and
- Within many slopes of 40 percent of less, erosional features resulted in localized steep slopes of greater than 50 percent (Photo 15). These localized steep slopes varied in size from 100 square meters (sq m) (1,076 sq ft) to areas greater than 0.3 ha (0.12 ac).

- **Ugum Watershed**

The topography of the Ugum Watershed is depicted in Figure 13. The Ugum's western boundary is marked by a steep ridge that borders the Geus, Toguan, and Umatac watersheds. Extending eastward from this ridge is a smaller ridge east-west running ridge that serves as the hydrologic boundary between the headwaters of the Bubulao and Atate Rivers. Both rivers flow east and eventually merge to form the Ugum River and ultimately the Talofofo River. Headwaters in the western portion of the Ugum originate near the tops of the mountains. Although the slopes range from moderately steep to undulating, the stream channels are incised (i.e., deeply cut with vertical banks) into the slopes. The terrain is characterized as hilly with wide river valleys (Photo 16).

PHOTO 15 STEEP SLOPES CREATED BY INCREASED EROSION.

PHOTO 16 LOOKING EAST AT THE LEYGO RIVER VALLEY IN THE UGUM WATERSHED.

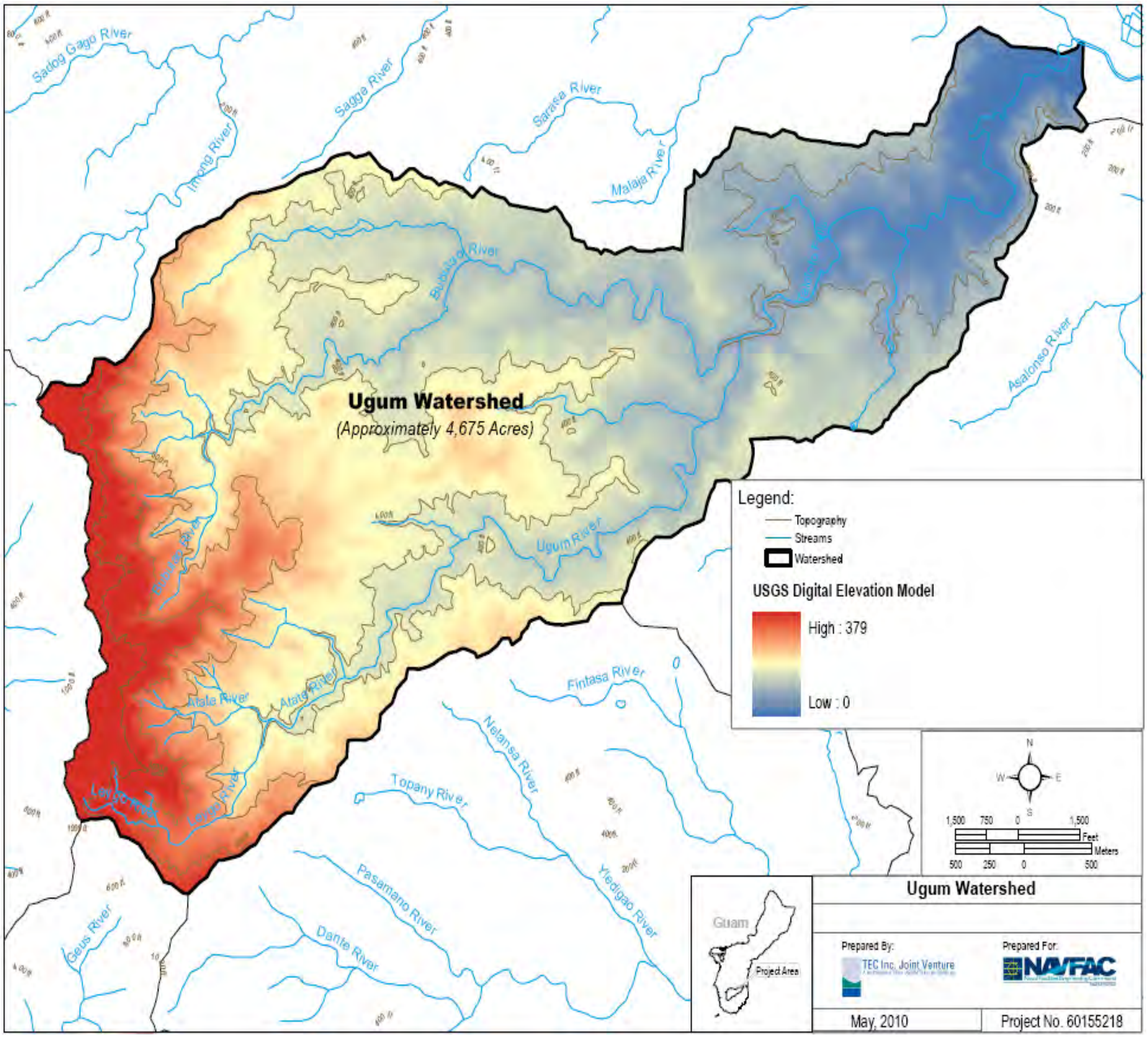


Figure 13 Digital Elevation Model of the Ugum Watershed

During the field investigations, slopes were measured using clinometers. Within the watershed, the visual observations generally conformed to the mapped slopes. However, differences that were observed were erosional features that resulted in of areas of very steep slopes. These areas varied in size from approximately 100 square meters (sq m) (1,076.4 square feet [sq ft]) to areas greater than 0.8 ha (2 ac). Although, the site investigation in the Ugum Watershed were limited to the BCA, these large bare soil erosional areas were common throughout the watershed (Photo 17).

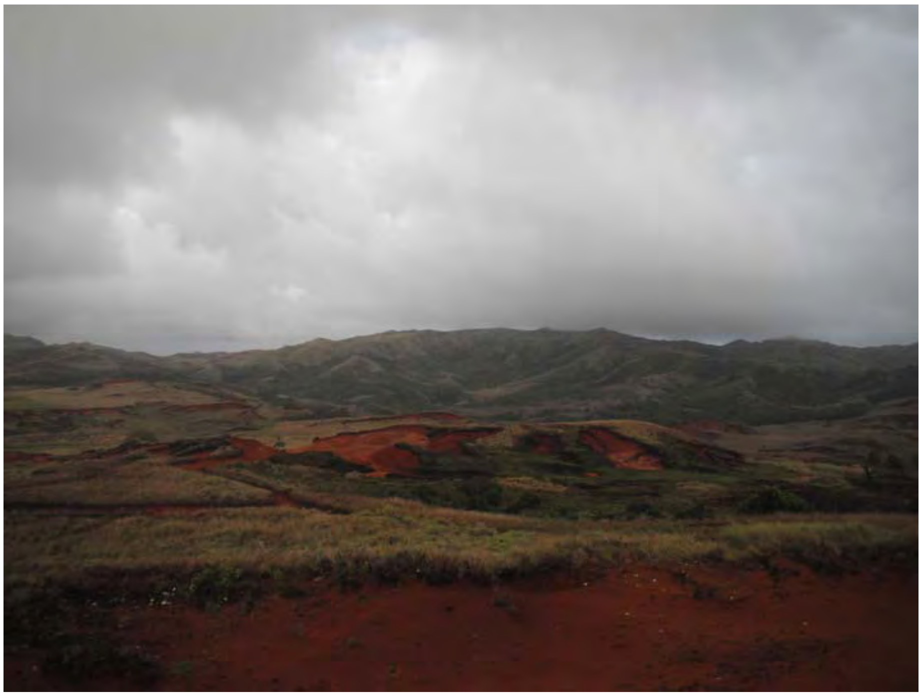


PHOTO 17 LOOKING EAST AT THE BCA.

3.2.1.4 Soils and Erosional Features

Guam has a diversity of soils that have developed over time. The factors that affect soil formation include the original parent material from which the soil was derived, the climate, topography, the type of vegetation and organisms, and the amount of time the soil has been forming. Most of the soils of Guam were either developed in limestone, in volcanic rock, or in bottomland or coastal deposits (WTRC, 2009).

Soils in the watersheds are members of the Agfayan, Akina, Inarajan, Sasalaguan, Toccha, and Ylig soils series. Descriptions of these soils are provided below. Table 1 identifies the typical soil profiles of these soils. Soils within the Umatac, Toguan, and Geus Watersheds are depicted on Figure 14. Soils within the Ugum watershed are depicted on Figure 15.

The Agfayan series consists of well drained, moderately slowly permeable soils that are very shallow and shallow to strongly weathered tuff. These soils are on volcanic uplands. They formed in residuum derived from marine-deposited tuff, tuff breccia, and tuffaceous sandstone. Depth to bedrock is 10 to 38 cm. (4 in to 15 in). Soil texture of top horizon is clay. Content of clay is 60 to 80 percent. The Agfayan soil covers approximately 0.8 percent of Guam's total land area (WTRC, 2009). Soil series descriptions and profiles are summarized in Table 1.

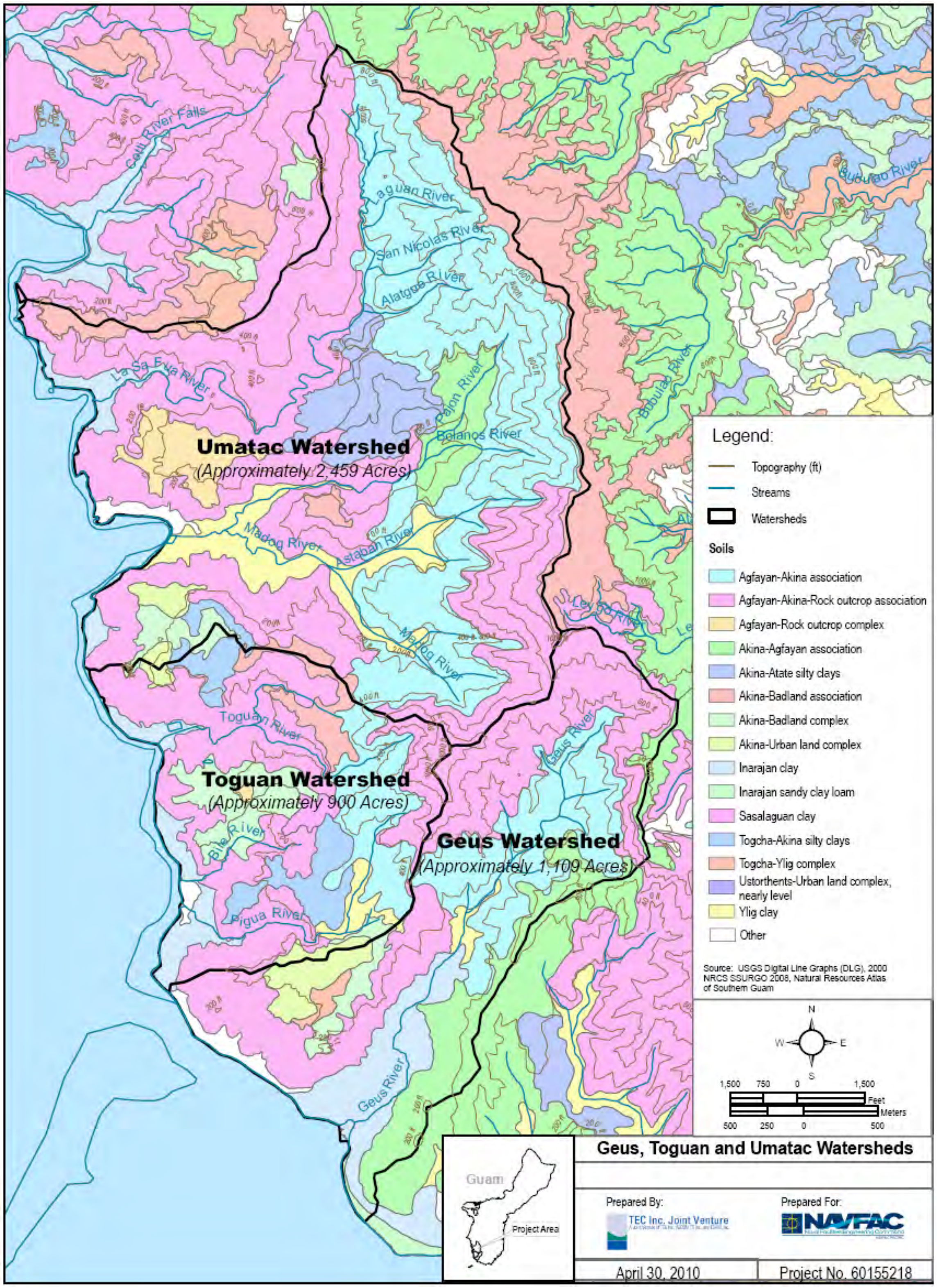


Figure 14 Soil Types of the Umatac, Toguan, and Geus Watersheds

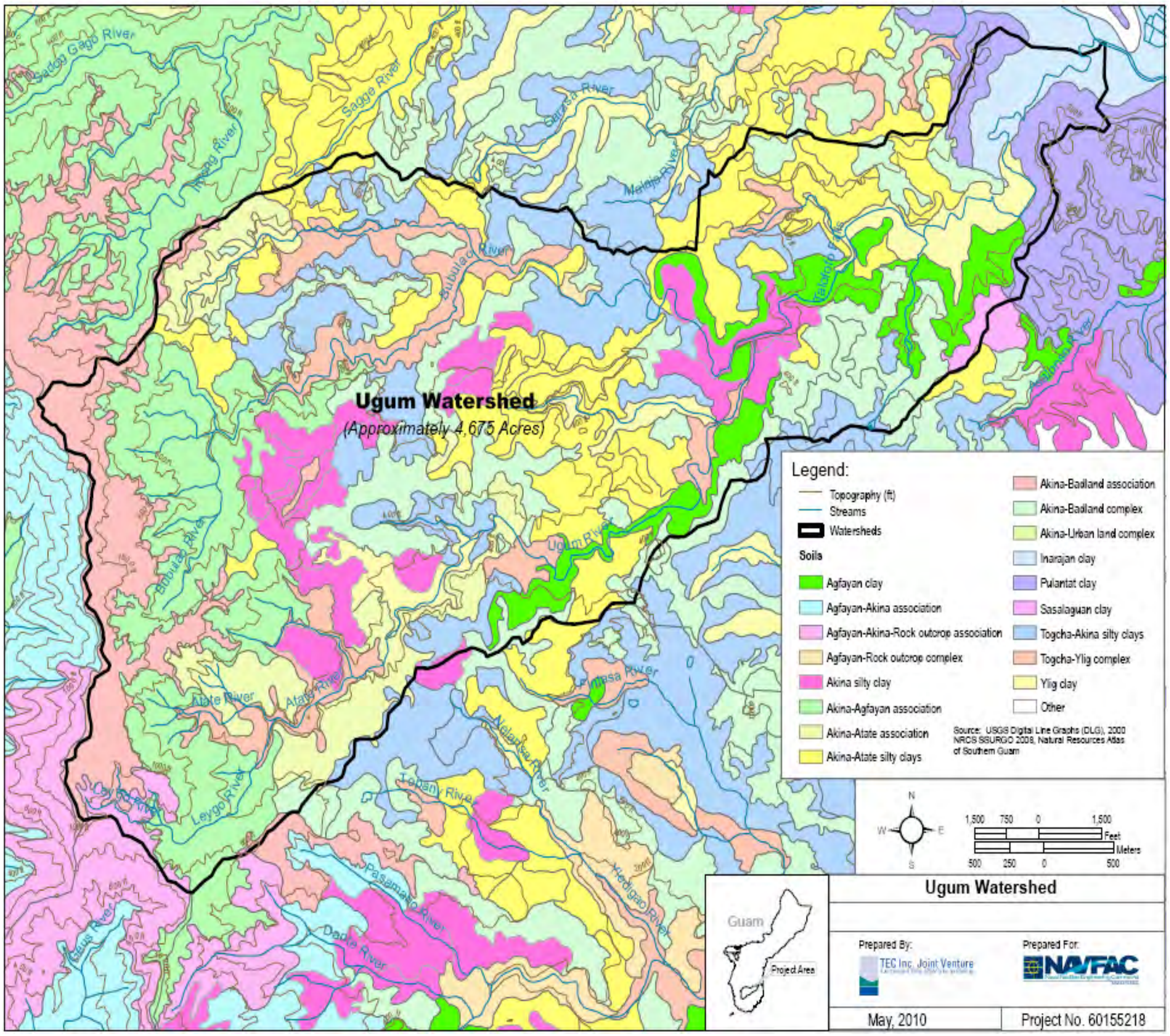


Figure 15 Soil Types of the Ugum Watershed

The Akina series consists of very deep, well drained, moderately slowly permeable soils on volcanic uplands. These soils formed in residuum derived from tuff and tuff breccia. Depth to saprolite is 51 to 102 cm (20 to 40 in). Soil texture of top horizon is silty clay or clay. Content of clay is 60 to 80 percent. The Akina soil covers approximately 1.4 percent of Guam's total land area (WTRC, 2009).

The Inarajan series consists of deep and very deep, somewhat poorly drained, slowly permeable soils on broad valley bottoms and coastal plains. These soils form in alluvium. Depth to bedrock is generally greater than 1.5 m (4.5 ft), but in some areas it is 102 cm (40 in). Soil texture of top horizon is dominantly clay or silty clay, but it ranges to sandy clay loam in some areas. Content of clay is 45 to 80 percent. The Inarajan soil covers approximately 2.9 percent of Guam's total land area. (WTRC, 2009)

The Sasalaguan series consists of well drained slowly permeable soils that are moderately deep to volcanic saprolite. They are on volcanic uplands, and formed in residuum from marine deposited tuffaceous sandstone.

The Togcha series consists of very deep, well drained, moderately permeable soils on volcanic uplands. These soils formed in slope alluvium dried from weathered tuff and tuff breccia. Depth to bedrock is cm (40 in) or more. Soil texture of top horizon is silty clay loam or silty clay. Content of clay is 55 to 60 percent. The Togcha soil covers approximately 2.0 percent of Guam's total land area (WTRC, 2009).

The Ylig series consists of very deep, somewhat poorly drained, moderately slowly permeable soils in seep areas on concave hillsides and in drainageways. These soils form in alluvium derived from weathered tuff and tuff breccia. The soils are hummocky in some areas. The depth to bedrock is 114 cm (46 in) or more. Soil texture of top horizon is silty clay or clay. Content of clay is 50 to 70 percent. The Ylig soil covers approximately 1.9 percent of Guam's total land area (WTRC, 2009).

- **Umatac Watershed**

As per the GIS coverage in Figure 11, the Umatac Watershed soils are comprised of 750 ha (1,853 ac) of Agfayan series soils, 158 ha (390 ac) of Akina series soils, 15.8 ha (39 ac) of Inarajan clay, 8.1 ha (20 ac) of Tocha series soils, 16 Ustorthents-urban land complex, 55.8 ha (138 ac) of Ylig clay, and 0.8 (2 ac) of unclassified soils.

- **Toguan Watershed**

Based on the GIS coverage in Figure 11, the Geus Watershed soils are comprised of 219.7 (543 ac) of Agfayan series soils, 63.5 ha (157 ac) of Akina series soils, 27.5 ha (68 ac) of Inarajan clay, 5.7 ha (14 ac) of Sasalaguan clay, 35.2 ac (87 ac) of Tocha series soils, 2.4 ha (6 ac) of Ustorthents-urban land complex, 9.3 ha (23 ac) of Ylig clay, and 0.8 ha (2 ac) of unclassified soils.

- **Geus Watershed**

As per the GIS coverage in Figure 11 the Toguan Watershed soils are comprised of 278.4 ha (688 ac) of Agfayan series soils, 92.7 ha (229 ac) of Akina series soils, 55.8 ha (138 ac) of Inarajan clay, 1.6 (4 ac) of Sasalaguan clay, 4.9 ha (12 ac) of Tocha series soils, 22 Ustorthents-urban land complex, 5.3 ha (13 ac) of Ylig clay, and 0.8 (2 ac) of unclassified soils.

- **Ugum Watershed**

As per the GIS coverage in Figure 12, the Ugum Watershed soils are comprised of 132.7 ha (328 ac) of Agfayan series soils, 1,221.3 ha (3,018 ac) of Akina series soils, 36.8 (91 ac) of Inarajan clay, 46.1 ha (114 ac) of Pulantat clay, 7.7 ha (19 ac) of Sasalaguan clay, 359.4 (888 ac) of Tocha series soils, and 87.8 ha (217 ac) of Ylig clay.

Table 1 Soil Series Description and Profile

Soil Series	Soil Profile
AGFAYAN	A horizon - Color: 10YR 2/1, 3/1, 3/2, 3/3, 2.5Y 3/2, 7.5YR 3/2. Texture: Clay. Structure: Fine granular or subangular blocky. A/C horizon - Occurs in some pedons. Bw horizon - Present in some pedons but not below 10 inches. Color: 10YR 4/2, 4/3, 5/3, 5/4, 2.5Y 5/3, 6/3, and with 5YR 4/6, 4/8 colors on some ped faces. Texture, structure: Similar to A horizon. C horizon - Present in some pedons below 7 inches. Color: 10YR 5/4, 5/6, 6/6, 2.5YR 5/2, 6/2, 7/2, 5Y 4/3. Structure: Massive, or rock structure. Cr horizon - Color: 10YR, 2.5Y, and 5Y hues, commonly with values above 4.
AKINA	Percent clay - Over 60 percent in the argillic horizon. A horizon - Color: 2.5YR 2.5/2, 3/4, 5YR 2.5/2, 3/2, 3/3, 3/4, 7.5YR 3/1, 3/2, 10YR 3/3. Texture: Silty clay, clay. Structure: Granular or subangular blocky. Pebbles: Ranges from 0 to 10 percent on the surface. B horizon - Color: Moist matrix 10R 3/4, 3/6, 2.5YR 3/4, 3/6. Structure: Prismatic, angular or subangular blocky. Reaction: Very strongly acid to medium acid. Other features: Sand-and pebble-sized saprolitic flecks are common in the lower B horizons. These commonly have color values and chroma above 3 and as high as 8. In some pedons the B horizon is not subdivided. C horizon - Present in some pedons. Cr horizon, saprolite - Color: Mixed, with dominant matrix color as 10R 3/6, 2.5YR 3/6, 4/6, 4/8, 5YR 6/8, 4/6, 2.5Y 8/2, 10YR 8/2. Other colors include 5YR, 7.5YR, and 10YR hues with color values above 3 and variable chromas. These subordinate colors are often present as discrete sand-and pebble-sized saprolitic flecks and bands. Texture: Rubs easily to clay loam, silty clay, clay. Structure: Massive, or rock structure.
INARAJAN SERIES	A horizon - Matrix color: 10YR 2/1, 3/1, 3/2, 4/1, 2.5Y 4/2, 5Y 4/1, 5/1.Mottle colors: 2/5YR 4/6, 5YR 4/4, 4/6, 7.5YR 4/4. Texture: Dominantly clay and silty clay, but ranges to sandy clay loam in some

Soil Series	Soil Profile
	areas. C horizon - Color: Both high and low chroma colors are present, either as matrix or as mottles. Common high chroma colors are 5YR 4/6, 4/8, 7.5YR 4/4, 5/6, 6/8, 10YR 4/3, 3/4, 4/4, 4/6, 5/4,5/6, 7/6, 2.5Y 5/4. Common low chroma colors are 10YR 4/1, 4/2, 5/1, 5/2, 2.5Y 5/2, 5Y 4/1, 5/1. Texture: Dominantly clay or silty clay, may include strata of fine sandy loam, sandy clay loam, silty clay loam, or clay loam. Rock fragments: 0 to 5 percent pebbles, mostly below 40 inches.
SASALAGUAN	Percent clay - More than 60 percent in the argillic horizon and 5 percent more than the A horizon. Depth to paralithic contact - 20 to 40 inches. A horizon Color: 2.5YR 3/6, 5YR 3/3, 3/4, 7.5YR 3/2, 4/4, 10YR 3/2, 3/3. Texture: Silty clay, clay. Structure: Granular, angular or subangular blocky. B horizon Color: Dominantly 2.5YR 3/6, 4/6, ranges to 7.5YR 3/2, 4/4, 5/4, 5/6, 10YR 5/6, 6/4, 7/4. Color, reticulate mottles: Hues 7.5YR through 5Y, chromas dominantly 4, range to 2, values 5 through 8. Cr horizon Color: Variable, matrix dominantly 2.5YR hues, range to 2.5Y. Subordinate colors highly variable.
TOGCHA SERIES	A horizon Color: 2.5YR 3/4, 5YR 3/3, 3/4, 7.5YR 3/2. Texture: Silty clay loam, silty clay. Structure: Granular or subangular blocky. B horizon Color: 2.5YR 3/4, 3/6, 4/6, 5YR 4/4, 4/6, 5/6. Texture: Silty clay or clay, C horizon Color: 2.5YR 3/4, 3/6, 4/6, 5YR 4/4, 4/6, 4/8, 5/6. Texture: Silty clay or clay
YLIG SERIES	A horizon - Color: 7.5YR 3/2, 10YR 2/1, 3/1, 3/2, 3/3. Texture: Silty clay, clay. Reaction: Strongly acid to slightly acid. Other features: 7.5YR 4/4 mottles in some pedons. Recent overwash of 5YR 3/4, 4/6, 10YR 3/4, 4/4 in some pedons. C horizon - Color: Most horizons have both high and low chroma colors. Subordinate colors are often in a reticulate pattern along pores and ped faces. High chroma colors: Dominant hues are 2.5YR, 5YR, but range to 10YR. Values are 2 through 5, chromas are 3 through 6. Low chroma colors: Hues are 10YR, 2.5Y, 2.5YR, 5Y, 5YR, 7.5YR. Values are 4 through 6, chromas are l and 2. Texture: Clay, silty clay, clay loam.Rock fragments: 0 to 10 percent.

3.2.1.5 Observed Soils in the Watersheds

Soils were investigated by the use of a soil probe that obtained a sample up to 30 cm (11.8 in) below the ground survey. Also in areas of erosion where headwall failure permitted a greater viewing of the soil profile, a small trowel was used to scrape away the exposed soil in a vertical line. This action exposed the soil profile at depth below what could be accurately checked with a soil probe.

Within the watersheds, the observed soils generally conformed to the mapped soil series; although, most soils in the watersheds displayed evidence of erosion (e.g., limited remaining A horizon, gullying, etc.). In many areas, only limited amounts of solum (i.e., the upper portion of a soil profile where the formation of topsoil occurs) were present and the saprolite (i.e., lower portion of the soil profile at the interface of weathering rock and soil) was clearly visible (Photos 18 and 19). Moreover, in many bare soil areas, little or no solum remains.

Soils often contained high clay content, as do most soils on Guam. Also, throughout the watersheds, evidence of recent burning (potash) was observed in the soil's A horizon. Evidence of burning was evident on vegetation. The endless cycle of burning has promoted the growth of only herbaceous vegetation (swordgrass) with patchy distributions. This, in turn, has produced increased erosion and large bare soil areas, which are very prevalent in the western portion of the BCA.

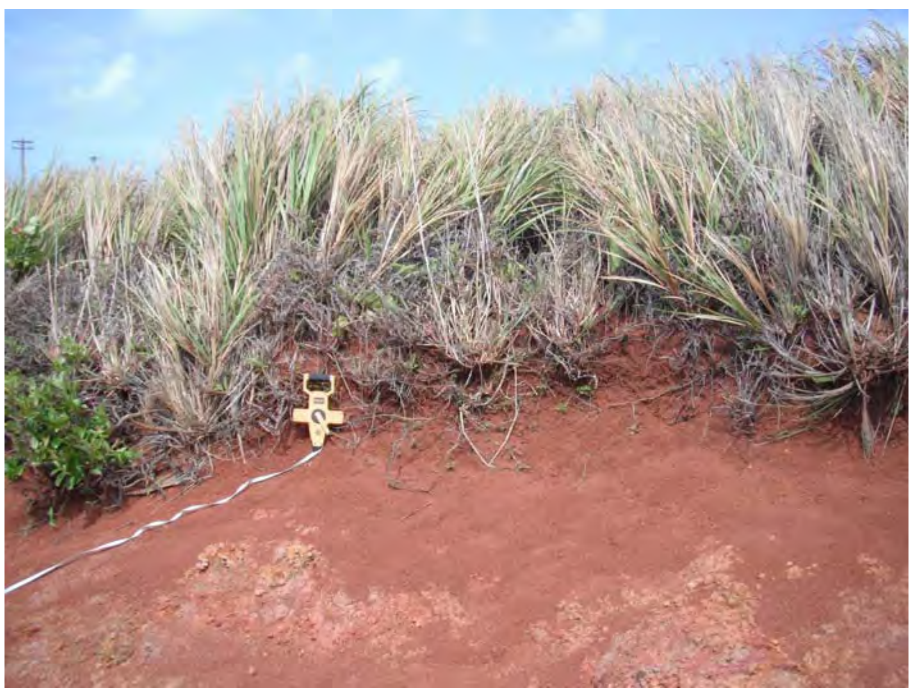


PHOTO 18 PHOTO OF SOLUM AND SAPROLITE WITHIN THE GEUS WATERSHED.

PHOTO 19 PHOTO OF SOLUM AND SAPROLITE ON TOP OF THE RIDGE THAT SEPARATES THE UGUM AND GEUS WATERSHEDS.

3.2.1.6 Erosion Features and Sedimentation

Within the watersheds, numerous erosional features (e.g., washouts, headwall failure, and active gullying, etc.) were commonly observed. Photographs 20, 21, 22, and 23, depict examples of headwall failure, sheet erosion, active gullying, and large erosional areas of bare soils greater than 0.8 ha (1.9 ac) in size, respectively.

Often the upper portion of feeder streams consisted of a 0.5-m (1.6 ft) wide channel of bare soil. This channel was often incised into the landscape up to 1 m (3.3 ft) deep. The banks of the streams and rivers in the watersheds exhibited different levels of erosion. Banks of the Ugum and Geus Rivers were generally vegetated, indicating limited erosion from the tops of the banks. In other watersheds the banks were nearly vertical, un-vegetated, and exhibited some features of undercutting.

As indicated in subchapter 3.2.1.3, large sediment deposits were witnessed at or near the mouths of both the Geus River and Ugum River. The sediments were soft and in some places over 0.6 m (2 ft) deep.

PHOTO 20 HEADWALL FAILURE IN THE UGUM WATERSHED.

PHOTO 21 AN EXAMPLE OF SHEET EROSION IN THE UGUM WATERSHED.

PHOTO 22 EXAMPLE OF ACTIVE GULLYING IN THE GEUS WATERSHED.

PHOTO 23 LARGE EROSIONAL AREA WITH ACTIVE GULLYING AND REMNANTS OF HEADWALL FAILURE.

3.2.1.7 Existing Roads, Trails, and Infrastructure

Within the Umatac, Toguan, and Geus Watersheds, infrastructure development occurs mostly along the coastal areas. The mountainous eastern region of all three watersheds is largely undeveloped. No development occurs within the BCA, except for a few isolated towers and monuments on points of high elevation.

The physical condition of the roads within the Umatac, Toguan, Geus, and Ugum Watersheds is highly variable. Within the watersheds there are four-lane paved thoroughfares (Route 2) as well as dirt four-wheel drive (4WD) trails.

- **Umatac Watershed**

The Umatac has urban development on the ridgeline along Route 2. There is also considerable urban development associated with the Umatac township in the lower 492 m (1,500 ft) of the Umatac river valley and in residential developments south of the Umatac Township and east of Route 2. Much of the eastern portion of the watershed is associated with the BCA and contains no developed roads.

- **Toguan Watershed**

The only urban development in the watershed consists of residences on both sides of Route 4 in the Bile and Pigua sub-watersheds (associated with the Merizo township) and some residential developments in the northwestern edge of the Toguan sub-watershed (associated with the Umatac township) and the southeastern edge of the Pigua sub-watershed (associated with the Merizo township).

- **Geus Watershed**

Within the Geus Watershed, roads, trails, and infrastructure are located in the western half of the watershed. Within the watershed Route 4 is a large, paved north-south running roadway along the coast. Starting at Route 4 and running inland for approximately 0.8 km (0.5 mi), several paved, small two-lane residential streets occur. In the eastern half of the watershed, the steep mountainous terrain precludes the placement of roads or infrastructure. Trails are limited to small, poorly defined hiking trail on the crest of the ridge that divides the Geus Watershed from the Ugum Watershed. There is also a large communications tower on top of Mount Sasalugulan. No paved roads travel to this tower.

- **Ugum Watershed**

Within the BCA there are no municipal or residential roads or infrastructure. There are several, unimproved, dirt tracks that are used by hunters and recreational off road vehicles. These tracks are often highly eroded and pock-marked with gullies and craters (Photo 24). Moreover, conversations with local land owners that occurred during the field efforts indicated that in their current state, the roads are impassible during the latter portion of the rainy season.

PHOTO 24 UNIMPROVED DIRT TRACK IN THE UGUM WATERSHED.

3.2.1.8 Land Ownership

Figure 16 identifies the land ownership in the project's watersheds. As can be observed in the figure, the government of Guam has sizeable holdings throughout the four watersheds.

- **Umatac Watershed**

The Umatac watershed encompasses 995.1 ha (2,459 ac) and includes both publicly and privately owned land (Figure 16). Publicly-owned land covers about 66 percent of the watershed and includes Government of Guam holdings and federal land. A breakdown of public land holding is the following: Government of Guam Lands 289 ha (789 ac), Chamorro Land Trust 50 ha (123 ac), the BCA 318 ha (787 ac), and the federal government owns approximately 31 ha (76 ac) of land that is part of the Naval Munitions Site to the northeast of the watershed (BSP 2007).

- **Toguan Watershed**

The Toguan watershed encompasses approximately 364 ha (900 ac) and includes both publicly and privately owned land (Figure 16). Publicly-owned land covers almost 73% of the watershed and consists of Government of Guam holdings totally approximately 364 ha (654 ac), including approximately 31 ha (54 ac) that comprise the BCA and 108 ha (267 ac) owned by the Chamorro Land Trust in the watershed. Approximately 37 percent of the land in the Toguan watershed is privately owned. Private land parcels are small and concentrated along the coastline and the southeast portion of the watershed.

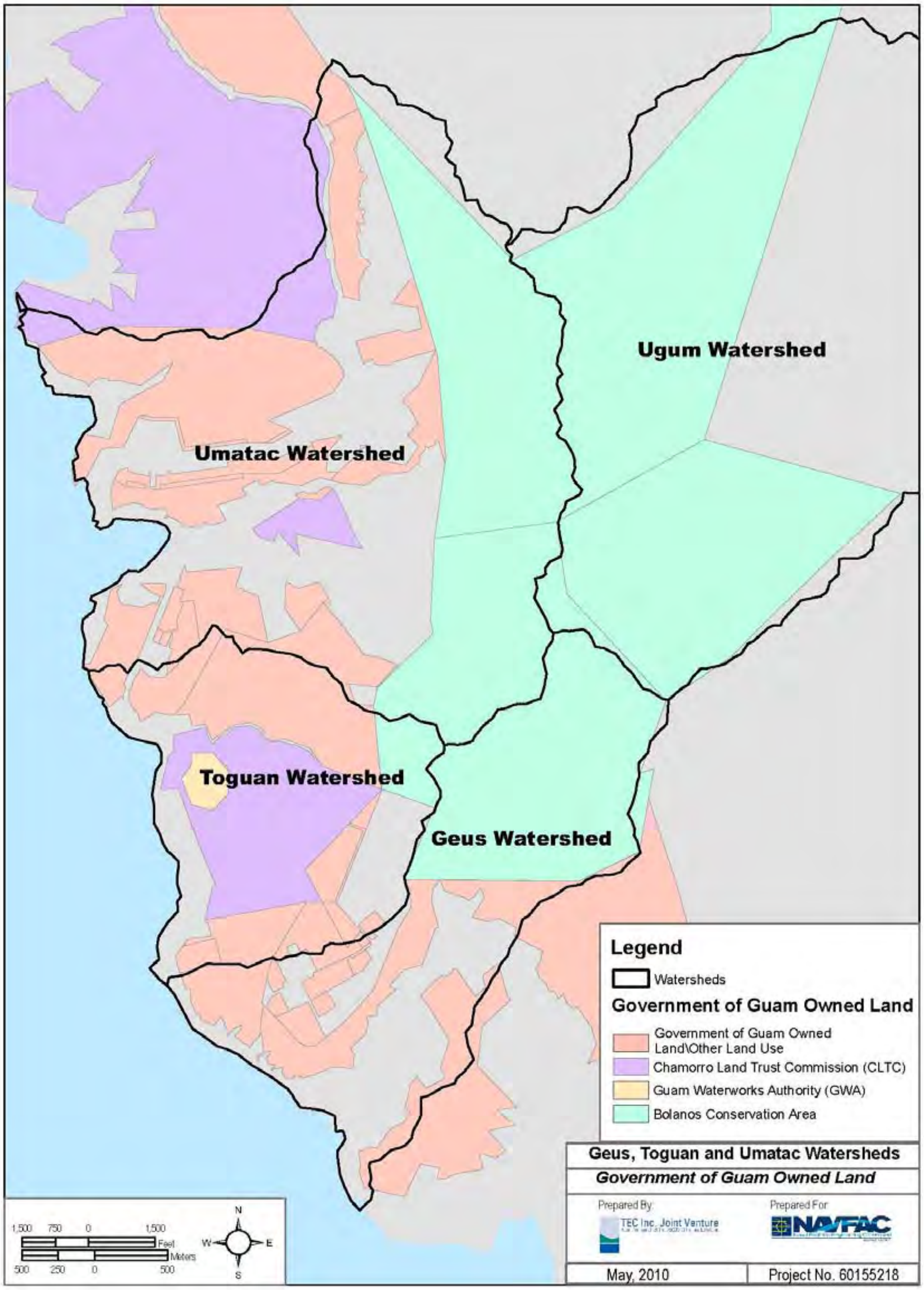


Figure 16 GovGuam Owned Land

- **Geus Watershed**

The Geus watershed encompasses 448.8 ha (1,109 ac) and includes both publicly- and privately-owned land (Figure 16). Publicly-owned land consists of approximately 316.9 ha (783 ac) of Government of Guam holdings covering approximately 71% of the watershed. Within the Geus Watershed, the BCA comprises 187 ha (462 ac) of the land area. The BCA is located in an inaccessible area in the northern portion of the watershed. Only about 14% of the land in the watershed is privately owned.

- **Ugum Watershed**

The Ugum watershed encompasses 1,892 ha (4,675 ac) and includes both publicly- and privately-owned land (Figure 16). Publicly-owned land covers 40% of the watershed and includes Government of Guam holdings and federal land. The Government of Guam owns approximately 739 ha (1,826 ac), most of it in the headwater areas of the watershed. The federal government owns approximately 28.3 ha (70 ac) that is part of Naval Munitions Site to the north and west of the Ugum Watershed (BSP 2008). All of the land area evaluated in this assessment within the Ugum watershed is in the BCA. Within the Ugum the BCA encompasses 563 ha (1,390 ac).

Approximately 1,125 ha (2,780 ac) within the Ugum watershed is privately owned, covering approximately 60% of the total watershed area. There are 35 parcels inside the watershed boundary; 18 of these straddle both sides of the boundary. The average size of the portions of parcels contained within the watershed boundary is 32.3 ha (80 ac). This increases to 85.4 ha (211 ac) when based on the total parcel acreage, including portions lying outside the watershed boundary.

3.3 Land Use and Zoning

This subchapter provides information on the land use and zoning in the four watersheds. Detailed information on the four watersheds are provided in subchapters 3.3.1 (Umatac) 3.3.2 (Toguan), 3.3.3 (Geus), and 3.3.4 (Ugum).

The 2000 Census of Population and Housing reports the population of Guam as 154,805 in 1999 (US Census Bureau, 2004). The majority of Guam's population is concentrated in the northern and central parts of the island, while populations in the southern part of the island are relatively small (BSP 2009). Table 2 identifies the populations of the four watersheds. The watersheds are sparsely populated, with practically all of the population concentrated in small towns along the coast.

Table 2 Population – Umatac, Toguan, Geus, and Ugum Watersheds

Watershed	Population
Umatac	1,269
Toguan	1,102
Geus	2,223
Ugum	503
Data based on US Census Bureau, 2004	

3.3.1 Umatac Watershed

3.3.1.1 Land Use and Zoning

Over 90% of the land, 926 ha (2,288 ac), within the Umatac watershed is zoned as Agricultural. The Agricultural Zone allows a variety of conditional land use activities in addition to those commonly associated with agriculture, including development for residential, public, and commercial uses. Such uses may require a Special Use Permit through the Territorial Land Use Commission. The remainder includes a 12 ha (30 ac) Planned Unit Development Zone, 30 ha (75 ac) of Military Lands, 19 ha (46 ac) of One-Family Dwelling Zone, 4.5 ha (11 ac) of Multiple Dwelling Zone, and 1 ha (2.45 ac) of Commercial Zone. A Planned Unit Development Zone is a substantial area in which development follows an approved plan. Military Lands within the watershed are part of the Naval Munitions Site that extends to the north and east of the Umatac watershed. Except for Military Lands, non-Agricultural zones are concentrated in the lower portion of the watershed around the mouth of the Madog River. Figure 17 shows zoning within the watershed.

Most of land within the Umatac watershed consists of natural areas (Figure 18). Existing urban built up areas and agricultural lands are predominantly located in lowland areas and comprise very little of the watershed.

Natural areas in the upper portion of the watershed include portions of the BCA, which is managed for hunting and outdoor recreation uses by the Government of Guam Department of Agriculture, Division of Aquatic and Wildlife Resources (GDAWR, 2005). The BCA encompassed 1,155 ha (2,854 ac), and extends into the village of Merizo. Natural areas in the upper portion of the watershed also include a small part of the Guam National Wildlife Refuge. Most of the refuge is an overlay refuge on lands administered by the U. Although the military mission has primacy on these lands, the US Fish and Wildlife Service assists in protecting native species and habitats through a Memorandum of Understanding (MOU) established between the three agencies. The MOU established a number of long-term management objectives for overlay units. These federal agencies, the MOU, and valuable ongoing management activities and interest in natural resource management constitute a major component of Guam's natural resource management approach (GDAWR, 2005).

Inajaran and Talofofo are two of the most active villages in Guam with regards to farming activity. The 2002 Census of Agriculture reports that, out of 153 farms on Guam, there were 22 farms in Talofofo and 21 farms in Inaharan. Combined, this comprises 28% of all farms on Guam. Additional, these two villages contained 45% of the total farm land acreage on Guam at the time, with 108 ha (267 ac) of farm land in Talofofo and 189 ha (468 ac) in Inajaran (NASS 2004). The 2002 Census of Agriculture reported no farms or farmland acreage for the village of Umatac at the time (NASS 2004).

3.3.1.2 Scheduled Development

No additional information regarding future development plans within the Umatac watershed was found during the course of this assignment.

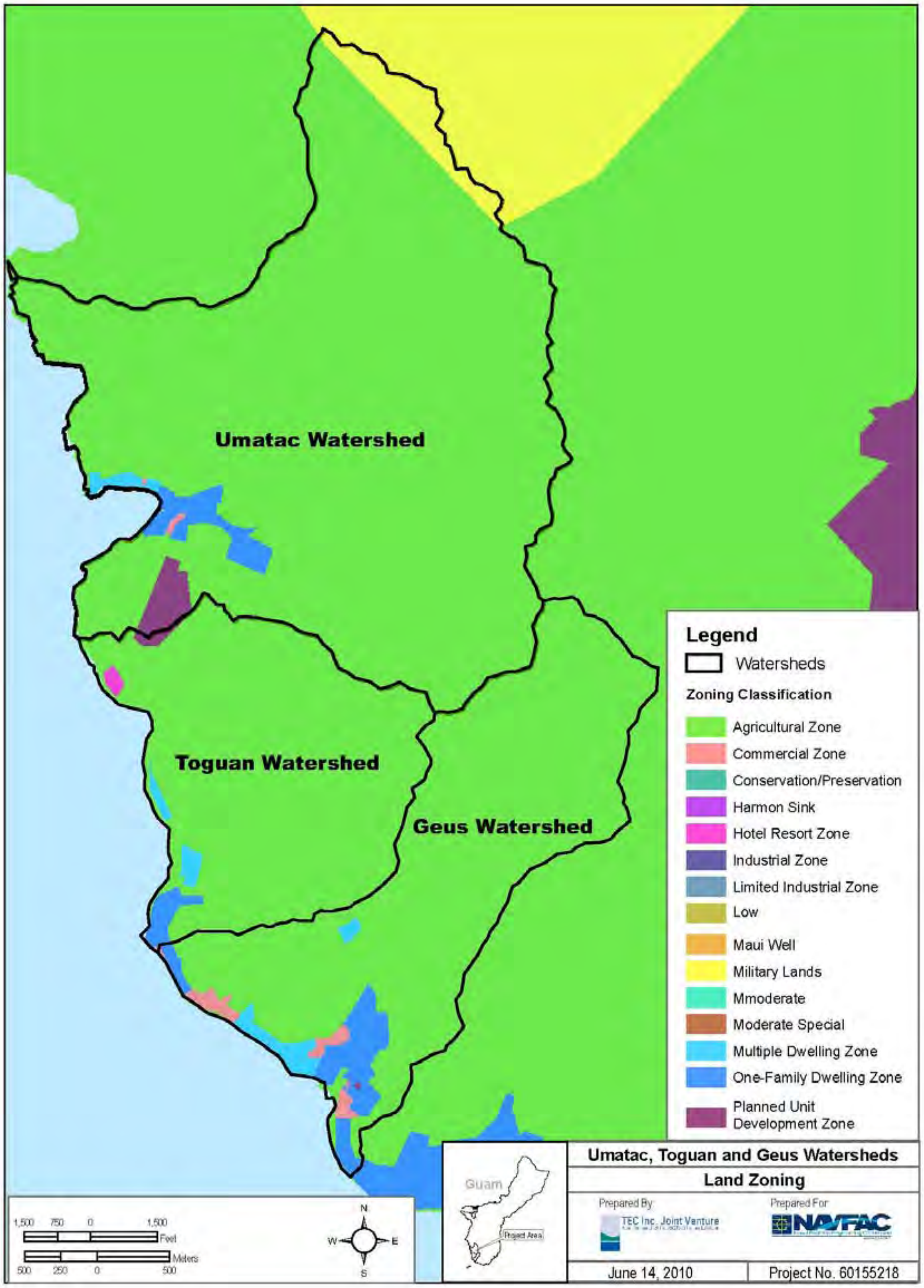


Figure 17 Land Zoning in the Umatac, Toguan, and Geus Watersheds

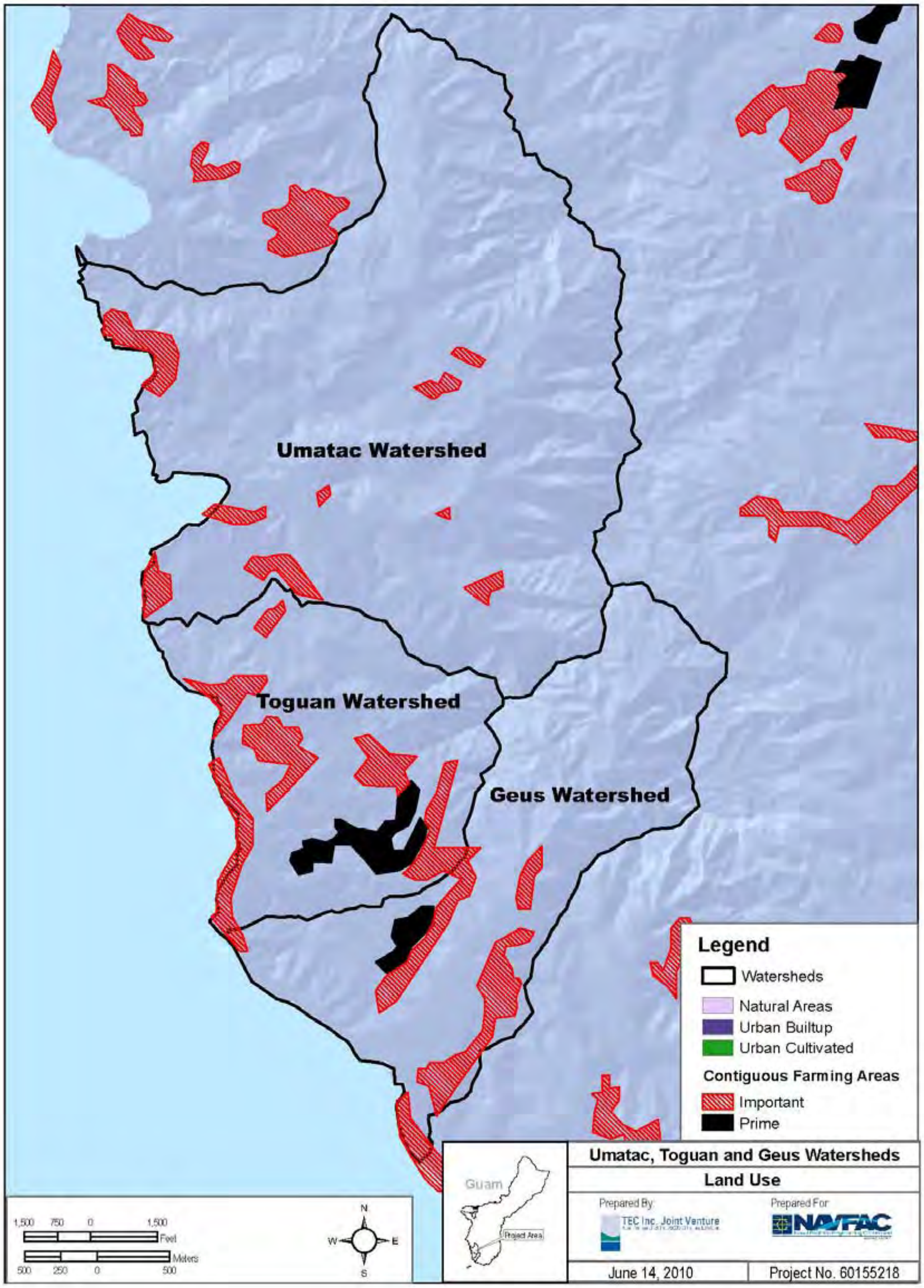


Figure 18 Land Use in the Umatac, Toguan, and Geus Watersheds

3.3.2 Toguan Watershed

3.3.2.1 Land Use and Zoning

Over 95% of the land, 347 ha (857 ac) within the Toguan watershed is zoned as Agricultural (Figure 17). The Agricultural Zone allows a variety of conditional land use activities in addition to those commonly associated with agriculture, including development for residential, public, and commercial uses. Such conditional uses may require a Special Use Permit through the Territorial Land Use Commission. The remainder includes a 2 ha (5 ac) Planned Unit Development Zone, 0.16 ha (0.4 ac) of Commercial Zone, 1.7 ha (4.3 ac) of Hotel Resort Zone, 7 ha (17.3 ac) of One-Family Dwelling Zone, and 5 ha (12 ac) of Multiple Dwelling Zone. A Planned Unit Development Zone is a substantial area in which development follows an approved plan. Non-Agricultural zones occur in the lower portion of the watershed near the coast. Figure 17 shows zoning within the watershed.

Most of land within the Toguan watershed consists of natural areas; however, a relatively large portion also consists of contiguous tracts of agricultural lands (Figure 18). Urban built up areas

within the watershed are generally small portions of larger urban areas that extend into neighboring watersheds to the north and south.

Natural areas in the upper portion of the watershed include portions of the BCA, which is managed for hunting and outdoor recreation uses by the GDAWR (2005. The BCA encompasses 1,155 ha (2,854 ac), and extends into the villages of Inajaran and Talofofo.

Although agricultural land occurs in the watershed, the area appears to have very little documented farming activity. The 2002 Census of Agriculture reports that, out of 153 farms on Guam, there were no farms in the village of Umatac and only 5 farms in the village of Merizo with just 10 ha (26 ac) of farmland (NASS, 2004).

3.3.2.2 Scheduled Development

No additional information regarding future development plans within the Toguan watershed was found during the course of this assignment.

3.3.3 Geus Watershed

3.3.3.1 Land Use and Zoning

Almost 90% of the land within the Geus watershed is zoned as Agricultural. The remainder includes a Planned Unit Development Zone, 0.2 ha (0.5 ac), Commercial Zones, 8.7 ha (21.5 ac), One-Family Dwelling Zones 28.3 (70 ac), and Multiple Dwelling Zones 10.5 ha (26 ac). Non-Agricultural zones are concentrated around Merizo in the lower portion of watershed along the coast. Figure 17 shows zoning within the watershed.

Most of land within the Geus watershed consists of natural areas; however, large contiguous tracts of agricultural lands also occur (Figure 18). Existing urban built up areas within the watershed generally occur in the lower portion of the watershed and near the shoreline.

Natural areas in the upper portion of the watershed include portions of the BCA, which is managed for hunting and outdoor recreation uses by the GDAWR. The BCA encompasses 1,155 ha (2,854 ac), and extends into the village of Talofofo.

Inajaran is one of the more active farming villages in Guam. However, very little farming activity occurs in the villages of Umatac and Merizo. The 2002 Census of Agriculture (NASS, 2004) reports that, out of 153 farms on Guam, there were 21 farms in Inaharan, comprising over 13% of all farms on Guam. Additionally, 189 ha (468 ac) of farmland is reported in Inajaran, comprising 28% of all farm acreage on Guam (NASS, 2004). The 2002 Census of Agriculture reported no farms in the village of Umatac and only 5 farms in the village of Merizo with just 26 acres of farmland (NASS, 2004).

3.3.3.2 Scheduled Development

No additional information regarding future development plans within the Geus watershed was found during the course of this assignment.

3.3.4 Ugum Watershed

3.3.4.1 Land Use and Zoning

Over 90% of the land within the Ugum watershed is zoned as Agricultural. The Agricultural Zone allows a variety of conditional land use activities in addition to those commonly associated with agriculture, including development for residential, public, and commercial uses. Such uses may require a Special Use Permit through the Territorial Land Use Commission. The remaining area includes 69 ha (170 ac) of a Planned Unit Development Zone, 28 ha (70 ac) of Military Lands, and a 8 ha (20 ac) area with no zoning designation. A Planned Unit Development Zone is a substantial area in which development follows an approved plan. The Planned Unit Development Zone extends south of the watershed boundary into the Inajaran watershed and encompasses 209 ha (518 ac) total. Military Lands within the watershed are part of the Naval Munitions Site that extends to the north and west of the Ugum watershed. Figure 19 shows zoning within the watershed.

Most of land within the Ugum watershed consists of natural areas (Figure 20). Urban built up areas and existing agricultural lands are predominantly located in lowland areas and comprise very little of the watershed

Natural areas in the upper portion of the watershed include portions of the BCA, which is managed for hunting and outdoor recreation uses by the public. The BCA encompasses 1,154 ha (2,854 ac), and extends into the villages of Umatac and Merizo, in addition to overlaying some military lands. Natural areas within the watershed also include a small portion of the Guam National Wildlife Refuge. Most of the refuge is an overlay refuge on lands administered by the US Air Force and US Navy. Although the military mission comes first on these lands, the US Fish and Wildlife Service assists in protecting native species and habitats through a Memorandum of Understanding (MOU) established between the three agencies.

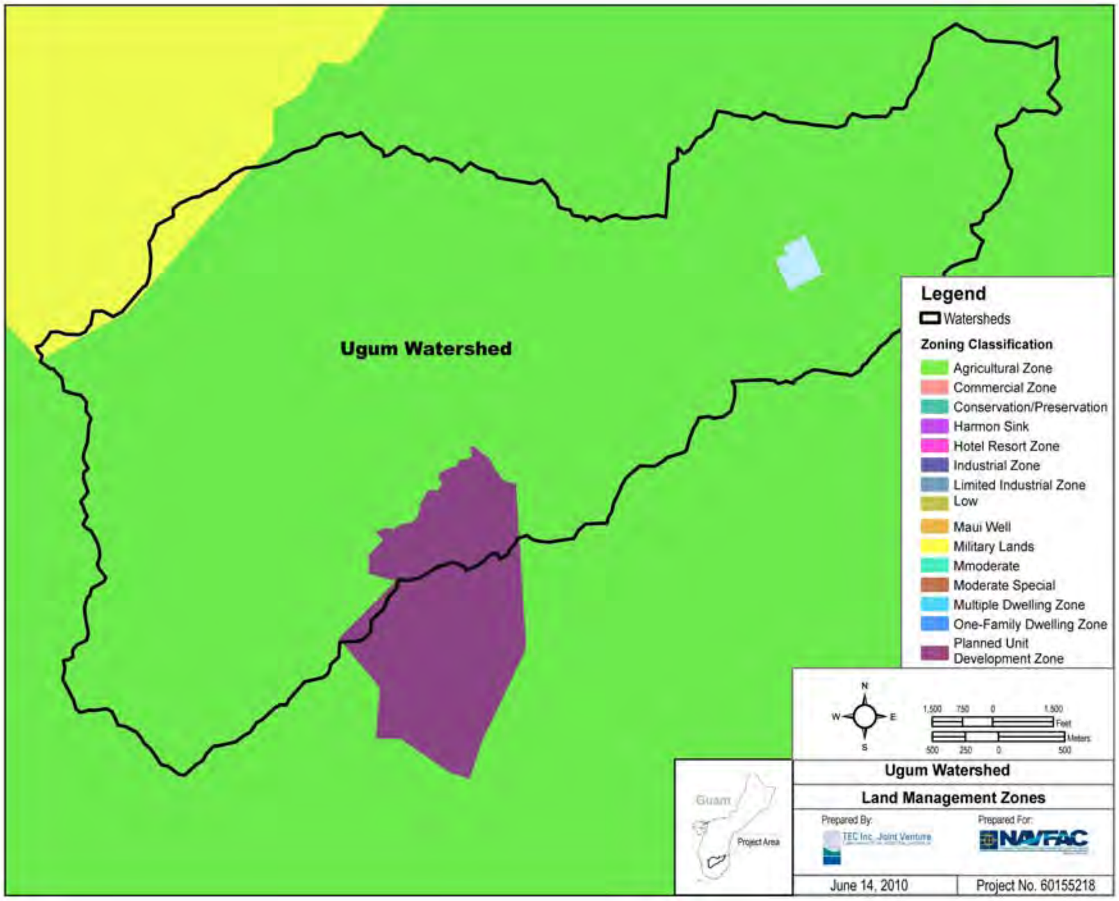


Figure 19 Land Zoning in the Ugum Watershed

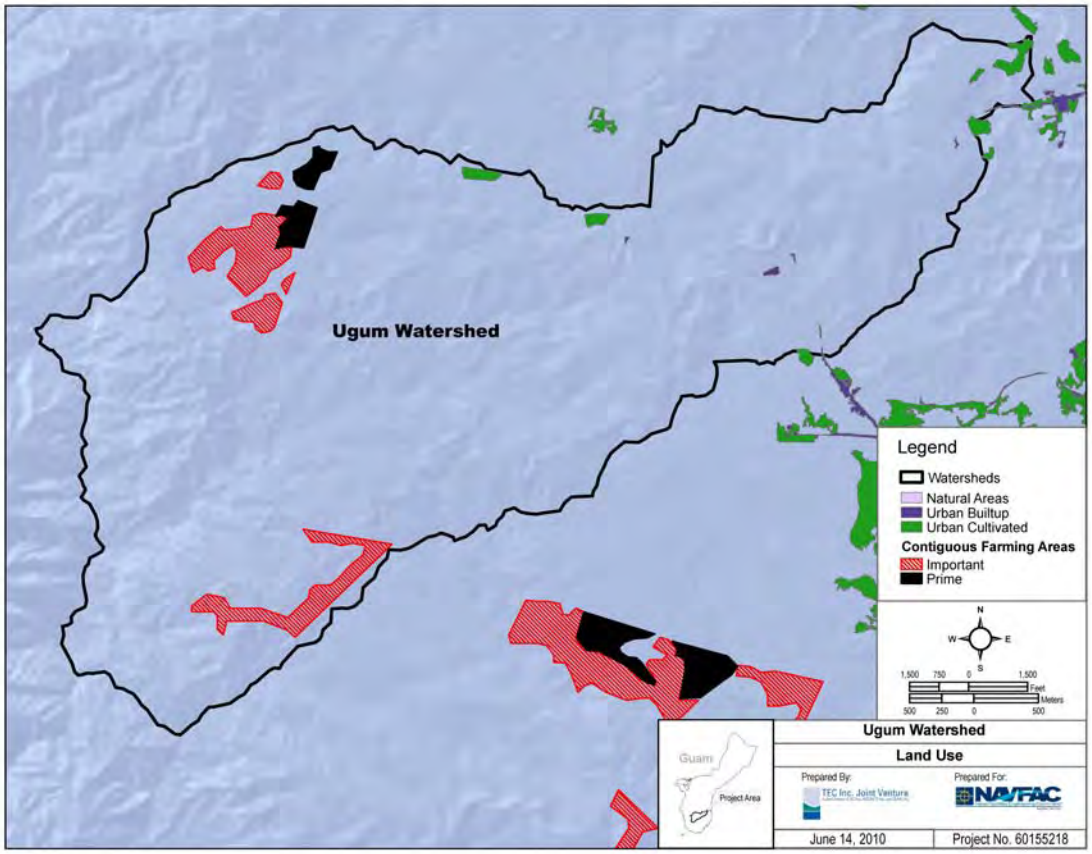


Figure 20 Land Use in the Ugum Watershed

The MOU established a number of long-term management objectives for overlay units. These federal agencies, the MOU, and valuable ongoing management activities and interest in natural resource management constitute a major component of Guam's natural resource management approach (GDAWR, 2005).

Talofofo and Inajaran are two of the most active villages in Guam with regards to farming activity. The 2002 Census of Agriculture (NASS, 2004) reports that, out of 153 farms on Guam, there were 22 farms in Talofofo and 21 farms in Inaharan. Combined, this comprises 28% of all farms on Guam. Additionally, these two villages contained 45% of the total farm land acreage on Guam at the time, with 108 ha (267 ac) of farm land in Talofofo and 189 ha (468 ac) in Inajaran (NASS 2004). Most of the existing cultivated cropland in the villages of Talofofo and Inajaran occurs in the coastal plain area; very little occurs within the Ugum Watershed (Figure 20).

3.3.4.2 Scheduled Development

A new sanitary landfill is being planned for construction in the DanDan area, roughly two miles west of the town of Majojloj and bordered to the north by the Ugum watershed (GEPA, 2004). In 2008, the Government of Guam received $2.1 million of federal funding to begin the design and siting of the landfill, which will replace the problematic Ordot dump.

A private development project (DanDan Estates) would build 920 residential units over a large area (approximately 1,133 ha [2,800 ac]) west of Malojloj (GWA, 2006), roughly 263 ha (650 ac) of which lie within the Ugum watershed.

3.4 GIS-based Model

A GIS model using the GIS data library coverages was constructed to apply the Revised Universal Soil Loss Equation (RUSLE) method to create a soil erosion potential map of the study area's watersheds. In addition, a GIS-based decision framework was constructed for choosing mitigation sites and strategies based on the geospatial data included in the GIS library. The models were developed using baseline conditions which will be the basis for assessing the management scenarios in subsequent sections.

Soil erosion potential was modeled in two ways:

- An ArcGIS based model.
- NOAA's N-SPECT.

The model inputs and baseline results are presented below for both models.

3.4.1 Arc-GIS Model

The long-term average annual soil loss was calculated using the USLE in the manner described in the University of Guam (UOG) Water and Environmental Research Institute (WERI) Technical Publication (TP) #117 *Developing a GIS-based Soil Erosion Potential Model of the Ugum Watershed.* Data for the USLE equation was be stored in ArcGIS 9.3 and combined to prepare the soil erosion potential map. The USLE equation is:

$$\mathbf{A = LS \times R \times K \times C \times P}$$

Where:

A = Average Annual Soil Loss
LS = Slope length-gradient factor
R = Rainfall and runoff factor by geographic location
K = Soil erodibility factor
C= Crop/vegetation and management factor
P = Support practice factor

Where:

A = Estimated Average annual soil loss: units are expressed in (tons per acre per year)

R= Rain Erosivity Factor: The erosive power of rainfall which is calculated as the product of the kinetic energy of the storm even and the 30 minute intensity

Expressed in $\frac{\text{feet – tons – inches}}{\text{acre – hour – year}}$

K = Soil Erodibility Factor: The soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as 72.6 ft (22.1m) length of the uniform slope (9%) in continuous clean-tilled fallow.

Expressed in $\frac{\text{tons -acre – hour}}{\text{feet – tons – inches – acre}}$

L = Slope Length Factor: The ratio of soil loss from the field slope length to soil loss from a 72.6 ft (22.1m) length under identical conditions, dimensionless.

S = Slope Steepness Factor: The ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions, dimensionless.

C = Cover Management Factor: The ratio of soil loss from an with specified cover and management to soil loss from an identical area in tilled continuous fallow, dimensionless.

P=Support Practice Factor: The ratio of soil loss with a support practice like contouring, strip cropping, or terracing to soil loss with a straight row farming up and down the slope, dimensionless.

3.4.1.1 Model Inputs

The model input used in this evaluation were the same as those implemented by WERI (2007). A description of the factors is provided below. Figures showing the model inputs are provided in Appendix A.

- **Soil Erodibility Factor - K**

The soils in the watershed are based on the electronic version of the Soil Survey of the Territory of Guam (NRCS, Young 1988), which delineated all local soil types. WERI in TP #117 assigned the K factor values for each soil type in the Appendix section (Table 12) of Young (1988). The same K factors selected by WERI are used in this analysis except for soil types present in the watersheds but not presented in TP #117. The K factor for Ustorthents is not provided in Young (1988). The value of K was assumed to be 0.24, similar to the Inarajan clay and Ylig clay based on the physical and chemical properties of the soils. Table 3 lists the soil types and K factors for soils in the four watersheds.

Table 3 K Factor Assignments

Soil Type	K Factor
Agfayan clay	0.2
Agfayan-Akina-Rock outcrop association	0.2
Agfayan-Rock outcrop complex	0.2
Agfayan-Akina association	0.2
Akina silty clay	0.2
Akina-Agfayan association	0.2
Akina-Atate association	0.2
Akina-Atate silty clays	0.2
Akina-Badland association	0.2
Akina-Badland complex	0.2
Akina-Urban land complex	0.2
Inarajan clay	0.24
Inarajan sandy clay loam	0.17
Pulantat clay	0.24
Sasalaguan clay	0.28
Togcha-Akina silty clays	0.15
Togcha-Ylig complex	0.15
Ustorthents-Urban land complex	0.24
Ylig clay	0.24

- **Cover Management Factor – C**

The vegetation cover factor (C factor) is used within the USLE to reflect the effects that vegetation cover, cropping, and management practices have on the soil erosion rate. A detail of the type of vegetation cover was provided by the Guam Department of Forestry in 2004.

This project referred to TP #117 to obtain the C factor values for particular vegetation in Geus, Togun, Umatac and Ugum watersheds. WERI selected C factors from the "Ohio Erosion Control and Sediment Pollution Abatement Guide, 1979" prepared by Ohio State University. A summary of C factor values are show in Table 4. WERI made the following assumptions in TP #117:

- Bare soil -there is no appreciable canopy cover and zero percent ground cover.

- Riverine, Scrub, and Scrub Forests - primarily comprised of trees with a canopy cover of 25 percent, the ground cover is estimated to be 60 percent.

- Savanna Complex - primarily composed of grass species and bushes; canopy cover is estimated at 25 percent, with predominantly grass species which provide an estimated 80 percent ground cover.

For this analysis it is assumed that the C Factor for agricultural fields, acacia plantations, coconut plantations, and tangantangan (i.e., Leucaena Stand) is low and the same as the C Factor for Riverine, Scrub, and Scrub Forests. It is assumed that the C Factor for bad land is the same as bare soil. For Urban Build Up and Urban Cultivated, a C Factor of 0.01 was selected from Department of Planning and Permitting Honolulu (1999) for grass sod assuming the areas are primarily covered with grass or landscaping. For wetlands, a C Factor of 0.01 was chosen assuming the dense vegetation is similar to Grass Sod is present.

Table 4 C Factor Assignments

Vegetation Type	C Factor
Acacia Plantation	0.041
Agriculture Field	0.041
Bad Land	0.45
Barren	0.45
Coconut Plantation	0.041
Leucaena Stand	0.041
Ravine Forest	0.041
Savanna Complex	0.013
Scrub Forest	0.041
Urban Build up	0.01
Urban Cultivated	0.01
Water	0
Wetland	0.01

- **Rainfall and Runoff Factor – R**

Rainfall influences soil erosion by each raindrop causing soil particles to detach and by the amount of rain over a specific time. The R-Factor is calculated by the summation of storm events and dividing by the number of years (Were, 2007)

$$R=\frac{\sum(E)(I_{30})}{N}$$

The R factor map was derived from the average annual R factor map developed in the Dumaliang study (1998). The contour lines were traced with polylines and assigned the appropriate R factor value, then converted to a raster file using interpolation to create a gradient between each line.

- **Elevations – LS**

The slope length factor (L) is the distance from the point where overland flow begins to where either deposition occurs or where the flow intersects a stream (WERI, 2007). The slope steepness factor (S) is related to the L factor and the slope angle in degrees.

The L Factors and S Factors were calculated from the USGS 10 x 10 meter digital elevation model (DEM). The L Factors and S Factors were calculated using a C++ program from van Remortel et al. (2004).

- **Support Practice Factor – P**

The P Factor is the ratio of soil loss with a support practice like contouring, strip cropping or terracing to soil loss with straight row farming up and down slope (WERI, 2007).

Currently there are no support practices in place within the study site. The common practice is to assign a value of 1 for the P factor. After calculating the estimated soil loss by USLE, the P factor values can be adjusted to forecast various erosion prevention measures. The USLE is recalculated for each proposed measure to determine how much the soil loss is reduced from its initial calculation.

Model Results and Discussion

The modeling approach presented in TP #117 (WERI, 2007) was verified for the Ugum watershed and then the same methodology was used for the other three watersheds. Average annual soil erosion potential is shown in Figure 21 for the Umatac, Toguan, and Geus Watersheds, and in Figure 22 for the Ugum Watershed. The highest estimate of soil erosion potential is 1,159.4 tonnes (1,278 tons) per acre per year. The maximum and average soil erosion potential statistics are provided by watershed in Table 5. The average soil erosion is 13.6 tonnes (15 tons) per acre per year for Ugum. These estimates of soil erosion potential for Ugum are similar to the values obtained for the Ugum watershed in TP #117 (WERI, 2007). The higher soil erosion potential estimates generally are located in the bad land or barren areas and in areas with steeper slopes.

This model provides local estimates of erosion potential, but does not provide estimates of sediment yield resulting from the total erosion occurring upstream or estimates of pollution (e.g., total suspended solids). Use of the NOAA N-SPECT model as described in the next section addresses these gaps in the analysis.

Table 5 Soil Erosion Potential Statistics

Watershed	Average Soil Erosion Potential (Tons/Acre/Year)	Maximum Soil Erosion Potential (Tons/Acre/Year)
Geus	35	1,270
Toguan	10	600
Ugum	15	1,142
Umatac	23	1,278

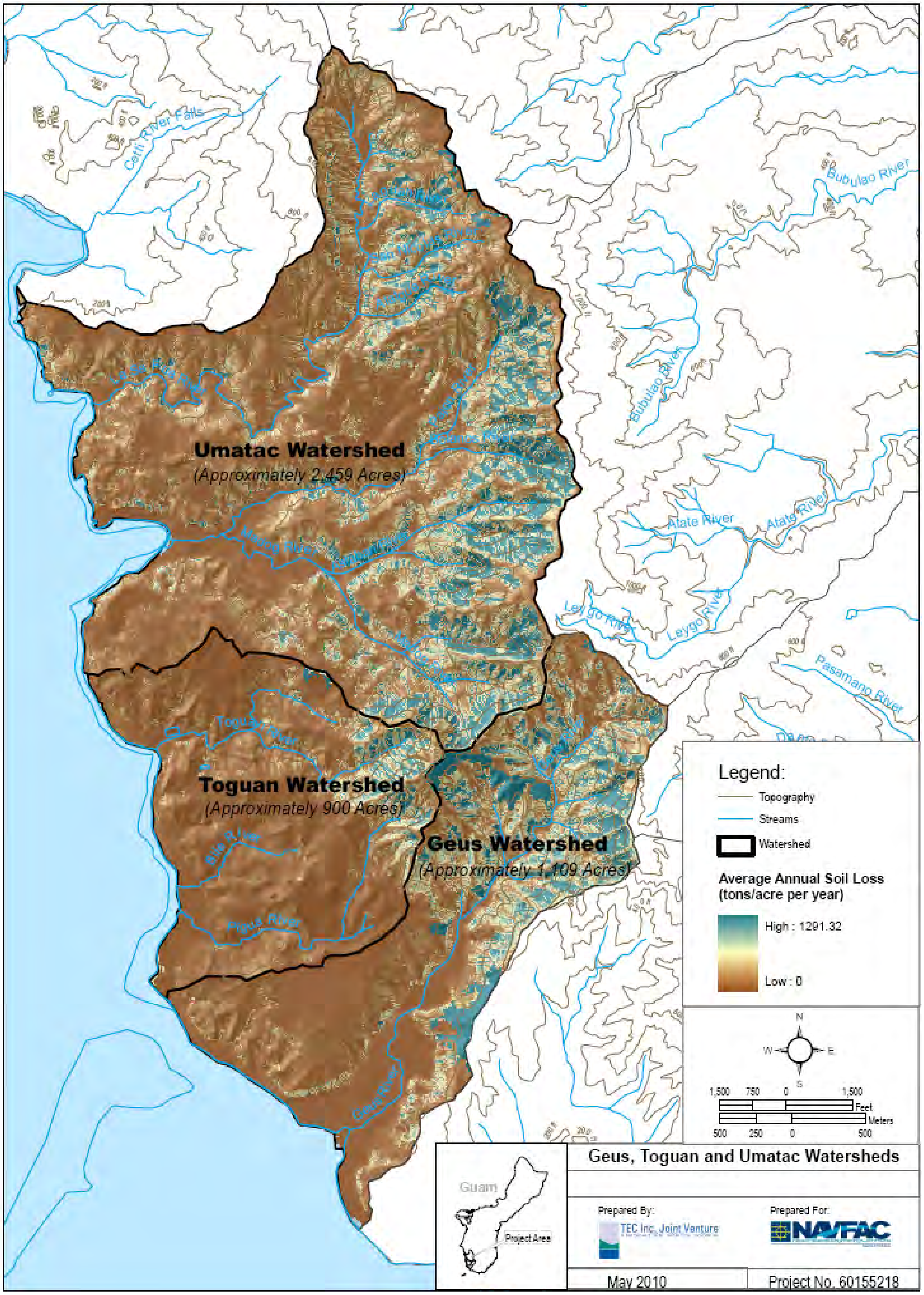


Figure 21 Average Annual Soil Loss Potential - Umatac, Toguan, and Geus Watersheds

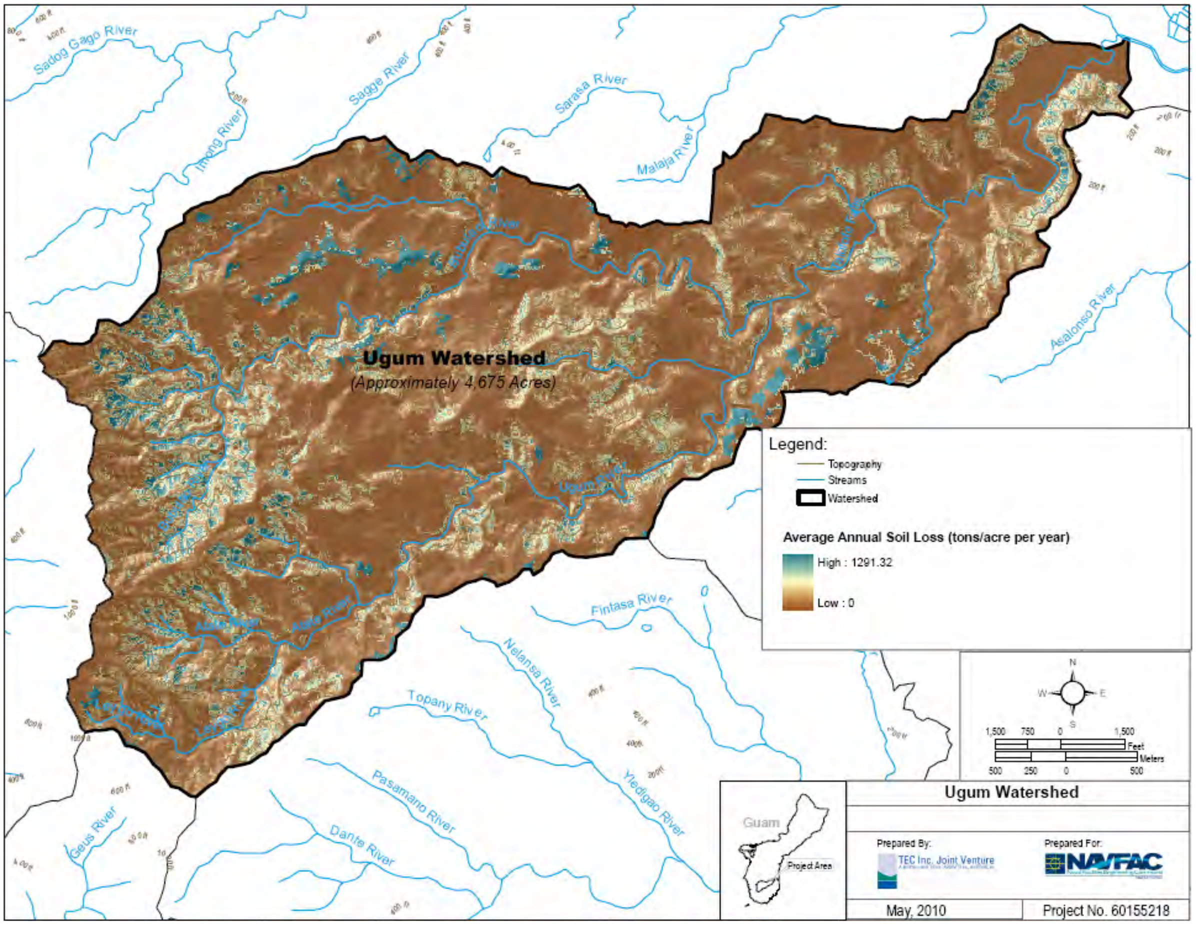


Figure 22 Average Annual Soil Loss Potential - Ugum Watershed

3.4.2 N-SPECT Model

NOAA's Coastal Services Center has developed a tool called N-SPECT, the Nonpoint Source Pollution and Erosion Comparison Tool. The N-SPECT tool is an extension to geographic information system (GIS). This model helps users to predict relation between nonpoint source pollution, land coverage and erosion.

N-SPECT combines a variety of tools to model runoff, sediment concentration, sediment accumulation and pollution loads, N-SPECT is capable of estimating the annual and storm event, as shown below.

N-SPECT MODEL	EVENT	ANNUAL
Runoff Model	SCS Runoff Curved Number	Modified SCS Curved Number
Erosion Model	MUSLE	RUSLE
Nonpoint Source Model	Event Mean Concentration	Event Mean Concentration

Using N-SPECT, the average annual soil erosion was estimated by TEC JV using the RUSLE erosion model. To calculate annual accumulated sediment and sediment concentration, N-SPECT combines three primary components. First, the Urban Hydrology for Small Watersheds: Technical Release 55 (TR-55) is applied to determine runoff values (NRCS, 1986). Second, the Revised Universal Soil Loss Equation (RUSLE2) is applied to determine erosion rates (Ranard et al., 1996). Finally, the following sediment delivery ratio is applied to roughly determine how much soil is transported through the watershed to the coastal areas (William, 1977):

$$SDR = 1.366 * 10-11 * (DA)-0.0998 * (ZL)\ 0.3629 * (CN)5.444$$

Where: SDR = Sediment Delivery Ratio
DA = Drainage Area
ZL = the relief – length ratio (m/km)
CN = SCS curve number

The SDR ratios range from 0.80 to 0.93. The SDR for Ugum was estimated at 0.35-0.55 in TetraTech (2006). The current estimates of SDR are relatively high. However, the soil types are primarily slow or very slow permeability soils and there are significant areas of the watersheds with grassland having a low coverage factor. These aspects of the watersheds lead to higher SDRs. Note that the model results for the management scenarios will be evaluated based on comparison to baseline. The differences in the SDR should drop out using this comparison.

N-SPECT-based RUSLE2 methodology can estimate the accelerated erosion in the watershed on the annual basis. It is a mathematical model based on the structure of Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) and includes those factors that represent climate, soil, landscape and management conditions which can impact erosion rate. The model is derived from the aggregation of sheet and rill erosion.

3.4.2.1 Model Inputs

- **Soil Erodibility Factor - K**

The soil and K factors are presented in TP #117. Figures showing the model inputs are provided in Appendix A. N-SPECT requires assignment of a hydrologic soil group to each soil type. The hydrologic soil group definitions are provided in
Table 6. The hydrologic soil group assignments to the soil types are shown in Table 7.

Table 6 Hydrologic Soil Group Definitions

Soil Group	Soil Group Characteristics
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well- to excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, and moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

From the N-SPECT Technical Guide Version 1.0 Release 1, November 2004

Table 7 Hydrologic Soil Group Assignments

Soil Type	Hydrologic Soil Group
Agfayan clay	3
Agfayan-Akina association	3
Agfayan-Akina-Rock outcrop association	3
Agfayan-Rock outcrop complex	3
Akina silty clay	3
Akina-Agfayan association	3
Akina-Atate association	3
Akina-Atate silty clays	3
Akina-Badland association	3
Akina-Badland complex	3
Akina-Urban land complex	3
Inarajan clay	3
Inarajan sandy clay loam	3
No Data	0
Pulantat clay	3
Sasalaguan clay	3
Togcha-Akina silty clays	2
Togcha-Ylig complex	2
Ustorthents-Urban land complex	4
Ylig clay	4

- **Cover Management Factor – C**

Guam 2005 high resolution land cover data was downloaded from the NOAA Coastal Change Analysis Program web site: http://www.csc.noaa.gov/digitalcoast/data/ccaphighres/download.html. N-SPECT includes the default C Factor and runoff curve numbers (CN) shown in Table 8 for each land cover classification. The runoff curve numbers are used in N-SPECT in runoff depth calculations.

Table 8 C Factor and SCS Curve Numbers

Classification	SCS Curve Numbers				C Factor	Wet
	CN-A	CN-B	CN-C	CN-D		
Background	0	0	0	0	0	No
No Data	0	0	0	0	0	No
High Intensity Developed	0.89	0.92	0.94	0.95	0	No
Medium Intensity Developed	0.77	0.85	0.9	0.92	0.01	No
Low Intensity Developed	0.61	0.75	0.83	0.87	0.03	No
Developed Open Space	0.49	0.69	0.79	0.84	0.005	No
Cultivated Land	0.67	0.78	0.85	0.89	0.24	No
Pasture/Hay	0.39	0.61	0.74	0.8	0.05	No
Grassland	0.3	0.58	0.71	0.78	0.12	No
Deciduous Forest	0.3	0.55	0.7	0.77	0.009	No
Evergreen Forest	0.3	0.55	0.7	0.77	0.004	No
Mixed Forest	0.3	0.55	0.7	0.77	0.007	No
Scrub/Shrub	0.3	0.48	0.65	0.73	0.014	No
Palustrine Forested Wetland	0	0	0	0	0.003	Yes
Palustrine Scrub/Shrub Wetland	0	0	0	0	0	Yes
Palustrine Emergent Wetland	0	0	0	0	0	Yes
Estuarine Forested Wetland	0	0	0	0	0.003	Yes
Estuarine Scrub/Shrub Wetland	0	0	0	0	0.003	Yes
Estuarine Emergent Wetland	0	0	0	0	0.003	Yes
Unconsolidated Shore	0	0	0	0	0.5	No
Bare Land	0.77	0.86	0.91	0.94	0.7	No
Water	0	0	0	0	0	Yes
Palustrine Aquatic Bed	0	0	0	0	0	Yes
Estuarine Aquatic Bed	0	0	0	0	0	Yes

- **Rainfall and Rainfall Erosivity**

Guam average annual rainfall for the period 1971-2000 was downloaded from the PRISM Climate Group website (**http://www.prism.oregonstate.edu/**). Contours lines were sketched from the figure provided by PRISM and interpolated into raster format. A grid file available on the PRISM web site

was not used in this analysis because it did not match the results in the completed map prepared by PRISM.
The rainfall for a recent event was identified to model the impacts from a high rainfall event. In June 2004, the Typhoon TingTing brought heavy rain (16 inches) to Guam. It is assumed that the rainfall was evenly distributed across the island.

The R factor map was derived from the average annual R factor map developed in the Dumaliang study (1998).

- **Elevation – LS**

The USGS DEM 10 meter coverages are the basis for estimating factors L and S.

- **Support Practice Factor – P**

The support practice factor is assumed to be 1 for the baseline analysis.

- **Total Suspended Solids Coefficients**

The default total suspended solids (TSS) coefficients provided by N-SPECT are presented in Table 9. These values were used to model TSS as a nonpoint source pollutant. The coefficients represent the contribution from the land cover classifications to the pollutant load.

3.4.2.2 Model Results

N-SPECT was used to predict erosion potential and non point source pollution from TSS in the four watersheds. The program was run with the model inputs described above for accumulated effects on an average annual basis which estimates the expected pollutant or sediment concentration at a cell including contributions from upstream cells. This estimate provides the basis for determining the net estimated difference in TSS loads at the mouth of the streams caused by changes in coefficient values for the management scenarios developed later in this report. N-SPECT was then run to estimate the baseline local effects which will be used to estimate the net change in TSS load in the immediate vicinity of the areas altered by the management scenarios.

- **Sediment Loads**

Accumulated sediment loads for baseline annual average rainfall conditions are shown in Figure 23 for the Umatac, Toguan and Geus Watersheds, and Figure 24 for the Ugum Watershed. Areas with higher sediment yield are shown in bright colors. For the Umatac Watershed both the La Sa Fua and Umatac Rivers the drainage patterns indicate that the rivers and their tributaries transport sediment quickly in the headwaters where accumulation is low however, in the lower reaches there appears to be opportunity for instream deposition reducing the nearshore environment receipt of materials that are transported from upstream sources. The same could be said for the Toguan and Pigua rivers however with the channelization of the lower Toguan and areas in the lower river with only a bedrock river bottom these estimates may not be indicative of reality as the N-SPECT model does not take into account river geomorphology just river bottom elevation data. For the Bile River the model indicates that the river would transport eroded soil quickly without any opportunity for instream deposition.

Table 9 TSS Coefficient

Classification	TSS Coefficient
Background	0
No Data	0
High Intensity Developed	71
Medium Intensity Developed	27
Low Intensity Developed	19.1
Developed Open Space	11.1
Cultivated Land	107
Pasture/Hay	55.3
Grassland	55.3
Deciduous Forest	11.1
Evergreen Forest	11.1
Mixed Forest	11.1
Scrub/Shrub	11.1
Palustrine Forested Wetland	19
Palustrine Scrub/Shrub Wetland	19
Palustrine Emergent Wetland	19
Estuarine Forested Wetland	19
Estuarine Scrub/Shrub Wetland	19
Estuarine Emergent Wetland	19
Unconsolidated Shore	70
Bare Land	70
Water	0
Palustrine Aquatic Bed	0
Estuarine Aquatic Bed	0

Within the Ugum Watershed the model indicates that for the headwaters of the Atate and Bubulao Rivers little deposition occurs within the boundaries of the BCA.

Sediment load local effects are shown on Figure 25 for the Umatac, Toguan and Geus Watersheds, and Figure 26 for the Ugum Watershed. The pixels with colors from yellow to red highlight the areas that contribute much of the overall annual sediment yield each watershed. It appears that many of the areas that produce high amounts of sediment are associated with steep slopes. However, the spatial patterns of sediment production are clearly a result of more than topography alone. The associations are relatively strong between areas with high sediment yields and areas classified in the land cover data as grassland or bare land. It is also evident that the amount of sediment produced by any one land cover class varies based upon other factors that are not clear in this comparison.

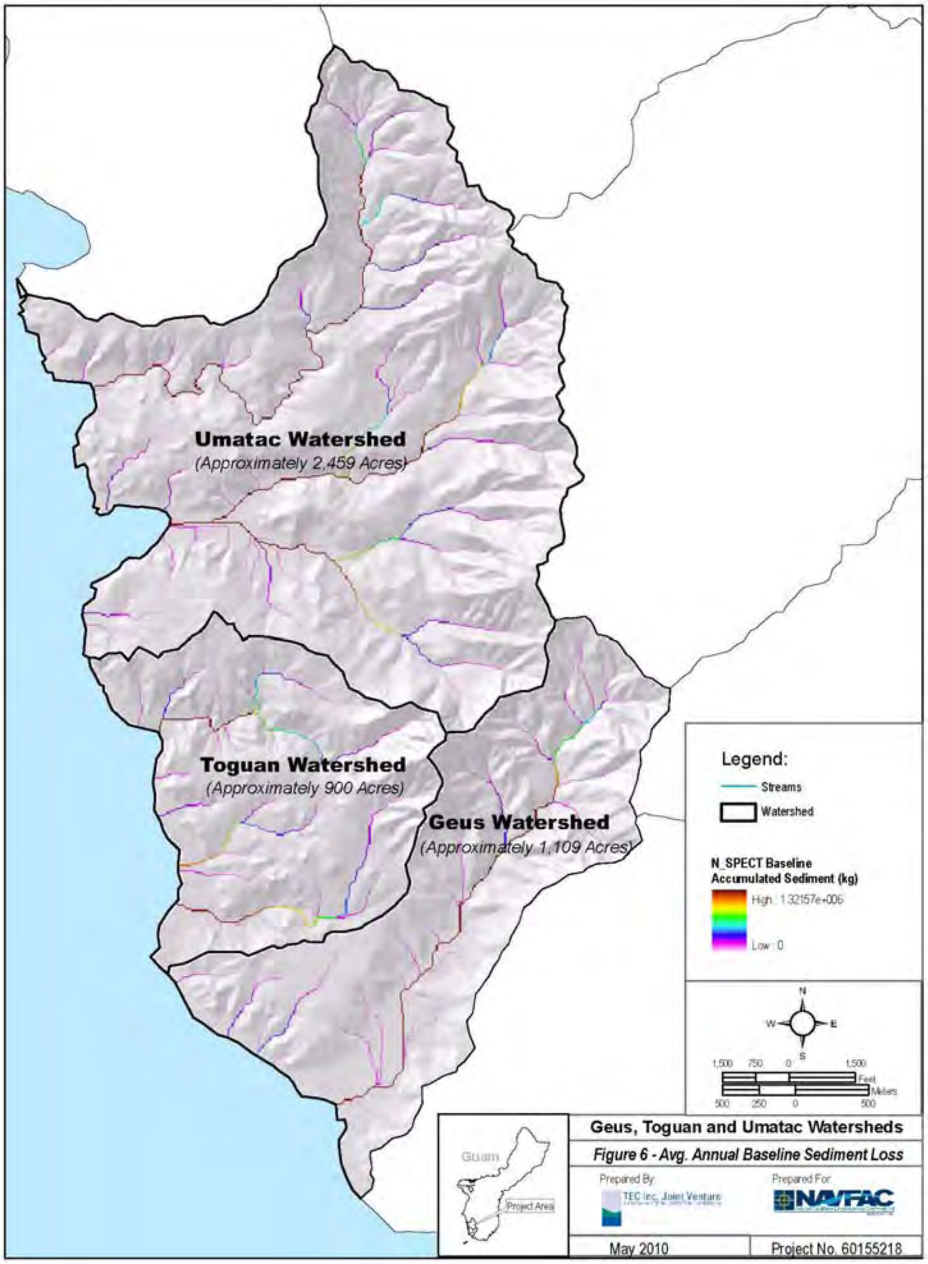


Figure 23 Accumulated Sediment - Umatac, Toguan, and Geus Watersheds

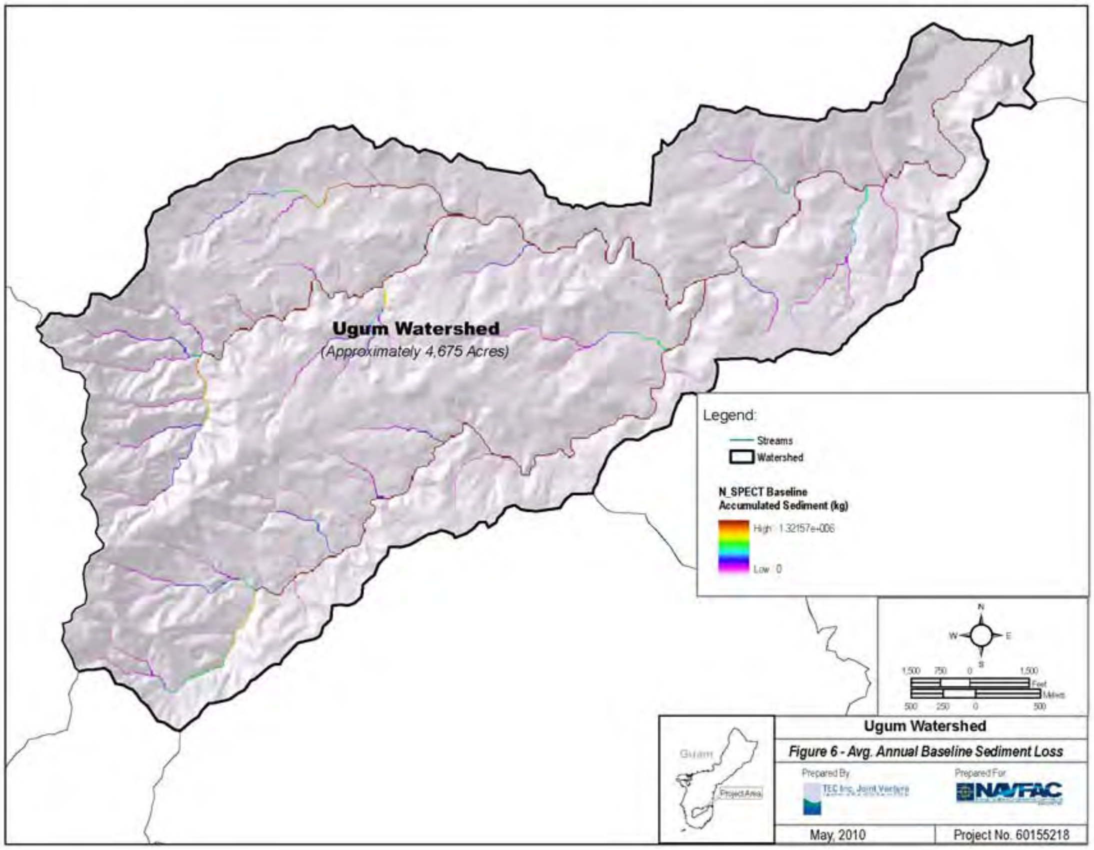


Figure 24 Accumulated Sediment - Ugum Watershed

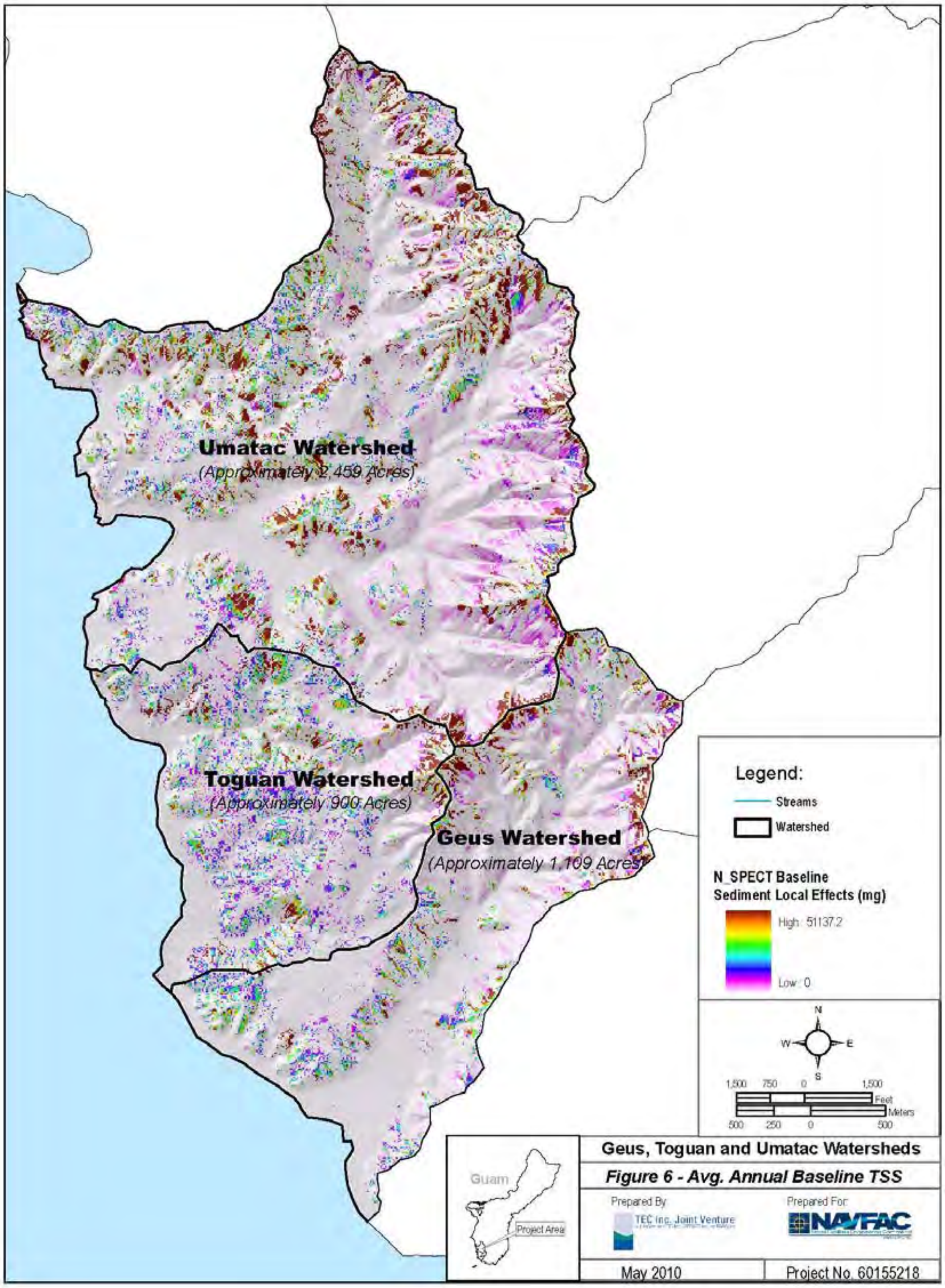


Figure 25 Accumulated Sediment Local Effects - Umatac, Toguan, and Geus Watersheds

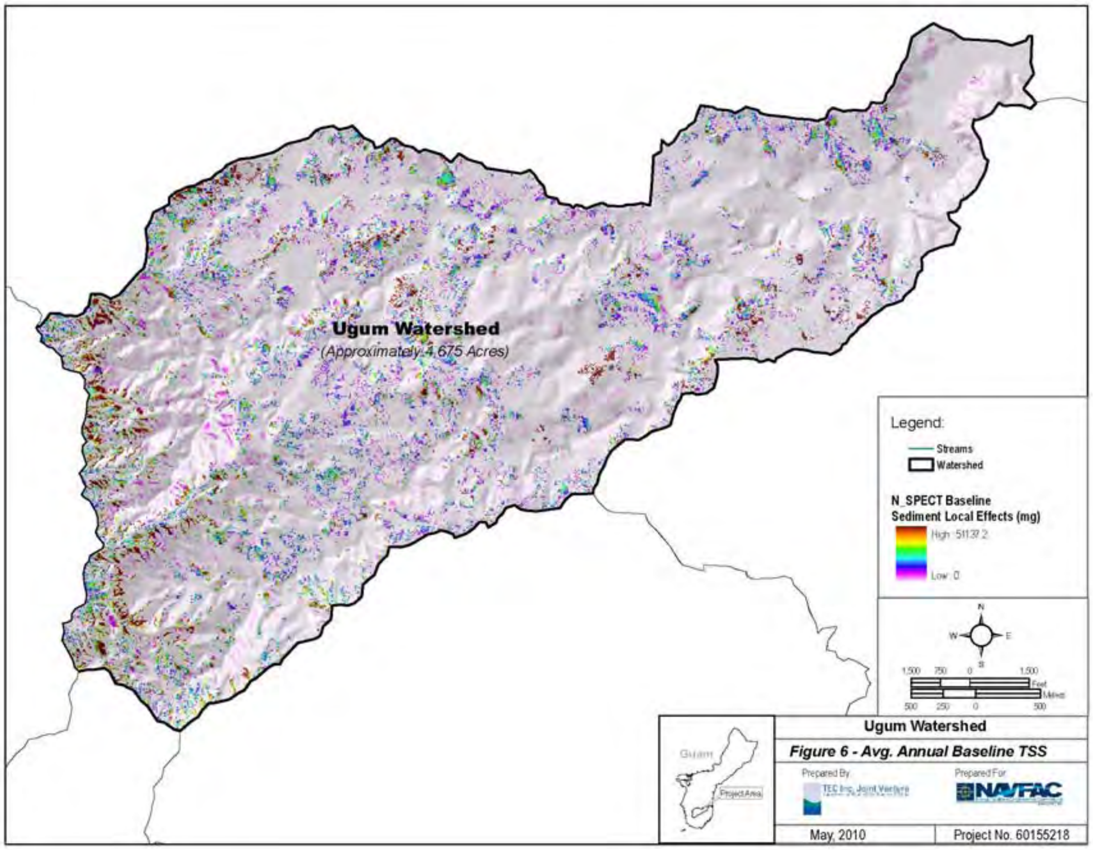


Figure 26 Accumulated Sediment Local Effects - Ugum Watershed

- **Total Suspended Solids**

TSS loads for baseline annual average conditions are shown in Figure 27 for the Umatac, Toguan and Geus Watersheds, and Figure 28 for the Ugum Watershed. For the Umatac Watershed both the La Sa Fua and Umatac Rivers the drainage patters indicate that the rivers and their tributaries transport TSS quickly in the headwaters where accumulation is low however, in the lower reaches there appears to be opportunity for instream increases of TSS. The same could be said for the Toguan and Pigua. For the Bile River the model indicates that the river would transport TSS quickly without any opportunity for increase TSS loading.

Within the Ugum Watershed the model indicates that for the headwaters of the Atate and Bubulao Rivers little TSS loading occurs within the boundaries of the BCA.

TSS load local effects are shown on Figure 29 for the Umatac, Toguan and Geus Watersheds, and Figure 30 for Ugum Watershed. The highest TSS loads are associated with the savanna areas, bare lands, developed open spaces and steep slopes. The lowest TSS loads are in the forested areas. However within the Umatac, Toguan and Geus Watersheds the greatest area extent of lands contributing to the TSS loading is in the lower reaches of the rivers and not on the steep slopes of the head waters whereas in the Ugum the TSS loading is from primarily the steep slopes and bare lands.

TSS loads for a high rainfall event are shown in Figure 31 for the Umatac, Toguan and Geus Watershed, and Figure 32 for the Ugum Watershed. The model results mimic the average rainfall results above. However, the extent of lower TSS accumulation in the headwaters reaches appear to extend further down river and the Pigua River TSS accumulation at the river mouth is greatly reduced indicating more TSS will enter the coastal areas.

TSS load local effects for a high rainfall event are shown on Figure 33 for the Umatac, Toguan and Geus Watersheds, and Figure 34 for the Ugum Watershed. The loading pattern is similar for the high rainfall event when compared to the to the annual average conditions except for the overall increase in TSS loading with highest TSS loads originating from in the areas of bare lands, developed open spaces and steep slopes. The loading pattern is similar for the high rainfall event to the annual average conditions with highest TSS loads in the areas of bare lands, developed open spaces, and steep slopes.

Total TSS baseline loads for each watershed were calculated for the Umatac at 997 tonnes/yr (1,099 tons/yr); for the Toguan 405.1 tonnes/yr (447 tons/yr); for the Geus at 312.1 tonnes/year (344 tons/yr); and for the Ugum 1,322.7 tonnes/yr (1,458 tons/yr).

Limited total suspended solids data is available for the rivers in the four watersheds. The average annual TSS yield estimates are summarized in Table 10 from measurements made by the United States Geological Survey. For the La Sa Fua River the average TSS yield for the period 2005 through 2009 is 1640.1 tonnes /yr (1,808 tons/yr). The baseline model TSS yield for the La Sa Fua River is 484.4 tonnes/yr (534 tons/yr), indicating the TSS yields from the model may be biased low.

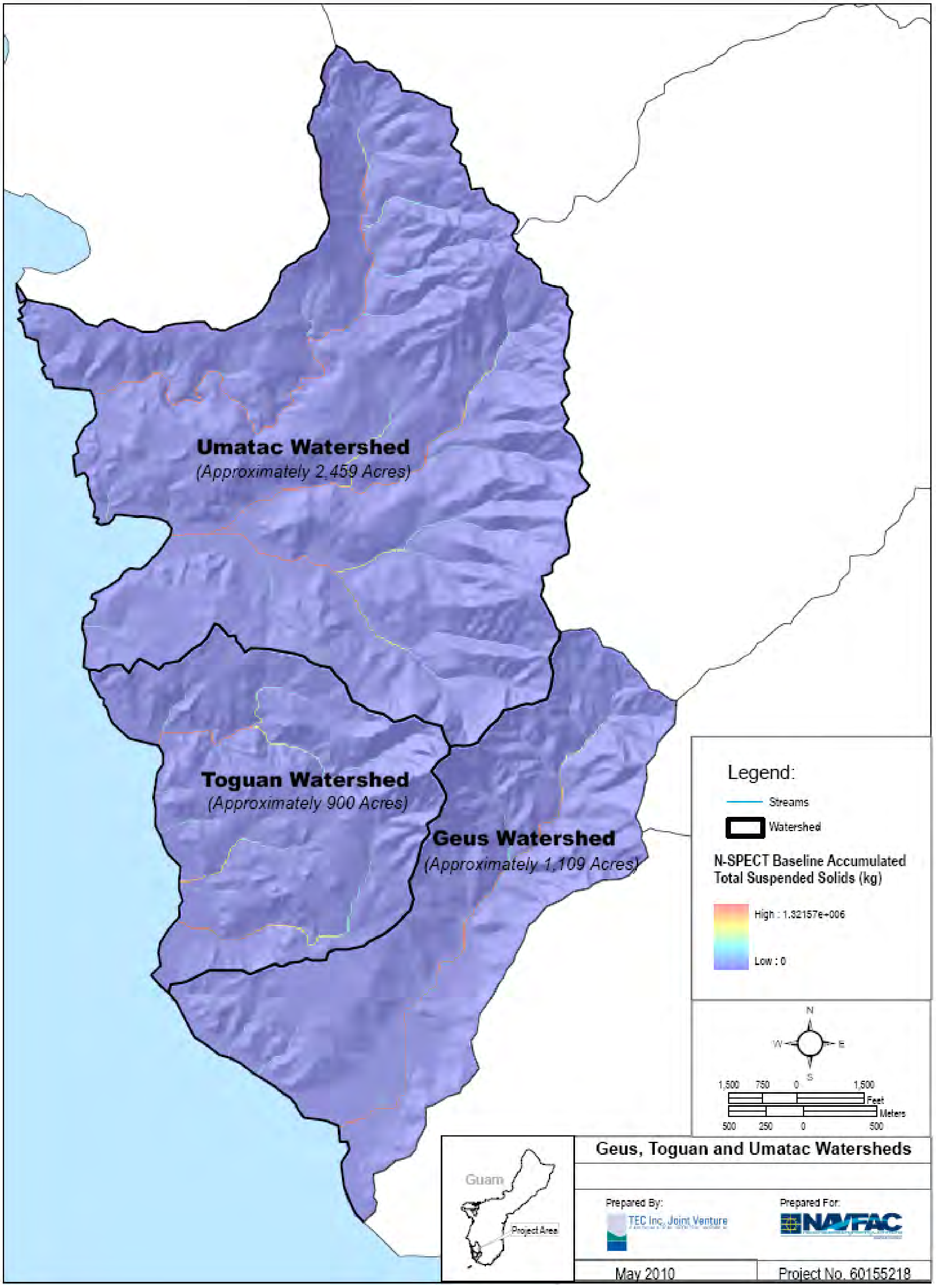


Figure 27 Baseline TSS Accumulation - Umatac, Toguan, and Geus Watersheds

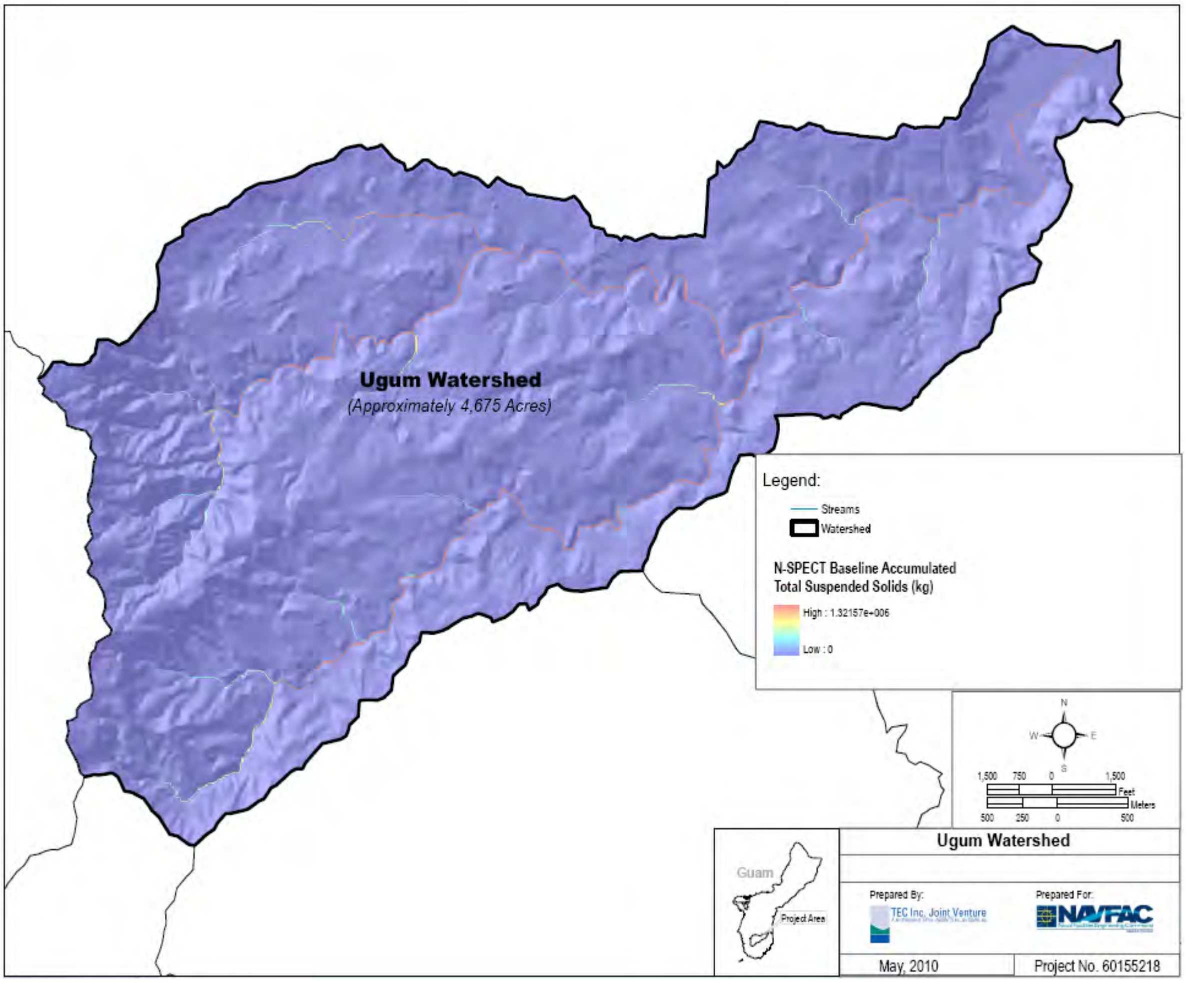


Figure 28 Baseline TSS Accumulation - Ugum Watershed

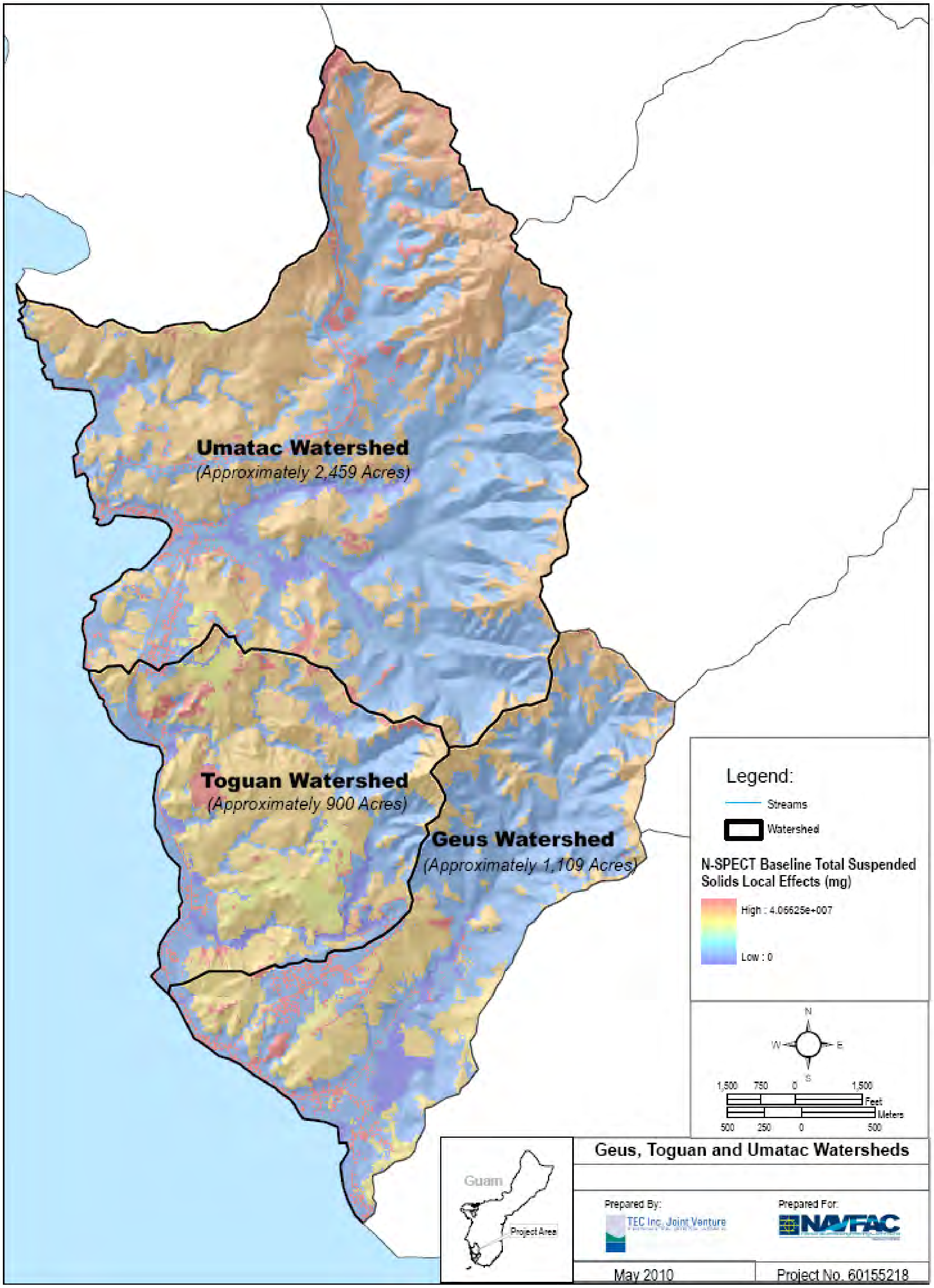


Figure 29 Baseline TSS Accumulation Local Effects - Umatac, Toguan, and Geus Watersheds

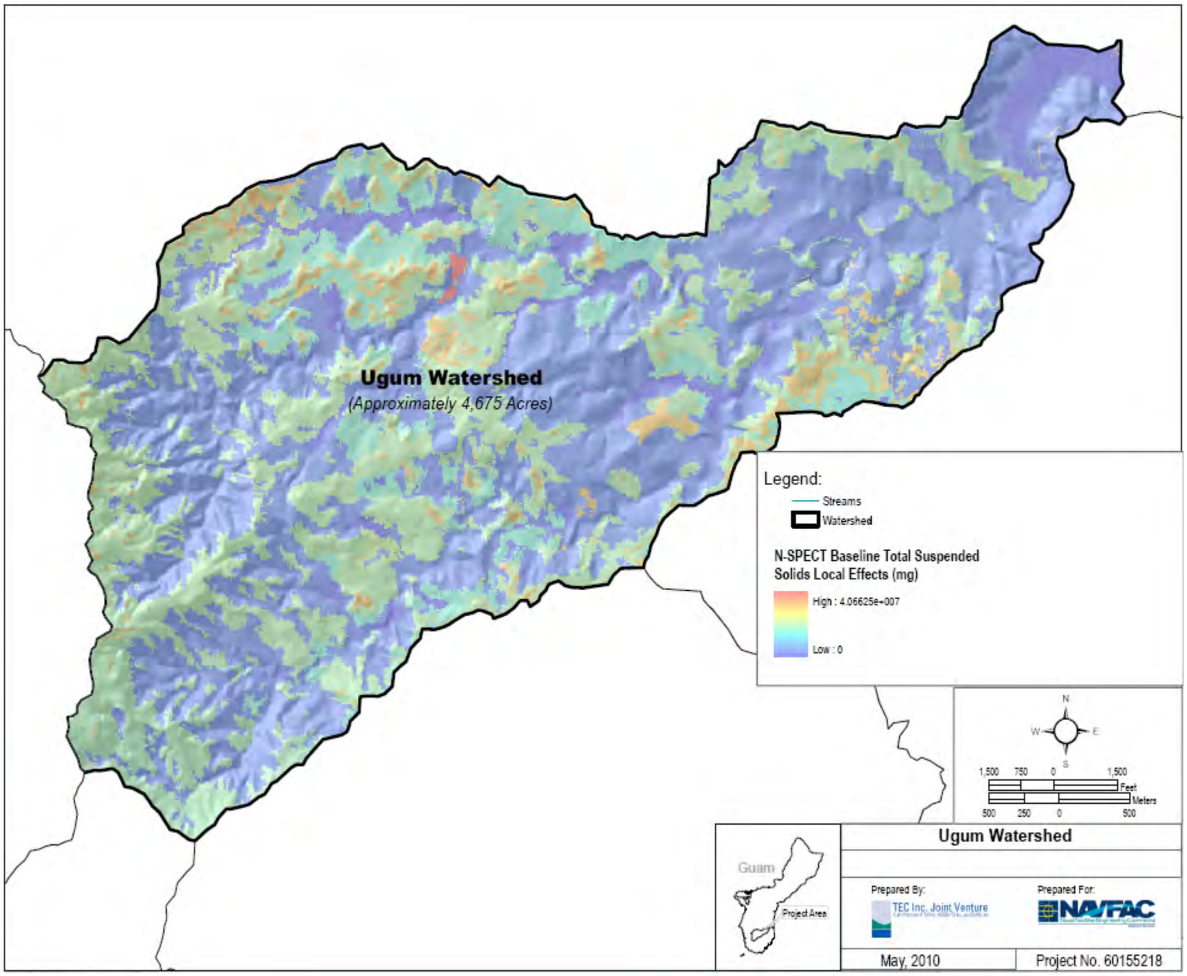


Figure 30 Baseline TSS Accumulation Local Effects - Ugum Watershed

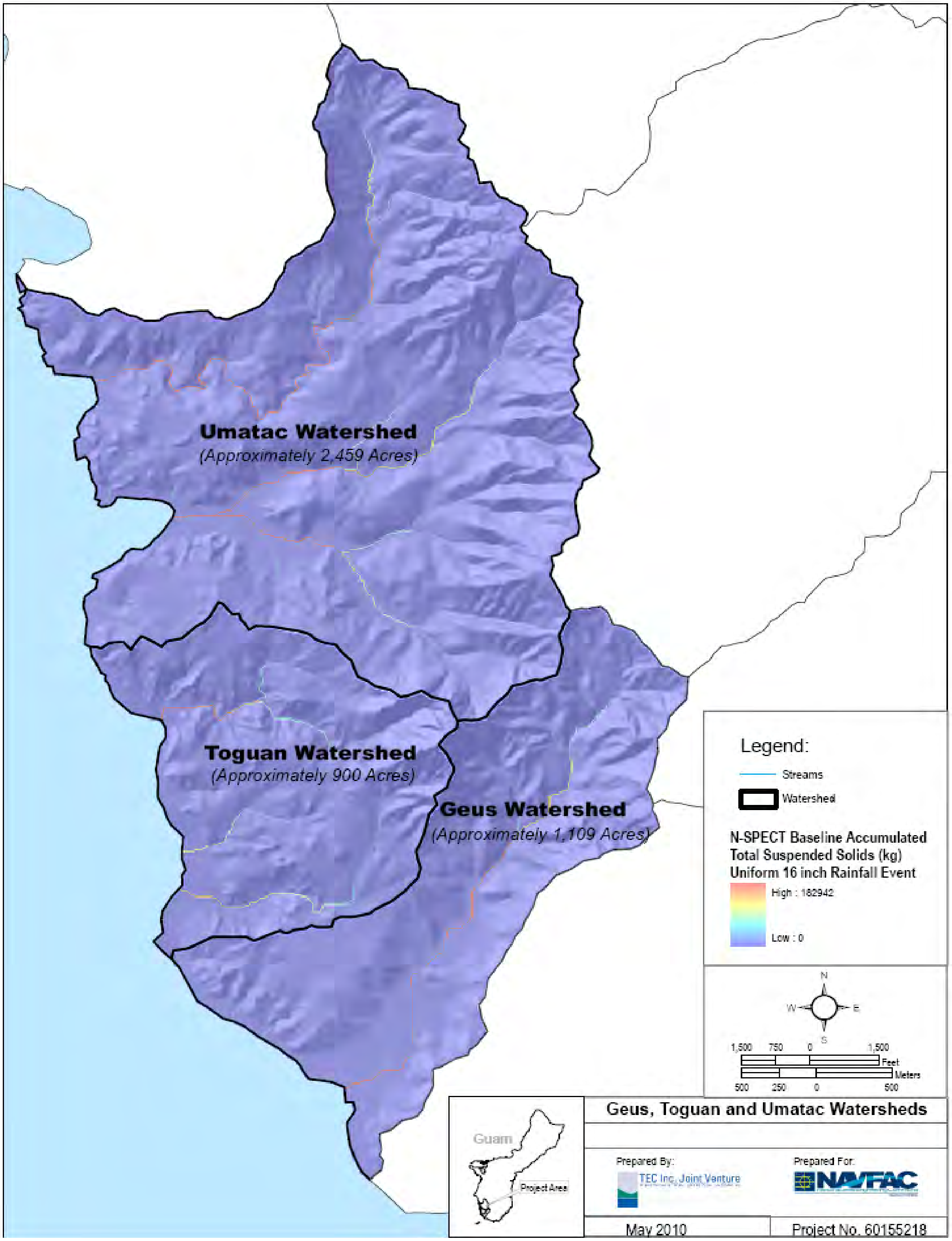


Figure 31 Baseline TSS Accumulation High Rainfall - Umatac, Toguan, and Geus Watersheds

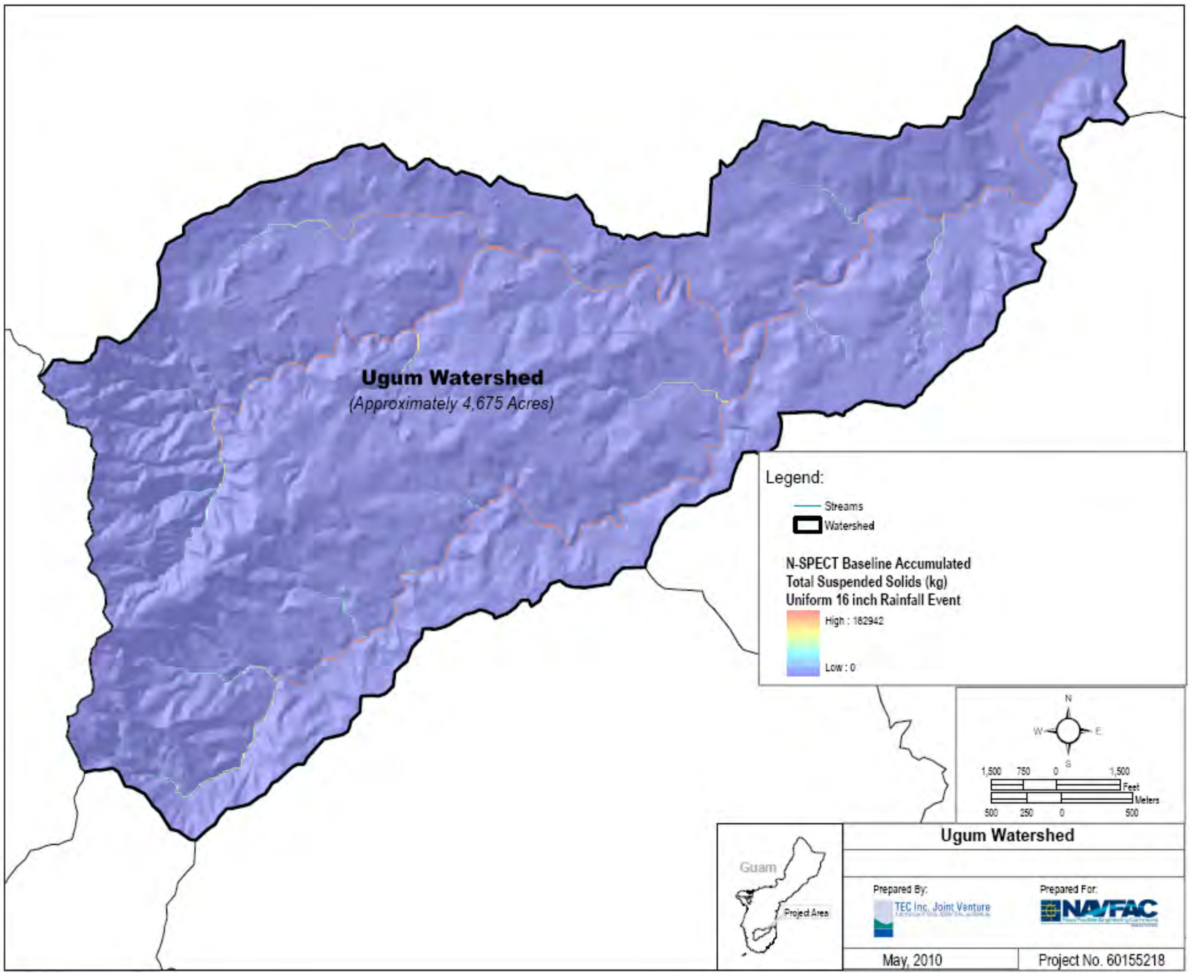


Figure 32 Baseline TSS Accumulation High Rainfall - Ugum Watershed

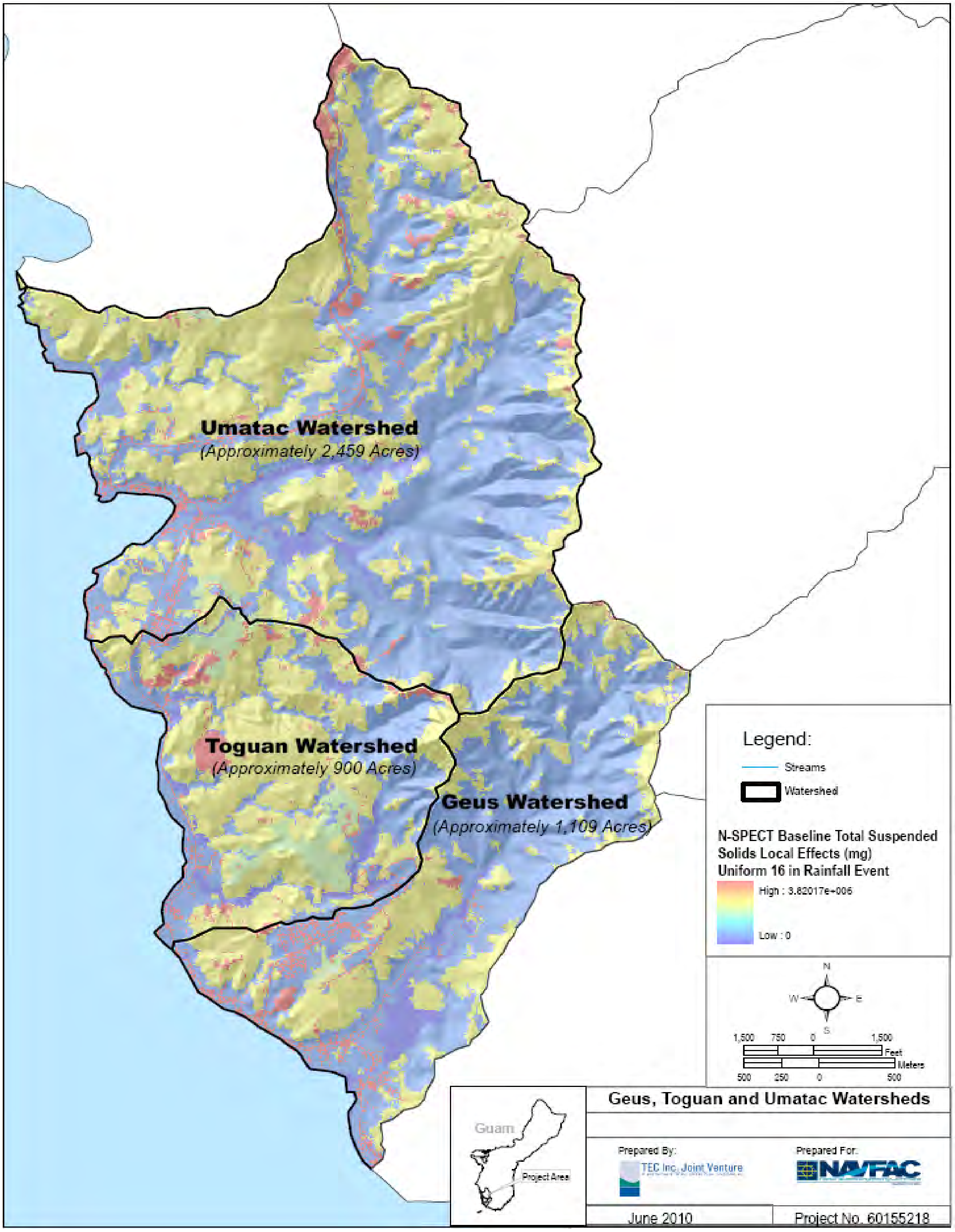


Figure 33 Baseline TSS Accumulation Local Effects High Rainfall - Umatac, Toguan, and Geus Watersheds

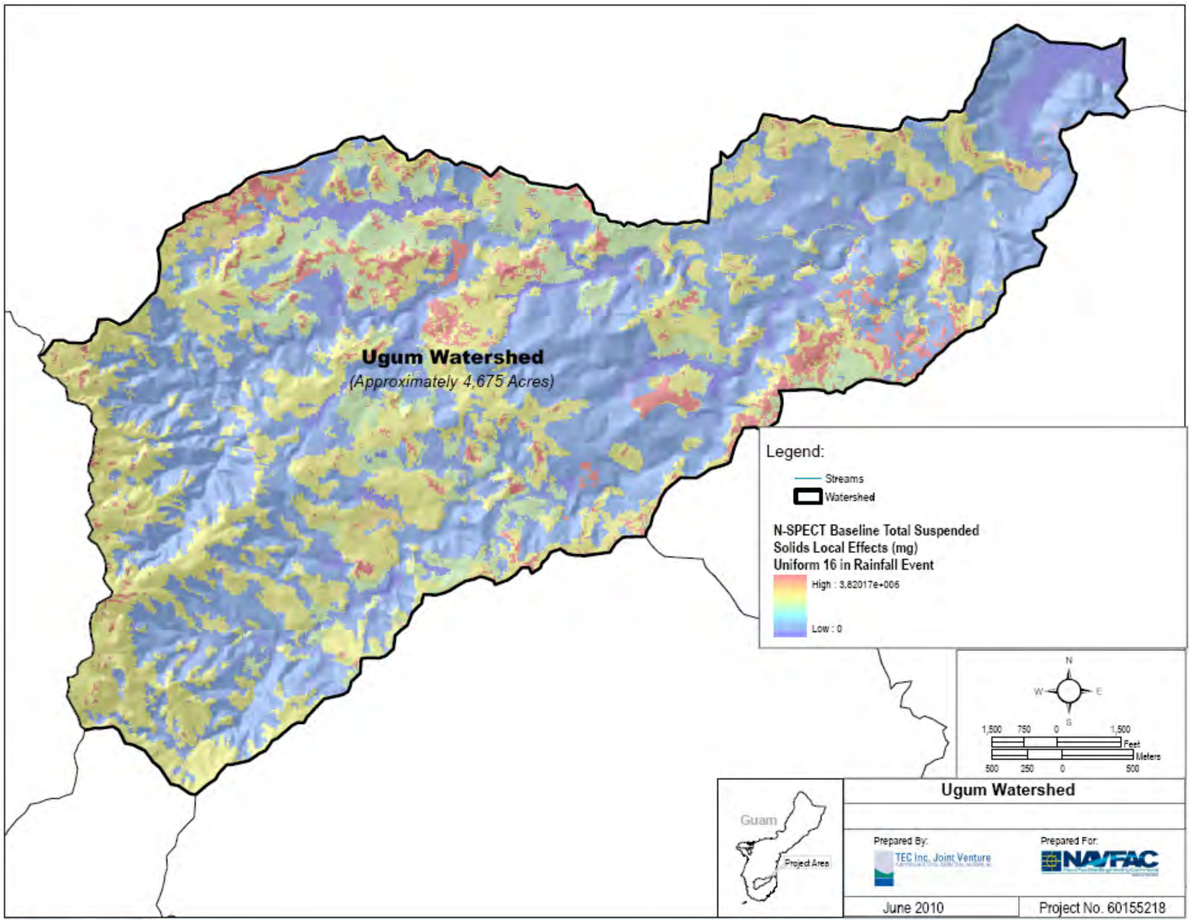


Figure 34 Baseline TSS Accumulation Local Effects High Rainfall - Ugum Watershed

Table 10 Average Annual TSS Yields

Year	Average of Suspended sediment discharge, tons per day (Mean)	
	tons/day	tons/year
2005	0.2	59
2006	0.9	342
2007	9.0	3,279
2008	3.2	1,167
2009	8.4	3,070
2005-2009	5.0	1,808

3.4.2.3 Gully Erosion

Gully erosion occurs in a watershed where sheet and rill erosion provides enough force to scour and erode a channel. Based on the limited field surveys performed significant gully erosion was not encountered in any of the watersheds. However areas with significant potential for gullying to occur are found primarily in the soils areas mapped as Akina-badlands and Agfayan-Akina. These areas are the primary locations for significant sheet and rill erosion potential. As such any conservative active gullying would make up less than 1 percent of the total watershed acreage.

3.4.2.4 Streambank Erosion

Streambank erosion is a natural process of loss of soil from streambanks through processes such as bank scour, sloughing, and woody debris jams. Erosion occurs in many natural streams that have vegetated banks. Quantification of this erosion can be made using the direct volume method:

$$\text{Streambank Erosion (t/yr)} = \frac{\text{linear ft x bank height(ft) x bank recession rate(ft/yr) x density (lb/ft}^2\text{)}}{\text{2000lb/ton}}$$

Due to lack of access to many of the watershed rivers as the field teams would have to cross private property direct observation in the Geus was not performed. Only the Toguan River (Photos 25 - 27) was surveyed along most of its length along with parts of the La Sa Fua River (Photo 28) were surveyed. In the Ugum River watershed portion of the BCA, the headwaters of the Atate (Photo 29) and Bubulao Rivers were generally less than two meters wide and showed no active streambank erosion.

The Sasa-Atantano Watershed Resource Assessment (2007) discussed the derivation of the bank recession rate as being determined by observing such features as bare banks, dry ravel, vegetative overhang, associated rills and gullies, exposed roots, slumps, fallen trees and washouts. As for this assessment a onetime survey of the river banks makes this determination impossible without examining pre-wet season streambank conditions vs. post wet season streambank conditions at specific locations of potential erosion. Based on this streambank erosion estimates are not included in this assessment.

PHOTO 25 TOGUAN RIVER NEAR HEADWATERS.

PHOTO 26 TOGUAN RIVER MID-STREAM

PHOTO 27 LOWER THIRD OF TOGUAN RIVER

PHOTO 28 LA SA FUA RIVER MID-RIVER LOCATION

PHOTO 29 ATATE RIVER (CENTER OF PICTURE) HEADWATER AREA

3.4.2.5 Factors Effecting Erosion and Sediment Yield

Soil loss from a watershed is influenced by a wide range of factors. Below are some of the more significant factors that impact soil loss on Guam.

- **Land Cover**

The type of vegetation cover is a key determinant of how much erosion will occur within a particular watershed. The vegetation acts to reduce the energy of the falling rain drops which detach soil particles by direct impact. Vegetation also provides a filtering mechanism to trap soil as it is eroded during rain events. Vegetation at or near the ground cover is the most important as well as forests with an understory or leaf litter.

- **Wild Fires**

Fires increase erosion potential through the removal of the vegetation cover and by physically altering the surface soils by fusing soil particles together reducing the natural permeability of the soils. Within southern Guam fires, which are often intentionally set in association with hunting practices, are a significant factor in increasing soil erosion. Most fires occur in the savanna areas of the watersheds and can effectively remove all of the sword grass biomass above ground from any area. This decreases the ability to reduce both the speed at which water flows over the soils and the force of rain on the soil.

It should be noted that although most of the swordgrass is removed above ground due to burning, the plant produces green shoots rapidly. However, if a fire impacts an area just before a significant rainfall event or the rainy season, increased erosional rates may occur.

- **Urban Development**

Urban development may increase soil erosion via construction of homes and roads which results in a decrease in permeable surfaces for infiltration to occur; thereby, increasing local run-off. The increased amount of impermeable surfaces may also increase the overall hydraulic efficiency of the watershed as this development becomes a conduit for the rapid transport of water into local rivers or the coastal environment

It should be noted that there are no planned significant urban development projects within the study area of all four watersheds. However, in the Ugum watershed, outside of the BCA, there are planned developments, including the completion of the new landfill. Based on this no additional sediment loading is anticipated for this land cover in each watershed.

- **Ungulates**

Feral ungulates root, wallow and browse, especially within the ravine forests of Guam. Although heartier alien trees may not be greatly affected by ungulate activity, this activity is thought to limit recruitment and regeneration of native species and retard the growth of understory vegetation as well as disturb soil on the forest floor. All of these activities increase the potential for soil erosion.

3.4.2.6 Assumptions and Limitation

The methods used in the development of this watershed assessment and the use of the USLE and N-SPECT models have several assumptions and limitations. Such limitations include, but are not limited to the following: the use of C Factors that are derived from US mainland species which may not be appropriate for the local plant species on Guam; and the model's inability to evaluate anything other than sheet and rill erosion and not other sources of eroded soil such as active gullying, stream bank erosion, landslides, or erosion on steep slopes.Based on these inherent limitations, the results presented in this assessment need to be looked at as a potential upper bound of the potential soil erosion produced that is delivered to the near shore coral reefs.

The model results presented above are based on the factors and coefficients provided with N-SPECT. The model has not been calibrated against site specific TSS loads in order to assess the accuracy of the model. The model does provide a means of assessing identifying areas causing significant TSS loading and of estimating the degree of change resulting from potential management strategies.

While the use of the ArcGIS is a simple implementation of the USLE equation which shows areas of sediment erosion potential but does not provide model results on how much eroded soil actually reaches the coastal environment. NOAA's N-SPECT model is based on updated algorithms, applies equations to estimate a sediment delivery ratio and estimates of non point source pollution (TSS), and provides an interface for implementing management strategies.

For the evaluation of the benefit to be derived from implementing conservation measures in each of the watersheds the use of N-SPECT is carried forward.

4 CONSERVATION SCENARIOS

4.1 Objectives and Issues

The objective of the conservation scenario(s) is to propose specific conservation practices and potential projects for the Umatac, Toguan, Geus, and Ugum watersheds that would reduce accelerated erosion and sedimentation in to the marine ecosystem. A key method in reducing the sediment transport and deposition is to reconvert swordgrass areas to forests and to stabilize bare soils areas through the planting of grasses, especially low-growing grasses such as vetiver (*Chrysopogon zizanioder*) and bahia grass (*Paspalum notatum*), which are hearty and provide less fuel for wildfires.

The restoration activities would occur on lands owned by the Government of Guam or lands that are located within the BCA. Issues with the afforestation include the following:

- Lands with slopes greater than 50 percent would not be selected due to feasibility issures.
- Burning – Fires are often intentionally set in association with hunting activities.
- Access – much of the potential area that would be candidates for restoration are located in areas with limited, if any, vehicular access. In order to promote efficient restoration activities roads would need to be constructed to the access area. Or, a helicopter could be employed; however, the costs of a helicopter are very high.

Any Government of Guam lands that are ultimately selected for restoration activities, will need to be protected in perpetuity. The Navy would fund the initial planting; however, should a conservation area be damaged or destroyed after planting, it would be the Government of Guam's responsibility to re-plant and maintain the conservation area.

In order to accomplish the goal of reducing sedimentation, two restoration strategies will be employed: passive and active.

4.2 Passive Conservation Strategies

Within the watersheds, conceivable passive restoration strategies include:

1. **Ungulate Control**: can be accomplished through increased harvesting and the construction of fences. Feral ungulates root, wallow, and browse, especially within the ravine forests of Guam. Although heartier alien trees may not be greatly affected by ungulate activity, this activity is thought to limit recruitment and regeneration of native species and retard the growth of understory vegetation as well as disturb soil on the forest floor. An effective ungulate control program requires removal rates greater than reproductive recruitment or ingress rates. Controlling the population of damaging animals for several years would allow understory plants to become established and reduce disturbance of the forest soils. This will require a long-term commitment to ungulate control as long as there are these types of animals on Guam (NRCS, 2007).

2. **Fire Breaks**: when properly planned and applied on the landscape in a setting where fire would naturally slow down, firebreaks can be effective to compartmentalize fire prone

areas. Firebreaks can be expensive to install and maintain but may also serve as access roads to support other treatment options to address wild fires (NRCS, 2007).

4. **Public Education:** Educating the public is a critical first step to address the human, and most complex variable, to support and ultimately endthe annual burn cycle. Public education complains would need to be conducted and coordinated with the ongoing public information campaigns developed and funded through the Guam Department of Agriculture (Forestry and Soil Resources Division). Hunter education efforts could also be initiated. Finally, signs in the watershed about fire prevention and reporting might also prove effective educational tools when combined with increased surveillance and enforcement (NRCS, 2007).

4.3 Active Conservation Strategies

4.3.1 Management Practices

Savanna vegetation enhancement fire suppression over several decades would allow secondary plant succession to proceed with woody trees and shrubs slowly dominating the sites. Secondary succession to woody trees can be accelerated with tree planting. Selection of adapted tree species, proper site preparation, planting techniques, and maintenance can convert a savanna plant community to a closed canopy forest community in less than five years. Fire suppression during the establishment period is critical. Ungulate exclusion is recommended for 18 to 24 months. Then, the site should be assessed for potential engineered or bio-engineered erosion control solutions.

4.3.2 Badland Treatment

Treatment of badland areas within the watershed has the potential to reduce sediment yield if vegetation can be successfully established. Each of these areas must be carefully assessed to determine the amount of active erosion, exposed saprolite, slope gradients, proximity to intact ecosystems and soil fertility. Disturbance of saprolite creates better and essential plant growth medium, but also alters the soil structure from erosion resistant, to erosion susceptible. (NRCS 2007).

NAVFACMAR has demonstrated success with converting bare soil areas (e.g., erosional areas, roads, etc.) to vegetated areas using bahia and vetiver grass species. These species are typically planted on two-foot centers and receive three fertilizer amendments during the first 90 days. Soil plugs are typically planted with the use of a motorized auger to increase efficiency and reduce physical labor. Examples (Photo 30) have shown that a bare soil area can have significant vegetative cover within one year.

PHOTO 30 A PARCEL OF LAND PLANTED WITH PASPALUM SP. GRASSES. THE PHOTOS WERE TAKEN IN THE MONTH OF SEPTEMBER DURING CONSECUTIVE YEARS – BEFORE AND AFTER PLANTING.

4.3.3 Prevention of Gullying

Generally, gullies are formed by an increase in surface runoff. Therefore, minimizing surface runoff is essential in gully control. (FAO, 2010; as cited in NRCS, 2007). In typical gully control, the three treatments followed in succession are the following::

(1) Improvement of gully catchments to reduce and regulate the run-off rates (peak flows);
(2) Diversion of surface water above the gully area;
(3) Stabilization of gullies by structural measures and accompanying revegetation.

Gully control in all watersheds would best be accomplished through revegetation. In areas of bare soil areas that are beginning to gully, the planting of vetiver grass and bahia grass grasses would attenuate sheet runoff and reduce erosion. Also, in areas dominated by swordgrass, the replanting of trees would reduce erosion.

4.3.4 Streambank Stabilization

Streams within the Geus and Ugum watershed were generally well-vegetated to the top and in some cases the sides of the banks. However, if a bare soil area is identified on top of the bank, priority should be given to planting this area with vetiver grasses.

4.3.5 Sediment Basins

Structural sediment control structures, such as retention basins, could be considered to reduce the sediment loading. These basins slow the average velocity of the design storm discharge to allow larger suspended sediment particles and bedload to settle. However, these structures require significant land area and water control structures engineered to resist erosion and failure during the most intense storm discharge. Also, these structures require monitoring and periodic clean out to maintain sediment trapping effectiveness (NRCS, 2007). As such, these structures would not be recommended for the rivers in the BCA due to limited access to perform the necessary maintenance. These structures could conceivably be placed along the Geus at the Route 4 Road crossing where the Government of Guam owns land adjacent to the river.

4.3.6 Mangrove Enhancement

Another method that may be considered to reduce sediment deposition on corals is the planting of mangroves. The prop roots of mangrove trees are adroit at retaining sediment, and also provide excellent habitat for fish species. The planting of mangroves or expanding the existing mangrove stands would be possible at locations near the mouths of many of the rivers in the four watersheds. However, prior to establishing mangroves, a site feasibility investigation should be conducted. The investigation should determine the amount of available soft sediments that can be converted to mangroves, as well as, a hydrologic analysis to determine in wave velocity and current patterns would support the formation of mangroves.

4.4 Potential Conservation Projects

Soil erosion in the watersheds is notable and should be addressed. Potential conservation projects in the watersheds should be targeted for two areas:

- **Savanna** areas where sheet erosion processes are dominant would benefit from planting of acacia and wildfire prevention until acacia has a chance to become established.

- **Bare soil** areas which are generally associated with slump failures and gullying, would initially benefit from planting vetiver or *Paspalum notatum* to control erosion. Post monitoring of the soils in these area may also identify a time in the future when then enough soil material has accumulated to plant Acacia.

4.4.1 Management Strategy Evaluation

According to the baseline modeling results presented in Section 3.3.2, TSS loading is most significant from the bare lands. TSS loading is also significant over large areas of grassland. The acreage for areas with slopes greater than 50 percent, land cover types, and soil types within the GovGuam owned land is summarized in Table 11. The management strategies considered will focus on replanting these areas within GovGuam owned land. Figure 16 shows the areas owned by GovGuam within the four watersheds. Areas owned by the Chamorro Land Trust Commission (CLTC) will not be considered for replanting. The Guam Water Authority property located within CLTC land is also not considered for replanting.

The following management scenarios were modeled:

1. Within GovGuam owned land (excluding CLTC land and locations with greater than 40 percent slope), all bare land is converted to vetiver grass land and all grassland is converted to forest area; see Figure 35.

2. Within GovGuam owned land (excluding CLTC land and locations with greater than 40 percent slope), all bare land is converted to vetiver grassland; see Figure 36.

Table 11 Slope, Land Cover and Soil Type Areas by Watershed

Item	Geus ha/ac	Toguan ha/ac	Ugum ha/ac	Umatac ha/ac
Watershed Area	449/1,109	364/900	1,892/4,675	995/2,459
Areas within GovGuam Land (excluding CLTC)				
Slopes > 50%	1.8/4.6	0.5/1.2	0.08/0.2	6/15.6
Land Cover				
High Intensity Developed	4/8.7	1.3/3.1	0/0.0	3/7.5
Developed Open Space	6/14.5	2.5/6.3	0/0.0	2.6/6.5
Grassland	125/308.6	103/254.9	275/678.8	306/755.1
Evergreen Forest	148/366.2	31/76.1	198/488.2	221/546.4
Scrub/Shrub	29/70.5	12/28.6	69/169.4	62/153.5
Palustrine Forested Wetland	0.2/0.6	3/6.9	1.0/2.5	0.7/1.7
Palustrine Scrub/Shrub Wetland	0/0.0	1.6/3.9	4.9/11.5	0/0.0
Palustrine Emergent Wetland	1.5	1.7/4.2	1.5/3.8	0/0.0
Bare Land	5/12.7	11/28.1	15/36.5	13.4/33.2
Water	0/0.0	0.04/0.1	0/0.0	0.2/0.4
Soil Types				
Pulantat clay	2.8/7.0	1.6/4.0	0/0.0	2/4.4
Inarajan clay	0/0.0	0/0.0	17/41.7	0/0.0
Agfayan clay	0/0.0	0/0.0	31/75.5	9/22.3
Sasalaguan clay	0.4/1.0	3/7.1	10/25.7	0.3/3.8
Akina silty clay	0/0.0	0/0.0	0/0.0	12/29.7
Akina-Atate silty clays	11/26.3	5/12.2	0/0.0	4/9.6
Togcha-Akina silty clays	90/223.0	25/61.2	0/0.0	228/563.1
Ylig clay	146/395.7	91/225.7	18/45.0	285/704.2
Agfayan-Rock outcrop	0.1/0.3	16/40.4	107/265.5	24/58.6
Akina-Urban land	43/106.3	0/0.0	234/577.4	26/65.6
Inarajan sandy clay	5/11.3	0/0.0	41/102.1	1.6/3.9
Agfayan-Akina association	0.3/0.6	0/0.0	0/0.0	0.3/0.8
Agfayan-Akina-Rock outcrop	0/0.0	0/0.0	66/164.2	0/0.0
Not Identified	0/0.0	51.2	25/60.7	6/15.6

Units: Acres

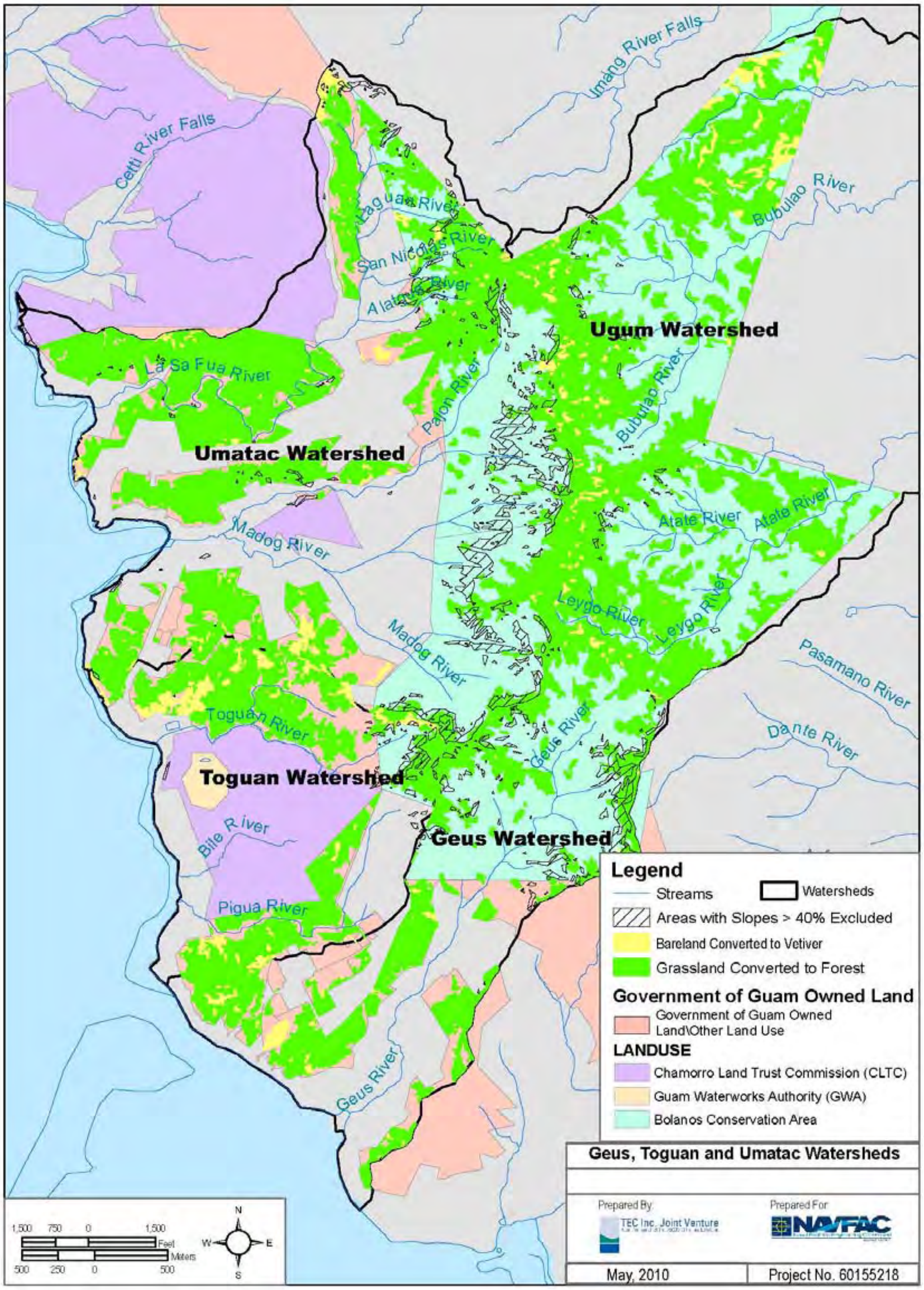


Figure 35 Management Scenario 1

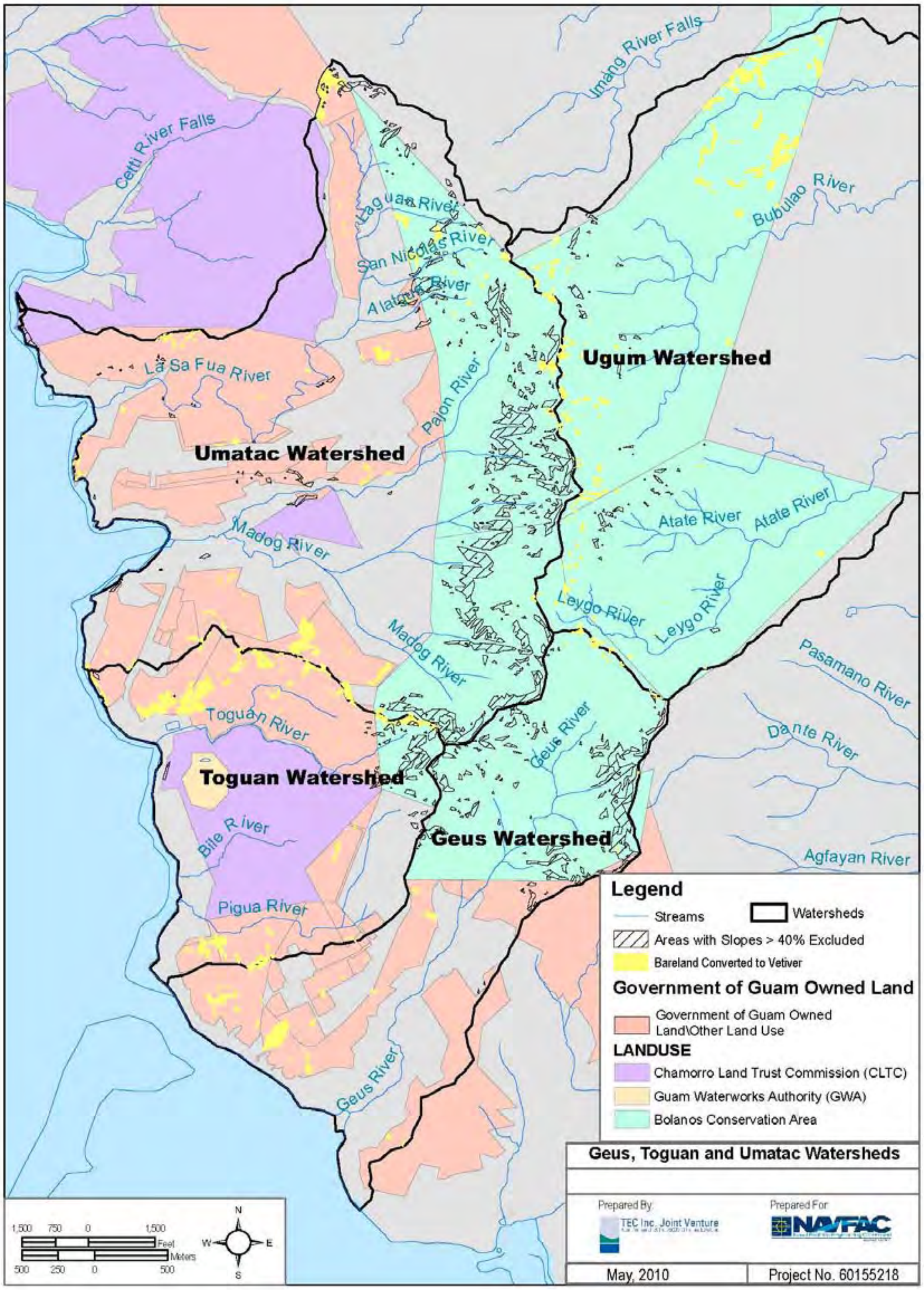


Figure 36 Management Scenario 2

For management scenario 1, the slope criteria as defined in the scope of work for areas to exclude from restoration areas is 50 percent. However, comparison of the 10 meter USGS DEM coverages did not show areas with slopes having greater than 50 percent slope which were identified during the field effort. The slope criteria were lowered to 40 percent to capture these areas. It is assumed that some areas with greater than 50 percent slope are missing due to the resolution of the USGS DEM coverage.

vetiver grassland is assumed to have a C factor of 0.009 compared to 0.13 for grassland based on the study conducted by Golabi et. al (undated) which demonstrated a 75-fold reduction in loading when bare land was converted to vetiver grassland. CN values for grassland are applied to the vetiver grassland. The C factor and CN values for mixed forest are applied to the forest area.

The TSS yield from the converted areas is lowered by the replanting. The percent change is calculated follows:

$$\text{Percent Change} = \frac{\sum \text{TSS (mg) Baseline Local Effects (LE)} - \sum \text{TSS (mg) Management Scenario LE}}{\sum \text{TSS (mg) Baseline Local Effects (LE)}}$$

The percent decreases within the converted areas are shown in Table 12. The percent reduction ranges from 75% to 83% depending on the management scenario and watershed.

Table 12 Percent Reduction in TSS Yield within the Converted Areas

Watershed	Management Scenario 1	Management Scenario 2
Geus	75%	75%
Toguan	79%	76%
Ugum	79%	83%
Umatac	76%	82%

The accumulated changes in TSS yield at the river mouths are shown in Table 13. The percent change is calculated as follows:

$$\text{Percent Change} = \frac{\text{TSS (mg) Baseline Accumulated Effects (AE)} - \text{TSS (mg) Mgmt. Scenario AE}}{\text{TSS (mg) Baseline Local Effects (LE)}}$$

The percent reduction in TSS yield caused by Management Scenario 1 ranges from 4.1 percent for the Bile River to 45.9 percent for the Pigua River. The largest change overall change in TSS yield is at the Talofofo River at 283 tonnes/year (312 tons/year). The percent reduction in TSS yield caused by Management Scenario 2 ranges from 0.4 percent for the Bile River to 9.1 percent for the Toguan River. Although the highest loss is from the bare lands, there is not enough converted land in Management Scenario 2 to make a significant change in the TSS yield at most of the rivers.

Table 13 Percent Change (Reduction) in TSS Yield at the River Mouths

Watershed	River	TSS Yield Change at Mouth			
		Management Scenario 1		Management Scenario 2	
		Percent	Tonne/Tons per Year	Percent	Tonne/Tons per Year
Geus	Geus River	41.6%	130/143	0.9%	2.7/3.0
Toguan	Toguan River	49.5%	102/113	9.1%	0.9/21
Toguan	Bile River	4.1%	3/3.7	0.4%	0.2/0.3
Toguan	Pigua River	45.9%	54/59	3.9%	4.5/5.0
Ugum	Talofofo River*	21.4%	283/312	1.8%	24/27
Umatac	La Sa Fua River	45.5%	220/243	2.9%	14/15
Umatac	Laelae and Madog Rivers	38.1%	195/215	3.1%	15/17

Note: * The TSS Yield change for Ugum is estimated at the point where the Talofofo River leaves the watershed.

The area replanted for both scenarios is shown in Table 14. The Management Scenario 1converted areas range from 114.5 ha (283 ac) for the Toguan watershed to 318.9 ha (788 ac) for the Umatac watershed. The largest reduction in TSS yield occurs in the Umatac River at 415.5 tonnes/year (458 tons/year). The Management Scenario 2 converted areas range from 5.2 ha (13 ac) for the Geus watershed to 14.6 ha (36 ac) for the Ugum watershed. The largest reduction in TSS yield occurs in the Umatac River at 13.4 tonnes/year (33 tons/year).

Table 14 Replanted Areas and TSS Yield Reduction by Watershed

Watershed	Management Scenario 1				Management Scenario 2			
	Hectares/Acres	% of Watershed	Tons/ Year	Tons/ Year/ Acre	Hectares/ Acres	% of Watershed	Tons/ Year	Tons/ Year/ Acre
Geus	129/318	28.6%	143	0.45	5/13	1.1%	3	0.24
Toguan	113/280	31.1%	176	0.62	11/27	3.0%	26	0.93
Ugum	289/713	15.2%	312	0.44	15/36	0.8%	27	0.73
Umatac	318/787	32.0%	458	0.58	13/32	1.4%	33	0.98

The areas selected for the Management Scenarios were divided into restoration zones. The areas were grouped based on access issues. The restoration zones are shown in Figure 37. A summary of the area and TSS yield by restoration zone is provided in Table 15.

Table 15 Area and Yield by Restoration Zone

Zone	Watershed	Management Scenario 1		Management Scenario 2	
		Area Ha/Ac	Tonnes/Tons per Year	Area Ha/Ac	Tonnes/Tons per Year
G1	Geus	30/76	31/34	3/7	1.4/1.6
G2	Geus	19/47	19/21	1/3	0.7/0.8
G3	Geus	7/18	7/8	0.4/1	0.2/0.2
G4	Geus	15/37	15/16	0/0	0.09/0.1
G5	Geus	159/45	58/65	0.8/2	0.3/0.4
T1	Toguan	163/55	87/96	8/19	15/17
T2	Toguan	37/92	52/57	2/6	5/5.4
T3	Toguan	3.6/9	5/6	0.4/1	0.5/0.6
Ugum1	Ugum	167/412	163/180	13/32	21/23
Ugum2	Ugum	123/304	121/133	2/4	2.7/3.0
Umat1	Umatac	97/239	126/139	1/3	2.6/2.9
Umat2	Umatac	35/86	45/50	0.4/1	0.6/0.7
Umat3	Umatac	36/90	52	4/10	9.9
Umat4	Umatac	11/26	15	0.1/1	0.5
Umat5	Umatac	149/370	215	4/20	20

4.4.2 Site Selection Rationale

4.4.2.1 Umatac

In the Umatac there are several parcels of land that should be considered for reforestation. These sites include the GovGuam land located on the north and south side of the La Sa Fua River and Gov Guam lands that parallels Rt 4 (Figure 37).

- **GovGuam Land Adjacent to La Sa Fua River**

Gov Guam land located on the north and south sides of the La Sa Fua River in the central portion of the Umatac watershed should be candidate areas for conservation. Although some portions of the parcel have steep slopes and there are several private land holdings along Route 2, access to this parcel can potentially be achieved from four different points:

1. The public "South Coast Trail" starting at the dump (near the Guam Power Authority facility) provides access to the western portion of this parcel, however, the beginning portion of this trail crosses private lands and permissions may need to be obtained prior to use of this route.
2. A side road off of Route 2 leading to a residential area could also be used to provide access to the western and central portion of this parcel; however, private land would need to be crossed to reach Gov Guam lands, requiring permissions.

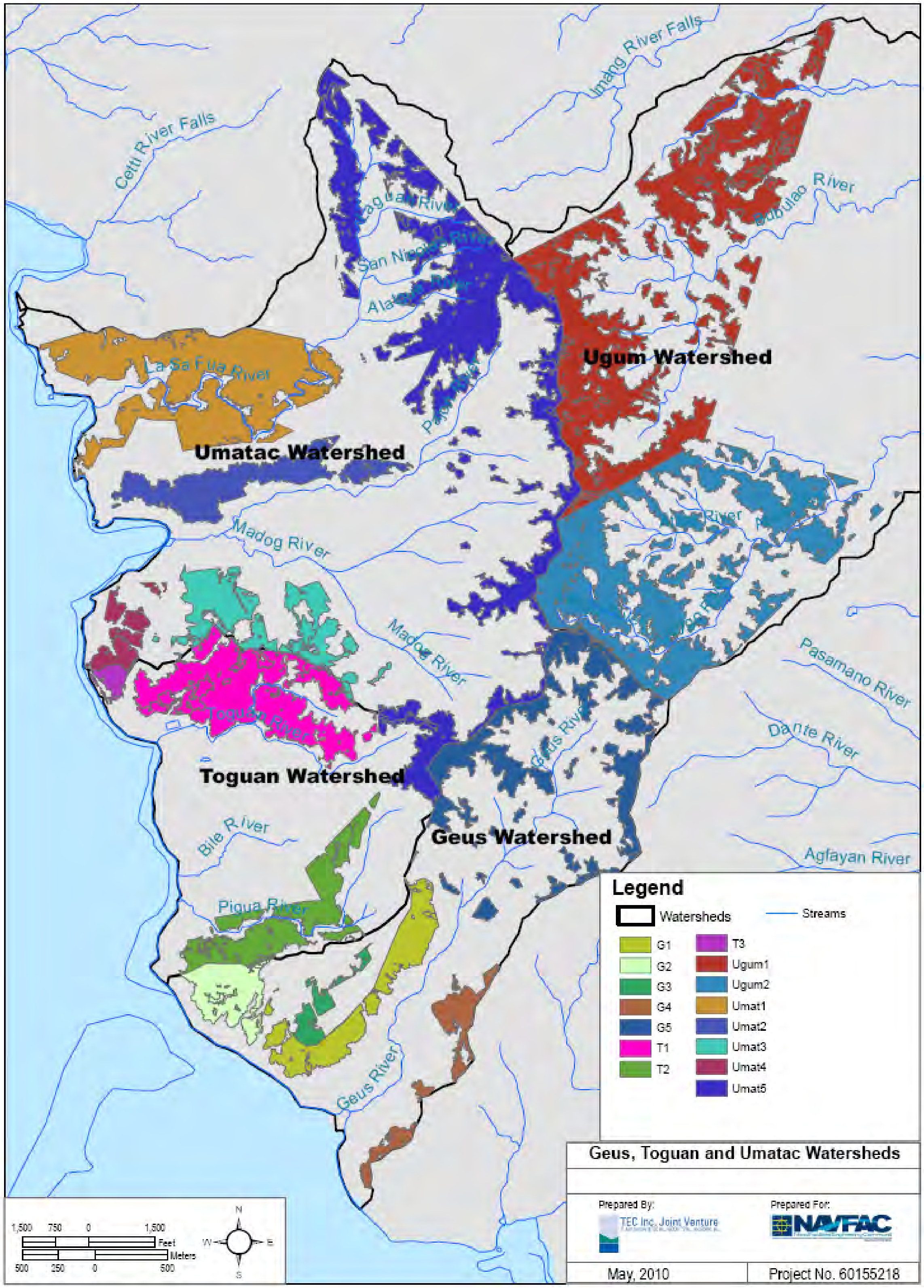


Figure 37 Conservation Zones

3. The Vietnam War Memorial and associated public lookout provide a parking and staging area for the central portion of this management parcel.
4. Gov Guam lands border Route 2 on the eastern edge of this parcel, providing direct access, but minimal staging room.

South of the La Sa Fua River, the slopes range from moderate to steep (10 to 40%) and vegetation cover is primarily savanna complex with some ravine forest along the river channel. The parcel has areas of moderate slumping, gullying, and sheet erosion.

North of the La Sa Fua River slopes vary from low to steep (0 to 50%) and vegetation cover is primarily savanna complex The parcel has areas of moderate to heavy slumping, gullying, and sheet erosion. Because the terrain is steep and the vegetation can be thick, construction of temporary/permanent trails would improve accessibility and travel time to and from planting sites. There is a lack of direct access roads to deliver supplies and construction of new access roads would be impractical. Therefore, helicopters would be needed to deliver supplies to this parcel. Although this parcel has considerable erosion problems and would greatly benefit from active management practices, the difficult access (steep terrain, distance, and private property) make this site a lower priority

- **Gov Guam Lands Parallel to Route 4**

Gov Guam land which runs parallel to and south of Route 4 in the central portion of the Umatac watershed. The Vietnam War Memorial and associated public lookout provide a parking and staging area. There are several private land holdings along Route 2 that would need either permission to cross or to be avoided. Slopes are generally steep, ranging from 20 to 40% and vegetation cover is predominantly savanna complex. No additional access roads or trails would need to be constructed. Sheet erosion is the primary erosional process, but there is some minor slumping.

4.4.2.2 Toguan

Within the Toguan Watershed, much of the GovGuam and Island of Guam Conservation Reserve Lands are candidates for restoration. Gov Guam land is located along the northern edge of the Toguan Watershed (adjacent to Management Area Um1). Route 4 and paved public roads provide easy access to the western portions of this parcel and a heavily eroded 4wd dirt road (off the Guam Power Authority facility access road) along the ridgeline provides access to the eastern portion of this parcel. Some improvement of this dirt road will be necessary if it is to be used for delivery of supplies by vehicle, as this road will be impassible in the wet season. However, no other new access roads would be needed. Slopes are predominantly between 0 and 20% with some steeper areas (20 to 40%) near the Toguan River. Most of this parcel is covered by savanna complex with ravine forest along the eastern edge. The parcel has areas of moderate to heavy slumping and gullying and has badlands located along the northern ridge likely due to erosion associated with 4wd dirt road.

Field observations identified several areas along the Toguan River that had severe, active bank erosion (Photo 27) that would benefit from streambank stabilization. However, potential streambank stabilization scenarios would involve the use of construction equipment and materials, requiring the construction of access roads to remote stream locations. Considering the small contribution of sediment from streambank erosion relative to the much greater sources of hillslope erosion (i.e., slumping, gullying, and sheet erosion), benefits of streambank stabilization would be minimal. This management practice is also problematic in that it would require the construction of new roads, which are potential sources of new erosion. In addition, management scenarios involving reforestation of savanna and badland treatment are expected to reduce peak runoff, thereby reducing severity of streambank erosion.

Gov Guam land is located along the southern edge of the Toguan Watershed. Paved public roads and a dirt road leading to the radio and communication towers provide easy access to the eastern portions of this parcel. A foot-trail starting at the cemetery and leading to the Merizo Massacre Memorial site and the "Priest's Pools" public trail starting near the Merizo Martyrs Elementary School both provide access to the western and central portions of this parcel. No additional access roads or trails would need to be constructed. Slopes are predominantly between 0 and 20% with some steeper areas (20 to 40%). The parcel is predominantly covered with savanna complex. The parcel has areas of sheet erosion and moderate to heavy slumping.

4.4.2.3 Geus

Within the Geus Watershed, much of the GovGuam and Island of Guam Conservation Reserve Lands are candidates for restoration. Soils throughout the area exhibit signs of erosion, also soils throughout the area show evidence of burning within the last two years. It is likely these areas burn fairly regularly as much of the GovGuam lands consist of grasses with no saplings present. The dominant vegetative cover is swordgrass, which usually has patchy distribution (approx 50 percent cover). Within the Gov Guam lands in the Geus watershed, separate polygons representing the restoration locations (i.e. G1, G2, G3, G4, and G5) are depicted on Figure 37. The restoration location are parcels of land that have similar attributes. The restoration locations are listed in the following paragraphs into the order in which restoration activities should be prioritized.

Locations G1 and 2 (Photo 31) are located on the side of a hill. At the base or the hill and along the top of the hill, there are residential homes and lots. In fact, on the top of the hill the home lots are part of the government's program of Land for the landless. The Land for the Landless Program was made available to Guam residents in 1985 and provided more than 1,000 lots in Dededo, Talofofo, Umatac, Inarajan, and Merizo that have benefited about 500 local families. Buyers were able to purchase these lots for $2,500 over a 10-year period. (Gov Guam, 2010). In addition, the program also has the obvious benefits of stopping erosion and the loss of property. Locations G1 and G2 are easily accessed by paved roads that would be suitable for carrying a truck, thereby reducing costs. Restoration of locations G1 and G2 would restore 57.9 ha (143 ac).

Location G3 is a series of non-contiguous plots located on the flat areas on top of a plateau. These areas are surrounded by residential and commercial entities. Observations performed during the field effort identified that large, domesticated water buffalo, cows, goats and other animals are brought to these areas for grazing opportunities. Restoration of locations G3 would restore 7.3 ha (18 ac).

Location G 4 (Photo 32) is located on the top of a ridge that forms the watershed southern boundary. This ridge has similar vegetative characteristics to the ridge that is home to G1 and G2. However, location G4 has no direct road access. Prior to the start of restoration activities, permission would need to be secured from land owners. Restoration of locations G4 would restore 15 ha (37 ac).

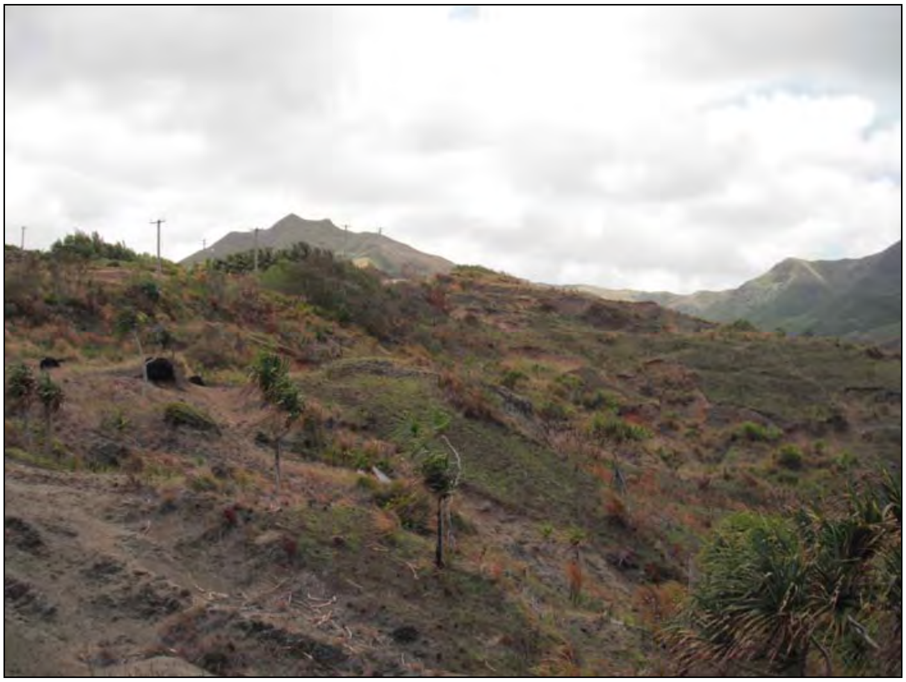


PHOTO 31 LOOKING WEST AT LOCATIONS G1 AND G2. IN THE UPPER LEFT CORNER, THE TOWERS ARE ASSOCIATED WITH GUAM'S "LAND FOR THE LANDLESS" DEVELOPMENTS.

PHOTO 32 LOOKING SOUTH ACROSS THE GEUS RIVER VALLEY. THE RIDGE IN THE BACKGROUND CONTAINS PARCEL G4.

Location G5 is essentially the eastern half of the watershed. The absence of road access and rugged, steep slopes would increase the costs of mitigation activities. Access to this area would be accomplished via helicopter or if in conjunction with potential road construction in the Ugum watershed. Also, the steep slopes present in this area would result is a series of non contiguous parcels separated by rugged terrain. Plot G5 seems infeasible due to the access and terrain limitations. Location G% has 58.7 ha (145 ac) for potential restoration.

4.4.2.4 Ugum

Within the BCA, there are large swaths of swordgrass and bare soil areas that present numerous restoration opportunities. However, site access is an issue. No municipal roads travel to and/or within proximity to the BCA. Roads in the BCA and central portion of the Ugum Watershed are unimproved dirt tracks. Moreover, these roads cross numerous private land holdings. In order to access the BCA by wheeled vehicle, permission would need to be obtained and several miles of dirt tracks would need to be upgraded. Helicopter transport is another option; however, this option results in considerable expense.

4.4.3 Management Practices Needed to Address Types of Erosion Present

Restoration management practices in the four watersheds would be targeted as the following:

1) Covert savanna areas to forests.
2) Convert bare soil areas to vetiver or bahia grass areas.

4.4.3.1 Conversion of Savanna to Forests

Conversion of savanna to forests is a labor-intensive endeavor that requires a good amount of time commitment before, during, and after the restoration activities. Once a site is selected, a three-step process (i.e., site preparation, planting, and site maintenance & monitoring) would be employed. This process is currently being utilized at Cetti Bay. A description of these three steps is provided below.

4.4.3.2 Site Preparation

Fertilizer and soil amendments mean the addition of both lime and fertilizer to give the trees nutrients which have been lost over time due to erosion and leaching. Since Acacia trees are being planted, no lime will be required; fertilizer, however, will be required.

In addition to preparing the soil, an ungulate exclusion fence would be constructed. The position and location of the fence should be carefully planned so that there are no portions of the fence that can be breached by ungulates.

4.4.3.3 Planting

Planting of Acacia would be based on the methods described in USDA, 2008. Seedlings will be planted in 3 m (10 ft) spacings. Each row should be staggered so that there is a tree or shrub to begin to capture organic material and stop the flow of water. The planting of *Acacia* sp.seedlings will restore organic matter and microclimate conditions on the site of highly degraded lands. Crown closure usually occurs within three years..

4.4.3.4 Site Maintenance & Monitoring

Monitoring of initial plantings will determine which native species have potential and those species will be used as the dominant species planted in subsequent years as Acacia is phased out of the planting mix (USDA, 2008).

Each tree should be staked and tied to prevent seedlings from falling over and being overtaken by grass. Each seedling should have colored flagging on it or the stake for easy location in the following year treatments (USDA, 2008).

Grass and weed vegetation that will continue to grow after the seedlings are planted will need to be removed. Grasses and weeds compete with the newly established seedlings for both moisture and nutrients and should be removed prior to (during site preparation) and three times following planting of seedlings. This active removal of grass and weeds will provide the seedlings with a competitive advantage over the grasses and the seedlings can quickly become established and occupy the site before the grasses are allowed to grow again. The objective is to establish canopy closure quickly so that the grasses will be shaded out (USDA, 2008).

Post-restoration monitoring of vegetation and soil accretion is further described in Chapter 5.

4.4.3.5 Conversion of Bare Soil Areas

Bare soil areas often exhibit the most severe soil erosion. Often only limited amounts of solum are present. As such, the planting of woody vegetation is not recommended as the limited soil resources will likely result in high mortality. Also, the seeding of the area with seeds of herbaceous vegetation is not recommended as the soil agitation may increase erosional rates. The conversion of bare soil areas would be accomplished by the planting of *Paspalum notatum* and vetiver grasses. The US Navy has had notable success in planting *Paspalum notatum* plugs on bare soil areas (Photo 30). Also, the planting of vetiver grass on the perimeter of bare soil areas has further assisted in sol stabilization.

Typically, *Paspalum notatum* plugs are planted on two-foot centers. The plugs are planted with the use of an auger. The planted areas typically require three amendments of 16 X 16 X 16 fertilizer over 90 days. The areas are not fenced.

4.4.3.6 Restoration Costs

Restoration costs are presented in Table 16 on a per acre basis, by species. In subchapters 4.4.2.2 and 4.4.2.3, costs are provided for the restoration costs for a 20.2 ha (50 ac) parcel (the amount of planting that would occur in one months' time). Also, identified in the costs are additional site specific costs (e.g., road construction, etc.) that may be necessary. Table 17 provides a breakdown of helicopter costs.

Table 16 Restoration Costs – Planting Per 0.4 ha (1 ac)

Item	Work Description	Number	Individual Cost	Total Cost
Planting of Acacia sp. and/ Native Trees	Plant Acacia seedlings in 5cm (2 in)" plugs & treat with herbicide*.	435	$23.00	$10,005.00
	Weeding - hand pull grasses & weed within 0.3 m (1 ft) radius around planted tree.	435	$2.00	$870.00
	Fertilizer 16-16-16	435	$0.25	$108.75
	Weed Whack: 0.3 (1m) - 1m (3 ft) radius around each tree	435	$2.00	$870.00
	Tie Flagging to Tree	435	$0.30	$130.50
Planting of bahia; vetiver sp. grasses**	Plant 12,600 plugs, including fertilizer	12,600	$4.25	$53,550.00
Fence Construction	Construction of fence to prevent ungulate intrusion	1	$4,000	$4,000
Transportation Costs				
Road Construction	Construction of dirt road suitable for carrying a truck. Costs identified per linear mile	1	$26,400	$26,400
Helicopter ***	Hourly Transport	1	$2,400	$2,400
Notes: *Herbicide would be utilized initially to remove the swordgrass, than Acacia seedlings would be planted. ** Grasses assumed for costing purposes to be planted at 4:1 bahia : vetiver. **Assumes a 408-kg (900-lb) pound payload capacity. Heliport Location is located in Barrigada. Assume 1 hour of flight time to load personnel and gear, fly to Southern Guam, and return to heliport. See Table 17 for a detailed breakdown of helicopter costs.				

Table 17 Helicopter Costs

Restoration Area Parcel	Plant Ratio (per Acre)	Weight (lbs) Transported Each Day	Number of Flight Hours Each Day	Total Cost Per Month (assume $2,400 per hour)
20 ha / 50 acre	19ha/48 ac tree, 0.8 ha//2 ac, grass	7,409	8	$454,421
16 ha /40 acre	16ha/39 ac tree, 0.4ha/1 ac grass	5,873	7	$360,203
12 ha /30 acre	12ha/29 ac tree, 0.4ha/1 ac grass	4,699	5	$288,227
18 ha /20 acre	8ha/20 ac grass	9,893	11	$606,784
Helicopter Costs based on weight the helicopter would need to carry each day, for 23 days in one month. A breakdown of the weight is as follows: - Four man work crew 318 kg (700lbs) (4 men @79 kg [175 lbs] each) for each additional 4-man crew, add 1 hour flight time per day - Grass plugs- weight per acre kg (12,600lbs) - Tree seedlings - weight per acre kg (1,740 lbs) - Fertilizer – 36 kg (80lbs) per acre (3 applications per planted area) - Potable water, tools, and other materials – 52kg (115 lbs) - Construction material - ungulate fencing @ 6 lbs per ft. @ 1,829.3 m (6,000 ft) per 20 ha (50 ac).				

The costs for restoration of a 20.2-ha (50-ac) plot are estimated at $890,000. These costs estimate that for each 50 acre parcel that is restored, 19 ha (48 ac) would be replanted with Acacia sp., 0.8 ha (2 ac) re-planted with *Paspalum notatum* and vetiver grass. The costs also include the construction of an ungulate control fence for each 20.2 ha (50 ac) parcel. The fence would measure approximately 1,829.3 m (6,000 linear feet).

The helicopter costs are based on the available commercial helicopters that service Guam. Currently, the largest commercial helicopter has a 408 kg (900 lb) payload and rents for $2,400 dollar an hour. Helicopter costs with respect to restoration are extremely expensive, mostly due to the fact that the available aircraft are not designed to carry large quantities of equipment, but rather, transfer passengers. Should a helicopter be needed, efforts should be explored to utilize a helicopter with heavy lift capabilities. For instance, there are some helicopters that can carry up to 3,629 kg (8,000 lbs) of payload, or all the equipment needed for one day of restoration in approximately one to two trips. Moreover, it should be recognized that planting is accomplished during the rainy season. Should a 408 kg (900-lb) passenger capacity helicopter be employed, considerations should be made for potential schedule disruptions due to inclement weather.

4.4.3.7 Umatac

The N-SPECT model was run to determine the benefits of converting all grassland to forests and all bare soil areas to bahia and vetiver grass. The model was run for all land areas in the Umatac with less than 40 percent slopes. Conversion of all areas would result in the removal of approximately 427.3 tonnes (471 tons) of sediment per year.

- **Restoration Costs**

A total of 328.2 (811 ac) are available for restoration in the Umatac. The costs for restoration under Management Scenario 1 are approximately $11.3 million dollars. The costs of Management Scenario 2 would be approximately $2 million dollars. Under both scenarios it is assumed three miles of roads are constructed and that a helicopter is not necessary. A breakdown of the costs for the individual restoration zones (Figure 37) in the watershed are provided below. For some of these locations, optional helicopter costs are provided.

Umat 1 – Conversion of all 96.7 ha (239 ac) of savanna to forest would cost approximately $3 million and the conversion of thee acres of badlands would cost $173,000 dollars. However, conversion of the savanna areas to forest north of the river would require approximately substantial helicopter costs (approx $2.3 million); as such, should restoration efforts occur in Umat1, they should be prioritized to occur south of the river and only occur north of the river, if necessary.

Umat 2- Conversion of 34.4 ha (85 ac) of savanna to forest and 0.4 ha (1 ac) of bare land would cost would cost approximately $1.08 million. Construction of access roads and helicopter support would not be needed for this management parcel.

Umat 3 - Conversion of 32.3 ha (80 ac) of savanna to forest would cost approximately $960,000 and restoration of 4 ha (10 ac) of badlands would cost approximately $575,000. Cost for improvements to an existing 0.8km (0.5) mile 4WD road would be approximately $15,000. Helicopter support would not be needed for this management parcel.

Umat4 – Conversion of 25 acres of savanna to forest would cost approximately $300,000 and restoration of bare lands (0.4ha [1 ac]) would cost $58,000. Construction of access roads and helicopter support would not be needed for this management parcel. The total cost would be approximately $358,000.

Umat 5 – Total restoration of Umat5 would cost of approximately $5.4 million dollars. Conversion of 141.6 (350 ac) of savanna to forest would cost approximately $4.1 million and restoration of bare lands 8.1 (20 acre) would cost approximately $1.2 million. Due to the remote location, delivery of supplies only by helicopter would be needed for all portions of this parcel at an approximate cost of $3.1 million. It should be noted that restoration costs could be substantially reduced by the construction of an access road (that would link to proposed access roads in the Ugum watershed). Cost for construction of a 2.4 (1.5-mi) access road would be approximately $40,000 and reduce and/or potentially eliminate the need for a helicopter.

4.4.3.8 Toguan

The N-SPECT model was run to determine the benefits of converting all grassland to forests and all bare soil areas to vetiver grass. The model was run for all land areas in the Toguan with less than 40 percent slopes. Conversion of all areas would result in the removal of approximately 159 tons of sediment per year.

Restoration Costs

A total of 103.4 ha (256 ac) are available for restoration in the Umatac. The costs for restoration plantings under Management Scenario 1 are approximately $4.25 million dollars. The costs for restoration plantings Management Scenario 2 would be approximately $1.5 million. Under both scenarios it is assumed 2 miles of roads are constructed and that a helicopter is not necessary. A breakdown of the costs for the individual restoration zones (Figure 37) in the watershed are provided below. When appropriate, separate costly line items (e.g., streambank stabilization, etc.) are provided.

T1 – Conversion of 55 ha (136 ac) of savanna to forest would cost approximately $3 million and restoration of 7.7 ha (19 ac) of badlands would cost approximately $1.1 million. Streambank stabilization of an estimated 0.9 km (0.6 mi) of the Toguan River would cost approximately $4.4 million. Cost for improvements to an existing 0.8 km (0.56 mi) 4wd road would be approximately $15,000 (note this road would also be used by management parcel Umat1). The total cost would be approximately $7 million. However, due to high cost to benefit ratio of streambank stabilization, this management practice is not recommended.

T2 – Conversion of 34.8 ha (86 ac) of savanna to forest would cost approximately $1 million and restoration of 6 acres of badlands would cost approximately $345,000. Construction of roads and/or the use of a helicopter are not envisioned under this scenario.

T3 – Conversion of 3.2 ha (8 ac) of savanna to forest would cost approximately $95,000 million. Construction of access roads and helicopter support would not be needed for this management parcel.

4.4.3.9 Geus

The N-SPECT model was run to determine the benefits of converting all grassland to forests and all bare soil areas to vetiver grass. The model was run for all land areas in the Geus with less than 40 percent slopes. Conversion of all areas would result in the removal of 133.4 tonnes (147.1 tons) of sediment per year. However, as stated previously, it is unlikely that converting polygon G5 would be feasible, costs are broken out by restoration costs for Parcels G1, G2, G3, and G4 (Figure 37). Costs for G5 are listed separately as they would require increased transportation costs. If location G5 is selected, it should be assumed a helicopter would be needed.

- **Restoration Costs**

A total of 129.9 ha (321 ac) are available for restoration in the Geus. In locations G1, G2, G3, and g4, a 72 ha (178 ac) are available for restoration. No helicopter or road construction costs are included for locations G1, G2, G3 or G4 as paved road travel to these locations. Based on the total acres within parcels G1, G2, G3, and G4 (67.6 ha [167 ac]) of grassland and 4 ha (11 ac) of bare land), the total restoration costs would be approximately $2.6 million dollars.

For Location G5, 58.7 ha (145 ac) (consisting of 57.9 ha [143ac] grassland and 0.8ha [2 ac] bare soils) are available for restoration at a cost of $2.6 million dollars. Helicopter costs for restoring all 58.7 ha (145 ac) would be approximately $1.4 million dollars. Thus, the total restoration costs would be approximately $4 million dollars.

For Location G5, helicopter costs significantly increase the cost of restoration, a breakdown of restoring a 20.2 ha (50-ac) and a 12.1 ha (30-ac) parcel in one month's time under Management Scenario 1 in parcel G5 are provided below. Also provided are the costs for restoring the 19 acres of bare soils under Management Scenario 2.

- 20.2 Ha (50-Ac) Parcel - Total restoration costs would be $1.36 million dollars If each 20 ha (50-ac) parcel takes one month to prepare and plant, assume 23 working days in one month. The flight costs (included in the $1.36 million) would be approximately $455,000.

- 12.1 Ha (30-ac) Parcel - The total costs of restoration for a 30-ac site would be approximately $820,000 dollars, including approximately $288,000 dollars in helicopter costs.

- 7.7 Ha (19-ac) parcel (Management Scenario 2) – The total costs would be $1.8 million dollars, which includes approximately $610,000 dollars in helicopter costs.

4.4.3.10 Ugum

The NSPECT model was run to determine the benefits of converting all grassland to forests and all bare soil areas to vetiver grass. The model was run for all land areas in the Ugum with less than 50 percent slopes. Conversion of all areas would result in the removal of 283 tonnes (312 tons) per year of deposited sediment. However, as stated previously, site access to the Ugum will be a major issue as numerous private property owners would need to be secured and a series of reliable roads constructed. Or, if it is not possible to secure private property owner's permission, a helicopter would need to be employed, and at substantial cost.

Restoration costs in the Ugum are presented as 20.2 ha (50-ac) units; however, two cost estimates are provided. The first costs estimate reflects costs that replant woody and herbaceous vegetation and construct an ungulate control fence (Management Scenario 1). The second cost (Management Scenario 2) assumes that the only restoration activity that would be selected is the planting of bare soil areas only. Under this scenario, the goal would be to arrest the notable soil erosion from exposed areas in the BCA. The costs are the following:

- **Restoration Costs**

Management Scenario 1

Under this scenario two sets of costs are provided: 1) the cost of replanting a 20.2 ha (50-ac) parcel, and 2) the costs for constructing suitable roads.

The costs for replanting of a 50-ac plot are estimated at $890,00 dollars (not including road construction costs). These costs estimate that for each 20.2 ha (50-ac) parcel that is restored, 48 acres would be replanted with Acacia sp and two acres re-planted with *Paspalum notatum* and vetiver grass. The costs also include the construction of an ungulate control fence for each 20 ha (50-ac) parcel.

It is also recommended for this scenario, roads should be constructed to transport saplings, equipment, and workers. The costs for road construction could vary between $158,000 to up to $324,000 dollars, depending on the areas selected within the Ugum. For estimation purposes, road construction costs in the Ugum are based on three geographic areas: The Atate Watershed; the Bubulao River Watershed, and the western highlands (although technically in both watersheds, this area represents the mountains and ridgeline that are west of the headwaters of the aforementioned rivers).

- Atate Watershed, it is assumed a road would be constructed starting near the former NASA installation. The road would need to travel approximately six linear miles at a cost of $158,400.

- Bubulao Watershed, it is assumed the start of road construction would occur near the municipality of Talofofo and travel on the ridge between Talofofo and Ugum rivers. It is estimated the road would to travel for at least nine miles at a cost of $234,400 dollars.

- Western Highlands – Approaching the area from the west is not possible due to the extreme slopes. The western highlands road would need to connect with the roads constructed in either the Atate and/or Bubulao Watersheds. Up to three miles of road need to be constructed at a cost of $90,000. Due to anticipated increased construction efforts in this area because of the terrain, road construction costs are assumed to increase.

Based on the total acres within parcels U1 and U2 (275.1 ha [680 ac] of grassland and 14.6 ha [36 ac] of bare land), the total restoration costs would be approximately $10.2 million dollars for plantings plus $324,000 dollars for road construction for a total cost of 10.5 million dollars.

Management Scenario 2

The costs for restoration of the 14.6 ha [36 ac] of bare soils in the BCA are estimated at a total of approximately $3.8 million dollars. The costs of the replanting activities and plants are $1.93 million. However, unlike the replanting of savanna and bare soil area that would occur in one contiguous parcel, the restoration of bare soil areas would require restoration activities to occur in numerous non-contiguous parcels. As such, the use of a helicopter may be beneficial. Costs for a helicopter for the restoration of 36 non-contiguous acres in assumed to be a 23 day event, at a total cost $450,000 dollars. Thus, the total costs for Management Scenario 2 are approximately $2.5 million dollars. Should the helicopter option not be selected, the road construction costs are provided in the previous section. Due to the large distances that would need to be travelled on foot, labor costs would likely double.

5 MONITORING

Both pre– and post-restoration monitoring are valuable tools to demonstrate success and too alert the responsible parties if a situation (e.g., plant health, erosion, etc.) is potentially threatening the success of restoration efforts. Monitoring is best accomplished by scientists on the ground physically examining plant health and conducting surveys in established monitoring plots. Aerial and satellite photos may be used to supplement finding or if very large restoration areas (more than 80.9 ha [200 ac]). The ultimate goal of a monitoring program is to provide the information needed to answer specific questions during decision making process, thus it is important to clearly define and specify the requirements in terms of information. Brief overviews of the monitoring methods are provided in the following Subchapters.

5.1 Baseline Studies

Prior to the start of any restoration effort, baseline studies should be conducted. These studies should include at the very least, coral reef surveys, stream surveys, water quality surveys, and terrestrial vegetation surveys. Baseline surveys should occur for more than one year prior to the start of any restoration and continue during and after restoration.

Due to the challenging and remote terrain that southern Guam possesses, monitoring activities should be discussed and approved by regulatory agencies prior to initiation. For instance, the construction of access roads to remote areas, may, if not done properly, increase erosion. Also, the tendency for portions of the land to slump could result in difficulty in assessing erosional and accretion rates. As such, monitoring plans should utilize the best available science, but be designed to be flexible enough to incorporate the need for modification due to unforeseen challenges.

5.1.1 Coral Reef Surveys

As this restoration effort is ultimately designed to benefit corals and coral reefs, an analysis of coral reefs will be crucial to determine the effectiveness of restoration and the likelihood of future coral reef enhancements (e.g., reef restoration, coral transplants, etc.).

Prior to restoration, a coral mapping program should be undertaken within 500 meters of the mouth of each stream. The mapping program should identify the location of corals and coral reefs and their composition (e.g., diversity, percent cover, rugosity, etc.). In conjunction with the coral reef surveys, seasonal monitoring of TSS levels in the mouths of the rivers should occur, along with a seasonal mapping of sediment deposition within 500 meters of the river's mouth. The mapping of sediment deposition will be crucial in determining the feasibility of future coral colonization in conjunction with the anticipated lowering of TSS levels. Although the there is high variability amongst coral species with respect to their physiological tolerance to sedimentation, it can be assumed that a reduction in deposition would increase the chances of coral colonization and improve the health of established reefs. Finally, in conjunction with monitoring efforts, seasonal surveys of coral health should be conducted. Any coral bleaching related to increased sea water temperatures and the rise of coral diseases which may not always be related to increased TSS levels, should be documented as well. However, it should be pointed out that adequate monitoring of coral recovery could require a 10 to 20 or even 50-year monitoring period.

5.1.2 Water Quality and Stream Monitoring

As identified in the subchapter 5.1.1, the quantification of TSS, sedimentation and other water quality parameters are crucial to the success of any mitigation activities. Baseline monitoring should include at a minimum the collection of river discharge data, and TSS levels within each river and at its mouth, and both TSS and sedimentation rates at several locations extending out from the mouths of the rivers. To accomplish this goal both manual and automatic sampling equipment can be utilized. These collected data will form the baseline for observations and measurements performed during the future monitoring to determine the success of the restoration efforts. In addition, at several locations on each river, detailed cross sections should surveyed so that stream bank erosional monitoring can occur to establish rates of soil and sediment erosion and deposition.

5.1.3 Vegetative and Soil Monitoring Plots

Monitoring plots should be established to determine the percent of vegetative cover, change in species composition, and the accretion of soil. Both the USDA and NRCS have available methods to accomplish this. Based on information presented in the NRCS's *Sasa-Atantano Watershed Resource Assessment* (NRCS, 2007), one monitoring technique that has been used to assess on-site soil movement in Guam and elsewhere is the use of erosion pins. This technique, described in detail in Schleman et al., consists of establishing an array of metal pins on the study site and periodically returning to measure the changes in soil depth around the pins. When a large number of pins are used, the average of the individual changes provides reliable estimate of the overall soil loss or deposition on a given area. Erosion pins and similar techniques have also been used to assess erosion rates from stream banks and to assess the expansion rate of gullies (NRCS, 2007). Although, it should be noted, that if an area experiences soil slumping, such as the volcanic soils of southern Guam, than erosion pins will not provide useful data. Thus, consultation with regulatory agencies to determine effective monitoring procedures for areas experiencing different levels of erosion will be crucial. One possible method to quantify soil accretion is to measure leaf litter and solum thickness with a thin diameter soil probe.

5.2 Photographic Record.

Photographs of terrestrial and aquatic locations should be collected before a restoration activity and then repeated during and after a restoration activity. The photograph should photograph the same location from the same perspective. Successive photos provide a record of change.

6 CONCLUSIONS

Although this is a preliminary evaluation, this watershed assessment provides for identification of areas that contribute significant erosion within each watershed and potential conservation measures that would help address the impacts to Guam's southern coral reef ecosystems. This evaluation of erosion sources and the estimation of erosion and sediment rates provide a basis for the development and implementation of a targeted and site-specific conservation plan that focuses on the major sediment source areas in the watersheds. The target areas include both barren lands/badlands, and savanna areas on Government of Guam owned properties.

Total TSS loads for each watershed were calculated for the Umatac at 997 tonnes/yr (1,099 tons/yr); for the Toguan 405.5 tonnes/yr (447 tons/yr); for the Geus at 312.1 tonnes/year (344 tons/yr); and for the Ugum 1,322.7 tonnes/yr (1,458 tons/yr).

Limited total suspended solids data is available for the rivers in the four watersheds. For the La Sa Fua River the average TSS yield for the period 2005 through 2009 is 1,640.2 tonnes/yr (1,808 tons/yr). The baseline model TSS yield for the La Sa Fua River is 484 tonnes/yr (534 tons/yr), indicating the TSS yields from the model may be biased low.

Lessons learned from other Guam restoration projects, along with a sound, site-specific resource management planning process, should provide for successful conservation projects in the Umatac, Toguan, Geus and Ugum Watersheds. Additional data gathering and analysis will be critical to effectively address the multiple concerns and complexities of conservation planning at the watershed scale for these large areas with complex ownership and resource management objectives.

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Appendix A Watershed Modeling Factors

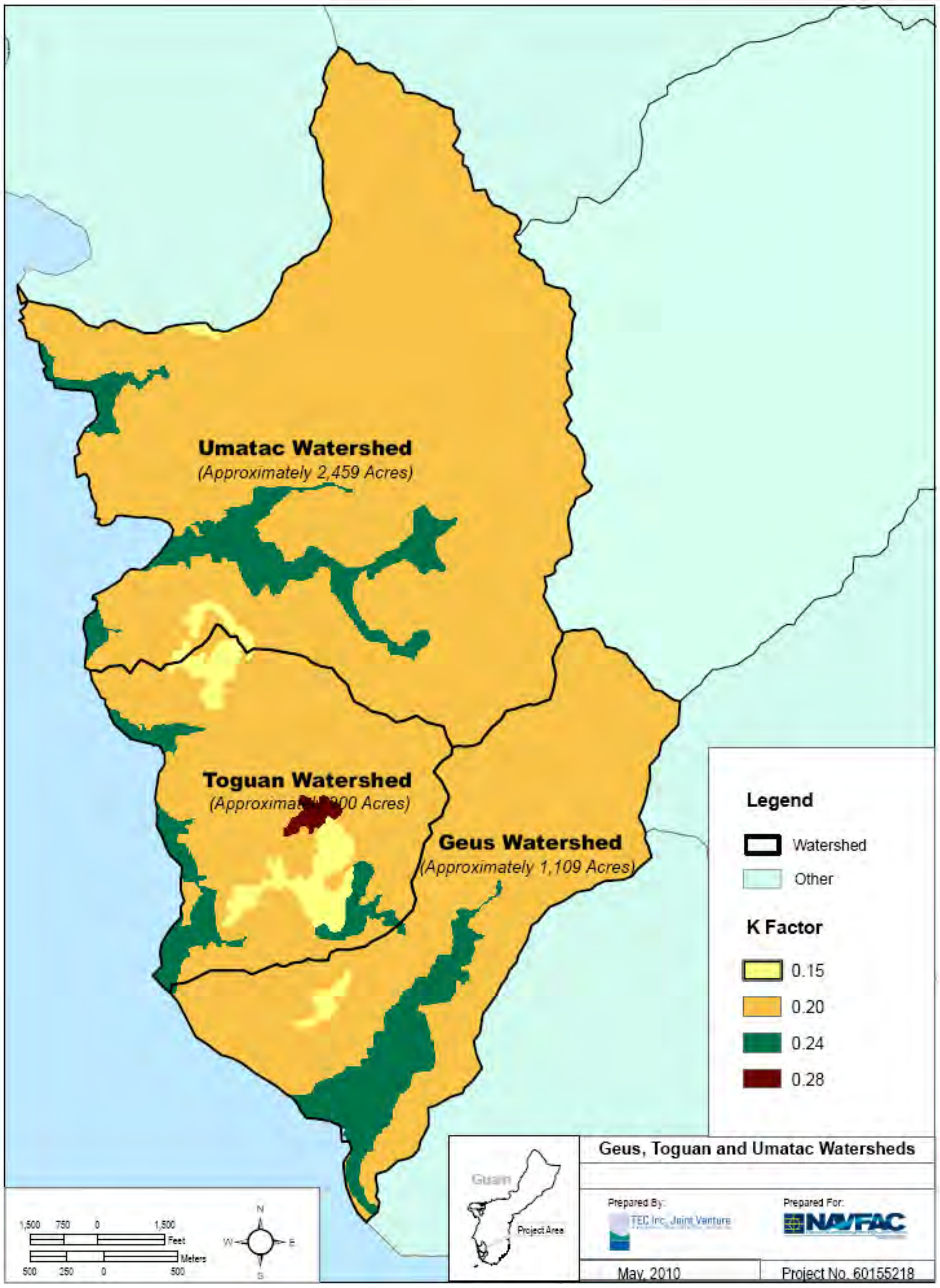


Figure A- 1 K Factor Umatac, Toguan, and Geus Watersheds (WERI and N-SPECT Models)

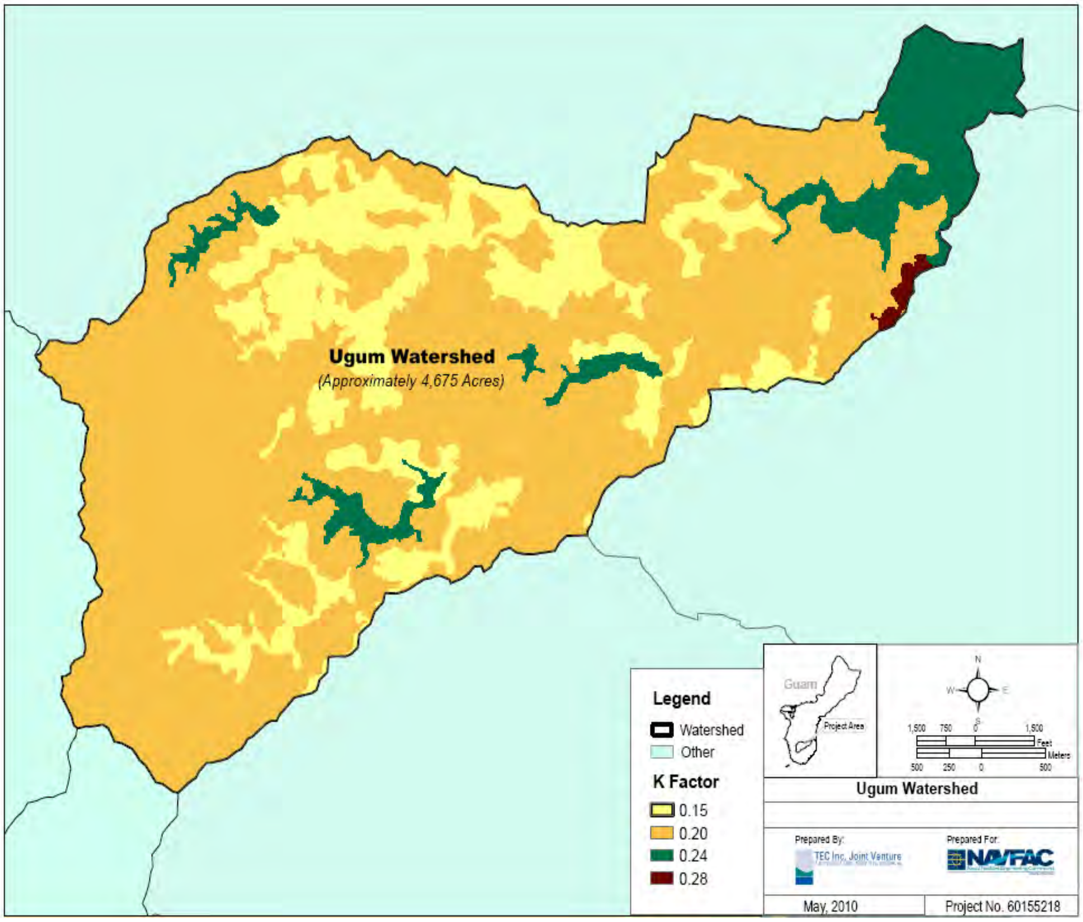


Figure A- 2 K Factor Ugum Watershed (WERI and N-SPECT Models)

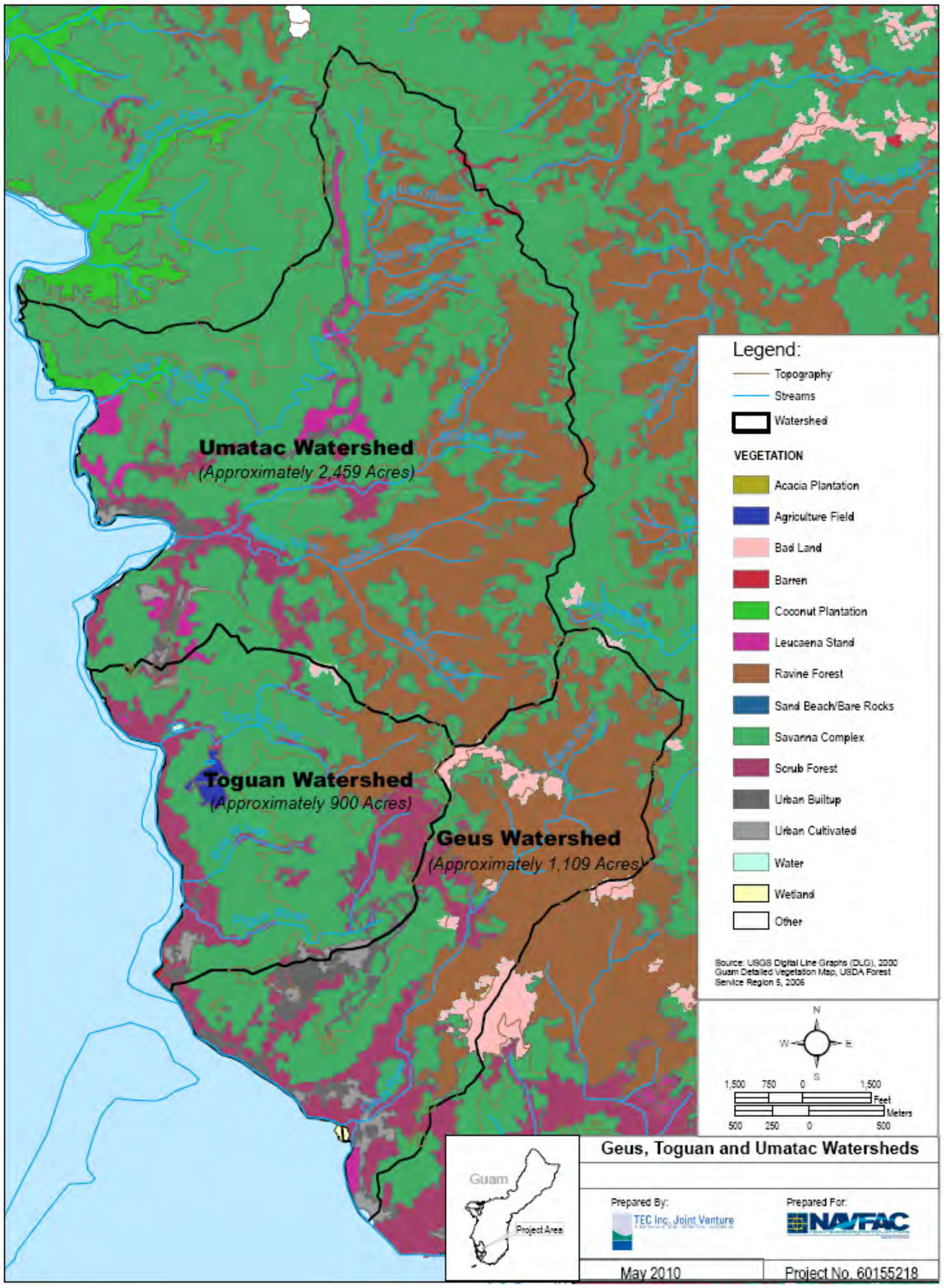


Figure A- 3 Vegetation Types Umatac, Toguan, and Geus Watersheds (WERI Model Only)

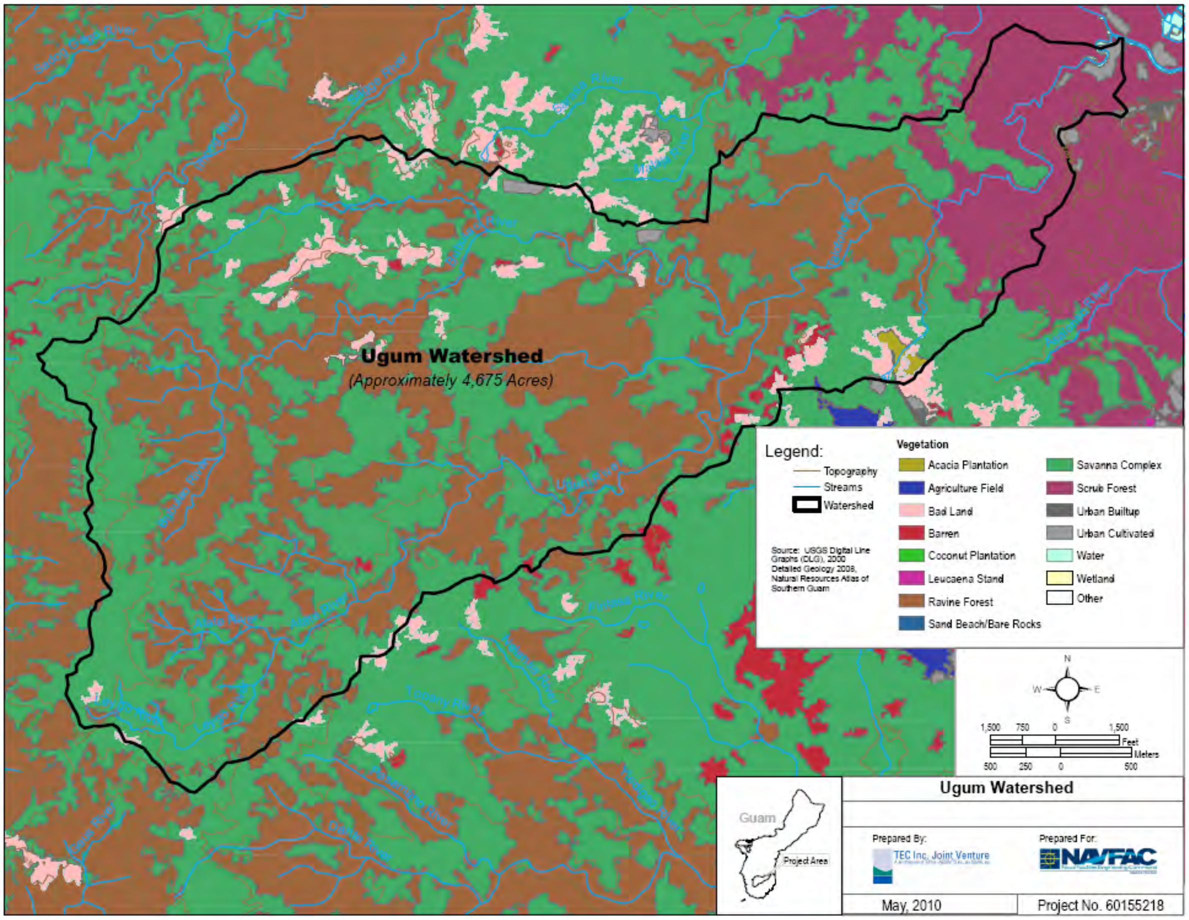


Figure A- 4 Vegetation Types Ugum Watershed (WERI Model Only)

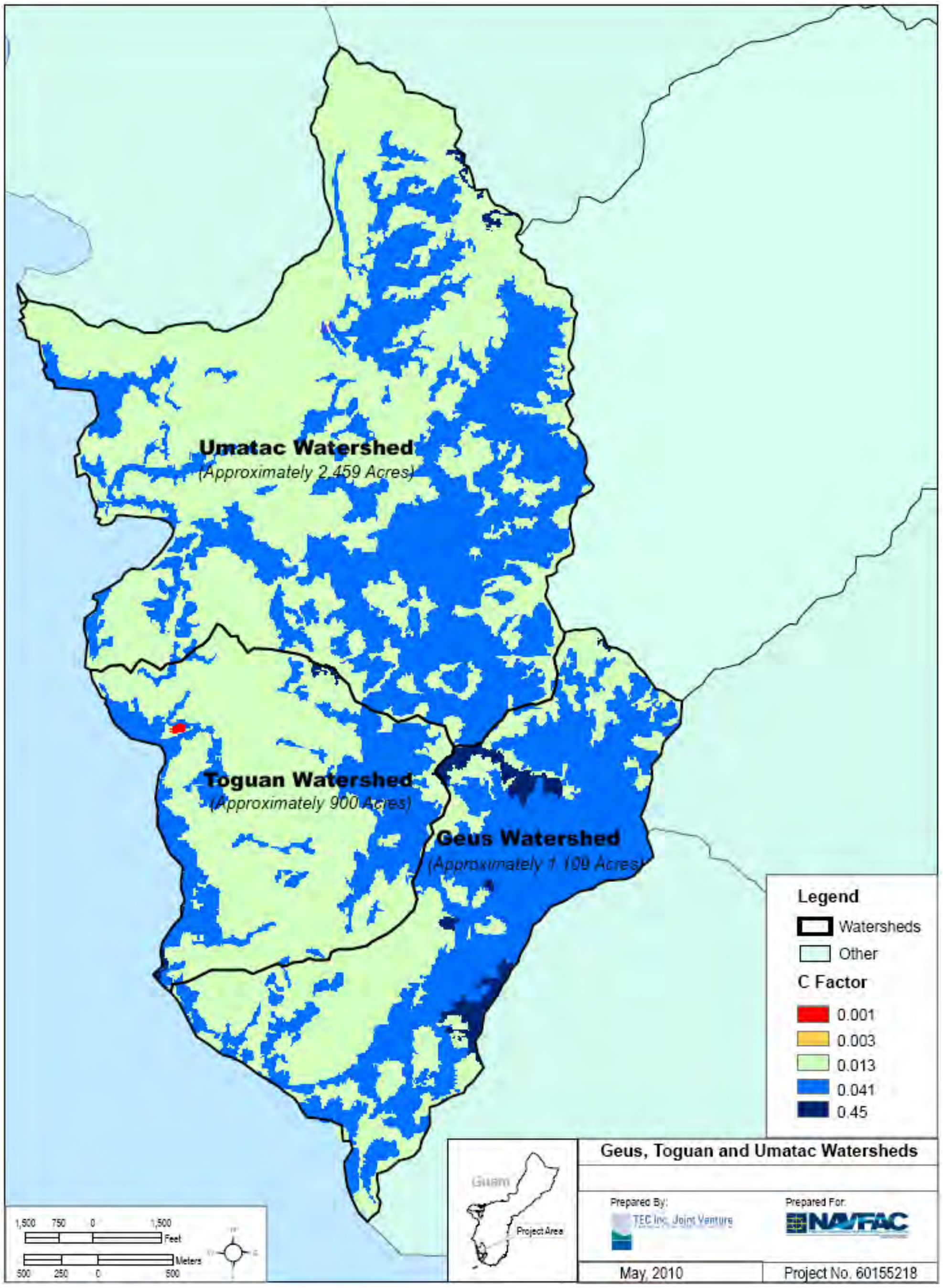


Figure A- 5 C Factor Umatac, Toguan, and Geus Watersheds (WERI Model Only)

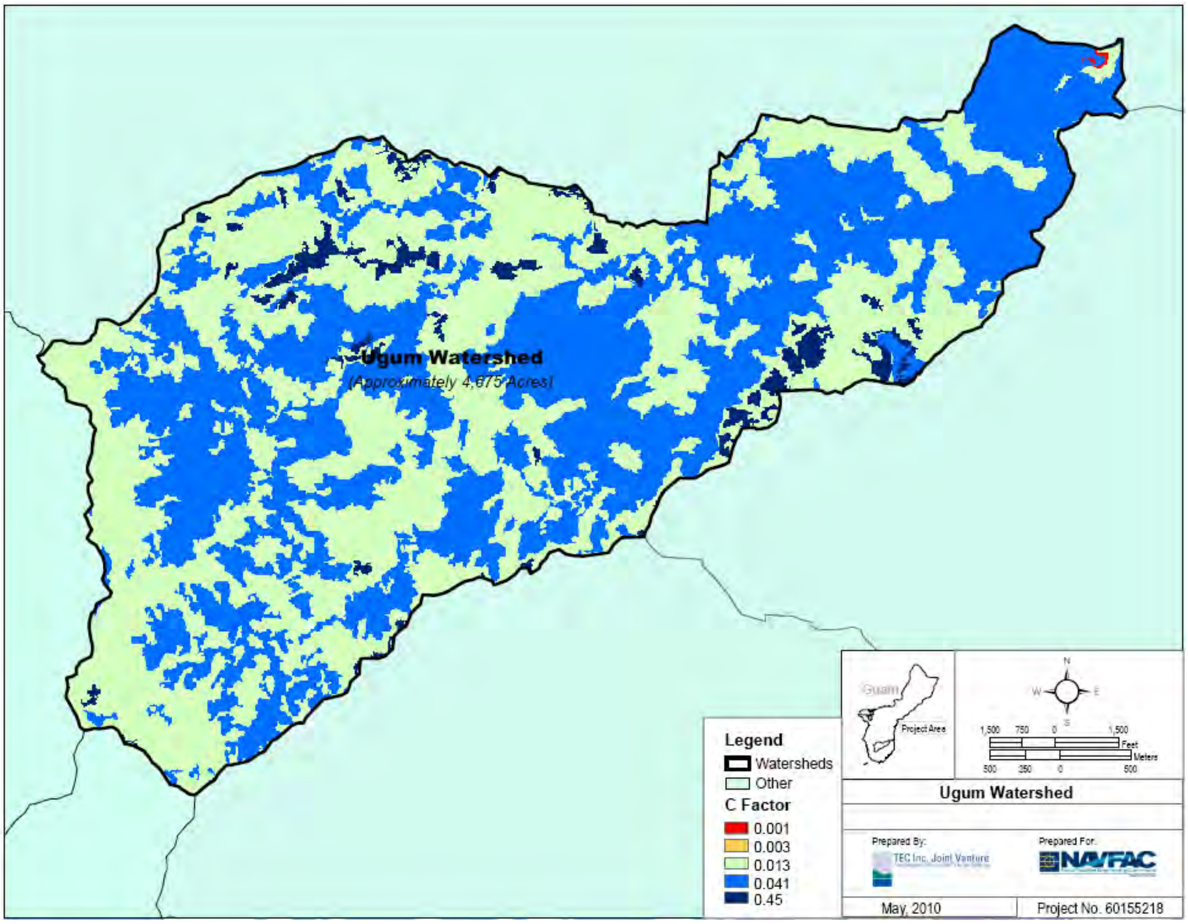
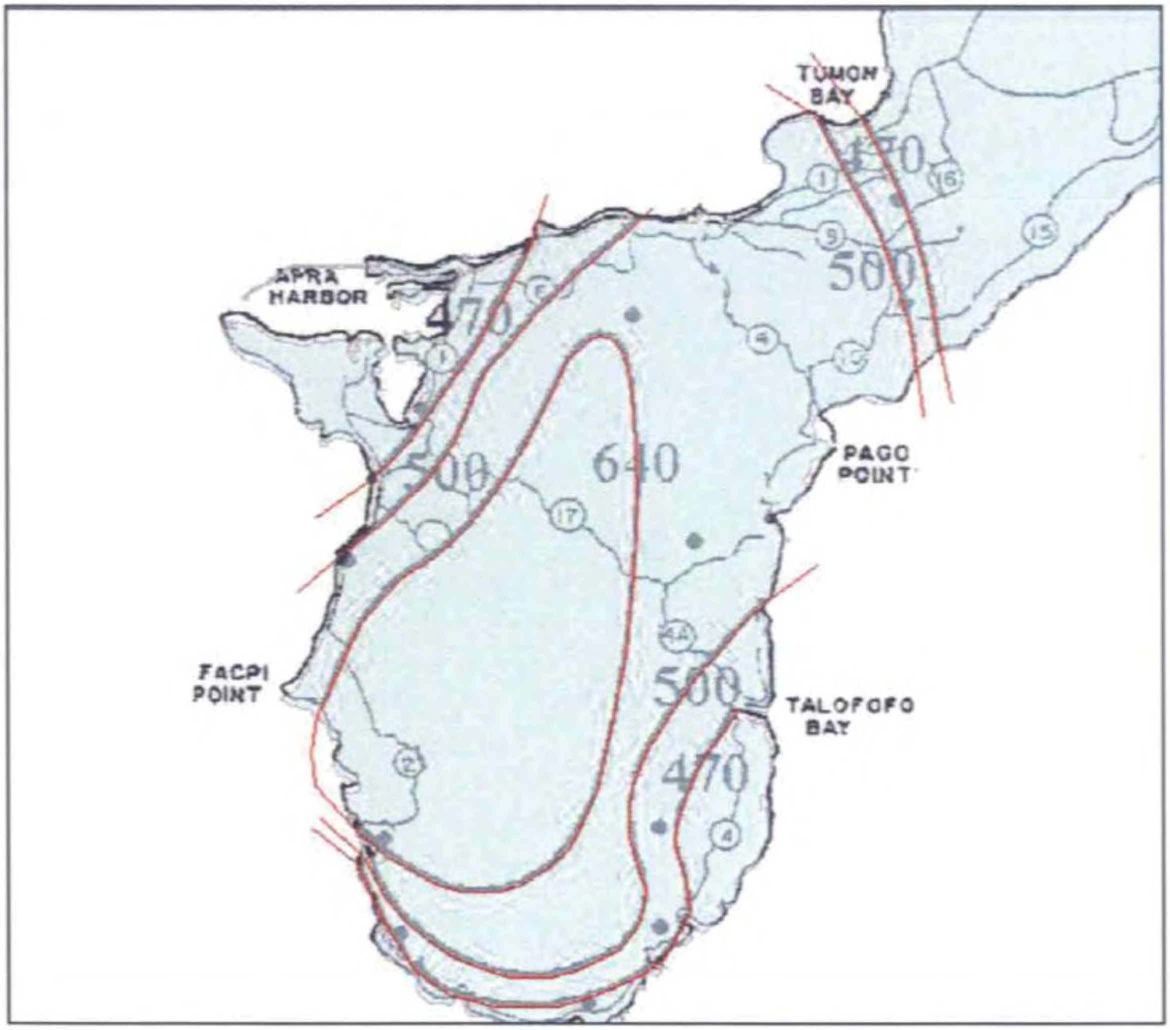


Figure A- 6 C Factor Ugum Watershed (WERI Model Only)



From Dumaliang (1998)

Figure A- 7 Rain Erosivity (R Factor) (WERI and N-SPECT Models)

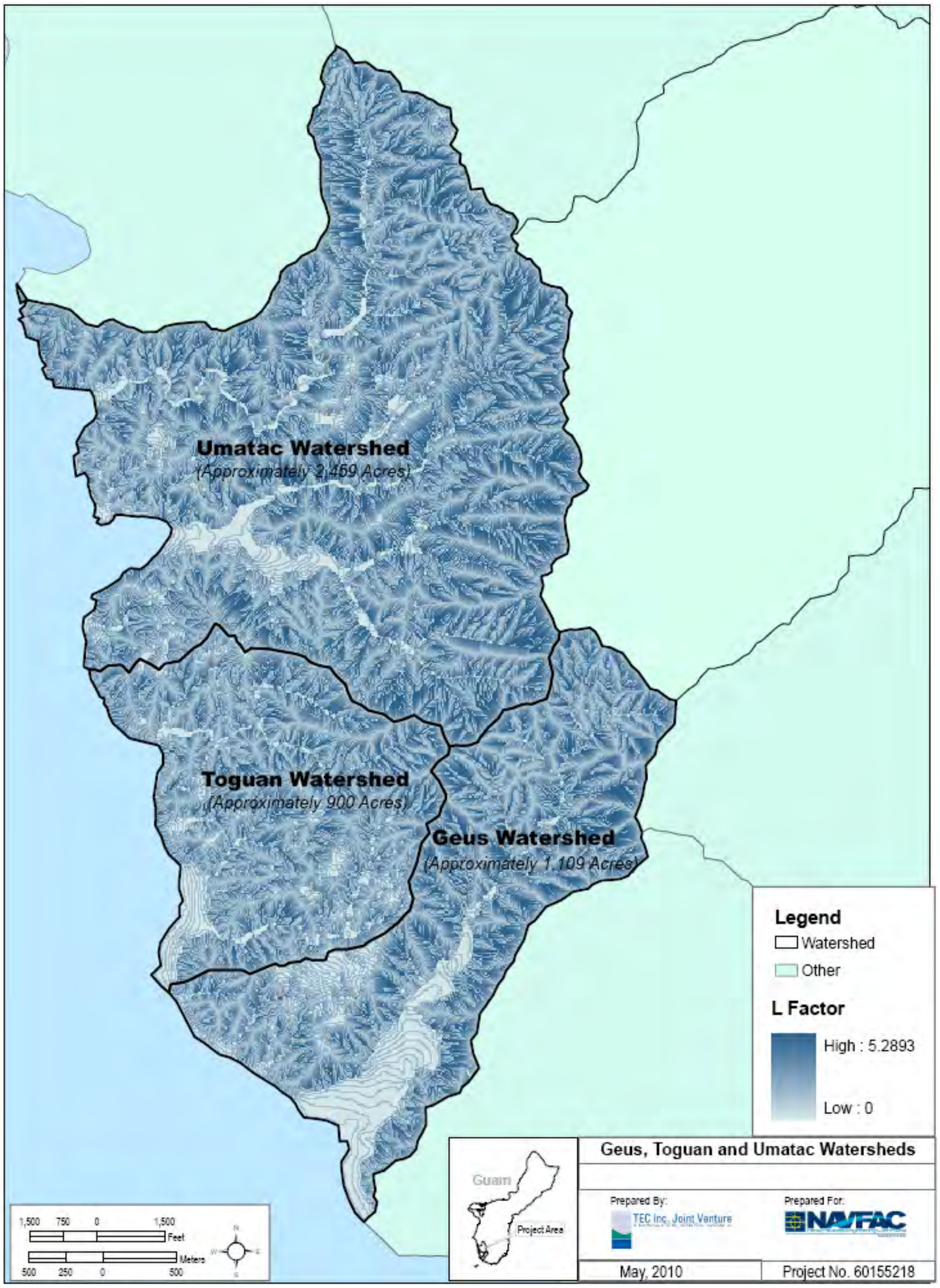


Figure A- 8 L Factor Umatac, Toguan, and Geus Watersheds (WERI Model Only)

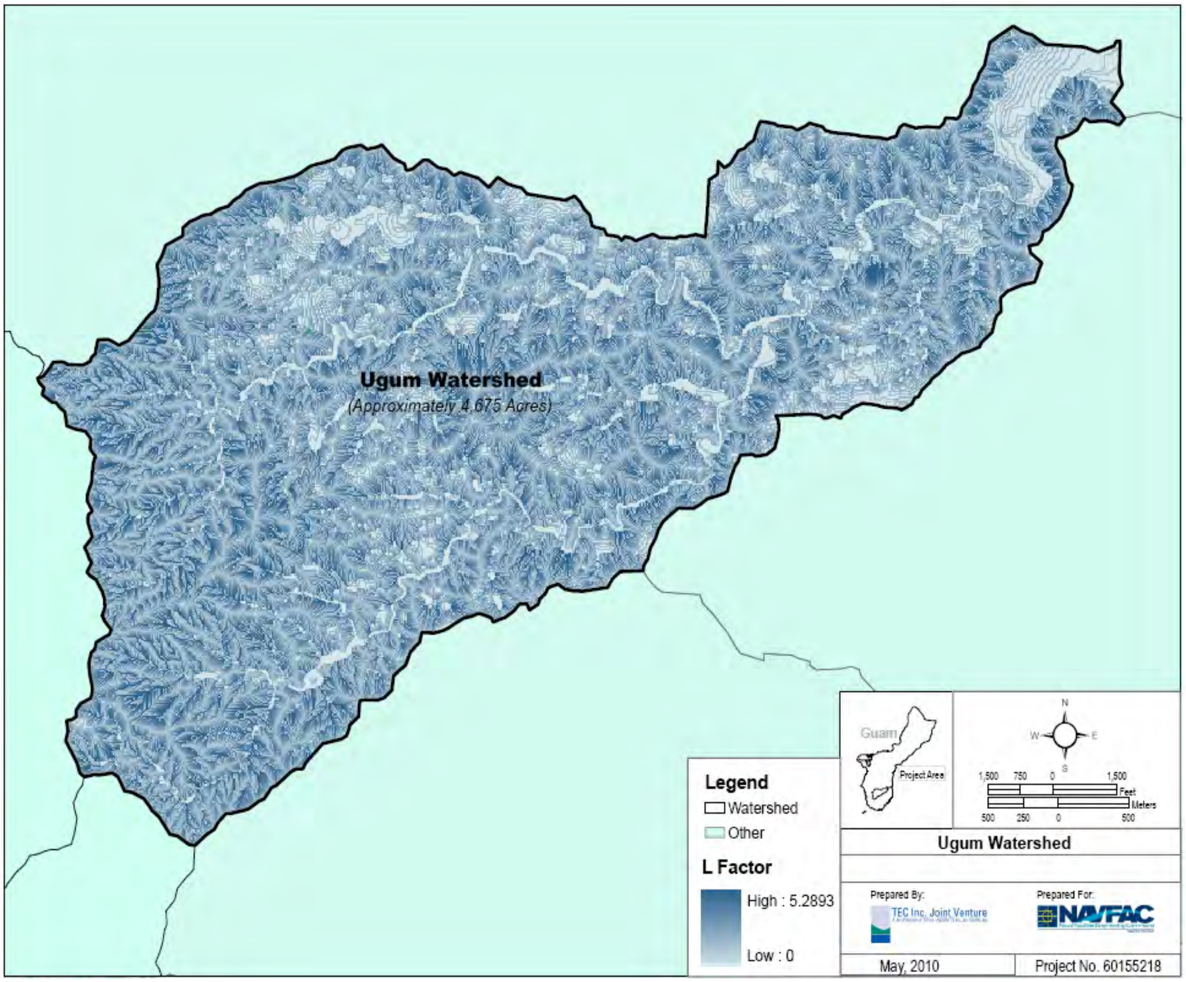


Figure A- 9 L Factor Ugum Watershed (WERI Model Only)

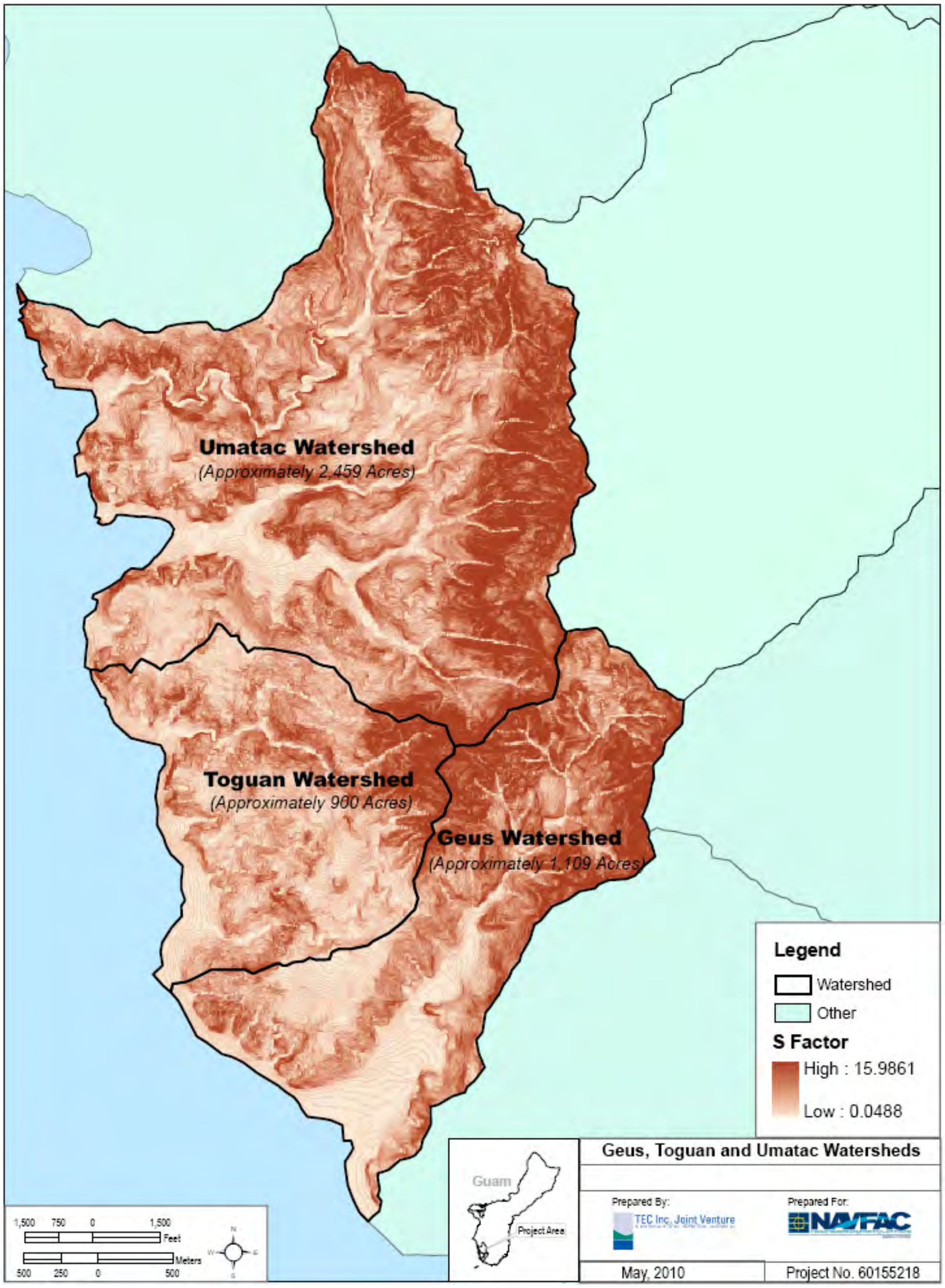


Figure A- 10 S Factor Umatac, Toguan, and Geus Watersheds (WERI Model Only)

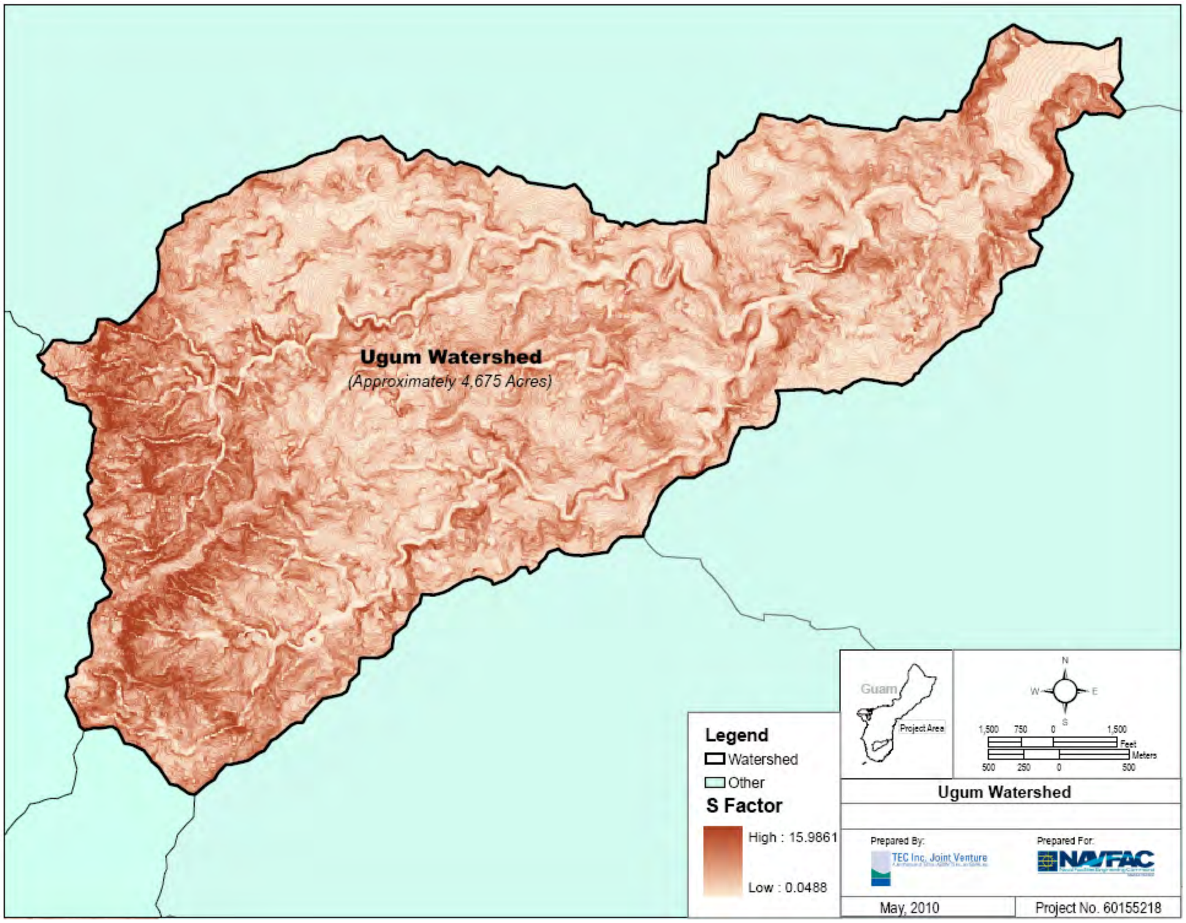


Figure A- 11 S Factor Ugum Watershed (WERI Model Only)

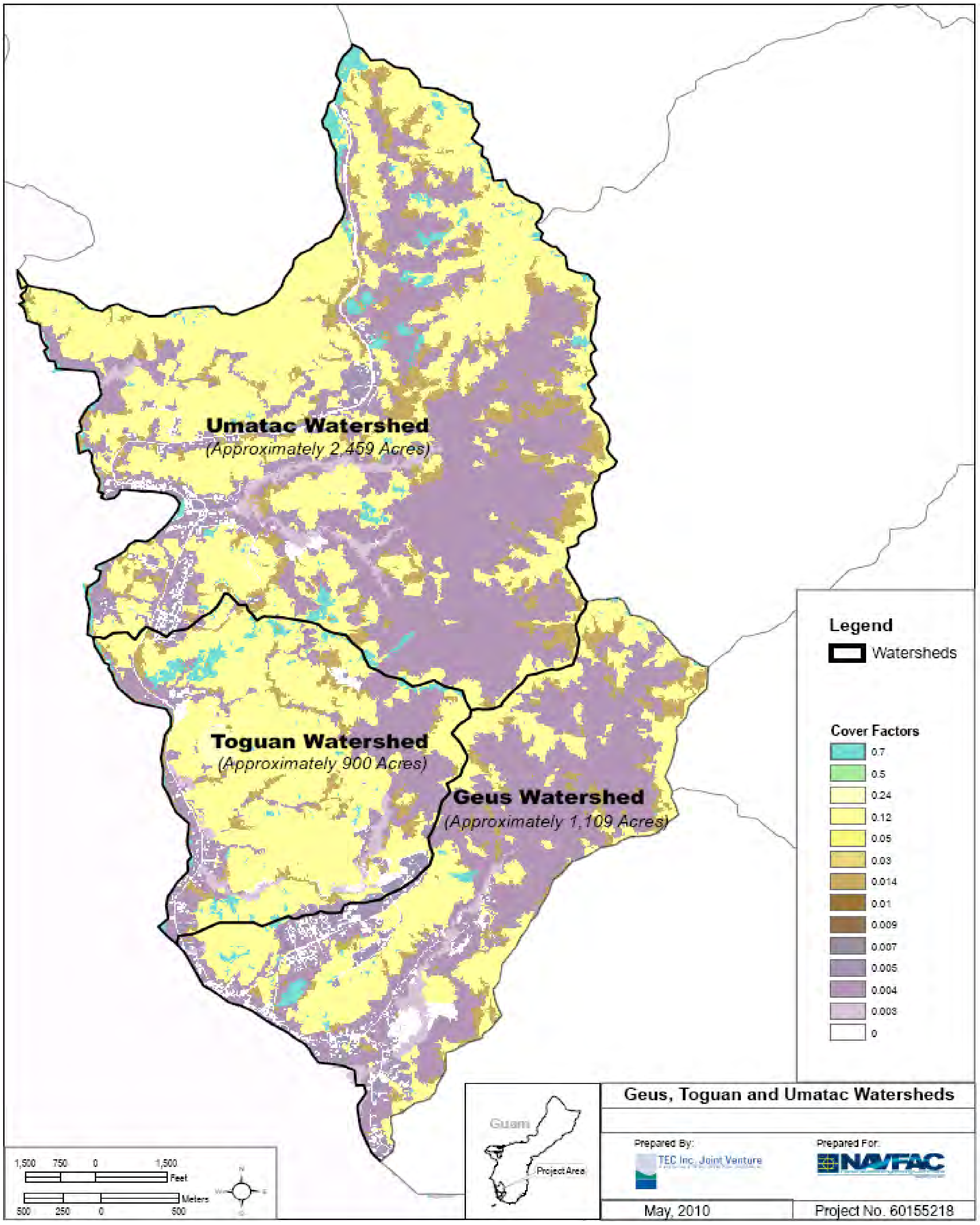


Figure A- 12 C Factor Umatac, Toguan, and Geus Watersheds (N-SPECT Model Only)

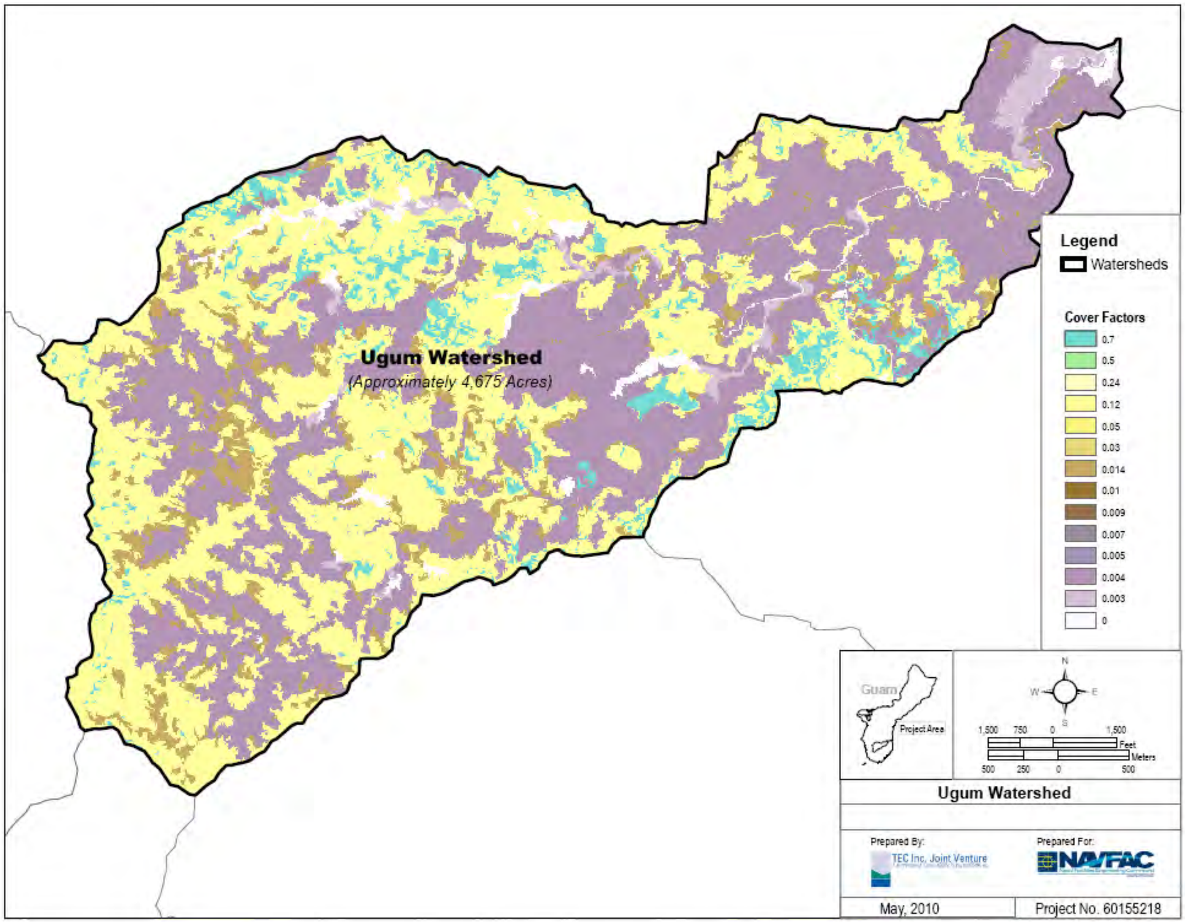


Figure A- 13 C Factor Ugum Watershed (N-SPECT Model Only)

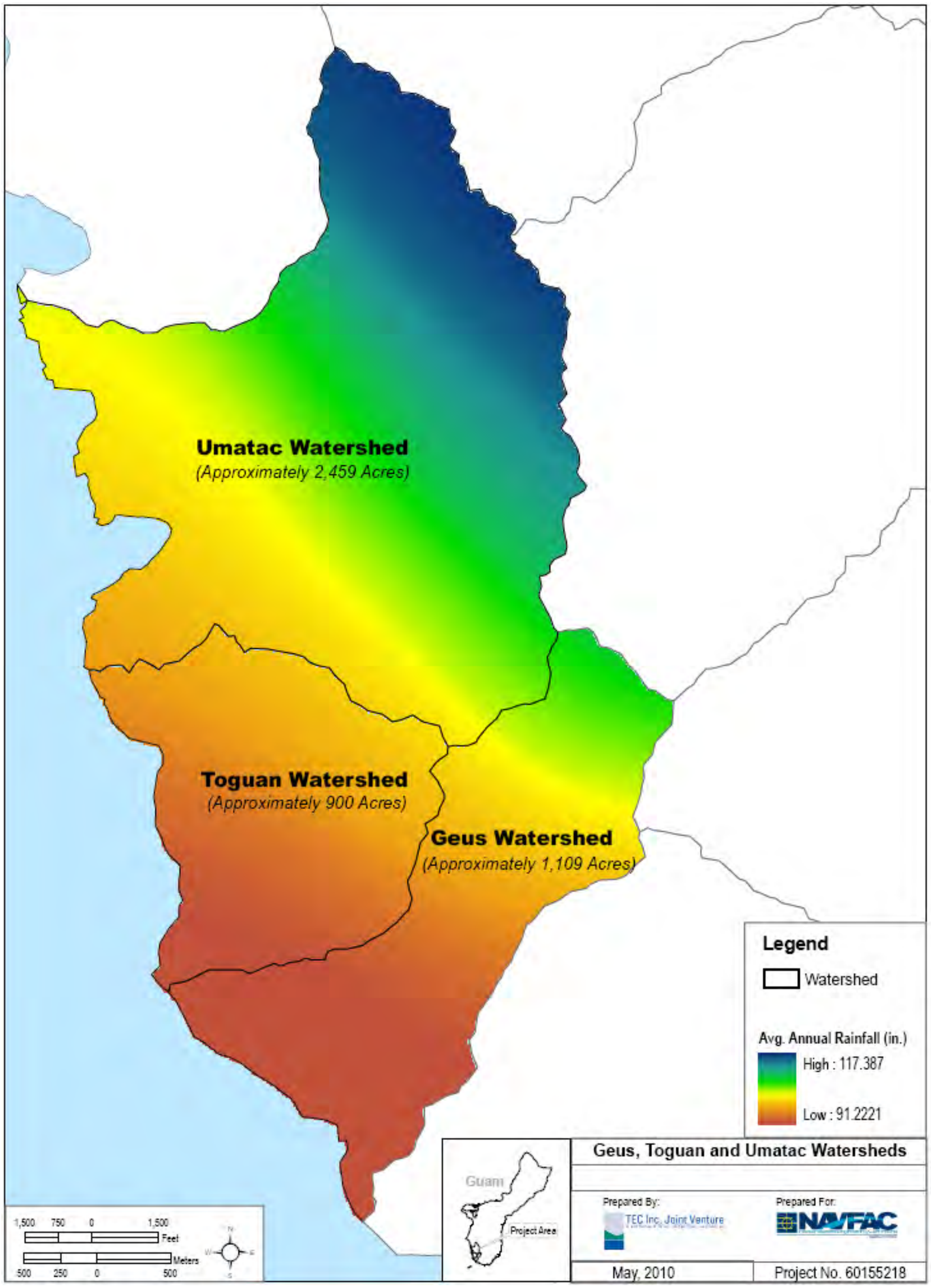


Figure A- 14 Annual Average Rainfall Umatac, Toguan, and Geus Watersheds (N-SPECT Model Only)

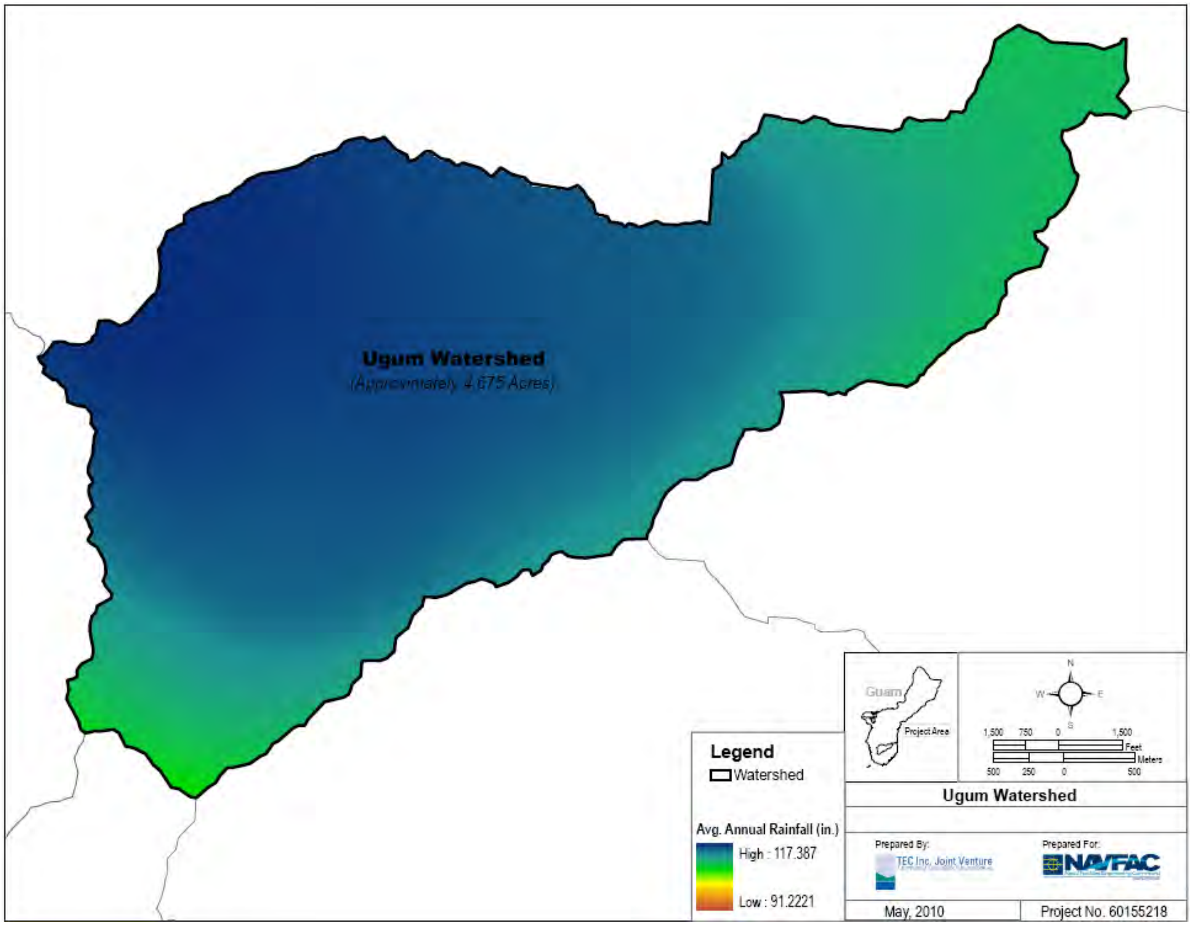


Figure A- 15 Annual Average Rainfall Ugum Watershed (N-SPECT Model Only)

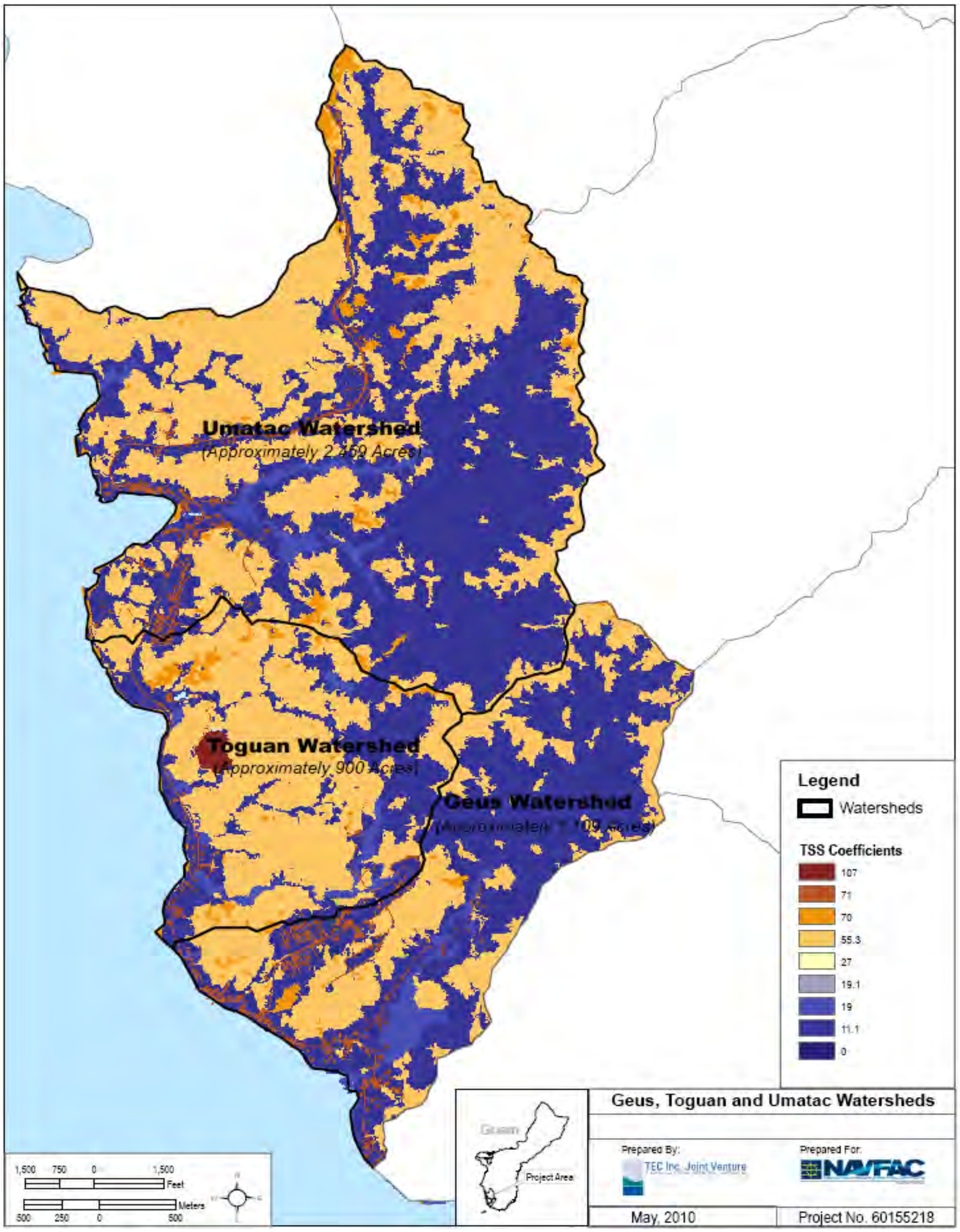


Figure A- 16 TSS Coefficients Umatac, Toguan, and Geus Watersheds (N-SPECT Model Only)

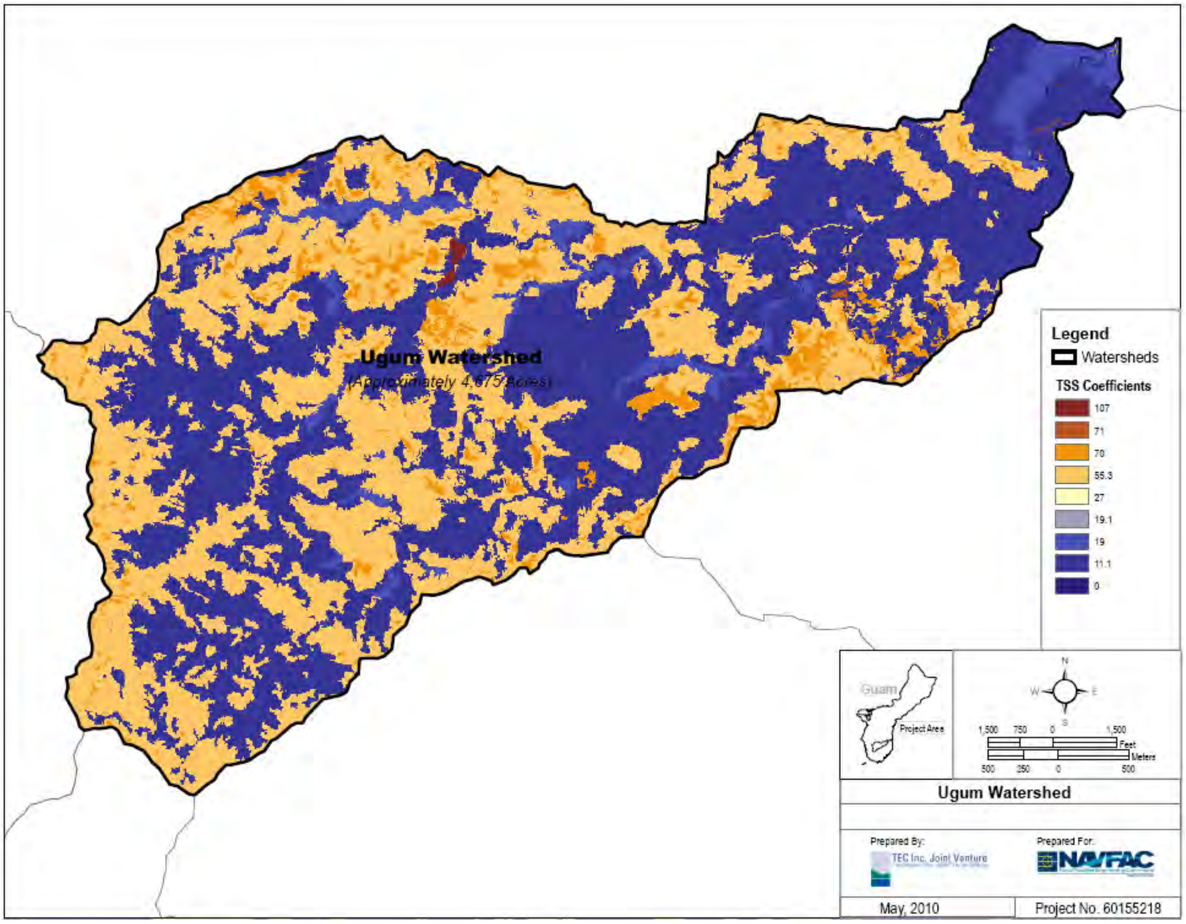


Figure A- 17 TSS Coefficients Ugum Watershed (N-SPECT Model Only)

2009

ASSESSMENT FOR PACIFIC SHEATH-TAILED BATS (*EMBALLONURA SEMICAUDATA ROTENSIS*) ON AGUIGUAN, COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

Compiled by Thomas J. O'Shea and Ernest W. Valdez

Draft

Contents

Section I. Executive Summary

The subspecies of the Pacific sheath-tailed bat that once occurred throughout the Mariana Islands (*Emballonura semicaudata rotensis*) has not been well studied biologically, despite its declining status. It is a small insectivorous bat, and in the Mariana Islands it is known only to roost in caves. All available data indicate that it now occurs only as a single remnant population on Aguiguan. Overall the species is categorized as Endangered by the International Union for the Conservation of Nature and Natural Resources. The subspecies is protected by the Commonwealth of the Northern Mariana Islands (CNMI) law, and is considered a Category 3 candidate for listing under the U.S. Endangered Species Act. This categorization under U.S. law is based on the imminence and magnitude of threats, but further actions have not had the highest priority possible in part because the remaining population on Aguiguan has been considered to be a subspecies of a more widely found species. However, a thorough, modern quantitative morphometric and molecular genetic analysis is needed to verify if the subspecific level in the taxonomic hierarchy is accurate or if full species designation may be warranted for the population in the Marianas Islands.

In this report we document results from a biological assessment for Pacific sheath-tailed bats carried out in 2008 on Aguiguan and Tinian, CNMI. The field work was done by a team consisting of a former Guam Division of Aquatic and Wildlife Resources biologist with past experience surveying for this species and four bat biologists from the U.S. Geological Survey (USGS) Fort Collins Science Center and the USGS Pacific Island Ecosystems Research Center. The assessment consisted of determining present abundance and use of caves on Aguiguan by these bats and interpreting these data in comparison with a synthesis of the literature and past unpublished data; establishing baseline site occupancy models of spatial foraging habitat use through monitoring of ultrasonic echolocation calls; determining basic aspects of diet through analysis of fecal material; sampling bats through capture to obtain new data on reproduction and body size, as well as to collect samples for future genetic analysis; and determining characteristics of temperature and humidity in caves. We conducted a review of specimens available in research museums, and obtained samples from guano deposits that may be useful in analysis for contaminants in comparison with analysis of guano from other islands where these bats have become extinct. We also conducted a limited survey for the presence of these bats on Tinian.

Our report summarizes previously unpublished results on numbers of Pacific sheath-tailed bats roosting in caves on Aguiguan in 1995 and 2003, and compares past results with findings from new surveys conducted in 2008. Overall, we examined the abundance, roosting behavior, and distribution of Pacific sheath-tailed bats on Aguiguan by searching caves and hollow trees for roosting bats during the day. Counts of bats at caves show that a small population of Pacific sheath-tailed bats continues to exist on Aguiguan, with a range of 359-466 individuals counted at five of 41 caves in 2008. Comparison with past counts suggests that this population has increased over the last 13 years. Bats appeared to prefer roosting in larger caves and displayed fidelity toward five of the seven roosts found occupied in the study.

Occupied caves were larger than most unoccupied caves but had similar conditions of temperature and humidity. In 2008 one cave consistently housed the largest colony, with a range of 308–382 bats counted, whereas counts at other occupied caves on Aguiguan yielded 1–64 individuals. Slight variability occurred in replicate counts on different dates during the 2008 survey. We found no evidence of hollow tree trunks being used as roosts. It is possible that a small number of colonies of these bats may remain undiscovered at inaccessible caves on Aguiguan.

Evaluation of trends in colony sizes of cave bats throughout the world generally relies on count data that are uncalibrated index values, which can be difficult to interpret. Therefore this assessment also sought to utilize a recently developed quantitative approach to establish a baseline site-occupancy model of spatial occurrence of foraging Pacific sheath-tailed bats on Aguiguan. This method uses detection of bat ultrasonic calls to assess presence-absence of foraging bats at night in relation to various habitat attributes. Thirty-one echolocation stations were deployed across Aguiguan between 25 June and 14 July 2008. Twenty-one of the 31 stations recorded ultrasonic pulses from sheath-tailed bats over a period of 19 days, with 35,858 calls recorded. Ten percent of the calls were characterized as peak activity, 40% as moderate activity, and 50% as brief passes. Analyses show that peak activity and occurrence is related to canopy cover, vegetation stature, and distance to known roosts. Native limestone forest is preferred foraging habitat. Echolocation calls of Pacific sheath-tailed bats were characterized for the first time, and search-phase calls were similar to those of other emballonurid bats that use a narrow bandwidth and short pulse duration to forage in cluttered vegetation.

There has been no prior information on the food habits of the Pacific sheath-tailed bat anywhere in the species' range. Herein we reported on new findings from analysis of fecal material from this bat on Aguiguan. We collected and analyzed 200 fecal pellets of bats from two roosts (Guano Cave and Crevice Cave). The diet of the Pacific sheath-tailed bat was diverse, but mostly consisted of small-sized prey ranging from 1.7 to 6.4 mm in length. Overall hymenopterans (ants, wasps, and bees), lepidopterans (moths), and coleopterans (beetles) were the three major food items in the diet of bats from both roosts. However, the ranking of volumes of each insect order consumed varied between roosts. At Guano Cave, hymenopterans made up 64% of the diet, followed by coleopterans (10%), and lepidopterans (8%). At Crevice Cave, lepidopterans made up 45% of the diet, followed by hymenopterans (41%), and coleopterans (10%). Within Hymenoptera, most of the prey items belonged to ichneumondoidea (parasitoid wasps), followed by formicids (ants belonging to Formicinae and Ponerinae; i.e., trap-jaw ants). Because alates (= winged adults) of ants and termites (isopterans) found in fecal samples generally have wings only when they are reproductive or establishing new colonies, it is likely that Pacific sheath-tailed bats take advantage of seasonal food sources. In other areas the occurrences of these winged forms are often present during the onset of rains; we sampled guano at the onset of the rainy season on Aguiguan (late June to early July). Lepidopterans, specifically microlepidopterans, likely were another seasonally abundant prey item. Silken fungus beetles and leaf beetles identified in the guano appear to be forest-dependent species and were a consistent component of the bats' diet. Not only do these and other prey items indicate that these bats forage mainly in forest habitat during late June and early July, but that they also capture prey near (above and below) the canopy. From these diet analyses, we categorize the Pacific sheath-tailed bat as an aerial insectivore or hawker, similar to other emballonurids around the world.

We also collected various other samples and obtained information on the biology and natural history of Pacific sheath-tailed bats on Aguiguan. We used standard means to capture Pacific sheath-tailed bats in mist nets while they dispersed or foraged through the forest, but these attempts were largely unsuccessful because these bats were highly maneuverable and easily avoided mist nets on close approach. We successfully captured 12 adult bats and one attached suckling young by using hand nets on bats in flight in the forest, or mist nets set in or near caves used as roosts. Both methods have logistical problems and limitations: in addition to the high maneuverability of the bats precluding use of mist nets in standard configurations, considerable time is required to accrue multiple captures using hand nets. Caves where bats roost are co-occupied by endangered Mariana swiftlets. Thus capturing bats at caves has the potential to disturb both the bats and the swiftlets. We found that these bats can be very sensitive to initial handling, but stress can be reduced by placing bats individually in cloth bags promptly after capture and before examining them. We determined body mass, length of forearm, and reproductive condition of the 12 adult bats. In addition to qualitative features of skull morphology, length of forearm has been given as a characteristic distinguishing between some subspecies of *E. semicaudata*. However, these new forearm measurements show that there is considerable overlap in body size between *E. semicaudata rotensis* and the other three subspecies of Pacific sheath-tailed bats. We also collected small wing biopsies from12 bats prior to release for some basic preliminary genetic analyses to ascertain genetic diversity of the population on Aguiguan and the depth of division of this subspecies based on comparison with published data on genetics of *E. s. semicaudata* from Fiji. This work will be carried out by USGS geneticists in 2009. We also prepared two museum voucher specimens of *E. s. rotensis*, increasing the number of known specimens from the Mariana Islands available in United States museums from two to four. We reviewed the literature and queried a limited number of online databases to compile updated information on specimens of Pacific sheath-tailed bats that might be available for taxonomic study. Considerable numbers of specimens including other subspecies are available worldwide (over 380), and about 22 additional specimens from the Marianas Islands (including Guam) are housed in museums in France and Japan. Expanded study of museum specimens and comparative genetic analyses are needed to fully ascertain the systematic status of the Pacific sheath-tailed bat population on Aguiguan.

There is limited information on reproduction in Pacific sheath-tailed bats in the CNMI or elsewhere. Six female bats captured by Wiles and others on Aguiguan late in the rainy season of 2003 were apparently not reproductive. In contrast, seven of the eight female bats we captured in June and July 2008 were either pregnant or lactating. We also observed 11 pups at roosts in caves during June and July 2008; all were singletons. None of the bats we captured were volant young of the year. The presence of reproductive females and pups or embryos in June and July but no volant young suggests the hypothesis that Pacific sheath-tailed bats on Aguiguan may have a diffuse seasonality in reproduction, such that the period of late gestation, lactation, and maturation of young coincides with the late June to early November rainy season. We observed one large embryo in a female dissected in June 2008, as was also observed in a female dissected by Lemke in June 1984. These dissections and the observations of 11 apparent singleton pups suggest a litter size of one. If reproduction occurs only once per year and litter size is one, then the capacity for population growth in Pacific sheath-tailed bats will be very limited. All bats that we captured at caves in 2008 and by others in years past were females, whereas 4 bats captured at dusk dispersing along a steep rocky hillside, not near any known colony, were males. This suggests that perhaps males may form bachelor colonies apart from roosts occupied primarily by females, as is known for other Old World species in the genus *Emballonura*. Elaborate social behavior patterns were also suggested by the audible communication sounds produced by bats that we observed foraging and dispersing through the forest and flying into caves.

The scientific literature includes speculation that the extinction of Pacific sheath-tailed bats on other islands may have been attributable at least in part to past use of organochlorine insecticides. However, there is no chemical or toxicological evidence that bears directly on this speculation. Analyses based on other species of insectivorous bats have shown that concentrations of organochlorine insecticides in bat guano can provide diagnostic evidence of mortality and population declines. Aguiguan has been mostly uninhabited since the use of organochlorines became widespread elsewhere in the world. Thus guano samples from sheath-tailed bats on Aguiguan could provide comparative baselines with which to compare contamination of guano from islands where these bats have become extinct (e.g. Guam). Therefore we used contaminant-free sampling approaches to obtain guano at 3 different depth levels (i.e., surface, 10 and 20 cm below surface) from two areas of a guano pile beneath roosting bats at Guano Cave. These samples are stored in the USGS laboratory at the Fort Collins Science Center and can be made available for future chemical analysis. However, because this guano was deposited over many years, the material also likely includes particles of guano from Mariana swiftlets. The degree of mixing of guano from these two sources should be estimated using microscopic techniques prior to chemical analysis.

Pacific sheath-tailed bats are only known from Tinian based on prehistoric deposits in caves. During the last 4 days and nights of our study we made an effort to document the presence of Pacific sheath-tailed bats on Tinian using echolocation detectors. We also queried knowledgeable individuals, and watched for bats and listened for audible calls during the echolocation surveys. We felt that our best chance for success in documenting bats on Tinian would be echolocation-based sampling in limestone forest areas because of their heavy use of this habitat for foraging on Aguiguan. We deployed two monitoring stations that sampled continuously all night long, both set out for one night in a forest in the Mount Lasso area and for a second night in the Kastiyu Forest. We also sampled for one night at each of these sites using ad hoc walking transects and echolocation detectors during the first part of the night, corresponding to peak times of bat echolocation activity on Aguiguan. No bats were detected. However, this survey was far from exhaustive, and additional effort using echolocation detectors over wider areas of forest and searches of caves will be needed to rule out the possibility that a small remnant population of these bats may still exist on Tinian. Similar echolocation-detector based surveys would also be useful on two other islands in the CNMI (Anatahan and Maug) where tentative sightings were reported in the early 1980s but never subsequently confirmed.

A number of considerations for future activities stem from the findings of this assessment. These are best characterized as activities related to management for conservation, monitoring, and research. Considerations for management for conservation include limiting disturbance of and access to caves used by roosting bats; and increasing the extent of native limestone forest, decreasing existing stands of invasive plants, and eliminating or avoiding actions that would reduce the amount of native limestone forest on Aguiguan. Considerations for future monitoring of sheath-tailed bats on Aguiguan include periodic monitoring of numbers of bats utilizing key caves, and monitoring the use of foraging habitat with echolocation detectors and site occupancy models. Considerations for research include searching the more inaccessible areas on Aguiguan for the presence of additional colonies that may occupy caves requiring technical climbing and caving skills to reach; increasing the foundation of ecological knowledge of this species pertinent to its conservation and management, including investigations into seasonal aspects of reproduction, roosting, and foraging biology; conducting a modern analysis of the taxonomic status of *Emballonura semicaudata* and its subspecies using combined quantitative morphometric and molecular genetic approaches; and further assessing the possible occurrence of Pacific sheath-tailed bats on Tinian and other islands.

Section II. Introduction and Objectives

Thomas J. O'Shea and Ernest W. Valdez

The subspecies of the Pacific sheath-tailed bat that once occurred throughout the Mariana Islands (*Emballonura semicaudata rotensis*) has not been well studied biologically, despite its declining status. It is a small insectivorous bat and in the Mariana Islands it is known only to roost in caves. Once found throughout the southern Mariana Islands, all available data indicate that it now only occurs as a single remnant population that roosts in a few caves on Aguiguan (e.g. Lemke 1986, see also Section III of this administrative report). There are three other subspecies of Pacific sheath-tailed bats distributed sporadically across southwestern Oceania (Koopman 1997, Helgen and Flannery 2002). However, there is little information available on basic biology of the species anywhere in its range. Reports on population status (summarized in Section III of this administrative report) suggest that in many areas it has seriously declined in abundance. A variety of factors have been hypothesized to be responsible for this decline, but no single cause has been pinpointed that is applicable to all areas. The most widely cited published assessment of the status of the Pacific sheath-tailed bat in the Mariana Islands is that of Lemke (1986), who reported seeing only a few bats on Aguiguan. Lemke's (1986) assessment prompted Nowak (1994, p. 92) to speculate that "this subspecies may thus rank as one of the world's most critically endangered mammals."

Several accounts are available that summarize the distribution, history of its status, and known aspects of the biology of Pacific sheath-tailed bats (e.g. , Bonaccorso and Allison 2008, Hutson and others 2001, U.S. Fish and Wildlife Service 2007; see also other sections of this administrative report). The declining status of Pacific sheath-tailed bat populations has caused it to be placed in various protected categories by different organizations and governments. Overall the species is categorized as Endangered by the International Union for the Conservation of Nature and Natural Resources (Hutson and others 2001, Bonaccorso and Allison 2008). The subspecies *E. s. rotensis* in the Commonwealth of the Northern Mariana Islands (CNMI) is protected by CNMI law, and is considered a Category 3 candidate for listing under the U.S. Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 2007). This categorization under U.S. law is based on the imminence and magnitude of threats, but further actions have not had the highest priority possible in part because the remaining population on Aguiguan is currently understood to be a subspecies of a more widely found species (U.S. Fish and Wildlife Service 2007, 2008). The currently accepted subspecies designation, however, is based on examination of a small series of specimens by Yamashina (1943) and a qualitative judgement with little systematic documentation by Koopman (1997). No thorough, modern quantitative morphometric or molecular genetic analyses have been conducted on this species throughout its range to determine if the subspecific level in the taxonomic hierarchy is accurate for the population in the Marianas Islands, or if full species designation may be warranted.

Given the lack of substantial background biological information pertinent to the conservation and management for Pacific sheath-tailed bats, our study had multiple objectives. In this report we grouped our results under seven separate topics or groups of topics. Each of the remaining sections treats these topics or groups of topics with separate statements of introductory information, materials and methods, results and discussion, and references cited. A final section summarizes considerations for future research and management for sheath-tailed bats on Aguiguan and elsewhere if pertinent.

Our primary effort was dedicated towards summarizing all past information on use of caves as roosts by these bats on Aguiguan, combined with results of new efforts in 2008 to re-visit these caves and obtain new counts for an up-to-date assessment of trends in abundance. Bats pose major challenges for arriving at valid estimates in population trends, many of which are reviewed in a series of papers in the volume edited by O'Shea and Bogan (2003) and summarized by O'Shea and others (2003). There are as yet no well-established, standard methods for estimating bat abundance or colony sizes with a statistically sound theoretical basis. Most bat researchers therefore rely on visual counts of bats emerging at dusk as an index to population size ("emergence counts" of Kunz 2003). As described in Section III of this report, such counts were the basis of the past estimates of colony sizes on Aguiguan and were duplicated in 2008. The surveys in 2008 were further supplemented by using a night vision device and infrared light to make daytime counts in one accessible cave, and by replicate counting to qualitatively assess variability in these counts. Information from the 2008 surveys were then combined with previously unpublished reports and data from the literature to synthesize all past and present knowledge on the distribution and status of this subspecies.

There has been one very recent major statistical advance in sampling bats for trend information. This has been the adapting of the newly developed site occupancy modeling approach in wildlife studies (e.g. MacKenzie and others 2002, 2006) to bats based on presence-absence data obtained through monitoring potential foraging habitat for their ultrasonic echolocation pulses. This combined approach was first used in studies of the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) by Gorresen and others (2008). It was adapted for the assessment of habitat use by sheath-tailed bats on Aguiguan in Section IV of this report by Gorresen and others, based in part on earlier demonstrations that bat echolocation activity can be detected in Aguiguan's native limestone forest by Esselstyn and others (2004). This carefully designed monitoring of bat-produced ultrasounds was intended to provide a baseline for future monitoring of sheath-tailed bat habitat use, an improved understanding of the areas these bats use for foraging on Aguiguan, and new information on characteristics of Pacific sheath-tailed bat echolocation calls and activity patterns.

Subsequent sections of this report deal with some basic biological and natural history information and samples pertinent to the conservation of sheath-tailed bats that were also obtained during the course of fieldwork on Aguiguan in parts of June and July 2008. These include the first description of insect prey of importance in the diet of these bats based on fecal analyses, results of the first attempts to capture sheath-tailed bats in foraging and dispersal areas, new information pertinent to understanding vital parameters of reproduction, obtaining of samples of guano for assessment of contaminant concentrations and biopsies for genetic studies in the future, new information on body size (of relevance to subspecies characteristics), and an updated summary of museums specimens of all subspecies now available for study at research museums around the world. We also report on a pilot study that attempted to assess the presence of echolocating sheath-tailed bats in likely foraging habitat on Tinian, where there has been no evidence of occurrence since pre-historic times.

Acknowledgments

The effort in 2008 was carried out through an interagency agreement between the U.S. Fish and Wildlife Service (FWS), Ecological Services field office, Honolulu, Hawaii and the U.S. Geological Survey (USGS) Fort Collins Science Center, based on a larger joint program in the CNMI by FWS and the U.S. Navy. Curt Kessler of FWS provided guidance and coordination, logistic support, and loan of equipment. Patricia Stevens of the USGS Fort Collins Science Center provided encouragement and oversight, as did Loyal Mehrhoff of the USGS Pacific Island Ecosystems Research Center. All phases of the project were enabled by the previous ground-breaking work on this subspecies by Gary Wiles and his colleagues, and by Wiles' guidance and knowledge of Aguiguan in the field. We thank the following individuals for review of various sections of this report: Frank Bonaccorso, Paul Cryan, Marcos Gorresen, Daniel Neubaum, Melissa Neubaum, T. Rodhouse, and Gary Wiles. Work in the field would not have been possible without the substantial assistance of Elvin Masga, Jess Omar, and Fabi Muna of the CNMI Division of Fish and Wildlife. Surveys on Tinian were aided by Ton Castro. Additional assistance was given by David Evangelista, Greg Camacho, John Salas, Mike Palacios, Rodney Camacho, and Jay Camacho. Marcos Gorresen and Frank Bonaccorso were supportive in the field and gave helpful suggestions throughout. Anne Brooke of the U.S. Navy provided initial suggestions in planning. Sylvan Igisomar, Director of the CNMI Division of Fish and Wildlife, gave enthusiastic approval, and the work was carried out under authority of Scientific Research Permit 01048-08 issued by the Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Section III. Current and Past Population Status and Use of Caves by Pacific Sheath-Tailed Bats (*Emballonura semicaudata rotensis*) on Aguiguan, Commonwealth of the Northern Mariana Islands

Gary J. Wiles, David J. Worthington, Jacob A. Esselstyn, Thomas J. O'Shea, and Ernest W. Valdez

ABSTRACT

The Mariana Islands subspecies of the Pacific sheath-tailed bat (*Emballonura semicaudata rotensis*) declined greatly in abundance and distribution during the 20th century. The island of Aguiguan now supports the only persisting population. We examined the abundance, roosting behavior, and distribution of this population by searching caves and hollow trees for roosting bats during surveys in 1995, 2003, and 2008. The only roosts of bats we found were in caves. Counts at caves suggest a substantial increase in abundance during the course of the study, with 98 bats recorded at five of 85 caves in 1995, 333–348 bats recorded at six of 57 caves in 2003 (including the discovery of one large colony previously unknown), and 359-466 bats recorded at five of 41 caves in 2008. Bats appeared to prefer roosting in larger caves and displayed significant fidelity toward five of the seven caves found occupied during the study. One cave consistently held the largest colony, with a range of 308–382 bats (mean [± SD] = 333 ± 33.6, n = 4) counted at emergence in 2008. Other caves served as roosts for 1–64 individuals. Most departures from roosts began 3.2 ± 8.7 min before sunset and ended 7.1 ± 8.1 min after sunset. We found no evidence of hollow tree trunks being used as roosts. As of 2008, the population of *E. s. rotensis* on Aguiguan probably numbered around 450–600 bats. Related research shows that the population relies heavily on native forest, regeneration of which is severely limited by feral goats (*Capra hircus*). Eradication of these goats combined with a reforestation program could increase and enhance foraging habitat of bats. Existing evidence supports the current designation of *E. s. rotensis* by the U.S. Fish and Wildlife Service as a candidate for listing as an endangered species under the U.S. Endangered Species Act.

INTRODUCTION

The Pacific sheath-tailed bat (*Emballonura semicaudata*) is distributed across much of Oceania, being found in the Mariana and Caroline Islands, Samoa, Tonga, Fiji, and Vanuatu (Flannery 1995, Koopman 1997, Helgen and Flannery 2002). These bats appear to be abundant at some locations, especially in the Caroline Islands (Bruner and Pratt 1979, Wiles and others 1997; G. Wiles, pers. observ.), but populations have inexplicably declined on many other islands (Lemke 1986, Grant and others 1994, Flannery 1995, Hutson and others 2001, Tarburton 2002, Palmeirim and others 2007). In the Mariana Islandss, where the endemic subspecies *E. s. rotensis* occurs (Koopman 1997), populations of sheath-tailed bats on Guam, Rota, and Saipan disappeared between the late 1940s and 1970s (Lemke 1986, Wiles and others 1995). The species occurred in recent prehistoric times on Tinian (Steadman 1999), but there are no historic records for this island. Lemke (1986) reported possible occurrences on Anatahan and Maug, but populations have not been confirmed on these islands, despite a number of visits by biologists to both islands since 1983. Although there are no previously published records of *E. s. rotensis* from Saipan, P. Krutzsch (in litt.) made several sightings of a few small insectivorous bats on this island in about 1945. These are considered to represent *E. s. rotensis* because no other microchiropteran bats occur in the archipelago.

The only known remaining population of this subspecies of Pacific sheath-tailed bat is on the island of Aguiguan (also known as Aguijan, Agiguan, and Goat Island). Biologists first recorded *E. s. rotensis* on Aguiguan in 1984 and 1985, when "three or four" bats were found in each of two caves (Lemke 1986). Subsequent observations from 1987 to 1992 documented up to 13 bats at one of the caves, but none was found at any of the few other caves examined, suggesting that the overall population was small (Rice and Taisacan 1993). The bats on Aguiguan were the only ones found in a search of 12 islands or island groups in the Northern Mariana Islands in 1983-1985 (Lemke 1986). Our main objective during this study was to conduct a more complete assessment of the Pacific sheath-tailed bat population on Aguiguan, and to synthesize all available past information pertinent to the status of this population. We developed a descriptive inventory and catalog of all caves that were searched for evidence of roosting sheath-tailed bats, including results based on field work in 2008 as well as unpublished data from our visits in 1995, 2002, and 2003. We also provide results of counts of numbers of bats using the caves that were determined to be occupied by bats. We interpret our results in relation to past findings of others as reported in the literature, explore possible causes for declines, and discuss possible measures that could enhance conservation of this population. Additional biological findings from field studies in 2008 are also provided in other sections of this administrative report.

STUDY AREA

Aguiguan (14°51'N, 145°33'E) is located in the southern Mariana Islands in western Micronesia and is administered by the U.S. Commonwealth of the Northern Mariana Islands (CNMI). The island is small (7.2 km^2) and comprised entirely of raised limestone karst, making it geologically similar to the neighboring islands of Tinian, Saipan, Rota, and much of Guam (Butler 1992, Stafford and others 2004, Jenson and others 2006). A large central plateau dominates the terrain and is bordered by a series of narrow terraces falling to the ocean. Coastal escarpments 10–40 m tall surround most of the shoreline. Maximum elevation is 166 m. Morphology of the island's caves is discussed in Stafford (2003) and Stafford and others (2004). Aguiguan's climate is tropical, with mean daily temperatures ranging from 24 to 32°C. Annual rainfall probably averages somewhat less than 2,000 mm, which is the approximate mean for Saipan 32 km to the north (Butler 1992, Lander 2004). Most rain occurs from July through November.

Aguiguan was mostly covered with native limestone forest until 1936 or 1937, when Japanese colonists began clearing large sections of the main plateau and larger terraces for sugar cane cultivation (Butler 1992). Former crop fields occupy 43% of the island and are now largely revegetated by weedy thickets of introduced plants, primarily *Lantana camara*, *Chromolaena odorata*, *Mikania scandens*, *Tridax* *procumbens*, and several grasses (Engbring and others 1986, Butler 1992, Rice 1993*a*). Limestone forest remains on about 45% of Aguiguan and grows on smaller terraces and steeper slopes (Esselstyn and others 2004, see Section IV of this report). Common tree species include *Guamia mariannae*, *Cynometra ramiflora*, *Pisonia grandis*, *Ochrosia mariannensis*, *Aglaia mariannensis*, *Ficus prolixa*, *Cerbera dilatata*, *Premna obtusifolia*, *Drypetes dolichocarpa*, *Erythrina variegata*, and *Psychotria mariana* (Chandran and others 1992; G. J. Wiles, pers. obs.), and canopy height is 7-15 m tall. Goats (*Capra hircus*) were introduced to the island in the mid-1800s (Butler 1992). Decades of overbrowsing by sizable feral goat populations have created an open forest understory dominated by two unpalatable species, *C. ramiflora* and *G. mariannae*, with little ground cover present. Goats have undoubtedly altered the species composition of the forest. Groves of secondary forest comprised of the introduced trees *Acacia confusa*, *Leucaena leucocephala*, *Triphasia trifolia*, and *Casuarina equisetifolia* occur at a number of disturbed sites. This habitat covers about 10% of the island and frequently contains some native trees (e.g., *O. mariannensis*, *G. mariannae*, and *Melanolepis multiglandulosa*) (Esselstyn and others 2004). Grassy and shrubby coastal strand occupies the remainder of the island. A control program greatly reduced goat numbers in 1989–1990 (Rice 1991, 1993*a*), but failed to eradicate them. Goats remained uncommon in 1995, but were again abundant from 2002 through 2008. The island has been uninhabited by people since the end of World War II, but is regularly visited by goat and coconut crab (*Birgus latro*) hunters from Tinian.

MATERIALS AND METHODS

Pacific sheath-tailed bats were surveyed during four trips to Aguiguan on 21–27 March 1995, 30 May–7 June 1995, 9–19 September 2003, and 19 June–15 July 2008. A few additional observations were made from 15–20 March 2002. Our study emphasized finding bats at roosting sites, thus we visited most caves previously known based on efforts of past researchers (Lemke 1986, Rice and Taisacan 1993), and also made extensive searches throughout the island for additional caves, rock crevices, and hollow trees that might serve as roosts for these bats. However, searches still remain incomplete because there are undoubtedly caves located in places that are inaccessible without technical climbing skills. We also did not find three small caves as reported by Butler (1992) and 13 caves (10 small, 3 possibly medium-sized) as reported by Stafford (2003), although Stafford (personal communication) reported no sightings of bats in these caves.

All accessible caves were entered and examined for bats or evidence of their occupation, including echolocation calls and guano. Colonies of Mariana swiftlets (*Aerodramus bartschi*), a cave-dwelling aerial insectivore, resided in at least nine of the island's caves. The presence of swiftlet guano often complicated our efforts because it can be difficult to distinguish from bat guano after it ages. However, we attempted to look for the distinctively shaped pellets of recent guano produced by insectivorous bats on walls and floors of caves in places apart from swiftlet nesting areas. Direct counts of bats roosting inside caves during the day were made whenever possible. In 2008, these were aided at some caves by the use of an infrared night vision device (model ATN NVM-14-3A, American Technologies Network Corporation, San Francisco, California) and an infrared illuminator. The interior dimensions of many caves were measured with a hip chain or visually estimated. Most of the entrances to larger caves were also measured. Interior size of caves was categorized as small, medium, or large. Small caves were generally ≤ 15 m long and 50 m^2 in floor area. Most consisted of low rock overhangs, narrow vertical crevices, or various cavities that were usually located at the bases of cliffs or underneath large boulders. Medium-sized caves generally had 50–100 m^2 of floor space and often had wider rooms than small caves. Large caves were usually >100 m^2 in floor size, with ceiling heights usually reaching 5–30 m. We also visually inspected hollow trees during the 1995 surveys to look for roosting sheath-tailed bats and guano deposits.

Evening emergence counts (Kunz 2003) of sheath-tailed bats were conducted at a number of caves that were potentially suitable for bats. Observers positioned themselves near the cave's opening, either inside or outside, to obtain the best possible vantage point for counting exiting bats. Observers remained quiet and motionless to avoid disturbing bats, and counts ended at total darkness (these bats emerge at early dusk, see below) or at least 15 minutes after the last bat emerged in cases where bats were present. Total numbers of bats exiting a cave were determined by subtracting the number of individuals entering from those departing. Observers used ultrasonic detectors (in 2003, model D-100, Pettersson Elektronik AB, Uppsala, Sweden; in 2008, AnaBat SD1 CF, Titley Electronics, Ballina, New South Wales, Australia) to assist in the detection of emerging bats at some sites. In 2003 and 2008 we used a mist net to capture a small number of bats flying inside one cave (Guano Cave, described below) on two days when counts at emergence were not conducted. In 2008 no counts were made after this potential disturbance took place.

RESULTS

Searches of Caves and Counts of Bats

We inventoried and cataloged 114 caves during the study, including sites recorded by Butler (1992) and Stafford (2003) but not visited by us (Appendix III-A). These represented 18 large, 9 medium, 74 small, and 13 undefined caves. We visited 85 caves in 1995; 57 caves in 2003, including nine not found in 1995; and 41 caves in 2008, including four not found in 1995 or 2003. Caves were distributed throughout much of Aguiguan, almost always in association with cliffs or fault lines. The two largest sites (Krisidu and Dangkolo Caves) featured single main rooms that were ≥ 50 m in length, were 15–20 m wide, and had ceiling heights of 15–20 m.

During surveys in 1995, we inspected 78 caves and conducted emergence counts at 10 caves, including two that could not be entered. Ninety-eight bats were recorded at five of the caves (Table III-1). The other five caves had no bats. Guano Cave was the only cave with bats visited in 1995 that was previously known to support bats (Table III-1). The four caves first documented in 1995 as having roosting bats were Cliff Cave, Pillar Cave, East Black Noddy Cave, and Crevice Cave. The largest colony numbered 69 bats at East Black Noddy Cave, with aggregations of 2–17 animals recorded at the other sites (Table III-1). In 2003, we inspected 52 caves and made emergence counts at eight caves, including three that were not entered. A total of 333–348 bats was counted at six caves, with bats present at the same five sites that were occupied in 1995 as well as at one newly discovered site (Fault Line Cave 1) that had a single bat (Table III-1). East Black Noddy Cave again held the largest colony, with an emergence count tallying 296 bats on 18 September. Other caves held up to 35 bats (Table III-1). Bat numbers were also larger at Guano and Pillar Caves in 2003 than in 1995.

In 2008, we visited 41 caves, inspected 34 caves internally, and made emergence counts at 18 caves, including seven that were not entered. Using minimum and maximum counts at occupied caves, a range of 359-466 bats was counted at five caves, with bats present at four of the six sites used in 1995 or 2003 and one new site, New Cave 1 (Tables III-1 and III-2). East Black Noddy Cave continued to hold the largest colony, with four emergence counts ranging from 308-382 bats (mean [± SD] = 333 ± 33.6). Internal counts at Guano Cave on six dates using the night vision device varied from 43-64 bats (mean = 55 ± 7.0). Other occupied caves held 2-12 bats. Compared to 2003, counts in 2008 were higher at East Black Noddy, Guano, and Cliff Caves, about the same at Crevice Cave, and declined to zero at Pillar Cave and Fault Line Cave 1 (Table III-1). All occupied caves were used throughout the survey period except New Cave 1, which held at least five bats on 4 July 2008, but none during visits on three other occasions in 2008 (Table III-Table III-III-2). Ten additional caves where multiple surveys were made showed no daytime use by bats (Table III-Table III-III-3).

From our observations it appears that Pacific sheath-tailed bats on Aguiguan prefer larger caves as diurnal roosts (Table III-4). Using our size criteria for caves, bats have been recorded in six large caves, one medium-sized cave, and one of unknown size. Variation in main entrance size of occupied caves ranged from 4 m wide by 25 m tall at Crevice Cave to about 1 m wide by 0.5 m tall at the upper entrance of East Black Noddy Cave (Table III-4). Swiftlets were present in seven of the eight caves inhabited by bats. We examined the trunk cavities of 22 hollow trees (21 *Pisonia grandis*, 1 *Psychotria mariana*), but found no evidence of occupation by bats. *Pisonia* hollows were typically 1–4 m tall and 20-45 cm in diameter, with their openings usually located near the base of the trunk.

Variability in Counts of Bats at Caves

Counts indicate that minor movement of bats among caves might take place, in some cases perhaps daily. We have no evidence that such movements will add a great deal of variability to the counts. Bats were always present at the two largest colonies, whereas caves with high variability in the presence or absence of bats during different visits all held small numbers of bats at any one time. Landing Cave was visited 11 times between 1984 and 2008, with bats seen on only two visits, both times in small numbers (≤ 4; Table III-1). Seasonal changes in attendance at roosts were not indicated by the results at Landing Cave: bats were present on 22 June in 1984 and 23 May 1992, whereas negative findings were recorded during June on three other visits in different years, as well as in months of January, March, and September (Table III-1). Similarly, Pillar Cave had no bats on five counts in five different years from 1985-1995 during the months of January, March, and June. However, from 2-10 bats were counted at Pillar Cave on three dates in March, June, and September in 1995-2003; none used Pillar Cave during the day on two dates in June and July 2008, but 16-21 bats entered the cave after dusk from elsewhere. Day-to-day differences were also noted within years and within field trips: Fault Line Cave 1 had one bat during the day in 2003, but none was present during the day on seven dates the cave was visited in 2008; five bats were observed at New Cave 1 on 4 July, but none on 25 June, 5 July, or 10 July in 2008; Cliff Cave had no bats in March 1995 but seven in June, and Pillar Cave had none in March 1995 but two in June (Tables III-1 and III-2).

Three roosts consistently had bats on each visit from 1995-2008: Guano Cave, East Black Noddy Cave complex, and Crevice Cave. The Guano and East Black Noddy caves have the largest colonies known, whereas Crevice Cave had only 2-3 adult bats on each count. Counts made during the day inside Guano Cave using a night vision device on six dates between 20 June and 7 July in 2008 (Table III-2) were different on each date, ranging from 43 to 64 bats (coefficient of variation 12.8 %). Counts made during flyouts at dusk at East Black Noddy Cave on four dates also varied similarly (coefficient of variation 10.1 %), and ranged between 308 and 382 bats. It is likely that some of this variation is due to movements of bats among different roosts, as is more clearly seen in the caves that vary from none to small numbers of bats. However, counts are also subject to a number of other sources of variability, including observer variability, environmental effects, and bias from unknown sources. Even using the night vision device with supplemental infrared illumination at Guano Cave, a single observer recording three separate tallies on each visit on five dates in 2008 had variability in counts within each day. On three of the five days the three separate counts only varied by a single bat each day. On two dates however, the three counts varied by a range of seven bats on one day and by 11 bats on the other. The range was primarily attributable to variability in the ability to discern large pups that roosted next to their mothers.

Observations of Sheath-Tailed Bat Behavior at Caves

Roosting behavior of bats was observed only at Guano and Crevice Caves. At Guano Cave in 1995, all bats roosted in one area of the cave spaced apart about 7–20 cm on the open dome-like ceiling in a small chute at the rear of the cave's dark main room. The roosting area was the ighest point in the cave. This same dome also was used in 2003 and 2008. In 2008 the night vision equipment allowed more detailed observation. The bats roosted singly (or a female next to young), were spaced about 5-30 cm apart on the ceiling and upper walls of the dome, appeared to have most of their ventral surfaces appressed to the rock surface with heads facing downwards, and were dispersed in a pattern intermediate between a regular and random spacing. This cave was also occupied by about 250 or more cave swiftlets. Most swiftlets did not roost in the dome occupied by the bats, but in adjoining areas of the large main room that were nearer the cave entrance. The few swiftlets that also roosted in the chamber were lower than the bats and against the walls of the dome at Crevice Cave in 1995, three bats roosted about 30 cm apart while roosting prone against the vertical wall of a side chamber. Although the room was in the darkest portion of the cave, the animals remained in dim twilight. This location was also occupied in 2003 and 2008. Because emergence and roost counts were similar at both caves, we are confident that few if any uncounted bats were hidden in cracks or crevices (we found no evidence that Pacific sheath-tailed bats at Aguiguan roost in narrow crevices or cracks in rock, and this is generally consistent with the literature for the species elsewhere). Bats were not detected during inspections of the main room at East Black Noddy Cave in 1995 and by K. Stafford (pers. comm.) in 2003, and therefore presumably roosted in an unexamined 7-m-long passage leading in from the upper entrance. We did not observe roosting bats at Pillar Cave, suggesting that roosting occurred in an inaccessible area. We were unable to enter Cliff Cave, and the bats at Fault Line Cave 1 and New Cave 1 were disturbed before they were observed.

Overall, total duration of sheath-tailed bat emergences from roosting caves averaged 18.3 ± 11.7 (SD) min, with most exits occurring during a mean period of 10.4 ± 5.6 min (Table III-5). On average, most departures began 3.2 ± 8.7 min before sunset and ended 7.1 ± 8.1 min after sunset. There was little or no overlap of activity between sheath-tailed bats and swiftlets during most (6 of 8) counts, with the period of most bat exits ending an average of 3.6 ± 6.6 min before the period of most swiftlet entries (Table III-5). However, scheduling of the emergence periods varied with colony size, with larger colonies emerging over longer periods, beginning earlier in relation to sunset, and ending closer to the time when swiftlets began entering the cave to roost for the night (Table III-6). Bats sometimes emitted audible high-pitched calls prior to emerging, presumably as they flew about inside the cave. Most individuals exited their caves by flying straight from the entrance, but some circled briefly outside before leaving the vicinity. At East Black Noddy and Guano Caves, a few emerging bats made one or several circling forays 5–15 m outside the caves' entrances, and then re-entered the cave or departed. Bats at smaller colonies exited singly, but at East Black Noddy Cave, some departed in groups of two to four. On 17 September 2003, a light rain shower several minutes after all bats had departed East Black Noddy Cave caused 50–75 bats to return immediately to the cave. This suggested that some bats linger in the general vicinity of the cave after emerging. Inspections of Guano Cave after counting ended in 2003 and 2008 showed that no bats remained inside immediately after the evening emergence was completed. We captured six bats inside Guano Cave in 2003, all of which were females.

In 2008, post-emergence use of caves as night roosts was detected at three caves, none of which were found to be used as day roosts during field work this year. We recorded 13 bats entering Pillar Cave from 18:47 to 19:02 h on 21 June, with chattering vocalizations heard from inside the cave several times afterwards, indicating that roosting had occurred. At least one of the calls came from the cave's outer room. Inspection of the cave with night vision equipment from 20:00 to 20:15 h found no bats present. On 7 July, during our only other evening count at this site, 21 bats entered from 18:41 to 18:56 h and appeared to remain inside. On 24 June we observed a single bat circling repeatedly inside the main entryway of Cave 63 (a small cave) at 1937 hr. On 11 July at 1847 we observed similar behavior by a bat that flew into the main opening of Fault Line Cave 1 and made audible vocalizations (short "chirps") as it remained inside for a few minutes. It then exited through a small opening at the ceiling of the cave after one of us entered at the main opening.

One other notable observation was that of an early evening (18:41-19:20 h) passage of at least 43-47 sheath-tailed bats flying singly past the vicinity of Caves 66-68, 94, 95, and 101 on several nights (see also Section VI of this administrative report). All of the bats followed a similar route through the forest understory, coming uphill from undetermined source to the west and continuing to the south or east. None came from any of the caves in the immediate area. Use of bat detectors revealed that few if any of the bats remained in the area after 19:20 to at least 22:00.

DISCUSSION

Pacific Sheath-Tailed Bats on Aguiguan

Our surveys in 1995, 2003, and 2008 represent the only attempts to assess the status of the Pacific sheath-tailed bat population on Aguiguan since 1984 (Lemke 1986). Over this period of time counts increased. We counted totals of 98 bats in 1995, 333–348 bats in 2003, and 359–466 bats in 2008. Bats occurred in only seven of the 95 caves examined (i.e., those entered or surveyed using emergence counts), even though many unoccupied sites appeared suitable as roosts. Despite good coverage of the island's inland cave system during the study, a few undocumented caves occupied by colonies of unknown size may be present. By comparison, most of the coastal cliffs ringing the island could not be surveyed for caves because they are difficult and dangerous to access. Several large caves are known in these escarpments, thus further assessment for their use as roosts by bats is needed, especially because *E. semicaudata* inhabits sea caves elsewhere in its range (Grant and others 1994). With the exception of one area, acoustic surveys conducted across the island in 2003 and 2008 did not detect concentrations of bat activity away from areas with known colonies (Esselstyn and others 2004, Section IV of this administrative report). Substantial early evening bat activity was noted in 2008 and to a lesser extent in 2003 at an acoustic station near the island's northeast coast, suggesting the presence of an undocumented colony in that general area. However, Pacific sheath-tailed bats are known to commute distances exceeding 5 km to reach foraging sites in Palau (Wiles and others 1997), thus it may be possible that the bats at this station originated from East Black Noddy Cave, which is located 1.7 km to the west. Based on the likelihood that small numbers of additional colonies may remain undetected, it is possible that the total current sheath-tailed bat population on Aguiguan numbers more than our maximum count of 466.

Our surveys documented larger numbers of sheath-tailed bats in 1995 than those counted by previous observers (Lemke 1986, Rice and Taisacan 1993), but much of this can be attributed to improved survey coverage. However, data indicate that marked population growth had occurred since 1995. Colony size grew at three of five caves from 1995 to 2003, with numbers expanding more than four fold at the largest colony. Additional but more modest growth continued from 2003 to 2008. Bat numbers at Guano Cave are particularly illustrative and have increased from four in 1985 (Lemke 1986) to about 55 in 2008. Perhaps the population of sheath-tailed bats on Aguiguan has been increasing since the mid-1980s after a past bottleneck. Typhoons can be a major source of bat mortality on other Pacific Islands (see below), and at least two major typhoons struck the island during this time (Lander 2004; C. Kessler, personal communication). However, the increase in numbers suggests that the sheath-tailed bat population on Aguiguan was not severely impacted by these typhoons. Although our results show some variability in counts that likely indicate movements of small numbers of bats among roosts, and we also note potential biases in variation in counts from other sources, such variation seems unlikely to explain the large increases in colony sizes we have documented at some caves. Instead we think our results reflect true growth in the populations using the major caves. Surveys at East Black Noddy (upper entrance) and Guano Caves included counts made by the same person (GJW) in all three surveys and were in close agreement with simultaneous counts made by the rest of us, thus major inter-observer variability should not be an important source of error in our results.

An increasing trend on Aguiguan since 1995 is especially noteworthy given the many reported declines elsewhere in the species' range in recent decades (Lemke 1986, Grant and others 1994, Flannery 1995, Hutson and others 2001, Tarburton 2002, Palmeirim and others 2007). Is it theoretically plausible that the changes in counts we observed are due to intrinsic population growth? A basic underlying model often used in analyses of population trend data is $N_t = N_0\lambda^t$, where N_0 is the initial population size, N_t is population size at time t, and λ is the population growth rate (*e.g.* Eberhardt 2002). An estimate of λ can be calculated using the equation $\ln(N_t) = \ln(N_0) + t\ln(\lambda)$. Although this model is based on a number of assumptions that are unknown for Pacific sheath-tailed bats and is usually applied for multiple time series, we use it in a simplified way to determine if it is plausible for the observed increases to be due to intrinsic population growth. The model yields an estimated λ = 1.13 at Black Noddy Cave and λ = 1.09 at Guano Cave between 1995 and 2008. There have been few empirically derived estimates for annual population growth rates in insectivorous bats, but those that have been calculated for growing populations of other species of bats using more sophisticated models and accurate vital parameter data are consistent with the calculations of λ for these two largest colonies of Pacific sheath-tailed bats at Aguiguan. These estimates for other species of insectivorous bats with seasonal breeding and litter sizes of one range from λ = 1.03-1.22 (Frick and others 2005, Pryde and others 2005). We do not suggest that the specific growth rates we calculated above should be considered accurate for this population, but only that they crudely demonstrate that it is indeed plausible that the magnitudes of the observed changes in counts may be due to population growth. The future trend of the population of sheath-tailed bats on Aguiguan is impossible to predict, but numbers of bats counted in 2003 and 2008 resemble those of the ecologically similar Mariana swiftlet, whose surveyed numbers regularly exceed 400 birds (Cruz and others 2008; G. J. Wiles, unpubl. data). This current similarity in abundance may indicate that bat numbers are reaching their upper limit on the island.

The colony of up to 382 bats at East Black Noddy Cave is by far the largest ever recorded for *E. s. rotensis*. Counts at other roosts on Aguiguan ranged from 1-64 individuals. Our capture of six females and no males at Guano Cave in 2003 and five females and no males at this cave in 2008 (see Section VI of this administrative report) suggests that this colony may have been comprised mostly of females. Aggregations of fewer than 25 bats and segregation of the sexes are common roosting traits among bats in the genus *Emballonura* (Flannery 1995, Bonaccorso 1998, Nowak 1999). Nevertheless, larger colonies with up to several hundred bats may have once been common in the Mariana Islands, as has been found with *E. s. palauensis* in Palau (Wiles and Conry 1990, Wiles and others 1997). Roosts of this size are also known for *E. s. sulcata* in Chuuk (Bruner and Pratt 1979). Amerson and others (1982) documented a cave in American Samoa with perhaps as many as 10,000 *E. s. semicaudata*.

Aguiguan's bats appear to roost exclusively in caves, which resembles the behavior of *E. s. semicaudata* and *E. s. palauensis* (Grant and others 1994, Wiles and others 1997). By contrast, some *E. s. sulcata* colonies select tree cavities as day roosts on Pohnpei (D. W. Buden, pers. comm.). Most other members of the genus reside in caves (e.g. Goodman and others 2006, Bonaccorso 1998), especially in or near the twilight zones of smaller caves, but several species also roost in foliage, hollow logs, and human-built structures (Flannery 1995, Nowak 1999, Kingston and others 2006). Results of surveys on Aguiguan (Table III-1) indicate that sheath-tailed bats may exhibit strong fidelity to some of these caves. Guano Cave, for example, appears to have been occupied since at least 1985, while three other caves (Crevice, East Black Noddy, and Cliff caves) were occupied during each of our visits in 1995, 2003, and 2008. Other sites, such as Pillar, Landing, Fault Line 1, and New 1 Caves, may be inhabited temporarily. We caution that we cannot vouch for the accuracy of counts made prior to May 1995 when none of us was present, especially those at Cliff and Pillar Caves. Surveys in 2008 were the first to attempt replicate counts at the same roosts on different days. Results from East Black Noddy and Guano Caves indicate that numbers of bats roosting at these sites will vary over periods of several days. Emergence counts like those made at East Black Noddy Cave can be susceptible to observer error, which may account for some of the variation recorded. However, the direct counts of roosting bats made at Guano Cave with night vision equipment should be more accurate. We recommend that future surveys at these two important roosts routinely incorporate counts on multiple dates to better assess their variation. The lack of measures of variation in counts of emerging bats is a common problem in studies of most species of bats throughout the U.S. and territories, but is critical for assessing trends in abundance (Ellison and others 2003).

This study is the first to document the use of caves as night roosts by *E. semicaudata*. Night-roosting behavior has many potential functions in bats (Ormsbee and others 2007). Each of the three caves observed to be used at night in this study was occupied at dusk or shortly thereafter, suggesting that food digestion was not a goal of the animals involved. Based on the presence of multiple animals and vocalizations, Pillar Cave may have served as a site for social interaction, such as mating or information transfer.

Decline of *E. s. rotensis* in the Marianas Islands

Causes for the overall decline of *E. s. rotensis* in the southern Marianas are unclear. Extirpations of sheath-tailed bats on Rota, Saipan, and Guam roughly coincided with declines or population losses in Mariana swiftlets, suggesting that both species experienced common threats, perhaps because of their similar roosting and feeding habits. Swiftlets no longer occur on Rota, but persist in low to moderate numbers on Saipan and Guam (Engbring and others 1986; Cruz and others 2008; G. Wiles, unpubl. data).

For example, human occupation and warfare during World War II heavily impacted many caves in the Marianas, when Japanese troops used caves as defensive fortifications. Grenades and flame-throwers were commonly used by the U.S. military to eliminate Japanese soldiers using these fortified caves. Such disturbance presumably harmed numerous bat and swiftlet colonies, but unless populations were completely eliminated should have been a temporary effect that would have subsided after the war.

Since then, visitation of caves by hunters, vandals, hikers, and guano miners has continued (U.S. Fish and Wildlife Service 1992), but has probably not been extensive enough at most sites since the 1980s to be problematic. On Aguiguan, several caves (including Guano Cave and Fault Line Cave 1) show evidence of extensive use by the Japanese before or during the war, and it is unlikely that bats occupied the caves at that time. However, there was no combat or destructive use of munitions in caves on Aguiguan (Butler 1992). Guano Cave has also been used for small-scale guano mining (U.S. Fish and Wildlife Service 1992). Many caves on other islands show similar signs of disturbance (U.S. Fish and Wildlife Service 1992; G. Wiles, pers. obs.). By contrast, Cliff Cave has probably never been entered by humans because of its high cliffside location. East Black Noddy Cave, which holds the largest documented number of bats on Aguiguan, has also probably received very little disturbance from people since the war because it is difficult to access. Entry of caves by introduced ungulates is also potentially disruptive, especially on Aguiguan, where feral goats habitually seek shelter in many caves.

Historical pesticide contamination may have posed significant problems for sheath-tailed bats in the Marianas, but this has not been thoroughly investigated (see Section VIII of this administrative report). Liberal use of compounds such as DDT and malathion is known to have occurred between the 1940s and 1970s (Baker 1946, Townes 1946, Drahos 1977, Jenkins 1983). Applications were most intense on Guam, Saipan, and Tinian (Townes 1946) because of their larger human populations and the presence of American military bases. Residues of the break-down product DDE have been found in swiftlet tissues and guano samples from Guam (Drahos 1977, Grue 1985), but tests by Grue (1985) yielded no evidence to support the hypothesis that poisoning by DDT or DDE had caused declines among Guam's avifauna. Concentrations of DDT and DDE in swiftlet guano measured in 1981 were much less than those associated with avian mortality or reproductive failure, and an order of magnitude less than concentrations in bat guano that can be linked to mortality in insectivorous bats (Clark and others, 1982, 1995; Clark and Shore 2001). Concentrations of contaminants have never been measured in sheath-tailed bat guano or tissues. Additionally, the carbamate and organophosphate insecticides that were also used are not persistent in tissues or guano, and exposure of bats or swiftlets to these compounds has not been assessed. Some of these compounds were likely responsible for deaths of bats in the United States in the 1960s (Clark and Shore 2001). It is also possible that sheath-tailed bats and swiftlets could have been at risk if they or their insect prey base were more susceptible to pesticide contamination than other animals because of physiological differences in organochlorine accumulation or differential vulnerability at various stages in their life history (Clark and Shore 2001). However, DDT was used extensively in Palau in the 1940s (Baker 1946) and probably thereafter, but sheath-tailed bats remain abundant there (Wiles and others 1997). Development of DDT as an insecticide did not occur until the 1940s (Metcalf 1973). It is unknown if other pesticides were used by Japanese colonists on sugar plantations at Aguiguan prior to World War II. Aguiguan was neither populated nor used agriculturally after the war, and thus it is unlikely that significant amounts of pesticides were applied to the island during the period when they were in use elsewhere in the Marianas. A likely absence of the intensive use of pesticides on Aguiguan could have contributed to the persistence of sheath-tailed bats there. The apparently low numbers of bats on Aguiguan in the 1980s in comparison with 2008 (e.g. at Guano Cave) are enigmatic in relation to effects of contaminants. Samples of guano from Aguiguan were taken in 2008 (see Section VIII of this administrative report) and their analysis for contaminants might be instructive in this regard.

Because *E. s. rotensis* forages almost exclusively in forests (Esselstyn and others 2004; see Section IV of this administrative report), it seems likely that extensive deforestation in the southern Marianas has contributed to reduced populations of sheath-tailed bats. From the 1920s to early 1940s, Japanese colonists cleared from 75% to as much as 98% of Saipan, Tinian, and Rota (Bowers 1951) and about 43% of Aguiguan (Engbring and others 1986) for agriculture and other activities. Construction of major American military installations on Guam, Saipan, and Tinian during and after the war caused additional habitat loss, as did extensive civilian development on Saipan and Guam in subsequent decades. On Aguiguan, few of the fields cleared before the onset of World War II have returned to forest cover. This means that the sheath-tailed bat population is largely restricted to feeding within the remaining 4 km^2 of forested land available on the island. There was no use of munitions in caves on Aguiguan during World War II (Butler 1992), and the large number of unoccupied inland caves with suitable temperatures (see also Section VI) suggests that roost site availability does not limit the population of sheath-tailed bats on Aguiguan. Deforestation is likely the major current limiting factor, and is known to be a major cause of bat declines and losses elsewhere in the world (e.g., Brosset and others 1996, Lane and others 2006; Wiles and Brooke, in press).

We found no evidence of predation on sheath-tailed bats on Aguiguan. Monitor lizards (*Varanus indicus*), which were likely introduced to the Marianas after European contact (Pregill 1998), are abundant on Aguiguan and represent a potential predator of sheath-tailed bats. They are adept climbers and may be able to reach day-roosting bats in hollow tree trunks or smaller caves with low ceilings. Although such predation may currently be insignificant, it may have influenced the selection of the roost sites in larger caves now used by bats. Introduced rats and large geckos are common in some caves and have the potential to take young bats at roosts on occasion. Rats are unlikely to reach the high walls and ceilings used by bats in most caves, however, and adult bats are typically alert and will fly readily when threatened. Avian predation is probably limited to occasional owls in migration and the resident diurnal collared kingfisher (*Todirhamphus chloris*). Predation by the introduced brown tree snake (*Boiga irregularis*) has devastated native wildlife populations on Guam (Fritts and Rodda 1998) and currently prevents swiftlet recovery on the island (Wiles and others 2003). Brown tree snakes conceivably contributed to declines or caused losses in sheath-tailed bats in southern Guam during the 1950s and 1960s, but probably played no role in the bat's subsequent demise in northern Guam. Snakes did not invade northernmost Guam in significant numbers until the late 1970s (Savidge 1987, Wiles and others 2003), which was at least a decade after serious declines in *E. s. rotensis* numbers were noted there (Perez 1972) and 6-7 years after the last known sighting in 1972. Brown tree snakes do not occur on Aguiguan, but have the potential to be predators of sheath-tailed bats if they were to reach the island.

Grant and others (1994) identified a succession of severe typhoons as a possible contributing factor in the recent decline of *E. s. semicaudata* in Samoa. This cause is unlikely to be related to the overall decline throughout the Marianas. However, because of Aguiguan's small land area and bat population, it is conceivable that an unusually intense storm or series of storms could severely impact the species by precluding foraging during storms, damaging important foraging habitat by destroying vegetation that its prey depends upon, or flooding colonies in seaside caves. Direct mortality from high winds blowing into exposed caves is also possible, as seen on Guam, where Supertyphoon Pongsona killed at least 30 roosting swiftlets at a cave in 2002 (C. Clark, pers. comm.).

When viewed in conjunction with the extirpation of Pacific sheath-tailed bats on other Mariana Islands, this study suggests that *E. s. rotensis* is highly vulnerable to extinction, with probably no more than a few hundred of these bats restricted to one very small island. Preservation of this bat hinges on the maintenance of forested habitat and safe roosting sites. Eradication or strict management of goats is a key recommendation for conserving Aguiguan's forests. This will greatly improve regeneration of native tree species and insure the long-term stability of forests on the island. A reforestation program should be initiated to replant sizable areas of weedy fields with native trees. *Emballonura s. rotensis* and virtually all other native wildlife species would benefit from such treatment. Although not frequent, human visitation to Aguiguan occurs, primarily by hunters from Tinian. Interest in developing the island for ecotourism has also been expressed in the past (J. de Cruz, pers. comm.). If human visitation increases from increased hunting or ecotourism, bat colonies at some of the easily accessible and reasonably well known caves (e.g., Guano Cave) will be at risk from irresponsible visitation. Additionally, ongoing efforts to prevent the establishment of brown tree snakes in the CNMI are an obvious priority for protecting this bat population.

Expanded study of sheath-tailed bats on Aguiguan is needed to provide additional information on population size, vital parameters, basic ecology and natural history, genetics, and important limiting factors. A priority for future surveys should be improved assessment of use of coastal caves in areas that cannot be reached without technical climbing expertise, as well as additional efforts to re-survey areas with caves visited in the past. We recommend that additional paleontological work, similar to that conducted by Koopman and Steadman (1995) and Steadman (1999), be conducted to learn more about past use of caves by these bats on Aguiguan.

Despite its rarity, neither the Pacific sheath-tailed bat nor its habitat is afforded protection in the U.S. possessions where it presently occurs. The species is on the CNMI list of threatened or endangered species, but this law provides no protection to the bat or its habitat. Under U.S. federal law, the U.S. Fish and Wildlife Service has categorized the bat as a candidate species, meaning that sufficient information is available to consider listing it as threatened or endangered. However, lack of funding, its subspecific status, and other constraints have precluded proceeding with listing (U.S. Fish and Wildlife Service 2002, 2007). Greater protection could prohibit take of the bat and help enhance its habitat and conservation.

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Table III-1. Numbers of Pacific sheath-tailed bats recorded at seven caves on Aguiguan, Mariana Islands, from 1984-2008, as determined by direct counts of day-roosting bats or evening emergence counts. Fields with dashes indicate that no counts were made.

	Cave									
					East Black Noddy					
Date	Landing	Guano	Cliff	Pillar	Upper Entrance	Middle Entrance	Crevice	Fault Line Cave 1	New Cave 1	References[a]
22 June 1984	3-4[b]	-	-	-	-	-	-	-	-	1
January 1985	0[b,c]	4[b]	0[c]	0[c]	-	-	-	-	-	1, 2
18 July 1985	-	2[b]	-	-	-	-	-	-	-	3
28 Feb-1 March 1987	0[c]	3[b]	-	0[c]	-	-	-	-	-	3, 4, 5
6-9 June 1988	0[c]	5[b]	-	0[c]	-	-	-	-	0[c]	3, 4, 5
21 September 1989	-	13[b]	-	-	-	-	-	-	-	3, 5
March 1992	0[b]	9[b]	0[c]	0[c]	-	-	-	-	-	3, 4
23 May 1992	2[c]	-	-	-	-	-	-	-	-	6
23, 26 March 1995	0[b]	15[b], 16[b]	0[c]	0[c]	64[c]	5[c]	-	-	-	7
31 May-6 June 1995	0[b,c]	17[b,c], 16[b]	7[c]	2[c]	-	-	3[b,c]	-	-	7
15-20 March 2002	0[b]	15[c]	-	5[c]	-	-	-	-	-	7

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13, 28 May 2003	-	-	-	-	-[d]	-[d]	2[b]	-	-	8
9-19 Sept 2003	0[b]	25-35[c]	4[e]	5-10[c]	280[c]	16[c]	2[c]	1[b]	0[b]	7
19 June-15 July 2008	0[b]	55[b,f]	6-12[c]	0[c]	277[c,g]	56[c,g]	2, 3[b,c]	0[b]	0, 5[b,c]	7

Note: Results from Cliff and Pillar Caves in 1985-1992 were obtained during evening arrival counts of Mariana swiftlets (Rice 1993*b*, Rice and Taisacan 1993). Bats were not detected during bat emergence counts at Dangkolo, Krisidu, West Black Noddy, New Cave 3, and No. 18 Caves in 1995; at Dangkolo, Krisidu, and E Caves in 2003; or at Dangkolo, New Caves 2 and 3, No. 26, 28, 64, 65, 66, 67, 95, and 102 Caves in 2008.

[a] References: 1, Lemke (1986); 2, Reichel and Glass (1988); 3, Rice and Taisacan (1993); 4, Rice (1993*b*); 5, unpublished CNMI Division of Fish and Wildlife trip reports; 6, Craig and Chandran (1992); 7, this study; and 8, K. W. Stafford (pers. comm.).

[b] Direct roost count.

[c] Emergence count.

[d] Bats were not detected and were likely missed.

[e] Partial emergence count.

[f] Number represents the mean of six direct roost counts made with a night vision device.

[g] Number represents the mean of multiple emergence counts (see Table III-2).

Table III-2. Count results at caves occupied by Pacific sheath-tailed bats on Aguiguan, Mariana Islands, from 19 June-15 July 2008.

Cave	Date	No. Bats Recorded	Survey Period	Survey Method	Notes
New Cave 1	25 June	0	Dusk	Emergence	Only the large entrance was counted
New Cave 1	4 July	5	Day	Internal	Bats were seen briefly only while in flight; caves walls not scanned for more bats
New Cave 1	5 July	0	Day	Internal	
New Cave 1	5 July	0	Dusk	Emergence	Both entrances counted
New Cave 1	10 July	0	Day	Internal	
Crevice Cave	23 June	3	Day	Internal	2 adults, 1 pup
Crevice Cave	23 June	2	Dusk	Emergence	
Crevice Cave	27 June	4	Dusk, night	Emergence, internal	3 adults departed, 1 pup remained
Crevice Cave	10 July	2	Day	Internal	2 adults
Guano Cave	20 June	56	Day	Internal	Night vision device used for count
Guano Cave	21 June	52	Day	Internal	Night vision device used for count
Guano Cave	25 June	64	Day	Internal	Night vision device used for count
Guano Cave	28 June	43	Day	Internal	Night vision device used for count
Guano Cave	30 June	58	Day	Internal	Night vision device used for count
Guano Cave	7 July	54	Day	Internal	Night vision device used for count
East Black Noddy Cave	22 June	308	Dusk	Emergence	270 bats counted at west entrance, 38 at middle entrance
East Black Noddy Cave	27 June	382	Dusk	Emergence	321 bats counted at west entrance, 61 at middle entrance
East Black Noddy Cave	1 July	323	Dusk	Emergence	260 bats counted at west entrance, 63 at middle entrance
East Black Noddy Cave	5 July	317	Dusk	Emergence	255 bats counted at west entrance, 62 at middle entrance

Table III-3. Survey efforts at caves visited more than once that were not occupied by day-roosting Pacific sheath-tailed bats on Aguiguan, Mariana Islands, from 19 June-15 July 2008.

Cave	Date	Survey Period	Survey Method	Notes
Dankolo Cave	23 June	Day	Internal	
Dankolo Cave	27 June	Day	Internal	
Dankolo Cave	27 June	Dusk	Emergence	
Dankolo Cave	10 July	Day	Internal	
Cave 28	23 June	Day	Internal	
Cave 28	23 June	Dusk	Emergence	
Stairway Cave	27 June	Day	Internal	
Stairway Cave	9 July	Day	Internal	
Cave 65	24 June	Dusk	Emergence	
Cave 65	26 June	Day	Internal	
Cave 66	24 June	Dusk	Emergence	
Cave 66	26 June	Day	Entrance	
Cave 66	26 June	Dusk	Emergence	
Cave 67	26 June	Day	Internal	
Cave 67	26 June	Dusk	Emergence	
Cave 68	24 June	Day	Internal	
Cave 68	27 June	Day	Internal	
Cave 68	3 July	Day	Internal	
Cave 68	13 July	Day	Internal	
Pillar Cave	21 June	Day	Internal	
Pillar Cave	21 June	Dusk	Emergence	16 bats entered cave at dusk to roost
Pillar Cave	7 July	Day	Internal	
Pillar Cave	7 July	Dusk	Emergence	21 bats entered cave at dusk to roost
Fault Line Cave 1	21 June	Day	Internal	
Fault Line Cave 1	24 June	Day	Internal	
Fault Line Cave 1	26 June	Dusk	Emergence	Only the rear entrance was counted
Fault Line Cave 1	30 June	Day	Internal	
Fault Line Cave 1	11 July	Day	Internal	
Fault Line Cave 1	11 July	Dusk	Internal	1 bat seen entering cave; cave inspection found no other bats
Fault Line Cave 1	13 July	Day	Internal	
Fault Line Cave 1	14 July	Day	Internal	
Cave 95	24 June	Day	Entrance	
Cave 95	26 June	Dusk	Emergence	

Table III-4. Descriptions of caves occupied by Pacific sheath-tailed bats on Aguiguan, Mariana Islands. (S) designates sites with swiftlet colonies.

Cave Name	Description
Landing Cave	Large. Main chamber is 23 m long, 15 m wide, and 16 m tall at highest point. Two smaller chambers extend roughly 35 and 13 m beyond rear of main chamber. Much of cave is well lit, but portions are completely dark. Cave is damp and algae grows on most surfaces. Entrance is about 8.5 m wide and 16 m high. (S)
Guano Cave	Large. Main chamber is 20 m long, 3-5.5 m wide, and 7-18 m tall, with nearly vertical walls and a dome-like ceiling. A smaller side chamber is 5 m long, 2-3 m wide, and 7-9 m tall. Both rooms are completely dark. Two entrances occur side by side and measure 7 m wide by 2 m tall and 1 m wide by 4 m tall. (S)
Cliff Cave	Size unknown, but probably medium-sized or large. Located high up a cliff; not entered. Cave has two entrances, with west opening being larger at about 1 m wide by 2.5 m tall. (S)
Pillar Cave	Large. A single tunnel. Front section is a large well-lit dome, 20 m long, 5-10 m wide, and 8-15 m tall. Rear section is narrow and dark, 30 m long, 0.7-2.5 m wide, and 3-10 m tall. Entrance is 10 m wide. (S)
East Black Noddy Cave	Large. Main room angles steeply upward and is 12 m long by 45 m wide, with a ceiling height of 3-5 m. Floor is a jumbled mass of boulders. A smaller room is at the bottom. Both rooms are completely dark. Three entrances exist. An upper western entrance, 1 m wide by 0.5 m tall, is located high up a cliff and connects to the main room via a 7-m-long and 2-m-wide passage. A lower middle entrance, 2 m wide by 3 m tall, is a nearly vertical shaft going upward about 12 m. A lower eastern entrance, 0.3 m wide by 0.6 m tall, connects to the smaller room. (S)
Crevice Cave	Large. Main section is a narrow crevice 30 m long, 1-2 m wide, and 25 m tall. It extends vertically to the terrace above and is open at the top along its entire

	length. Bats inhabit a small dimly-lit upward curving chamber off to side, which is 5 m long, 0.3-1.2 m wide, 8 m tall, and the darkest part of the cave. Main entrance is 4 m wide by 25 m tall. (S)
Fault Line Cave 1	Medium-sized. Main chamber is 15 m long, 5-6 m wide, 10 m tall, and dimly lit. Two main openings present, with largest being 0.6-1.0 m wide and 2 m tall.
New Cave 1	Large. Main chamber is 9-10 m long, 5 m wide, and 7-10 m tall, with two large entrance chambers connecting to it. The largest of these is 10 m long, 3-6 m wide, and 4-15 m tall, and full of boulders; the second is 15 m long, 2-5 m wide, and 2-5 m tall. At least two other smaller openings also present. (S).

Table III-5. Emergence times of Pacific sheath-tailed bats and arrival times of Mariana swiftlets during evening counts at caves on Aguiguan, Mariana Islands.

			Sheath-Tailed Bats		
Cave	**Date**	**Time of Sunset (hr)**	**Time of initial and Final Exits (hr)**	**Time of Most Exits (hr)**	**Arrival Times of Most Swiftlets (hr)**
East Black Noddy Cave	26 March 1995	1829	1828-1841	1830-1838	1840-1900
East Black Noddy Cave	17 Sept 2003	1818	1810-1828	1812-1823	1820-1845
East Black Noddy Cave	18 Sept 2003	1818	1808-1828	1810-1823	-[a]
East Black Noddy Cave	22 June 2008	1850	1833-1857	1835-1850	1852-1910
East Black Noddy Cave	27 June 2008	1851	1836-1912	1844-1902	1905-1915
East Black Noddy Cave	1 July 2008	1851	1835-1911	1840-1855	-
East Black Noddy Cave	5 July 2008	1852	1834-1905	1840-1900	-
Guano Cave	23 March 1995	1829	1839-1846	1839-1846	1840-1855
Guano Cave	31 May 1995	1844	1844-1855	1844-1855	1902-1919
Guano Cave	18 March 2002	1828	1833-1912	1833-1851	-
Guano Cave	10 Sept 2003	1824	1807-1825	1810-1820	-

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Guano Cave	21 June 2008	1850	1837-1900	-	-
Cliff Cave	1 June 1995	1844	1840-1850	1840-1850	1900-1910
Cliff Cave	21 June 2008	1850	1852-1903	1852-1900	-
Pillar Cave	1 June 1995	1844	1846	1846	1900-1914
Pillar Cave	15 March 2002	1828	1845-1850	1845-1850	-
Crevice Cave	6 June 1995	1845	1837-1900	1837-1840	-
Crevice Cave	23 June 2008	1850	1844-1848	1844-1848	-

[a] - = times not recorded.

Table III-6. Characteristics of Pacific sheath-tailed bat emergence periods in relation to colony size. Specific times for emergence periods appear in Table III-5.

Characteristic	**Large Colonies (≥ 232 bats)**	**Small Colonies (≤ 69 bats)**
	Mean ± SD	Mean ± SD
Length of emergence period from 1st bat to last	27.5 ± 7.9 min (*n* = 6)	13.8 ± 10.6 min (*n* = 12)
Length of period when "most" bats emerged	15.3 ± 3.3 min (*n* = 6)	7.7 ± 4.6 min (*n* = 11)
Beginning time in relation to sunset	9.8 ± 3.4 min before (*n* = 6)	0.5 ± 8.6 min after (*n* = 11)
Ending time in relation to sunset	5.5 ± 3.7 min after (*n* = 6)	8.1 ± 9.8 min after (*n* = 11)
Ending of period when "most" bats emerged in relation to period of most swiftlet entries	0.7 ± 3.2 min before (*n* = 3)	5.4 ± 7.7 min before (*n* = 5)

Appendix III-A. Descriptive catalog of all caves visited on Aguiguan in March, May, and June 1995, September 2003, and June-July 2008. Caves were entered whenever possible and were categorized as small, medium, or large in overall size (see Methods section of this report). Cave and entrance dimensions (m) were measured or visually estimated for many of the caves and are reported with the following abbreviations: l, long; w, wide; and t, tall. Caves had no Pacific sheath-tailed bats, Mariana swiftlets, guano, or nests unless specifically mentioned. Coordinates are those taken in 2008, and are in datum WGS 84, 55 P.

No.	Other Name	Description and Comments
1.	Landing	Large. About 100 m north of the old boat landing site and about 30 m inland from ocean in an indentation in the cliff wall. Main chamber is 23 l x 15 w, and 16 t at highest point. Two smaller chambers extend about 35 l and 13 l beyond rear of main chamber. Entrance: about 8.5 w x 16 t. Curtain-like rock formations are present. Cave is damp with algae growing on most surfaces. Bats present in 1984 and 1992, swiftlets are currently present. A little human-made debris present.
2.	Guano	Large. Main chamber (20 l x 3-5.5 w x 7-18 t) branches to left with a smaller side chamber (5 l x 2-3 w x 7-9 t) on the right. Two entrances (7 w x 2 t, 1 w x 4 t) separated by a rock. All bats roost in main chamber. Swiftlets are present. Old boards and other human debris present. Coordinates 343039E, 1642089N
3.	-	Small. Cave-like hole under a huge boulder; 4 l, low ceiling, has a second opening on other side, small flowstone pillar inside. Cave is located in the “Crack.”
4.	-	Small. Vertical crevice; 5 l x 0.3-0.6 w x 3 t. Small opening at end. Cave is located in the “Crack.”
5.	-	Small. Horizontal hole beneath a large boulder; 9 l x 2 t. Cave is located in the “Crack” just below Cave 3.
6.	-	Small. Hole in cliff face.

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7.	-	Small. Hole in cliff face.
8.	-	Small. Hole in cliff face.
9.	-	Small. Hole in cliff face.
10.	-	Small. Hole in cliff face.
11.	New 1	Large. Located 25-30 m southwest of New Cave 3 along the same small limestone ridge and at same elevation. Main chamber is 9-10 l x 5 w x 7-10 t, with two large entrance chambers leading into it and at least two other smaller openings also present. Largest entrance chamber is 10 l x 3-6 w x 4-15 t, full of boulders indicating past ceiling collapse, 2-3 large vertical *Ficus* roots present, not safe to enter main chamber via this entrance. Second entrance chamber is 15 l x 2-5 w x 2-5 t, main chamber accessible via this entrance. Both entrances used by swiftlets. Appears suitable for bats, swiftlets are present. Formerly known as #6 Cave when first discovered in the late 1980s; its location was incorrectly mapped in some CNMI field trip reports (e.g., Reichel and Camacho 1989). Coordinates 343187E, 1641656N
12.	E	Size unknown. Located along cliff face below old Japanese road. Single entrance is split into three parts by two boulders. These open into a nearly vertical shaft (20-25 m deep) that is too steep to descend without equipment. Chamber continues on out of sight at bottom. Two entrance openings measure: 1.5 w x 1 t, 0.3 w x 1 t. Perhaps suitable for bats.
13.	D	Small. Next to Cave B and near Caves A and C. Entrance splits off into two smallish chambers, with longest being 10 l. Most of cave is well lit. Entrance: 5 w x 1-2 t. Parts appear suitable for bats. Part of Orphan Kids Cave Complex in Stafford (2003). Coordinates 343205E, 1641432N.
14.	C	Small. Near Caves A, B, and D. Vertical crevice that is a true cave; 10 l x 0.5-1 w x 6 t.
15.	B	Medium. Next to Cave D and near Caves A and C. Main shaft slopes downward (35 l x 2-7 w), with a smaller one angling slightly upward (10 l). A smallish room exists midway just before shafts split. Main entrance: 1 w x 1 t.

		Upper shaft has a second tiny opening. Perhaps suitable for bats, but not swiftlets. Part of Orphan Kids Cave Complex in Stafford (2003).
16.	A	Medium. Near Caves B, C, and D. Room slopes down at 45-degree angle; 19 l x 4-12 w. Upper section is well lit. Two entrances: 5.2 w x 1.5 t, 2 w x 0.7 t. Part of Orphan Kids Cave Complex in Stafford (2003). Coordinates 343190E, 1641390N.
17.	Crevice	Large. Main portion of cave is a narrow crevice that appears to be open along the top; 30 l x 1-2 w x 25 t. Crevice is so tall that it extends to the terrace above. Entrance: 4 w x 25 t. Floor angles upward, with a 2-m tall step of loose rock midway through, which makes access to rear difficult. Most of cave is dimly lit, but a rear room has more light. Cave is reminiscent of a slot canyon in the southwestern U.S. A small upward curving side crevice is located 13 m from the entrance on the right wall; 5 l x 0.3-1.2 w x 8 t; several bats are present here, with a small amount of guano found on the floor at the entrance of this feature. Guano is absent from rest of cave. Insect Bat Cave in Stafford (2003). Coordinates 343541E, 1641526N
18.	-	Small. Vertical crevice about 50 m east of Crevice Cave. Tall but not too long. Extends upward to the terrace above, with potential for a hidden cave to be located much higher up the cliffside.
19.	Dangkolo	Large. Huge central room (52 l x 15 w x 20 t), with two deeper side chambers, one at each rear corner. Side chambers are 6-10 m deeper than main room. Entrance: 4 w x 0.9 t. Cave is extremely damp, with a faint mist hanging in air. Appears suitable for bats, swiftlets are present. Coordinates 343542E, 1641686N.
20.	-	Small. Vertical crevice with darkened ceiling; 3-10 l. Appear suitable for bats.
21.	-	Small. Vertical crevice with darkened ceiling; 3-10 l. Appear suitable for bats.
22.	-	Small. Vertical crevice with darkened ceiling; 3-10 l. Appear suitable for bats.
23.	-	Small. Low ceiling.
24.	-	Small. Low ceiling.

25.	-	Small. Located close to large natural window in top of cliff face.
26.	-	Large. An attractive cave, open and well lit; 18 l x 8 w x 4-10 t. Perhaps suitable for bats, but probably not for swiftlets. Hollow Column Cave in Stafford (2003).
27.	-	Small. Located about 4 m high in an indentation in the cliff; 4.5 l x 2 w x 6 t. Open and well lit. Goat sign.
28.	-	Medium. Vertical slot; 25 l x 2-3 w x 10 t. Fairly well lit, but two high ceiling domes appear dark enough to be suitable for bats and swiftlets; a small (0.6 w x 1.0 l) dome just inside the entrance look good for bats too. Large rocks cover much of floor part way inside. Large broken stalagmite leans across cave near entrance. Goat sign. Toppled Column Cave in Stafford (2003). Coordinates 343914E, 1641548N.
29.	-	Small. Located part way up cliff side. A crevice that may extend inward a fair distance. Did not enter; entry would require some effort to climb up the cliff. Perhaps suitable for bats. Part of Natural Arch Cave in Stafford (2003).
30.	-	Small. Located about 4 m high on a sheer rock wall. Entrance: 7-8 w x 1 t, with a pillar located near the middle. Did not enter. Interior appears dark. May be too shallow for bats, but should be checked. Part of Natural Arch Cave in Stafford (2003).
31.	-	Medium. Main room is 10 l x 9 w x 10 t, with a large open ledge on the right side. A smaller room (6 t) in the rear is located about 3.5 m above the floor and angles upward to a dome ceiling. The smaller room appears especially suitable for bats and swiftlets. Note: cliffs above this site and the last few previous caves contain a series of good ledges and formations at mid-level. Smaller and crevices could be present and may potentially hold bats.
32.	-	Large. Main room: 23 l x 6-8 w x 8-10 t. Large opening: 10 w. Two darker domes in the rear. Appears quite suitable for bats and swiftlets. Goat sign. Part of Diamond Cave in Stafford (2003).
33.	-	Small. Adjacent to previous cave, with 3 columns located in between them. Chamber is a tunnel: 15 l x 0.6-5 w x 2-6 t. Higher dome in rear appears suitable for bats. Goat sign. Part of Diamond Cave in Stafford (2003).

34.	-	Large. Must climb up about 4 m to enter cave. Main room is large and auditorium-like; 15 l x 31 w x 10 t. Open, airy, and well lit. Entrance: 31 w x 10 t. A smaller dark room (4 w) is located in the rear and is elevated 10 m above main floor. Could not enter small room, but no bats or swiftlets were present. Small room appears excellent for both species. Goat sign in main room. *Lantana* grows in front of main entrance. Goat Cave in Stafford (2003).
35.	-	Small. A small overhang; 3 l x 4 w x 1 t.
36.	Krisidu	Large. Huge main room (75 l x 20 w x 15 t), with a smaller but long tunnel extending farther inward from right rear corner. Entrance: 7 w x 1.3 t. Very moist inside. Appears suitable bats and swiftlets. Site No. 48 in Butler (1992); Liyang Atkiya in Stafford (2003).
37.	Stairway	Large. Located just west of the foot path leading down cliff side. Main room is large and open; 8 l x 30 w x 5-7 t. A small dark side chamber is on right side of main room; 20 l x 2-4 w x 1-2.2 t. Lots of boards and human debris in main room. Side room appears suitable for bats, swiftlets are present. Site No. 11 in Butler (1992). Coordinates 345682E, 1642066N.
38.	-	Small. Attractive cave, somewhat circular; 6 l x 8 w x 1-2 t. Two pillars inside. A 4-inch by 4-inch plank and some small pieces of wood are inside. Goat sign.
39.	-	Small. 4-6 l x 10 w x 1.2-2 t. Two entrances and two pillars. Goat sign.
40.	-	Small. Narrow horizontal crevice under rocks.
41.	-	Small. Narrow horizontal crevice under rocks.
42.	-	Small. Horizontal crevice under a rock; 5 l x 3-6 w x 0.8-1.3 t.
43.	-	Small. Comprised of two vertical crevices, 2.5-4 t, with dark areas.
44.	-	Small. Horizontal crevice under a boulder, with two rocks supporting the east side; 6 l x 8 w x 1-2 t.

45.	-	Small. Cave-like hole in lower cliff wall; 0.7-2 t.
46.	-	Small. Cave-like hole in lower cliff wall, with two low side rooms; 0.3-1 t. May be Site No. 44 in Butler (1992) and Waypoint Cave in Stafford (2003).
47.	-	Small. Cave-like hole in lower cliff wall, with two low side rooms; 0.3-1 t. May be Site No. 44 in Butler (1992) and Waypoint Cave in Stafford (2003).
48.	-	Small. Narrow vertical crevice in lower cliff; 10 l x <1 w x 10 t. South wall is a fallen rock slab.
49.	-	Medium. A two-leveled hole (one hole above the other) in lower cliff. Cannot reach the upper hole, which has dark entrance and is 2 w x 2 t. Rest of site is open. May be suitable for bats. Site No. 45 in Butler (1992); part of Tridacnid Cave Complex in Stafford (2003).
50.	-	Large. Very open and well lit; 20 l x 7-15 w. Entrance: 8 w x 6 t. A small hole in the right upper rear corner may be suitable for bats. It is high above the floor, but its interior is not visible from below. Much goat sign. Site No. 45 in Butler (1992); part of Tridacnid Cave Complex in Stafford (2003).
51.	-	Large. Attached by an elevated cliff side ledge to the previous cave. Comprised of two rooms (totaling 35 w), with the ceiling low (1 t) almost throughout, but reaching 2 t in part of the front room. Back room is completely dark. Two entrances: one is 4 w x 1 t, second is small. Unexploded bomb near entrance. Cave appears suitable for bats. Site No. 45 in Butler (1992); part of Tridacnid Cave Complex in Stafford (2003).
52.	-	Small. Located along bottom of cliff. May be Cabrito Cave in Stafford (2003).
53.	-	Small. Located along bottom of cliff. May be Cabrito Cave in Stafford (2003).
54.	-	Small. Located along bottom of cliff. Cave is: 10 l x 2.5-4 w x 2-3 t. Moderately lit. Discarded piece of Tupperware lies outside front of cave.
55.	-	Small. Circular main room (7 l x 5-6 m x 3-4 t), with small chamber on side (1 t). Entrance: 2.5 w x 3 t. Appears suitable for bats. Much goat sign inside.

56.	-	Small. Located at bottom of a cliff wall; 8 l x 3-7 w x 0.7-1 t. Rock fortification is piled on left side of entrance. Goat sign and skulls inside.
57.	-	Size unknown, perhaps large, viewed from long distance. A large vertical slot located in the upper third of a coastal cliff. Entrance is perhaps 3 w x 12-14 t. Cave depth difficult to judge, but may not be deep. Perhaps suitable for bats and swiftlets.
58.	-	Size unknown, perhaps small, viewed from long distance. A small vertical slot located near top of a coastal cliff. Can not judge cave depth. Perhaps suitable for bats and swiftlets.
59.	-	Size unknown, perhaps small, viewed from long distance. A horizontal cave located half way up a coastal cliff. Two or three dark openings present, not large. Can not judge cave depth. Perhaps suitable for bats.
60.	-	Small. Located at the opposite end of the same crevice holding the previous cave. A covered-over T-shaped crevice. One side is very narrow and cannot be entered. Not suitable for bats.
61.	-	Small. Located at end of a large fissure. Cave is 10 l x 2 w x 10 t. Dark at rear, with several small crevices at rear.
62.	-	Small. Could not enter. Deep vertical crevice; 10 l x 1 w x 16 t. Most of crevice is open at top, but several small holes lead out of sight and appear potentially suitable for bats.
63.	-	Small. Difficult to enter. A well-lit nearly vertical crevice (1.8 l x 5 w x 4 t) is the main room, with a small chamber (6 l x 1 w x 3 t) on east side and a narrow crevice (3 l x 0.4 w x 3 t) on the west side; entrance is 6 w x 1.5 l. Located beneath some boulders on edge of open forest and east side of karst rock associated with the "Fault Line"; located 10-15 m east of Cave 65. Part of the "Fault Line" cave complex. One bat seen circling inside entrance room after dark in 2008, but follow-up daytime visit 2 days later found no roosting bats.
64.	-	Large. An interesting cave with many different features, making description difficult. A large and fairly well lit central room is present, with a smaller room to the north that is accessed by crawling through a diagonal slot; combined size of rooms is 16 l x 8-10 w x 1-15 (?) t. A long narrow crevice (16 l x 0.3 w) extends from opposite end of main room. At least five entrances present; largest is 2 t x 0.4 w, another larger entrance is partially

covered by several *Ficus* roots. Part of the "Fault Line" cave complex. No human debris or guano. Appears suitable for bats, but entrances may be too small for swiftlets. Coordinates 344844E, 1643303N.

65. - Small. Cave is a thin vertical side crevice along east side of a large open fissure; 9 l x 0.3 w x 3.5 t. Crevice is too narrow to continue after 2 m. Part of the "Fault Line" cave complex. Coordinates 344840E, 1643270N.

66. - Medium. At the end of a fissure. Could not get down to the cave floor or see the rear of the lower main room. Entrance: 4 w x 1-5 t, with a tall (11 t) slender crevice on left side. Part of the "Fault Line" cave complex. Perhaps suitable for bats.

67. - Small. At end of an open slanting fissure; 10 l x 1-1.2 w x 5-6 t. A true cave exists at rear, which is 5 l x 0.3-0.5 w x 1-5 t. Part of the "Fault Line" cave complex. Dark, but probably not suitable for bats. Not suitable for swiftlets.

68. - Medium. Comprised of a series of small low rooms, with multiple entrances, runs along base of hillside and is never more than a few m deep. Overall floor space is fairly large; about 40-50 m long, parts of cave are only 0.8-1.2 m tall. One room is 1.5-1.8 t and a side crevice is 3-4 t. Lighting is dim to almost dark. Old boards present. Looks suitable for bats. Site No. 6 in Butler (1992). Coordinates 344765E, 1643135N.

69. - Small. An overhang in a cliff face; 3 w x 4 t. One of David Steadman's excavation sites.

70. - Small. A vertical crevice; 6 l x 3 t.

71. - Small. A crevice turning into a small cave; 10-15 l x 2-3 t. Dimly lit inside.

72. - Small. Rockshelter under a large boulder; 5 l x 6 w x 2.5 t.

73. - Small. Rockshelter under a large boulder; several meters in all dimensions.

74. - Small. A vertical crevice; 5 l x 2 w x 15 t.

75. - Small. Rockshelter overhang; 4 l x 6 w x 0.8 t.

76.	East Black Noddy	Large. Located at east end of a broad circular indentation in cliff side along the north shore. Three entrances, as mapped by Stafford (2003), all of which are somewhat cryptic until closer inspection is made. Middle entrance (2 w x 3 t) is a nearly vertical shaft going upward about 12 m from ground level, but is too steep to climb safely. East entrance (0.3 w x 0.6 t) is a few meters to the left on an adjacent ledge. West (uppermost) entrance is circular in shape and about 0.6-1 m in diameter and is located about 11-13 m high on cliff face near a wavy rock formation; this is about 15 m west of middle entrance and about 3 m east of the rock pillar standing below on the ground. Human entry is easiest via the east entrance, which accesses a small first room attached to a much larger main room (12 l x 45 w x 3-5 t). This room angles steeply upward, but climbing is treacherous. Middle entrance is not visible from this room. Bats and swiftlets are present. Part of Swiftlet Cave in Stafford (2003). Coordinates 344004E, 1642923N.
77.		Cave number not in use.
78.	West Black Noddy	Large. Located at west end of a broad circular indentation in cliff side along the north shore. A single open room (20 l x 10 w x 12 t) with a large entrance (12 w x 12 t). Most of cave is dimly lit, but a small indentation on south wall may be dark enough to attract bats and swiftlets. Part of Swiftlet Cave in Stafford (2003).
79.	-	Small. A crevice among boulders, dimly lit, open on both ends; 5 l x 1.5 w x 3 t.
80.	-	Small. Rockshelter under a boulder; 10 l x 3 w x 1 t.
81.	Cliff	Size unknown, probably medium or large. Located high up cliff side and is too treacherous to reach without climbing gear. Cave has two entrances: west opening is largest, with two pillars inside giving the appearance of splitting the opening into three sections; may be 1 w x 2.5 t overall. East opening is a bit higher and has some rock extending down over part of the top. Bats and swiftlets are present. Viewed from coordinates 343432E, 1642715N.
82.	Pillar	Large. Long narrow cave, with a pillar inside near the entrance. Front section of cave is a large well-lit dome; 20 l x 5-10 w x 8-15 t. Rear section is a dark narrow tunnel; 30 l x 0.7-2.5 w x 3-7 t, but is 10 t in one area. Entrance: 10 w. Bats and swiftlets are present. Coordinates 343363E, 1642648N.

83.	-	Small. Rockshelter; 7 l x 5 w x 2 t. Fairly well lit inside.
84.	-	Small. Located in rock pile; 3 l x 0.3-0.7 w x 0.7-1.2 t. Dark at the end. May be Booney Bee Sink in Stafford (2003).
85.	-	Small. Upward angled rock overhang, narrow in rear; 5 l x 1.2-5 w x 1-4 t. Perhaps suitable for bats.
86.	-	Small. Overhang under boulder; 8 l x 5 w x 1 t. Three openings, dimly lit inside, well ventilated. Goat sign inside. Fortified, two rocks piles at entrances, with one entrance having four wooden posts present to support boulder. Probably Site No. 25 in Butler (1992). Coordinates 343408E, 1642122N.
89.	-	Small. Single room, 7 l x 3-5 w x 2 t. Probably moderately-well lit at times. Goat sign. Listed as Find Site 3 in Butler (1992).
91.		Cave number not in use.
92.	Elvin's	Small. Begins with a 4-m deep vertical entry shaft, floor then angles downward out of sight. Difficult to enter. No dimensions available. Located along the east wall of a long (> 100 m) fissure just west of New Cave 1.
93.	-	Large. Large open rockshelter-like site under a huge fallen boulder, with overall size being 20 l x 30 w x 1-5 t. Most of underhang is well lit, but two small dark areas are present at base of boulder. Site does not look suitable for bats. A smaller overhang occurs on backside of boulder.
94.	Fault Line 1	Medium. Main room is 15 l x 5-6 w x about 10 t overall. Lower half of room has a level floor, while the other half angles steeply upward. Roof is formed by a large fallen rock slab. Two main openings exist, with several small holes present at top of one side. Largest entrance is triangular shaped and is 2 t x 0.6-1 w. Second entrance is a diagonal crevice and is tight to squeeze through. Part of the "Fault Line" cave complex. Some old lumber and human debris occur inside. One bat present in 2003. May be appropriate for swiftlets. Included under Site No. 6 by Butler (1992).
95.	-	Small. Located adjacent to and below Fault Line Cave 1. Roof is formed by a fallen rock, with main room being 12 l x 1-2.5 w x 4-7 t. Mostly well-lit, but has a couple of darker areas. Three entrances, with the lower one being

an open crevice that is 3-4 l x 0.3-1 w x 2-6 l. Part of the “Fault Line” cave complex. Probably not suitable for bats or swiftlets.

96.	-	Small. A narrow crevice, 10 l x 0.3 w x 6-7 t. Mostly open, but has some closed ceiling in rear. Located just west of the “Fault Line” near a natural arch in the rocks. Part of the “Fault Line” cave complex.
97.	-	Small. Located on lower side of a boulder next to cliff base; 2 l x 1.5 w x 0.5 t; *Ficus* roots cover part of the entrance.
98.	New 2	Small. Located in same karst hole as the main entrance to New Cave 1; found opposite this entrance perhaps 5-10 m away; also located about 25 m southwest of New Cave 3. Cave has one room, 10 l x 5 w x 2 t.
99.	New 3	Large. Located along the same small limestone ridge as New Caves 1 and 2, about 25 m to the northeast. Two entrances are known. The southwest entrance is 1 x 1.5 w and drops into a deep shaft that could not be entered; swiftlets mostly enter this hole. The northeast entrance (50 m northeast of the first entrance) is actually comprised of four entrances. These fall sharply downward about 20 m, but the shaft is too steep to descend. A rope is needed for access. The chamber at the bottom is fairly dark, extends inward out of sight, and could be large. Main opening at this entrance is 5 w x 2.5 t and occurs under a fairly flat rock; single small openings occur on both sides of the main entrance; swiftlets mostly exit this entrance. Many old boards and other human debris lay on the inner level below the entrance, but nothing is visible at the bottom. Appears suitable for bats, swiftlets are present. Site No. 55 in Butler (1992). NE entrance coordinates 343232E, 1641708N; SW entrance coordinates 343201E, 1641682N.
100.	-	Size unknown, probably small. Located partway down along the west wall of the “stairway” passage near Stairway Cave. A narrow crevice in the rock leads to a vertical shaft estimated at 30 m deep. The shaft and its entrance are triangular shaped and about 5 m wide on each side. Cannot see the bottom well enough to know whether rooms are present.

101. - Size unknown, probably small. Uppermost site in the "Fault Line" cave complex; located about 30 m uphill from Fault Line Cave 1. Has 3 main entrances that fall 15 m to a level floor; these are too steep to enter. Dimensions not estimated. Cannot see entire interior, thus may be larger than expected.

102. - Small. Located between Caves 63 and 66 at south end of the bottom "step" inside the "Fault Line." Dimensions: 4 l x 1.5 w x 2.5 t. Part of the "Fault Line" cave complex.

103. - Medium. The entire feature is large in size, but most of it is uncovered by ceilings. A front vestibule (24 l x 4-8 w x 18 t) and two large side rooms (east room: 22 l x 8 w x 8-12 t; west room: 20 l x 8 w x 12-14 t) are all uncovered and therefore do not provide cave environments. Front vestibule empties out onto a sheer cliff, which falls about 30 m to the terrace below. The only true cave occurs in the middle of the south wall. It has an entry chamber (10 l x 2-3 w x 2-3 t) that goes straight in, with a side room (also 10 l x 2-3 w x 2-3 t) facing west near the rear. Looks suitable for bats. Entry is via the side of the front vestibule and requires a fairly risky climb down. Coordinates 344316E, 1642923N.

<u>Other Caves Described in Butler (1992).</u>

87. - Listed as Site No. 30. Located at cliff base. A rockshelter with a lower chamber (5 l) on east side leading upward to a larger overhang (3-4 l x 15 w) with a low ceiling. Larger overhang is 3 m above ground level; its floor has been leveled with stacked rocks. Human debris present.

88. - Listed as Site No. 29, with photograph presented. Located at cliff base. Small rockshelter; 3-4 l x 3 w. Vertical logs positioned across part of entrance.

90. - Listed as Site No. 56. Entrance opens into a "large" dark room that was not visited. Rocks stacked around the entrance.

Other Caves Described in Stafford (2003).

104.	-	Listed as Swarming Termites Cave. Located in the eastern region of the middle terrace. Small.
105.	-	Listed as Liyang Lomuk. Located in the north-central region of the middle terrace. Small.
106.	-	Listed as Lizard Cave. Located in the north-central region of the middle terrace. Small.
107.	-	Listed as Spider Cave. Located in the north-central region of the middle terrace. Small.
108.	-	Listed as Scorpion Cave. Located in the north-central region of the middle terrace. Medium-sized?
109.	-	Listed as Goat Fracture Cave. Located in the northwest region of the lower terrace. Small.
110.	-	Listed as Anvil Cave. Located in the northwest region of the upper terrace. Medium-sized?
111.	-	Listed as Dove Cave. Located in the northwest region of the upper terrace. Small.
112.	-	Listed as Almost Cave. Located in the northwest region of the upper terrace. Small.
113.	-	Listed as Screaming Bat Cave. Located in the northwest region of the upper terrace. Two small caves present. Named for several fruit bats vocalizing nearby at night (K. Stafford, pers. comm.).
114.	-	Listed as Biting Mosquitoes Cave. Located in the northwest region of the upper terrace. Small.
115.	-	Listed as Isotope Cave. Located in the northwest region of the upper terrace. Medium-sized?
116.	-	Listed as Pepper Cave. Located in the northwest region of the upper terrace. Small.

Section IV. Habitat Occupancy and Detection of the Pacific Sheath-Tailed Bat (*Emballonura semicaudata rotensis*) on Aguiguan, Commonwealth of the Northern Mariana Islands

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ABSTRACT

We used occupancy analysis to quantify Pacific sheath-tailed bat (*Emballonura semicaudata*, Emballonuridae) foraging activity and its relationship to forest structure and proximity to cave roosts on Aguiguan Island in the Commonwealth of the Northern Mariana Islands. Canopy cover, vegetation stature and distance to known roosts were covariates that best explained bat occurrence. Additionally, we provide quantitative descriptions of the echolocation calls of *E. semicaudata.* Search-phase calls were characterized by a relatively narrow bandwidth and short pulse duration typical of insectivores that forage within vegetative clutter. Two distinctly characteristic frequencies were recorded: 30.97 ± 1.08 kHz and 63.15 ± 2.20 kHz.

INTRODUCTION

The Pacific sheath-tailed bat (*Emballonura semicaudata*) was once common and widely distributed across the southwestern tropical Pacific. It is the only insectivorous bat recorded from much of this region (Koopman 1997), and four subspecies have been described: *E. s. rotensis* from the Mariana Islands (Guam and the U.S. Commonwealth of the Northern Mariana Islands [CNMI]), *E. s. palauensis* from Palau, *E. s. sulcata* from the Caroline Islands (Chuuk and Pohnpei), and *E. s. semicaudata* from Vanuatu, Fiji, Tonga, and Samoa (Independent and American). Although populations appear sizable and stable in some locations, mainly in the Caroline Islands (Wiles and others 1997), they have declined considerably in other areas, including the Mariana Islands, Fiji, Samoa, and possibly Tonga (Hutson and others 2001, Helgen and Flannery 2002). In the Marianas, the endemic subspecies *E. s. rotensis* formerly inhabited Guam, Rota, Aguiguan, Tinian, Saipan, and possibly Anatahan and Maug (Lemke 1986, Flannery 1995, Ellison and others 2003). Currently, it appears to be almost entirely extirpated from the Mariana archipelago, with a single remnant population of this subspecies occurring on the small uninhabited island of Aguiguan. The species is listed as Endangered by the World Conservation Union (Chiroptera Specialist Group 2000) and the Government of CNMI (Anonymous 1991). *Emballonura. s. rotensis* and *E. s. semicaudata* are category 3 candidates for listing under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2007). The threats to the Aguiguan population primarily include habitat loss from past clearing of native forest for agriculture, with subsequent replacement by invasive vegetation (Esselstyn and others 2004), habitat degradation from feral goat browsing (goats were introduced in the mid-1800s; Esselstyn and others 2004), and a small population size with limited distribution that leaves it vulnerable to extirpation by typhoons (Chiroptera Specialist Group 2000).

Current status assessments of *E. s. rotensis* on Aguiguan indicate that the population numbers about 400-500 individuals based on counts of 359-466 bats at caves (see Section III of this administrative report), roosts are limited to caves (Section III of this administrative report), and the bat primarily uses forest habitat (Esselstyn and others 2004). Although critical for assessments of population status, the estimation of population size is complicated when bats use more than one roost and when the location of occupied caves are incompletely known, particularly if surveys of caves for bats are not completed simultaneously or in a short time period. Movement of bats among alternate caves may cause counts to be annually or seasonally variable even if population size remains fairly constant. Consequently, variability in counts can make assessments of bat population trends difficult (for more details on problems in estimating bat population size see papers in O'Shea and Bogan 2003).

Occupancy analysis is a fairly new technique only recently being applied to bat studies in which echolocation calls are used as a measure of occurrence and activity (Gorresen and others 2008). The technique corrects for bias in estimates of spatial occurrence by accounting for imperfect detection (i.e., bats present but not detected; MacKenzie and others 2002). It also generates metrics with associated variance estimates that permit comparative analyses (i.e., future assessments of occupancy and distribution over time). We used occupancy analysis primarily to quantify Pacific sheath-tailed bat foraging activity on Aguiguan. Secondary objectives included further study of the relationship of foraging activity to forest structure and land-cover composition and the temporal use of forest habitat and proximity to cave roosts. We also provide quantitative descriptions of the echolocation calls of *E. s. rotensis* because there is little published information on the calls of this or other species of the genus *Emballonura*.

MATERIALS AND METHODS

Study Area

Detailed descriptions of the environment on Aguiguan (14°51' N, 145°33' E) are available in Engbring and others (1986), Esselstyn and others (2004) and Wiles and others (Section III of this administrative report), and are summarized below from these sources. Aguiguan is located in the southern Mariana Islands in western Micronesia. It is a small (7.0 km^2) limestone island with a flat central plateau encircled by escarpments and terraces. A ridgeline along the northern edge of the island attains a maximum elevation of 166 m.

Landcover on Aguiguan is comprised of 4 general types of vegetation: native limestone forest; non-native forest; non-native shrubland; and coastal scrub and grassy areas. Native limestone forest occurs on about 49% of the island and is mostly found on steep slopes and terraces. The forest canopy reaches up to 15 m and intense browsing by feral goats (*Capra hircus*) has formed an open understory in most areas. Although Aguiguan is now uninhabited by people, the central plateau (making up about 42% of the island area) was cleared for agriculture between about 1936 and the early 1940s. This area is now primarily comprised of non-native secondary shrub and forest vegetation. Shrubland consists of dense 1-3 m tall thickets and most non-native forest occurs in small patches 5-10 m in stature. Coastal scrub, grass and unvegetated areas make up the remaining 9% of the island's landcover.

Study Design and Analysis

Thirty-one stations were surveyed for Pacific sheath-tailed bat activity between 25 June and 14 July 2008. Stations were established at or near locations initially sampled by Esselstyn and others (2004) and generally spaced at 370-m intervals. Sampling techniques and measures of bat activity and habitat use followed the approach developed by Gorresen and others (2008) for the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) in which bat vocalizations (i.e., echolocation "calls") were recorded at a series of stations ("sites") on consecutive nights. Calls were recorded on Aguiguan with Anabat II detectors (Titley Electronics, Ballina, New South Wales, Australia) over 3-5 nights at each site, and were written to a compact flash card with a Zero-Crossings Analysis Interface Module (ZCAIM; Titley Electronics). Call files were processed with AnalookW software (version 3.3f; Titley Electronics; available at http://www.hoarybat.com; accessed July 2008) to filter ambient noise. Graphic files were visually inspected to ensure that residual noise was not interpreted as echolocation calls or call components ("pulses"). Descriptive characteristics of search-phase echolocation calls extracted by AnalookW included minimum (F_{min}), maximum (F_{max}) and characteristic (F_c) frequencies (kHz); frequency range (difference between F_{max} and F_{min}); pulse duration (ms); and time (T_c) from the start of pulse to F_c (ms). Parameters F_c and T_c were derived only from the "body" (i.e., flattest portion) of the pulse as defined AnalookW, whereas the entire pulse was used to characterize the other parameters. Detailed definitions of these call parameters are provided by Gannon and others (2004). *Emballonura semicaudata* is the only species of echolocating bat known from the Marianas Islands (Flannery 1995, Esselstyn and others 2004) and there were thus no questions about the species identity of the calls we recorded.

Occupancy analysis (MacKenzie and others 2002) was used to assess the relationship between habitat attributes and the proportion of occupied sites (Ψ), to adjust Ψ for a detection probability (*p*) of less than one, and to produce associated measures of uncertainty for comparative analyses. Occupancy analysis was performed with the software program PRESENCE (version 2.0; available at http://www.mbr-pwrc.usgs.gov/software.html; accessed September 2008).

We developed *a priori* models in which bat occupancy was a function of habitat covariates; i.e., Ψ(Cov)$p(\cdot)$. We used our constant parameter model, $\Psi(\cdot)p(\cdot)$, as a reference null model from which to compare habitat effects on occupancy. Because of small sample size, interactions between covariates were not examined. Weather conditions were uniform during the 3-week period of sampling, therefore no sampling covariates were used to adjust detection probabilities; i.e., $\Psi(\cdot)p$(Cov) models were not examined (e.g., where *p* could be a function of wind or rain).

Habitat attributes that were visually and qualitatively assigned into binary categories included understory clutter (open-uncluttered; closed-cluttered) and dominant vegetation (native; exotic). Attributes with more than 2 levels were quantified with indicator variables, and included stem diameter

(<10, 10-30 and >30 cm dbh), vegetation stature (<5; 5-10; >10 m height) and canopy cover (<30%; 30-70%; >70% closure). Proximity from each survey station to 7 known roost sites was calculated as the nearest neighbor distance in ArcGIS 9.2 (ESRI 2006). To improve model performance, proximity was standardized to have a mean of 0 and a standard deviation of 1 (Donovan and Hines 2007). The seven known roosts analyzed included Landing, Pillar, Guano, Crevice, Cliff, East Black Noddy, Fault Line 1 (as described n Section III of this administrative report).

Although habitat use may be defined simply by the occurrence of a species, this is a non-discriminating criterion because bats can commute through areas not used for foraging. Therefore we distinguished areas of higher and lower activity based on the number of echolocation pulses in recorded bat call files. In addition to the use of a "no threshold" of activity (i.e., all echolocation pulses were used), we identified observations where the total number of pulses within each 1-min period exceeded one of three nested series of thresholds: 50^{th} (median), 70^{th} and 90^{th} percentile. These higher activity events were coded as 1 in matrices that tallied their incidence for each site and each night. Zeros were assigned to matrix cells for periods in which there was no recorded activity or pulse numbers were below the selected activity threshold. Detection probability and occupancy estimates for each survey site were calculated in program PRESENCE. The relationship of known roost proximity to bat arrival time (defined as the first hour with detections) was examined by correlation analysis.

Occupancy models were first ranked according to AIC values (Burnham and Anderson 2002). We subsequently used single-variable models within 2 AIC units of the best model as candidates for building 2-variable models. Models with a greater number of covariates were not considered because of the relatively small number of sites (n = 31). Interpretive results are presented only for the top-ranked models. Model goodness-of-fit was assessed with a parametric bootstrap procedure (MacKenzie and Bailey 2004), in which a Pearson X^2 test statistic p-value <0.05 and an estimated over-dispersion parameter <0.5 or >1.5 were measures indicative of a significant lack of model fit.

RESULTS

Bat Echolocation Calls

Pacific sheath-tailed bats were recorded at 22 of the 31 sites (Figure IV-1) sampled over a period of 19 nights on Aguiguan (for a total of 109 detector-nights). The distribution of pulses (38,858 pulses in 1,224 tallies of 1-minute duration) was highly skewed with a large proportion of filtered call files comprised of few pulses (Figure IV-2). One-half of all bat detections consisted of brief passes with less than 15 pulses per 1-minute interval. In contrast, 10% of observations were of peak activity events indicative of sustained foraging bouts with between 63 and 422 pulses. Another 40% of observations ($\geq 50^{th}$ to $<90^{th}$ percentile) were of moderate activity in which total pulses numbered between 15 and 62.

The search-phase echolocation calls of *E. s. rotensis* were characterized by a fairly uniform narrowband, quasi-constant frequency (QCF) structure (Figure IV-3). The central shallow-modulated part of a QCF pulse was accompanied by a descending FM terminal element, and an ascending component to each pulse was also usually present. Two distinctly characteristic frequencies (F_c) were recorded: a 30.97 ± 1.08 kHz ("low") and 63.15 ± 2.20 kHz ("high") (Table IV-1). Despite greater atmospheric attenuation at higher frequencies under humid conditions (Lawrence and Simmons 1982), about three-quarters of the characteristic frequencies recorded were of the high harmonics (relative humidity was usually >80% on Aguiguan; T. O'Shea, USGS, pers. comm.). Although the Anabat echolocation system does not fully measure multi-harmonic information (Fenton and others 1999), the proportion of low versus high frequencies recorded may reflect shifts in the main energy from one dominant harmonic to another (e.g., "harmonic alternation"; Jung and others 2007), or the effects of microphone sensitivity (higher frequencies are more readily detected than lower frequencies) and the distance between a bat and detector (lower frequencies are less affected by distance; C. Corben, *in litt*.; http://users.lmi.net/corben/hrmncs.htm#Harmonics). No evidence of other harmonics was observed, but these may be present (e.g., 3^{rd} and 4^{th} harmonics; Ibáñez and others 2002) and "masked" by more dominant harmonics. The overall frequency range (i.e., difference between the maximum and minimum frequencies) was fairly narrow for both harmonics (low: 1.83 ± 1.10 kHz; high: 11.04 ± 4.05 kHz). Both low and high frequency pulses were of relatively short duration and the time to attain a characteristic frequency comprised most of the pulse extent (low: 1.44 ± 0.47 ms, T_c = 1.31 ± 0.37 ms; high: 2.75 ± 0.56 ms, T_c = 1.73 ± 0.46 ms).

Habitat, Occupancy and Detection Probability

Canopy cover, vegetation stature and distance (proximity to known roosts) were covariates that best explained bat occurrence across all threshold levels in models that accurately fit the data (Table IV-2). Each of these variables alone or in combination with one other accounted for up to 66% of AIC model weight.

Bat occupancy was related to canopy closure in a somewhat complex manner. It was highest at sites with high canopy closure and lowest at sites with moderate canopy closure, whereas it appeared intermediate at sites with low canopy closure (Table IV-3 and Figure IV-4). This may simply be due to the effects of small sample size on parameter estimation (*n* = 3 for low canopy closure sites). It may also reflect bat use of open canopied habitats adjacent to forest (all 3 sites were within 200 m of forest edge). Generally, occupancy in habitat characterized by high canopy closure was about 0.80 (e.g., $\hat{\Psi}$ = 0.84 ± 0.09 and 0.79 ± 0.11 in single-covariate 50^{th} and 70^{th} percentile models, respectively). Higher levels of other covariates acted to increase occupancy to over 0.90 (e.g., $\hat{\Psi}$ for high canopy closure sites near known roosts was 0.93 ± 0.06 for the 50^{th} percentile model).

Vegetation stature exhibited a positive and direct relationship with occupancy, particularly in combination with other covariates. For example, occupancy in tall stature forest ranged between 0.55 ± 0.36 and 0.96 ± 0.06 depending on proximity to known roost caves, and 0.06 or less for mid- and low stature sites (90^{th} percentile model; Table IV-3 and Figure IV-4).

Similarly, proximity to known roost caves consistently appeared as a significant covariate accounting for bat occupancy. Generally, occupancy at sites near roosts was about 0.85 (e.g., $\hat{\Psi}$ = 0.87 ± 0.09 and 0.83 ± 0.10 in single-covariate 50th and 70th percentile models, respectively; Table IV-3). Higher levels of other covariates also acted to further augment occupancy estimates. In addition to its effect upon the likelihood of bat use of particular habitats, roost proximity was also closely related to the timing of bat arrival at a site. The hour of first bat detections occurred significantly earlier at sites near caves (r = 0.64, *p*-value = 0.002; Figure IV-1). Detections at sites far from roost caves also tended to occur infrequently and at irregular intervals.

Bat occurrence was widespread on Aguiguan (observed Ψ = 0.71 when all bat detections were included; Table IV-4). As expected, peak bat activity was limited to a smaller proportion of sampled area than that indicated by simple presence alone. The 50th, 70th and 90th percentile null reference models (i.e., those with no habitat covariates) exhibited average $\hat{\Psi}$ of 0.62 ± 0.09, 0.59 ± 0.09 and 0.27 ± 0.08, respectively. In other words, whereas bats were detected across almost 3/4 of all sites, peak activity was observed at only 1/4 of the sampled landscape. Likewise, the probability of detecting bats was related to the activity threshold level. For example, *p* for all detections was 0.76 ± 0.05 but declined to 0.61 ± 0.09 for the 90th percentile threshold.

DISCUSSION

As first established by Esselstyn and others (2004), Pacific sheath-tailed bat activity was found to be closely associated with native limestone forest and proximity to known cave roosts. We also determined bat occupancy to be related to habitat characteristics typical of more structurally developed and mature forest; i.e., closed canopied and tall stature stands. However, scattered detections in open (non-forest) areas were notable because they indicate an ability to traverse and perhaps forage over such habitats. Moreover, the existence of at least one unknown roost is suggested by the early arrival and high activity of bats near several northeastern sample sites (stations “e” and “i”; Figure IV-1). Such roosts may contribute additional individuals to the current counts of 359-466 bats (Section III of this administrative report).

The high number of unoccupied but apparently suitable caves (Sections III and VI of this administrative report) suggests that the population size of *E. s. rotensis* may not be limited by roost availability. Instead, population size may be restricted by the small amount of mature native limestone forest (3.4 km^2) present on Aguiguan. On the other hand, the mobility of sheath-tailed bats (Wiles and others [1997] report commuting distances of at least 5 km in Palau) and their (albeit limited) use of exotic or less structurally complex vegetation is encouraging because it may mean that moderately more habitat is available than that solely provided by native limestone forest. Alternatively, it could also indicate that the population may be exceeding carrying capacity of the preferred habitat and that activity in areas with non-native vegetation represents a “spilling over” into suboptimal habitat.

The search-phase calls produced by *E. s. rotensis* were characterized by a relatively narrow bandwidth and short pulse duration typical of insectivores which forage close to and among vegetative clutter (Neuweiler 1989, Jung and others 2007). These call attributes are similar to other emballonurids that forage near vegetation such as *Rhynchonycteris naso* and *Balantiopteryx* spp. (O'Farrell and Miller 1997, Ibáñez and others 2002). This inference is supported from our direct observations and those by Esselstyn and others (2004) of bats flying slowly and "erratically" while foraging within forest between 1 m of the ground and up to tree-tops. Esselstyn and others (2004) also observed bats foraging above the forest canopy. Use of open areas near forest edges also was confirmed by our echolocation recordings.

The metrics generated by this study can serve as a quantitative baseline for future assessments of status following changes in habitat due to management activities (e.g., feral goat control) or other factors (e.g., typhoon impacts). For instance, our sites can be re-sampled and analyzed with multi-season models (MacKenzie and others 2002) to determine whether the proportion of occupied sites that exhibit peak activity have decreased or increased following loss or recovery of native limestone forest habitat. We also found the use of nested activity thresholds for quantifying peak bat activity to be useful in identifying high occupancy locations and making inferences about important habitat attributes.

Although relative variance (as measured by CV) of $\hat{\Psi}$ and *p* was generally greater at higher activity thresholds, standard errors were similar across thresholds (e.g., $\hat{\Psi}$ $(\overline{\mathrm{SE}})$ for all null models was about 0.08; Table IV-4). This means that future occupancy surveys may focus on sites with high expected activity. These "core" sites are generally in tall stature native limestone forest and are more easily traversed and sampled than the dense thickets of exotic shrub (primarily *Lantana camara*) that comprise about one-half the island's landcover.

The current study was designed to randomly resurvey as many as possible of the 50 sites established on a systematic grid by Esselstyn and others (2004). However, not all locations were accessible (because of impenetrable *Lantana camara* thickets and the brief 19-day period available to us), and the 31 sites actually surveyed do not represent a fully random subset of the original 50 locations. Departure from a probabilistic sampling design may bias $\hat{\Psi}$ and *p* (upward in our case since proportionally fewer sites in non-forest were available to us than initially available to Esselstyn and others 2004). Therefore, future surveys of Pacific sheath-tailed bat occupancy on Aguiguan should seek to fully sample the grid of 50 sites if island-wide characterization of habitat use is a primary objective. However, if monitoring bat activity in preferred habitat is the main objective, the $\hat{\Psi}$ and *p* variances produced by this study may be used as a guide to generate a revised sampling design following the methods presented by Bailey and others (2007). For example, a design comprised of 30 sites sampled for 4 nights (or alternatively, 25 sites for 5 nights) is needed to attain a desired CV of $\leq$0.05 given an expected Ψ of 0.93 and $p = 0.78$ (as observed for the median activity threshold in mature native limestone forest near known roosts; Tables IV-3 and IV-4).

The importance of native limestone forest to the persistence of *E. s. rotensis* on Aguiguan cannot be over-emphasized. Bat species specialized to forage near or within forest on average face a greater extinction risk than aerial insectivores or species with comparatively flexible foraging strategies (Kingston and others 2003, Safi and Kerth 2004, Lane and others 2006). Moreover, minimum area thresholds of species occurrence indicate that island occupancy by insectivorous bats may be strongly limited by resource requirements (Frick and others 2008). Given the island's very limited resource base and size, the extreme isolation of the population, its vulnerability to typhoons (e.g., Grant and others 1994), and the species' relatively narrow habitat preference and specialized foraging strategy, it is imperative that efforts to reverse the decline in native limestone forest on Aguiguan be implemented to ensure the long-term survival of the Pacific sheath-tailed bat.

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Table IV-1. Characteristics of "low" and "high" harmonics in the search-phase calls of *E. s. rotensis*. Variables measured include minimum (F_{min}) and maximum (F_{max}) frequencies (kHz); frequency range (F_{max} - F_{min}); characteristic (F_c) frequency (kHz); duration of entire pulse (ms); and time (T_c) from the start of pulse to F_c (ms). The number of call files and pulses examined were 33 and 245 for low harmonics and 45 and 509 for high harmonics, respectively.

Harmonic	Parameter	F_{min}	F_{max}	Range	F_c	Duration	Tc
"Low"	Minimum	26.85	31.01	0.24	27.03	0.49	0.49
	Maximum	32.79	33.33	5.39	33.06	3.11	2.36
	Mean	30.43	32.26	1.83	30.97	1.44	1.31
	SD	1.13	0.64	1.10	1.08	0.47	0.37
"High"	Minimum	40.20	58.82	1.43	50.63	0.26	0.28
	Maximum	64.00	67.23	23.29	66.12	4.07	3.80
	mean	53.33	64.37	11.04	63.15	2.75	1.73
	SD	4.12	1.22	4.05	2.20	0.56	0.46

Table IV-2. Summary of model selection for 4 activity threshold levels: none, and 50th, 70th and 90th percentiles of bat call pulse number. ΔAIC is the relative difference in AIC values from the model with the smallest AIC value; *w* is the AIC model weight; *k* is the number of parameters; X^2 is the test statistic for model fit; *p*-value is the probability of observing a test statistic ≥ X^2 based upon 999 parametric bootstraps; and ĉ is the estimated over-dispersion parameter. Estimated occupancy is presented in Table IV-3 only for models (indicated below in bold) for which ΔAIC ≤ 2 and model goodness-of-fit is adequate (*p*-value ≥ 0.05 and ĉ ranging between 0.5 and 1.5).

Threshold	Model	ΔAIC	*w*	*k*	X^2	*p*-value	ĉ
none	canopy	0.00	0.82	4	147.2	0.024	2.62
none	distance	4.60	0.08	3	153.0	0.023	2.70
none	stature	5.66	0.05	4	171.0	0.022	3.08
none	null	6.93	0.03	2	172.8	0.030	2.94
none	native-exotic	8.07	0.01	3	181.3	0.018	3.21
none	understory	8.93	0.01	3	172.9	0.024	3.11
none	stem diameter	9.87	0.01	4	181.5	0.018	3.22
50	**canopy & distance**	0.00	0.45	5	55.5	0.357	1.01
50	**canopy**	1.02	0.27	4	50.2	0.386	0.96
50	**distance**	1.58	0.21	3	50.8	0.403	0.92
50	stature	5.64	0.03	4	50.4	0.391	0.89
50	null	6.78	0.02	3	48.4	0.435	0.85
50	native-exotic	7.40	0.01	4	48.5	0.398	0.86
50	stem diameter	7.70	0.01	3	48.9	0.370	0.90
50	understory	7.83	0.01	3	48.5	0.406	0.88
70	**canopy & stature**	0.00	0.35	6	40.4	0.705	0.74
70	**canopy & distance**	1.64	0.15	5	40.9	0.717	0.73
70	**canopy**	1.83	0.14	4	38.5	0.765	0.71
70	**distance**	1.85	0.14	3	38.6	0.761	0.69
70	distance & stature	3.07	0.08	5	39.3	0.720	0.71
70	stature	3.48	0.06	4	39.0	0.712	0.71
70	null	5.02	0.03	2	38.2	0.718	0.69
70	stem diameter	5.84	0.02	4	38.6	0.717	0.68
70	native-exotic	6.09	0.02	3	38.5	0.698	0.70
70	understory	7.02	0.01	3	38.1	0.735	0.69
90	**distance & stature**	0.00	0.66	5	82.8	0.099	1.52
90	stem diameter [1]	3.01	0.15	4	121.0	0.012	2.24
90	distance	4.56	0.07	3	68.8	0.238	1.25
90	stature	4.75	0.06	4	95.0	0.064	1.74
90	stem diam. & stature	4.93	0.06	6	111.1	0.014	2.05
90	native-exotic	11.87	0.00	3	132.7	0.027	2.37
90	understory	11.99	0.00	3	76.6	0.193	1.40
90	canopy	13.13	0.00	4	81.3	0.148	1.46
90	null	14.82	0.00	2	94.5	0.118	1.69

[1] Model “stem diameter & distance” failed to convergence and was excluded from output.

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Table IV-3. Occupancy estimates ($\hat{\Psi}$) for existing combinations of variables. Results are shown only for top-ranked models (indicated in bold in Table IV-2) for each of 3 activity threshold levels: 50^{th}, 70^{th}, and 90^{th} percentiles of bat call pulse number (the "no threshold" models did not meet goodness-of-fit criteria and are not presented). Estimates for the continuous variable "distance" are derived from mid-range examples of post hoc categories "near", "middle", and "far". Results are sorted by ascending occupancy estimate within each threshold and model.

Threshold	Model	$\hat{\Psi}$	SE	95% CI
50	canopy "middle", distance "far"	0.092	0.092	-0.088 – 0.272
50	canopy "middle", distance "middle"	0.323	0.158	0.012 – 0.633
50	canopy "low", distance "far"	0.422	0.349	-0.263 – 1.106
50	canopy "high", distance "far"	0.559	0.243	0.084 – 1.035
50	canopy "middle", distance "near"	0.562	0.239	0.093 – 1.031
50	canopy "low", distance "near"	0.746	0.257	0.242 – 1.249
50	canopy "high", distance "middle"	0.817	0.103	0.615 – 1.020
50	canopy "high", distance "near"	0.928	0.064	0.803 – 1.053
50	canopy "middle"	0.274	0.135	0.010 – 0.539
50	canopy "low"	0.667	0.272	0.133 – 1.201
50	canopy "high"	0.839	0.094	0.655 – 1.023
50	distance "far"	0.196	0.140	-0.079 – 0.471
50	distance "middle"	0.633	0.099	0.440 – 0.827
50	distance "near"	0.869	0.087	0.698 – 1.041
70	canopy "middle", stature "middle"	0.112	0.107	-0.097 – 0.321
70	canopy "low", stature "middle"	0.582	0.380	-0.163 – 1.327
70	canopy "high", stature "middle"	0.681	0.150	0.387 – 0.974
70	canopy "middle", stature "tall"	0.712	0.247	0.229 – 1.194
70	canopy "high", stature "short"	0.791	0.241	0.319 – 1.263
70	canopy "high", stature "tall"	0.977	0.036	0.906 – 1.047
70	canopy "middle", distance "far"	0.115	0.107	-0.095 – 0.326
70	canopy "middle", distance "middle"	0.322	0.157	0.014 – 0.629
70	canopy "low", distance "far"	0.463	0.351	-0.224 – 1.150
70	canopy "high", distance "far"	0.466	0.275	-0.073 – 1.005
70	canopy "middle", distance "near"	0.521	0.242	0.046 – 0.995
70	canopy "low", distance "near"	0.734	0.260	0.224 – 1.244
70	canopy "high", distance "middle"	0.750	0.121	0.513 – 0.986
70	canopy "high", distance "near"	0.884	0.087	0.713 – 1.055
70	canopy "middle"	0.277	0.137	0.010 – 0.545
70	canopy "low"	0.668	0.273	0.134 – 1.203
70	canopy "high"	0.792	0.107	0.583 – 1.001
70	distance "far"	0.210	0.147	-0.078 – 0.498
70	distance "middle"	0.506	0.109	0.293 – 0.720
70	distance "near"	0.832	0.103	0.629 – 1.034
90	distance "far", stature "short"	0.000	0.000	0.000 – 0.000
90	distance "near", stature "short"	0.000	0.000	0.000 – 0.000
90	distance "far", stature "middle"	0.006	0.014	-0.021 – 0.034
90	distance "middle", stature "middle"	0.060	0.067	-0.070 – 0.191

90	distance “middle”, stature “tall”	0.554	0.363	-0.157 – 1.265
90	distance “near”, stature “tall”	0.959	0.064	0.834 – 1.083

Table IV-4. Occupancy ($\hat{\Psi}$) and detection probability (*p*) estimates for null and top-ranked models (indicated in bold in Table IV-2) for each of 4 activity threshold levels: "none", and 50th, 70th, and 90th percentiles of bat call pulse number. "Null" indicates models with no habitat covariates included. "Obs Ψ " is the observed or "naïve" estimate for occupancy (i.e., not adjusted for detection probability). Mean, standard error and associated coefficient of variation (CV) were derived from parameter estimates for all sampled sites.

Threshold	Model	Obs Ψ	$\bar{\hat{\Psi}}$ ($\overline{\text{SE}}$)	CV	*p* (SE)	CV
none	null	0.71	0.72 (0.08)	0.11	0.76 (0.05)	0.07
50	null	0.61	0.62 (0.09)	0.14	0.78 (0.05)	0.07
50	canopy & distance	0.61	0.63 (0.14)	0.22	0.78 (0.05)	0.07
50	canopy	0.61	0.57 (0.14)	0.24	0.78 (0.05)	0.07
50	distance	0.61	0.63 (0.11)	0.17	0.78 (0.05)	0.07
70	null	0.58	0.59 (0.09)	0.15	0.70 (0.06)	0.09
70	canopy & stature	0.58	0.58 (0.16)	0.27	0.70 (0.06)	0.09
70	canopy & distance	0.58	0.60 (0.15)	0.25	0.70 (0.06)	0.09
70	canopy	0.58	0.56 (0.15)	0.26	0.69 (0.06)	0.09
70	distance	0.58	0.60 (0.11)	0.19	0.70 (0.06)	0.09
90	null	0.26	0.27 (0.08)	0.31	0.59 (0.10)	0.17
90	distance & stature	0.26	0.27 (0.08)	0.32	0.61 (0.09)	0.16

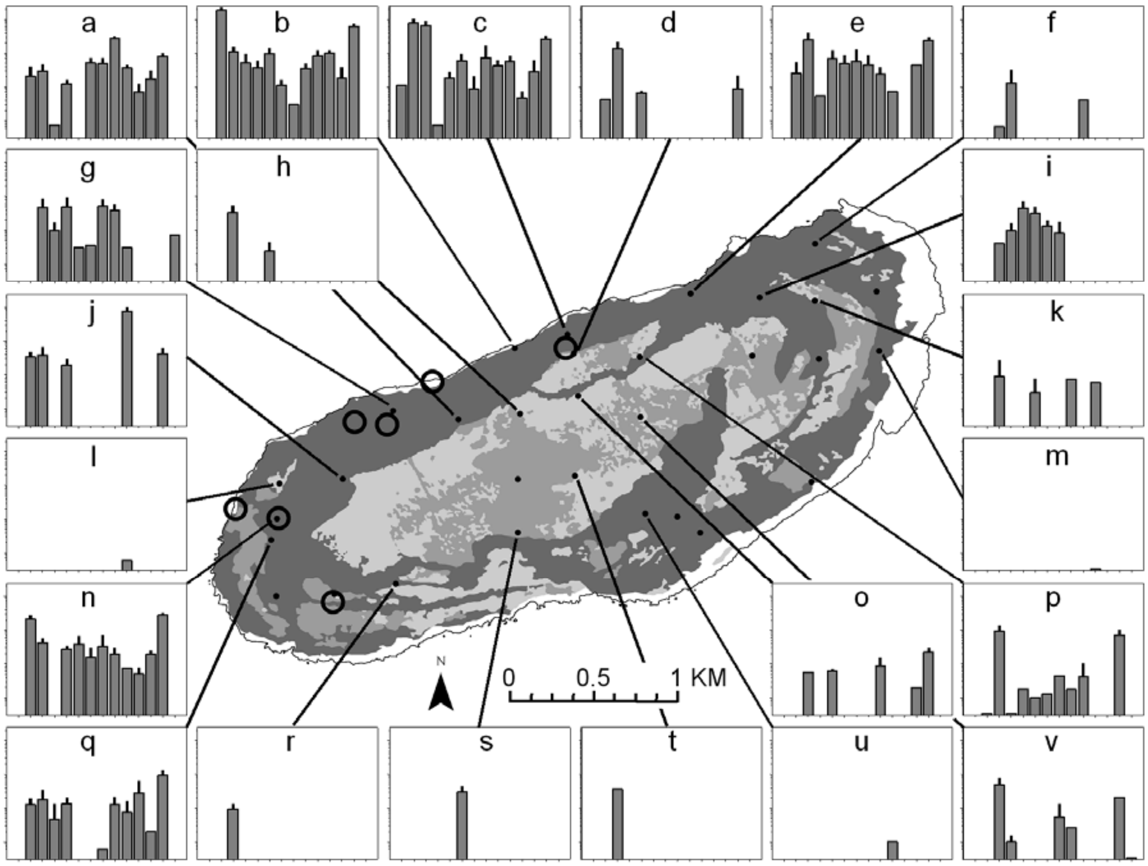


Figure IV-1. Distribution of survey stations and *E. s. rotensis* activity by hour of night for all sites with detections on Aguiguan. X axis on each inset bar graph is hour of night beginning at 1700 and ending at 0600. Y axis is natural log of mean pulse total (+ 1 SD; major tick marks range from 10^0 to 10^3). Bars with no SD whisker had only a single observation in the hour. Graph axes are shown in detail for each site (labeled a-v) in Appendix IV-1. Open circles on background image indicate known roost locations and points designate sample sites. Landcover classes shown include native limestone forest (dark gray), non-native forest (mid-tone gray), non-native shrubland (light gray), and coastal scrub, grass and unvegetated areas (white). Landcover map courtesy of Fred Amidon (USFWS, *in litt.*).

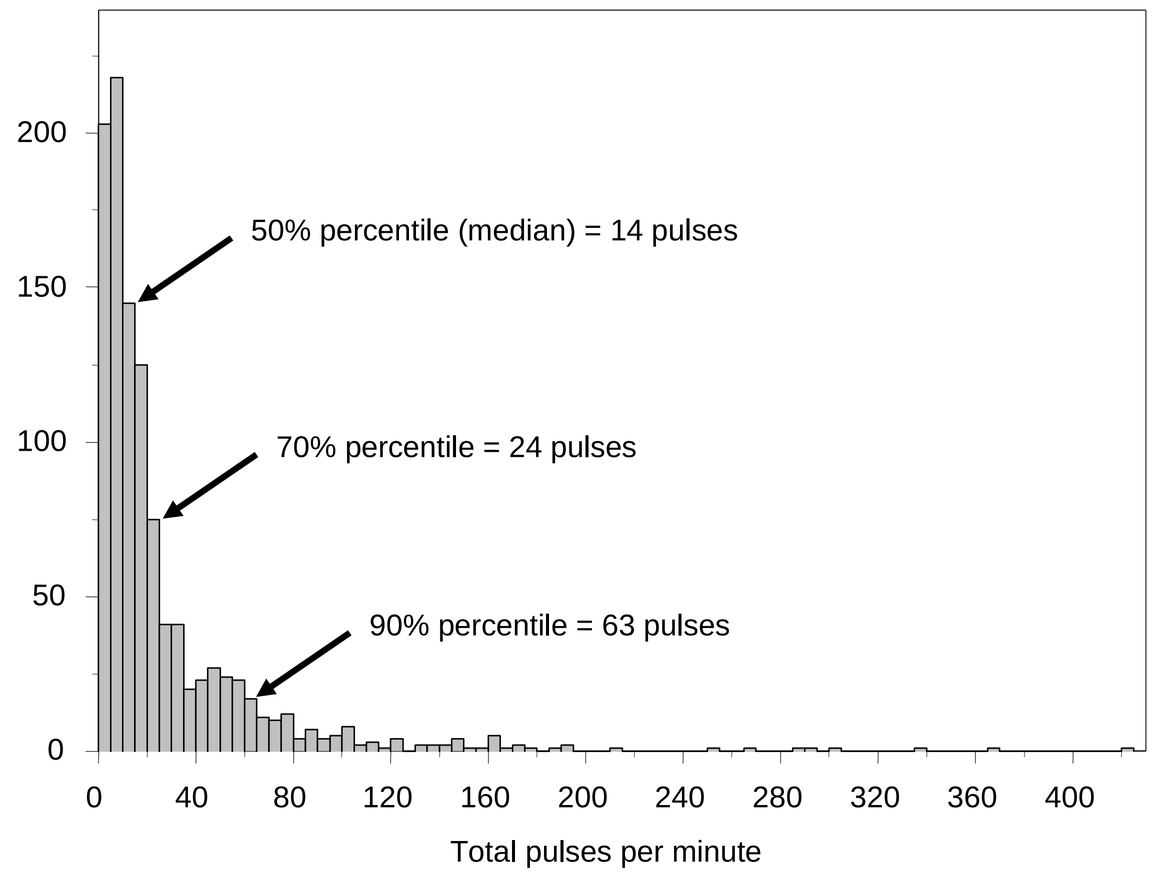


Figure IV-2. Distribution of total bat call pulses per 1-minute interval (*n* = 1,224). One-half of all bat detections consisted of brief passes with less than 15 pulses. Higher thresholds of activity indicative of sustained bouts of foraging were defined with 50th, 70th and 90th percentiles of pulse number.

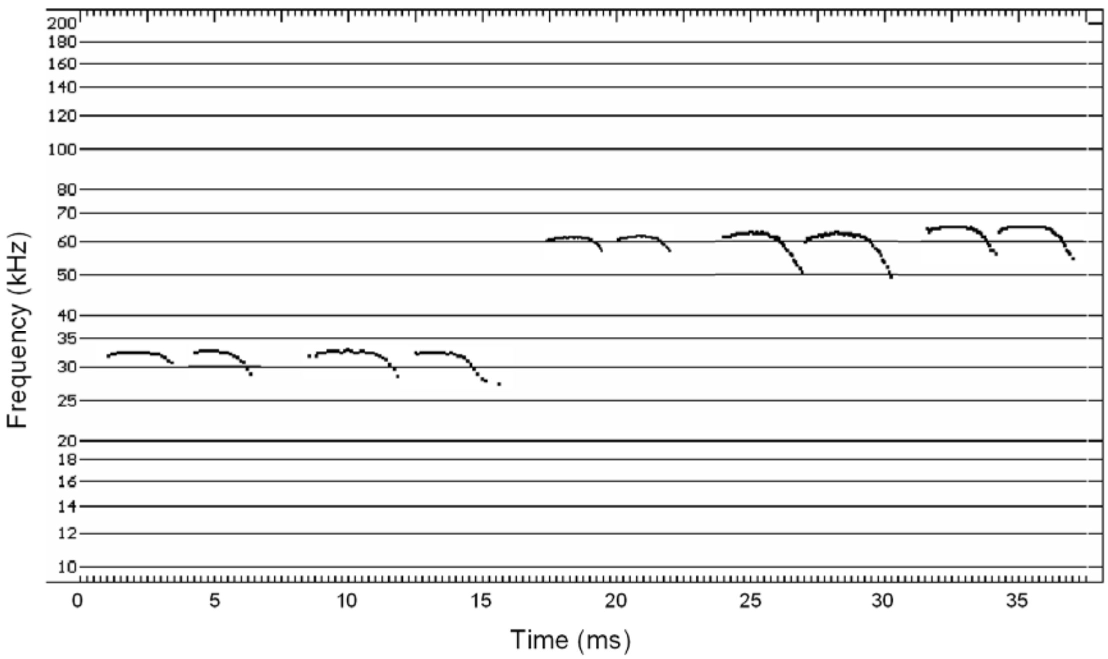
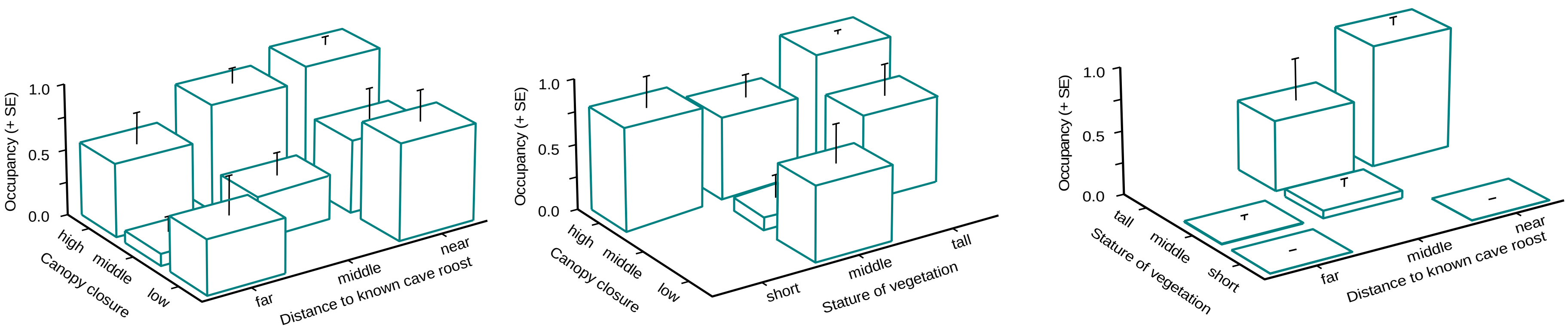


Figure IV-3. Examples of pairs of characteristic pulses in the search-phase calls of *E. s. rotensis*. Note that paired examples were derived from different Anabat call files, and the time between pulses was compressed to permit display of various pulses.



50th percentile threshold   70th percentile threshold   90th percentile threshold

Figure IV-4. Occupancy estimates (mean ± 1 SE) for existing combinations of habitat covariates at the 50th, 70th and 90th percentile thresholds of activity (results shown only for models with lowest AIC values and adequate goodness-of-fit).

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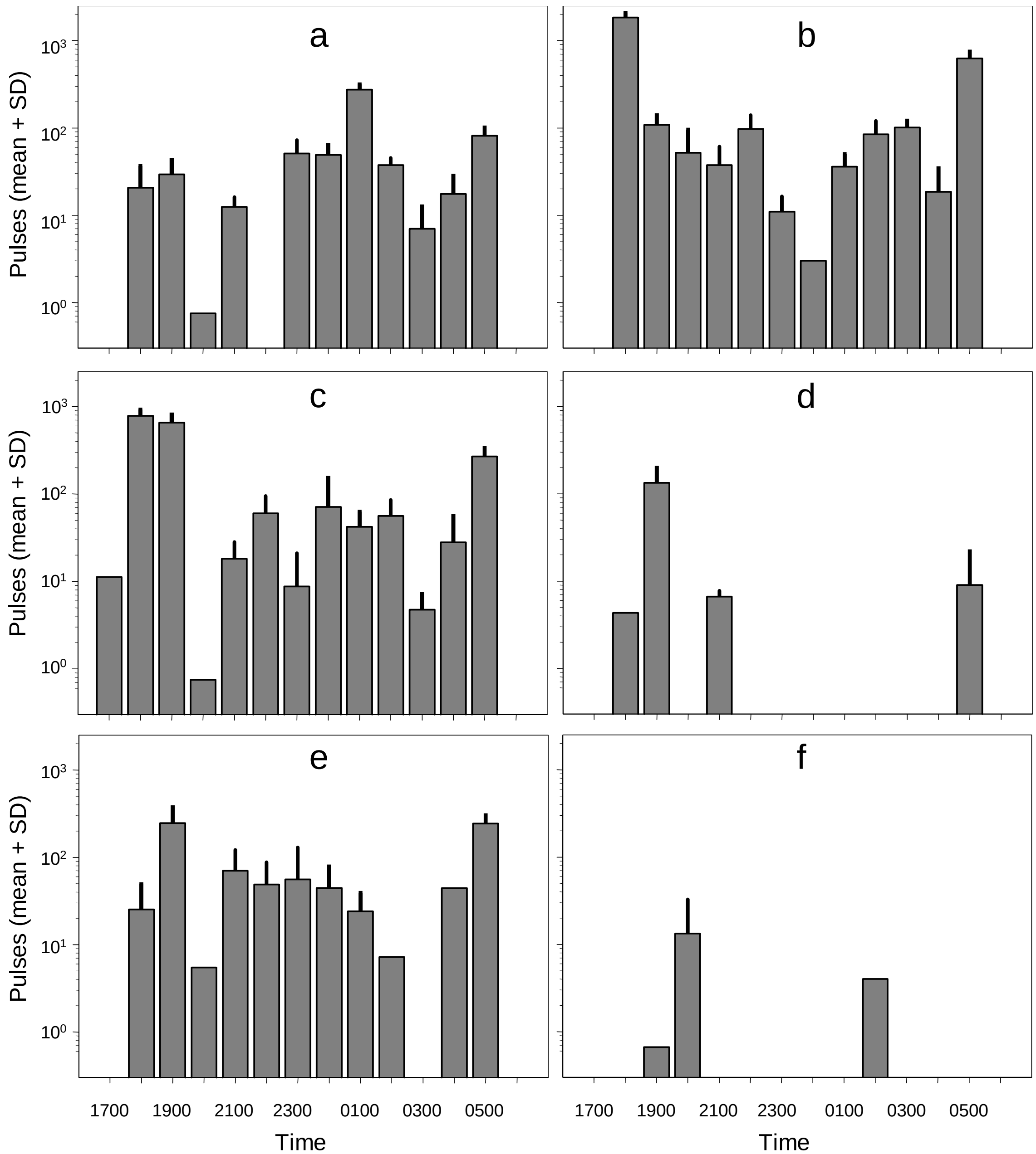
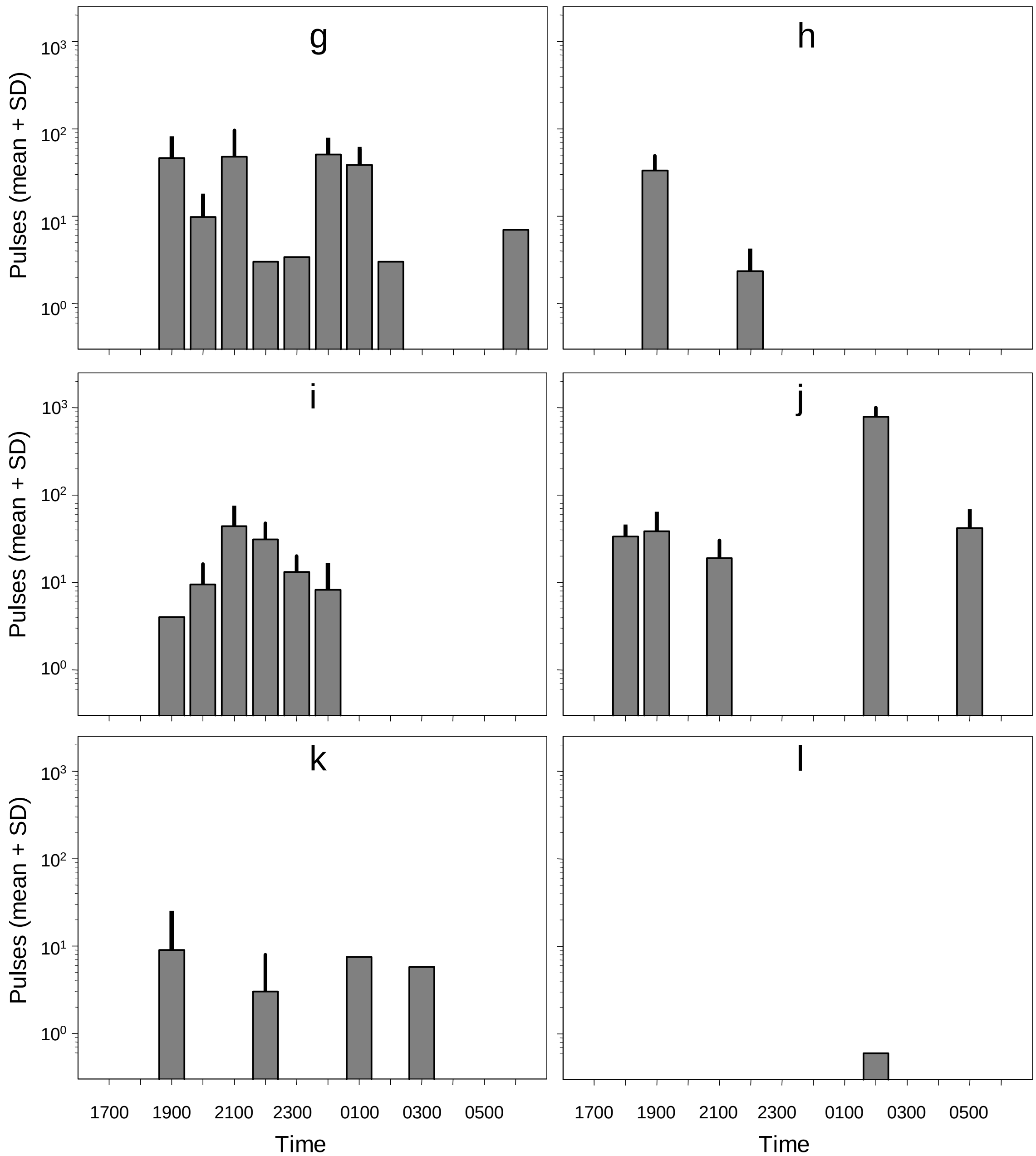
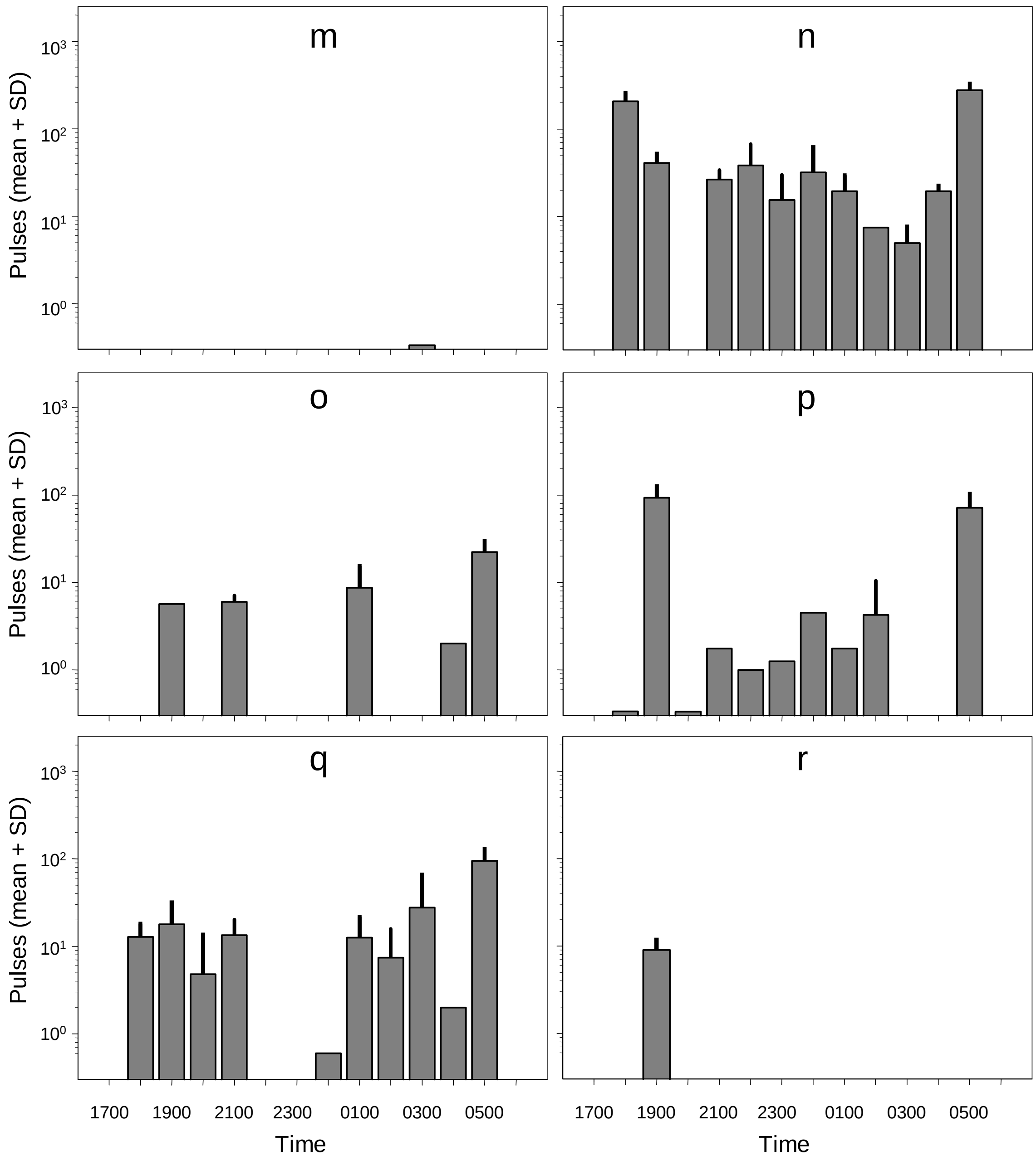


Appendix IV-1. *E. s. rotensis* activity by hour of night for all sites with detections on Aguiguan. X axis on each inset bar graph is hour of night beginning at 1700 and ending at 0600. Y axis is natural log of mean pulse total (+ 1 SD). Bars with no SD whisker had only a single observation in the hour. Graphs are shown as insets for each site (labeled a-v) in Figure IV-1.



Appendix IV-1 continued.



Appendix IV- 1 continued.

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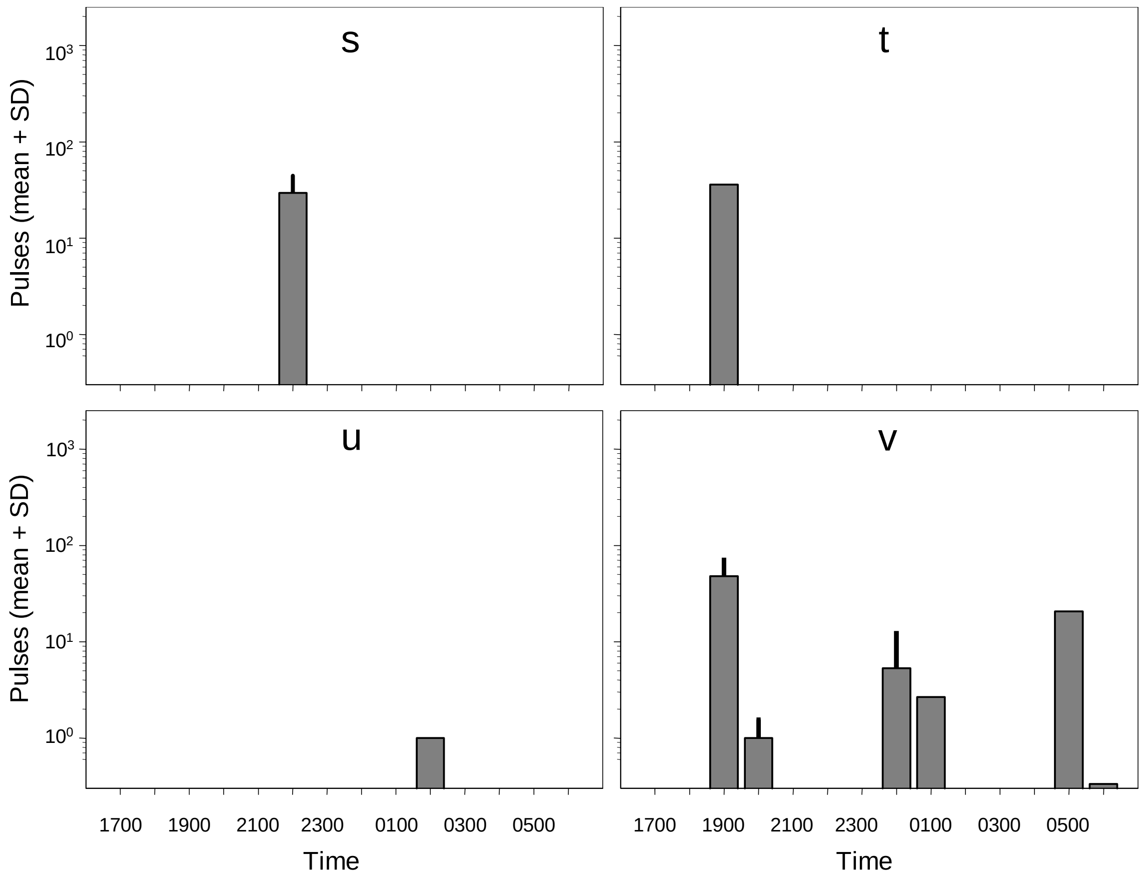

Appendix IV-1 continued.

Section V. Food Habits of the Pacific Sheath-Tailed Bat (*Emballonura semicaudata rotensis*) on Aguiguan, Commonwealth of the Northern Mariana Islands

Ernest W. Valdez

ABSTRACT

*Emballonura semicaudata rotensis*is is an endemic subspecies of the Pacific sheath-tailed bat known only from the Mariana Islands. It is extinct on all of the Mariana Islands where it once occurred except for the small limestone island of Aguiguan that supports an isolated remnant population. There is no information about the food habits of Pacific sheath-tailed bats. In 2008, I conducted an investigation of food habits of *E*. *s*. *rotensis* based on analysis of fresh fecal pellets from bats roosting in Guano and Crevice Caves on Aguiguan. I analyzed 100 pellets from each roost and found that major orders of insects consumed by *E*. *s*. *rotensis* from Guano Cave (based on % volume) included hymenopterans (64%), coleopterans (10%), lepidopterans (8%), isopterans (8%), and psocopterans (5%). Major prey items of bats from Crevice Cave included lepidopterans (45%), hymenopterans (41%), coleopterans (10%), and isopterans (5%). Most of the identified hymenopterans found in the guano from both roosts belonged to ichneumondoidea, followed by prey items belonging to formicinae and ponerinae. Because alates of formicines and ponerines, as well as isopterans, generally have wings only when they are reproductive or establishing new colonies, often at the onset of rains, it is likely that these food items occur in the diet of *E*. *s*. *rotensis* seasonally. Microlepidopterans were another likely seasonally abundant prey item consumed by *E*. *s*. *rotensis* include were lepidopterans. Beetles (Coleoptera) that were likely forest-dependent species were a consistent component of the diet. Most insect prey items were small ranging from 1.7 to 6.4 mm in length. From observations and diet analyses, *E*. *s*. *rotensis* can be categorized as an aerial insectivore or hawker, similar to other emballonurids around the world.

INTRODUCTION

Emballonura semicaudata rotensis, the subspecies of the Pacific sheath-tailed bat unique to the Marianas Islands, is an insectivorous microchiropteran that occurred historically on multiple islands including Guam (Lemke 1986, Koopman 1997). This bat is now extinct throughout its range except for the small (7.2 km^2) uninhabited island of Aguiguan in the Commonwealth of the Northern Mariana Islands (CNMI, Hutson and others 2001). At present, this bat is listed as a Category 3 candidate for listing under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2007) and is categorized as Endangered by the International Union for the Conservation of Nature and Natural Resources (Bonnacorso and Allison 2008, Hutson and others 2001). Exact reasons for its decline are unknown, but it is has been suggested that *E*. *s*. *rotensis* had succumbed to a series of events during a short period of time that eventually led to its demise throughout most of its historic range (Hutson and others 2001, U.S. Fish and Wildlife Service 2007, 2008, Bonaccorso and Allison 2008). Some of these events include:

disturbance of caves (especially during military operations in World War II), the only structures known to be used as roosts by these colonial bats in the CNMI (see Section III of this administrative report); loss or destruction of forest habitat used for by foraging bats during World War II and subsequent clearing for development; use of insecticides; typhoons; and perhaps invasive predators on some islands. All these factors are cited as possibly directly or indirectly impacting populations of this subspecies (Hutson and others 2001, Bonaccorso and Allison 2008, Cruz and others 2008). Although the use of insecticides and loss of forest habitat have been suggested as possible causes of declines, there is no baseline information about the kinds of insects that these bats eat. Understanding food requirements is an important componet for conservation and management of wildlife. Therefore, my objective was to determine what types of prey items are used to meet the dietary needs of Pacific sheath-tailed bats on Aguiguan.

MATERIALS AND METHODS

The food habits of insectivorous bats are typically determined by identification of chitinous fragments of insects in guano (Whitaker 1988). These bats masticate insects into small fragments that are best identified in guano rather than in stomach contents because the latter contain larger amounts of unidentifiable digestible material and require sacrificing individuals to obtain ingesta. Guano can be sampled non-invasively, which is of importance in studies of bats that are of conservation concern. On Aguiguan I sampled guano beneath daytime roosts of Pacific sheath-tailed bats at two caves. Guano Cave (Datum: WGS 84; 55P, 343039E, 1642089N, elev. 100m), the larger of the two roosts, houses one of the larger colonies of sheath-tailed bats on Aguiguan, with 43-64 bats counted in the roost in June and July of 2008 (see Section III of this administrative report). This cave is also shared by a colony of about 200 or more Mariana swiftlets (*Aerodramus bartschi*). Roosting bats were positioned about 15-20 m above the cave floor in a distinctive domed ceiling at the end of the deepest chamber of the cave, whereas most of the swiftlet nests were located closer to the outside opening on the inside wall of the same chamber, about 3-15 m above the cave floor. Most of the guano on the floor of the cave had accumulated over many years and had disintegrated into a fine powder, making it difficult to distinguish bat guano from swiftlet guano. To obtain comparative material, on 25 June 2008 I placed a 1 m x 1 m plastic sheet on the cave floor directly beneath the roosting bats and a similar sheet beneath the area where swiftlets roosted. On 30 June 2008, the sheets were retrieved from the roost and placed in plastic re-sealable bags.

We also sampled guano at a second roost that was not used by swiftlets. On 27 June 2008 I placed a 0.5 m x 0.5 m plastic sheet 1 m beneath a small group of bats (2-3 adults, 1 pup) in Crevice Cave (Datum: WGS 84; 55P, 343541E, 1641526N, elev. 72m). This roost can be described as a chute, chimney, or vertical solution tube in the back portion of the main cave. Because I observed only 3 bats using this roost, I left the plastic sheet under the bats for a longer period of time (13 days) to allow for a larger accumulation of guano.

During the period of guano sampling I also collected arthropods (mostly insects) as a reference collection for fecal analyses. Insects were collected mostly at night following techniques described by Kunz (1988), including use of a sweep net, beating of vegetation, and setting out a black light. I also attempted to collect insects using sticky-traps made of 76.2mm x 127mm index cards coated with an insect barrier (Tanglefoot Tree Pest Barrier ®). I attached these traps to twine and hung them vertically from the canopy, but abandoned this method after rain disintegrated the cards. Arthropods were placed in vials of 95% ethanol and identified at the Museum of Southwestern Biology, University of New Mexico, Albuquerque.

In the field I examined fecal material of bats and swiftlets to ascertain if these could be readily distinguished in the fresh samples. Intact fecal pellets produced by *E*. *s*. *rotensis* were elliptical and averaged about 4 mm long by 2 mm wide. Intact guano produced by swiftlets was globular, as observed for other small insectivorous birds, but varied in size. Swiftlet guano also could be differentiated by uric acid crystals combined with digested insects; uric acid crystals were not present in bat guano. Finally, microscopic inspection affirmed these gross differences: insect matter consumed by bats was always chewed into much smaller fragments than those found in swiftlet fecal matter. Using the aforementioned criteria for distinguishing bird and bat guano, I sorted formed guano pellets of *E*. *s*. *rotensis* from powdered guano, then grouped fecal material according to roost. Pellets were randomly sub-sampled and analyzed following techniques described by Whitaker (1988). Fecal pellets were placed in watch glasses with 95% ethanol and teased apart under a stereo-zoom microscope. Insect prey found in the guano were identified to the lowest taxonomic level, usually to family, using Chujo (1970), Borror and White (1970), White (1983), Whitaker (1988), Arnett (2000), Arnett and Thomas (2001), Arnett and others (2002), and Triplehorn and Johnson (2005) as guides for identification.

A single pellet represented one sample, and a total of 200 intact fecal pellets (100 from each roost) were analyzed. Percent volume and frequency were calculated for each prey item (Whitaker 1988). In addition to fecal analyses, I used digital calipers (Mitutoyo ®) to measure length x width, in mm to the nearest 0.01, of a single representative from my reference collection of arthropods that were similar in appearance to matched prey items found in the diet of *E*. *s*. *rotensis*.

RESULTS

The major food items consumed by *E*. *s*. *rotensis* from Guano Cave were hymenopterans at 64% volume and 95% occurrence (Table V-1). Prey items belonging to Ichneumonoidea (parasitic wasps) had the greatest percent volume (25%) and percent occurrence (45%) among identified hymenopterans. Prey items in the Formicidae (ants) were also identified within the Hymenoptera, including ants belonging to Formicinae (7%, 12%) and Ponerinae (2%, 12%, Table V-1). I identified the ponerines (i.e., trap-jaw ants) by the distinct shape of their mandibles, antennae, and fragments of head capsules, and believe that the individuals consumed by *E*. *s*. *rotensis* belong to the genus *Anochetus*. Other key prey items found in the guano of *E*. *s*. *rotensis* from Guano Cave included coleopterans (beetles) at 10% volume and 73% occurrence, followed by microlepidopterans (moths, 8%, 38%), isopterans (termites, 8%, 10%), and psocopterans (bark lice, 5%, 26%, Table V-1). All other identified prey items had values of 1% volume or less and did not occur frequently (Table V-1).

Pacific sheath-tailed bat fecal samples from Crevice Cave primarily contained microlepidopterans (45% volume, 86%occurrence) and hymenopterans (41%, 82%; Table VI-1). Ichneumonoids had the greatest percent volume (31%) and percent occurrence (46%) values among identified hymenopterans. Formicines contributed to 7% of the volume and were encountered in 26% of the samples (Table V-1). Coleopterans contributed to 10% of the volume consumed by the bats at Crevice Cave and were encountered in 68% of the samples examined (Table V-1). Within Coleoptera, beetles belonging to the Cryptophagidae (silken fungus beetles) accounted for 3% of the volume and were encountered in 18% percent of the samples (Table V-1). Isopterans contributed to 5% of the volume and were occurred in 6% of the samples from Crevice Cave (TableV-1). All other identified prey items had values less than 1% for percent volume and 5% or less for percent occurrence.

Measurements of arthropods matched with those consumed by Pacific sheath-tailed bats ranged in size from the smallest, a scolytine at 1.72 mm x 0.85 mm to the largest, a ponerine, at 7.6 mm x 1.63 mm (Table V-2). Isopterans were the next largest prey item at 6.13 mm x 1.55 mm, and could be considered the longest (11.87 mm) if wings are included in the measurements. I did not have a voucher specimen of an ichneumonoid from Aguiguan in my reference collection. Therefore, I used the size of the ichneumonoid wings found in the guano to estimate total size of the prey item, and then measured a formicid of similar size to provide an approximate length and width (Table V-2).

DISCUSSION

Results from this study represent the first documented information on the food habits of Pacific sheath-tailed bats. From observations of dusk and night-time flights of these bats in the forest on Aguiguan (described in Section VI of this administrative report) and those of Esselstyn et. al. (2004), foraging activity occurs near (above and below) the canopy of the native forest Sampling of echolocation activity on Aguiguan during the same period when I collected guano (see Section IV of this administrative report) also indicated that Pacific sheath-tailed bat activity occurred mostly in stands of native limestone forest. The activity observations and the types of food items determined from analyses of guano demonstrate that Pacific sheath-tailed bats on Aguiguan share the same feeding behavior (i.e., aerial insectivore or hawker) as noted for other members of Emballonuridae (Bonaccorso 1998, Lim and Engstrom, 2001). However, prey items found in this study differ slightly from those of other emballonurids elsewhere (Bradbury and Vehrencamp 1976).

Results from my analyses indicate that sizes of prey items or related insects consumed by Pacific sheath-tailed bats on Aguiguan were small (ranging from 1.7 mm to 6.4 mm in length). Hymenopterans, coleopterans, and lepidopterans were the three major groups of insects consumed by bat*s* from both roosts. Interestingly, ranking of orders by greatest percentages of volumes and frequency of occurrence differed between roosts. Although there were noticeable differences for hymenopterans at both roosts, the greatest observed differences were for the percent volumes of lepidopterans, with a greater consumption of moths in samples from Crevice Cave. The overall percentages of volumes and frequencies of occurrence for coleopterans in the diet of *E. s. rotensis* were nearly equal in guano sampled at the two roosts.

Within the Hymenoptera, I found that the percentages of volumes and occurrences of ichneumonoids consumed by bats from both roosts were similar. These parasitic wasps seemed to be a consistent prey item of Pacific sheath-tailed bats during the time I sampled guano. Based on samples from Guano Cave, I believe that formicids found in the diet of these bats may have been taken opportunistically during periods when alates form large swarms; usually during breeding or establishment of new colonies (Triplehorn and Johnson 2004). This also holds true for isopteran alates present in the bat guano (Triplehorn and Johnson 2004). Often swarms of ant and termite alates are associated with the onset of seasonal rains (Triplehorn and Johnson 2004). Rebello and Martius (1994) noted that in the Amazon peak periods of isopteran alate abundance occurred at the beginning and end of rainy seasons, but were lowest during the height of the rainy season. I collected guano on Aguiguan during the early part of the rainy season (late June to early July) and the presence of these ant and termite alates may be consistent with opportunistic feeding on these insects by Pacific sheath-tailed bats during the onset of the rains. Opportunistic feeding on winged formicids or isopterans by insectivorous bats is not uncommon and has been reported for other species elsewhere (Razakarivony and others 2005, Rakotoarivelo and others 2007).

It is interesting to note that even though Crevice and Guano Caves were only about 500 m apart there was a slightly higher presence of lepidopterans over hymenopterans in guano from Crevice Cave. I suspect that the higher abundance of lepidopterans at Crevice Cave may reflect greater availability and abundance of these insects, as noted for ant and termite alates. The intraspecific partitioning of resources and territories among individual bats has been noted for other emballonurids (Bradbury and Vehrencamp 1976) and could be a contributing factor for difference in food habits of bats sampled at different roosts.

From analyses of guano, I found fragments of coleopterans in some fecal pellets that had been broken down into a paste-like texture, likely by chitinase produced by bacteria in the gastrointestinal tracts of the bats. Whitaker and others (2004) noted that during summer feeding by bats in North America, harder and larger pieces of insects often pass through the digestive tracts of bats undigested. In part this is related to the fast (~30-60 min) transit time in the digestion of food by insectivorous bats (e.g., *Myotis lucifugus*; Buchler 1976). However, Whitaker and others (2004) also suggested that after an insect has been chewed into small pieces, the presence of chitinase helps break down connective tissue, making it easier to digest prey items. Whitaker and others (2004) also found that during winter months, chitinase activities are lower because bats are in torpor and often have little amounts of food. Because chitin remains in the gut for a longer period of time, this allows for a longer period for the breakdown of insect parts by chitinases. Because of the presence of highly digested beetle parts in the guano, I believe that some Pacific sheath-tailed bats may digest certain food items longer (i.e., beetles) with chitinase, especially during periods when food resources are low or preferred items are unavailable.

The concurrent analyses by Goressen and others (Section IV in this administrative report) show that native limestone forest habitat is a key component to the foraging behavior of Pacific sheath-tailed bats on Aguiguan. Coleopterans identified from fecal analyses also provide specific information on the importance of native forests. For example, cryptophagids feed on fungi and vegetation matter at different levels of decay, and many scolytines feed on dying trees (Triplehorn and Johnson 2005). Because of their ecology and fidelity to dying or decaying trees the presence of these beetles in the diet of Pacific sheath-tailed bats on Aguiguan provides additional evidence that the bats are foraging in and near the forests. Although beetles are not present in large volumes, they occur in a large proportion of the fecal pellets examined and are thus an important part of the diet..

My results suggest that during the onset of the rainy season (late June to early July) mature, native forests are important in providing food resources for Pacific sheath-tailed bats. I suggest that forest management emphasize practices that are not likely harmful to populations of small insects for future conservation of this bat on Aguiguan. For example, use of herbicides to control invasive vegetation must account for likely effects on native plants that support insect populations, and use of insecticides in native forests could alter the prey base of the bats. This study only represents a snap-shot of time in understanding what prey items are consumed by Pacific sheath-tailed bats on Aguiguan. I believe that the diet of this bat could be complex, likely includes other unidentified food items, and may change with variation in seasonal availability of prey, environmental variation, or reproductive conditions of the bats. Therefore, to better manage forest and perhaps other habitat needed for foraging by bats, I suggest that future studies investigate the feeding ecology and behavior of these bats during other periods of the year.

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Table V-1. Percent volumes and percent occurrences of food items of the Pacific sheath-tailed bat (*Emballonura semicaudata rotensis*) from Aguiguan, as determined by fecal analyses. Sample sizes from each cave are noted in parentheses. Values in bold represent overall percentages for volumes and occurrences of each order.

	Guano Cave (n=100)		**Crevice Cave (n=100)**	
Prey Item	**% Vol.**	**% Occurrence**	**% Vol.**	**% Occurrence**
Ichneumonoidea	25	45	31	46
Formicinae	7	12	7	26
Ponerinae	2	12		
Unkn. Hymenoptera	31	63	3	18
HYMENOPTERA	**64**	**95**	**41**	**82**
Curculionidae	<1	2		
Scolytinae	1	9		
Cryptophagidae	<1	4	3	18
Mordellidae	<1	3	<1	6
Chrysomelidae			1	1
Unkn. Coleoptera	8	60	6	53
COLEOPTERA	**10**	**73**	**10**	**68**
Microlepidoptera	8	38	45	86
LEPIDOPTERA	**8**	**38**	**45**	**86**

ISOPTERA	**8**	**10**		**5**	**6**
Pseudocaeciliidae	5	26		<1	2
PSOCOPTERA	**5**	**26**		**<1**	**2**
Cicadellidae	<1	4		<1	2
Unkn. Auchenorhyncha	<1	7		<1	2
HEMIPTERA: Auchenorhyncha	**<1**	**11**		**<1**	**4**
DIPTERA	**<1**	**1**		**<1**	**5**
UNKNOWN INSECT	**1**	**10**		**<1**	**20**
FEATHER FRAGMENT	**1**	**24**			
UNKNOWN	**2**	**4**			

Table V-2. Measurements (length and width) of a single representative from some of the prey items consumed by Pacific sheath-tailed bats on Aguiguan were recorded to the nearest 0.01 mm. Lengths are measured from tip of head or mandible, whichever extends furthest, to the end of body; lengths in parentheses represent length of head to posterior tip of wings. Widths are measured at the widest point of the insect, including head or body, but not legs. Missing values are marked with hyphens. Asterisks denote the estimated length and width of consumed Ichneumonoidea, based on measurements of a formicid of similar wing size.

Insect	**Length in mm**	**Width in mm**
Ichneumonoidea*	3.38 (4.15)	0.73
Formicinae	5.10 (6.07)	1.20
Ponerinae	7.60 (-)	1.63
Curculionidae	2.37	1.20
Scolytinae (large)	2.57	0.95
Scolytinae (small)	1.72	0.85
Cryptophagidae	3.28	1.50
Mordellidae	3.32	1.26
Chrysomelidae	6.07	3.91
Microlepidoptera	2.69 (3.14)	0.94
Isoptera	6.13 (11.87)	1.55
Pseudocaeciliidae	2.75 (3.36)	0.98
Cicadellidae	2.89 (3.76)	1.36

Section VI. Capture, Morphometrics, Museum Specimens, and Other Sampling and Observations of Pacific Sheath-Tailed Bats (*Emballonura semicaudata rotensis*) on Aguiguan, Commonwealth of the Northern Mariana Islands

Thomas J. O'Shea and Ernest W. Valdez

ABSTRACT

In 2008, we used standard means to capture Pacific sheath-tailed bats in mist nets on Aguiguan while they dispersed or foraged through the forest, but these attempts were largely unsuccessful because the bats were highly maneuverable and easily avoided mist nets on close approach. We successfully captured 12 adult bats and one attached suckling young by using hand nets on bats in flight in the forest, or mist nets set in or near caves used as roosts. Both methods have logistical problems and limitations: in addition to the high maneuverability of the bats precluding use of mist nets in standard configurations, considerable time is required to accrue multiple captures using hand nets, and caves where bats roost are co-occupied by endangered Mariana swiftlets. We also found that these bats can be very sensitive to initial handling. We discuss suggestions for capturing and handling bats in future studies. Despite limited numbers of bats captured, forearm measurements show for the first time that there is considerable overlap in body size with the other three subspecies of *Emballonura semicaudata*. In addition to variation in skull morphology, size was previously thought to be another trait that may vary with subspecies. We also collected small wing biopsies from these 12 bats prior to release for some basic preliminary genetic analyses to ascertain genetic diversity of the population on Aguiguan, and the depth of division of this subspecies based on comparison with published data on genetics of *E. semicaudata semicaudata* from Fiji. Although not part of the original proposal, laboratory phases of the genetics analyses are planned for 2009 by the U.S. Geological Survey. We also prepared two museum voucher specimens of *Emballonura semicaudata rotensis*, increasing the number of specimens from the Mariana Islands available in United States museums from two to four. Considerable numbers of specimens of the other subspecies are available worldwide (over 300), and about 22 additional specimens from the Marianas Islands (including Guam) are housed in museums in France and Japan. Expanded study of museum specimens and comparative genetic analyses would be needed to fully ascertain the systematic status of the Pacific sheath-tailed bat population in the Mariana Islands. All bats captured at caves by us in 2008 and by others in years past were females, whereas the 4 bats we captured at dusk dispersing along a steep rocky hillside, not near any known colony, were males. This tentatively suggests that perhaps males may form bachelor colonies apart from roosts occupied primarily by females, as is known for other species of Old World species in the genus *Emballonura*. Elaborate social behavior patterns were also suggested by the audible communication sounds produced by bats that we observed foraging and dispersing through the forest and flying into caves. Thermal

characteristics of caves on Aguiguan show little variability, and relative humidity is high. Cave temperatures are similar to those used by other tropical emballonurids elsewhere, and do not suggest that the availability of caves with special thermal or humidity characteristics is a limiting factor for Pacific sheath-tailed bats on Aguiguan.

Introduction

There have been few attempts to capture Pacific sheath-tailed bats for scientific research in the Commonwealth of the Northern Mariana Islands or Guam. Lemke (1986) summarized the early literature documenting the taking of two bats for museum voucher specimens on Aguiguan in 1984, 14 bats for taxonomic study on Rota in 1932, and six bat specimens on Guam in 1887, all obtained by unspecified techniques. We were interested in capturing bats on Aguiguan for a variety of purposes, particularly at locations other than roosts. We hoped to gain additional data pertaining to body size, reproduction, and population sex and age composition. There is very little prior information on these biological attributes of this subspecies. We also sought to (1) obtain biopsy samples that could be used in future genetics research aimed at determining both the genetic diversity and degree of genetic distinctiveness in this population; (2) examine and sample the bats for ectoparasites; (3) sample fresh guano for food habits analysis; and (4) deploy miniature radio transmitters to assess movements and possibly determine the locations of previously unknown roosts. In separate sections of this administrative report we provide results of findings on reproduction (Section VII) and food habits (Section V). Herein, we provide a summary of all other efforts at capturing sheath-tailed bats on Aguiguan and resulting data and observations. We also provide a summary of available museum records for *Emballonura semicaudata* from throughout its range that may be useful to future researchers, and a descriptive summary of the temperature regimes and humidity in some of the caves on Aguiguan. The purpose of describing temperature and humidity regimes of caves was to determine if enough variability in these factors existed to support a hypothesis that numbers of suitable caves might be a limiting factor for this population. We also offer suggestions for future researchers regarding the capture of sheath-tailed bats on Aguiguan and how the risks of capture stress can be minimized.

MATERIALS AND METHODS

Capturing, Handling, and Sampling Bats

In most studies elsewhere, small insectivorous bats are typically captured at roosts or as they fly close to open sources of freshwater in pools and ponds to drink or feed or at constricted “flyways” along edges or through vegetation (Kunz and others 1996). There were no sources of open freshwater on Aguiguan and we did not observe natural flyways that would facilitate capture of bats. Additionally, sampling directly at roosts in this study was complicated by the presence of endangered cave swiftlets at nearly all roost locations and their overlapping times of ingress and egress with bats at dusk; it was also complicated by the potential of creating disturbance to the extent that bats might abandon roosts.

Therefore we initially attempted to capture bats in flight in the forest as they were foraging or dispersing from roosts, or at caves on return flights from foraging after swiftlets had settled in for the night. We risked disturbance by capturing bats within a roost during the day only once at Crevice Cave and once at Guano Cave, both instances took place near the end of the study.

We attempted to capture bats in the following seven ways, which met with only limited or no success. These were: (1) placing mist nets in the forest a short distance below Guano Cave with the intent to capture bats as they returned from foraging, after swiftlets had gone to roost; (2) placing mist nets within the outer opening of East Black Noddy Cave with the intent to capture bats as they returned from foraging (after swiftlets had gone to roost and most bats had emerged); (3) placing mist nets in the forest below the canopy on the first forested terrace above East Black Noddy Cave to capture them as they foraged or dispersed to forage; (4) placing mist nets in the forest below the canopy at various other locations in native limestone forest to capture them as they foraged; (5) setting a short mist net across the opening of the outer, shallow, chamber of Guano Cave to intercept bats taking refuge after we intentionally disturbed them, a few at a time, during the day in their regular roost within the same cave; (6) similarly using a short mist net and insect sweep net at Crevice Cave during the day; (7) using a hand insect sweep net and stationary mist nets to capture bats in flight as they dispersed up the hillside among the boulders and cliffs near Fault Line Cave 1 (Cave 94). Locations and descriptions of caves are provided in Section III of this administrative report.

Captured bats were examined to determine sex and age (adult or volant juvenile based on the degree of closure of the phalangeal epiphyses following Anthony 1988), and weighed on a Pesola spring balance calibrated in the field (to 0.1 g). Wings, ears, uropatagia, and fur of bats were examined with a 20x magnification visor and fine-point forceps for visible ectoparasites. Prior to field preparation of museum vouchers, specimens were also examined under a 14-60 x stereo-zoom microscope for ectoparasites. We also measured forearm length (to 0.1 mm) with dial calipers, and took small (3 mm diameter) circular punches of the wing membrane in the proximal plagiopatagium using skin biopsy tools after sterilization of the wing with a general antiseptic. Biopsies were immediately placed in 95% ethanol in the field and were stored at -80˚C after return to the laboratory in Fort Collins in late July. Sampling of wing tissues following this methodology is a standard procedure in bat genetics research (e.g. Worthington Wilmer and Barratt 1996, Neubaum and others 2007). Other methods also are standard procedures in bat field research (see Kunz 1988).

Records of Specimens in Museums

We tabulated records of *Emballonura semicaudata* in various museum collections around the world to provide an estimate of the range of localities and number of specimens that may be available for future studies of the taxonomy of these bats. We tabulated sources from the literature that refer to specimens, and also queried the online database of the Global Biodiversity Information Facility (http://www.gbif.org/). The results are probably a minimum number because some major museums do not have searchable databases online. However, there also may be some overlap between specimens referenced in publications and those retrieved online, although we avoided duplicate counting of these when obvious to us.

Temperature and Humidity of Caves

We sampled relative humidity manually using a sling psychrometer at about 1.5 m above ground, recording wet and dry bulb temperatures. We sampled temperatures using Thermocron iButton data loggers (model DS1921, Dallas Semiconductor Corporation) that are factory calibrated at a level of precision of ± 1 °C. We programmed the loggers to record temperature hourly. Two data loggers were placed together at each sampling point to insure redundancy in obtaining temperature data in the event one logger failed. When both loggers were functional we took the average of the two readings (most differences were low and none at caves exceeded 1.5° C, see results). We calculated summary statistics for each station based on time periods that ran for complete 24 hour cycles to avoid including biases from any particular time of day. For logistic reasons we could not run all loggers simultaneously for the same number of days. Therefore we also provide and compare summary statistics for all stations between 7 July and 10 July, a period when all loggers were operating simultaneously. In most cases we took temperature readings at the rock surface because these bats roost singly appressed to the rock walls or ceilings (see Section III of this administrative report). We had access to two roosts that were regularly occupied by bats. We did not attempt to measure temperatures at the precise places where bats roosted because we did not want to risk disturbing them. We placed dataloggers at two locations in Crevice Cave after the bats left to forage at dusk, with the highest about 0.5 m from where the bats roosted. At Guano Cave we recorded temperatures directly below the area used by the roosting bats (see Section III of this administrative report) up to a height of 6 m, about 4-6 m directly below the area occupied by roosting bats. Here, at a more shallow domed area closer to the mouth of Guano Cave, and at Fault Line Cave 1 we took readings at multiple heights above the cave floor by taping data loggers to tall poles we propped against the cave wall. Ambient temperatures for the study period were taken at base camp on the Aguiguan central plateau (coordinates 344803E and 1642496N, WGS 84 55 P). At camp paired data loggers were suspended on a cord in mottled shade at heights that were 1 m, 2 m, and 3 m above cleared level ground. We viewed gathering of data on temperature and humidity within caves as a preliminary, exploratory attempt to characterize the amount of variability in these attributes. Our analysis of the temperature data from these caves is limited to calculation of summary statistics for hourly temperature readings at each station, with a qualitative discussion of their attributes and variability in relation to knowledge about cave environments used by emballonurids and other tropical bats elsewhere.

RESULTS AND DISCUSSION

Capture and Handling

We attempted to capture bats on 13 different dates during our field work on Aguiguan (Table VI-1). We captured 12 adult bats, plus an attached single young of one female (Table VI-2). None of these had any visible ectoparasites. The first three bats we captured appeared stunned by handling, and one of these died. In the latter case, the bat was held for about 10 minutes while photographed using a flash, measured, and examined under illumination of a headlamp. This handling routine was also followed in the case of the two stunned bats; however, these two bats were placed in small cloth bags after handling, then later sampled for wing biopsies prior to release. During subsequent captures we immediately placed captured bats individually in small cloth bags with minimal handling or shining of lights before taking measurements or inspecting them closely. When thus handled the bats seemed less stunned and flew readily upon release. It appears that to avoid stunning or death, sheath-tailed bats should not be subject to intense handling immediately following the initial shock of capture. Instead the bats should be placed individually in cloth bags and left undisturbed and out of the beams of headlamps for 10 minutes or more before resuming handling (10 minutes was the shortest interval we measured between placing a bat in a cloth bag and its removal and release without signs of stunning).

We abandoned our original intent to apply radio transmitters to Pacific sheath-tailed bats in part because of the possible detrimental effects of the lengthy handling (20-40 minutes or more) prior to release that tagging would require. This extra time would be necessary to allow the colostomy cement used for attachment of the tag to dry under the high humidity at Aguiguan. We intended to apply tags primarily to bats captured during foraging to try to locate unknown roosts, but such capture attempts were only minimally successful (see below) until the last few days of our field work when subsequent tracking would be infeasible. However, considering the capture successes on 11-13 July (Tables VI-1 and VI-2) when no mortality and almost no stunning occurred after quickly placing bats in cloth bags and not handling them for at least 10 mins after capture, future researchers should not be discouraged completely from using radio telemetry as a tool to answer specific biological questions about sheath-tailed bats. All of the bats captured within Guano Cave on 12 July flew readily on release after being held in cloth bags from 10 mins to up to 2 hours (1 case) and then handled for about 5-10 minutes additional time after being held in bags. None flew outside of the cave in the daylight, and all returned to the main roosting chamber. Future researchers should use the approach of initially holding the bats in cloth bags with minimal disturbance prior to handling, and cautiously attempt to attach radio tags to a small number of bats to further determine if radiotagging will be a feasible tool for study. Radiotagging to locate roosts may have other limitations: one tag we activated and placed within Guano Cave below roosting bats had the signal severely attenuated by the rock and was only detectable at the cave mouth.

We saw Pacific sheath-tailed bats easily avoid mist nets on multiple occasions when we tended nets in the forest, and in the rocks along likely dispersal routes and foraging areas. These bats are light and maneuverable fliers. Other species of *Emballonura* elsewhere in the Paleotropics are also known to be highly acrobatic flyers, adapted to foraging in the understory for aerial and foliage-perched insects (Bonaccorso 1998). Pacific sheath-tailed bats on Aguiguan easily detected and avoided nets in open areas, turning to fly over or along the lengths of nets when within 1 m or less of the mesh (some of these observations are listed in Table VI-1). We found that the best method for capturing bats under these circumstances was to use a hand-held insect collecting net, sweeping flying bats into it. This seemed to be especially efficient when bats were flying close to mist nets. Unfortunately, this method is most effective only during the short interval at dusk, such as when we captured bats dispersing in the vicinity of fault Line Cave 1 (Cave 94). Few bats were observed in this area after the first 30-60 minutes after dark. Using sweep nets will only yield a small number of bats, caught one at a time during a short period each night. Obtaining larger samples will require considerable effort on multiple nights using more than one observer with sweep nets. Use of sweep nets might be suitable, for example, in capturing small numbers of bats for possible radiotagging to attempt to locate unknown roosts or foraging areas. Capturing bats at roosts may be more efficient for obtaining larger sample sizes for assessment of reproduction, sex, age and morphometrics. Attempts in the future will need to devise ways to sample bats at roosts without unintentional capturing of cave swiftlets which occupy the same caves used by the bats. Development of novel methods for capturing these bats should also be considered.

Observations of Feeding and Dispersing Bats, and Sex and Age Composition of Captured Bats

Our attempts to capture bats in the vicinity of Cave 94 (Tables VI-1 through VI-3) were based on observations made early in the study during searches for previously unknown roosts along the fault line that is a dominant feature of the area (see Section III of this administrative report). We saw Pacific sheath-tailed bats dispersing uphill and foraging at various heights under the canopy, ranging from about 1.5 to 5 m, while we were standing near openings of inaccessible caves to observe possible emergences of bats at dusk (none emerged). Some of these bats would pause to forage in a characteristic “beat” (sensu Vaughan 1959) flying back and forth in elliptical patterns about 20 m long for a few (e.g. 2-4) minutes, including insect pursuit phases heard on echolocation detectors, whereas most seemed to fly directly through the area heading uphill. Multiple bats were seen foraging and dispersing through this area on several nights (Table VI-4). This minor concentration of bats led us to believe that there is an undiscovered roost nearby. This is suggested by the following lines of evidence: 1) The first observations of bats in flight ranged from 18:31 to 18:50 h, overlapping with the times of initial exits of sheath-tailed bats we observed at caves used as roosts (Section III of this administrative report); 2) This much activity was not observed at dusk below the forest canopy at a distance of about 90 m above and 115 m inland from the largest known colony at East Black Noddy Cave (see below); 3) Echolocation activity at dusk at a point near the sea cliffs below the fault line was low when monitored with a hand-held bat detector on 2 July, indicating that not many bats had followed the cliff edges from Black Noddy Cave to enter the forest and fly up the fault line at this point on the island; 4)We captured four bats as they dispersed through the area, and all were adult male (this was the only place males were captured), whereas all 12 bats we captured at Guano Cave and East Black Noddy Cave were adult females, as were 6 and 2 bats captured at Guano Cave in 2003 and1984, respectively (see Lemke 1986). This suggests that the unknown roost may harbor a bachelor colony. Such predominantly male colonies are known for some other insectivorous bat species, as well as in other species of *Emballonura* in the paleotropics (Bonaccorso 1998). All these observations are preliminary, however, and more dedicated field work will be necessary to determine if males form bachelor colonies and if undiscovered roosts exist in the "Fault Line" area (near Caves 66-68, 94, 95, and 101) of Aguiguan. These bats have been observed commuting distances of 5 km during evening dispersal (Wiles and others 1997), so it is also possible that the observations were of bats originating at a more distant site than the immediate area where they were observed. Sex composition of bats using caves could also vary seasonally and with mating or breeding behavior, but this also will require additional detailed field research to determine.

A few other noteworthy observations were made of sheath-tailed bats at dusk or while foraging or dispersing. As noted above, we set up mist nets under the canopy in the forest on the first terrace above East Black Noddy Cave on 1 July (Table VI-1). Although 323 bats were observed exiting the cave that night between 18:35 and 19:11 h (Section III of this administrative report), only 2 bats were observed in the forest about 115 m away and 90 m above the cave (see coordinates in Table VI-1) during and after the emergence period (Table VI-1). This suggests that the bats using this cave either disperse widely soon after exiting, or do not enter below the canopy until they are farther from the cave.

Interesting observations were made at Pillar Cave at dusk on 21 June and 7 July (see also Section III of this report) when 13 and 21 bats, respectively, entered the cave from elsewhere and used multiple audible communication sounds between 1841 h and 1902 h. No bats were observed roosting in this cave during the day in 2008, but smaller numbers (2-10) had used the cave in 1995, 2002, and 2003 (Section III of this administrative report). These and other observations suggest that these bats use some caves at night for social reasons. We also heard social calls given by some bats dispersing at dusk in the vicinity of Fault Line Cave 1 (Cave 94), and by one bat that entered this cave at dusk on 13 July. It entered the cave while emitting single audible chirps with 1-5 sec pauses between chirps, until it exited the cave through a small opening in the ceiling. Audible calls of these bats were high pitched chirps that varied from about 1 to 5 syllables, and to our ears reminded us of directive calls of pallid bats (*Antrozous pallidus*) heard in the desert southwestern United States (e.g. Orr 1954, Brown 1976, O'Shea and Vaughan 1977). Communication calls of sheath-tailed bats were also heard as these bats dispersed and foraged in the forest. On 2 July we tended nets set below the canopy in the forest and noted a few bats dispersing through the area up until 19:00 h, but then there was no notable activity of bats in flight. Beginning around 22:15 h we began to observe bats flying between the forest floor and canopy producing audible social calls, and once saw three bats flying in a group. On the following night we saw bats in the same area earlier, from 19:00-22:50 h, heard audible calls, and observed one bat chasing another near but below the canopy. Bat social activity and behavior may change from place to place and from night to night as well as seasonally.

Museum Specimens, Morphometrics, and Subspecies Designations

The female bat that died during handling and a subsequently captured male that appeared stunned were saved as museum study skins and skeletons, with soft tissues (heart, kidney, liver, spleen, lungs, and muscle) preserved in 95% ethanol. These two specimens are a small but important addition to the few specimens of this subspecies available in museum collections and have been deposited in the Museum of Southwestern Biology (MSB) at the University of New Mexico, Albuquerque (MSB 125656 and 125657). Soft tissues are cataloged as NK104278 and 104279.Historic specimens were reviewed by Lemke (1986) and are briefly repeated here. There are six specimens in France's National Museum of Natural History in Paris. These were collected in 1887 on Guam. Four of these six were mentioned by Oustalet (1895, cited by Lemke 1986) but no details about them have been published other than Lemke's (1986) clarifications. In 1932 a total of 14 bats were collected on Rota and formed the basis of the subspecies description by Yamashina (1943). In June 1984, Lemke (1986) collected two females at Guano Cave on Aguiguan, and these specimens are housed at the American Museum of Natural History (AMNH 256514 and 256515). These and the two specimens we collected are the only samples of this subspecies in museum collections in the United States.

Published data on morphometrics of this subspecies are apparently limited to perhaps two bats mentioned by Yamashina (1943) and the two bats collected by Lemke (1986). The forearm lengths and body masses we measured on bats released after capture provide an improved estimate of the range of body sizes known for *Emballonura semicaudata rotensis* based on both the minima and maxima of forearm lengths of adult males and adult females (Table VI-3). It is important to note that the subspecies designations for *E. semicaudata* follow geographic distributions, but also have been morphologically defined on the basis of body size and qualitative features of skull morphology in small numbers of specimens, with a linear series from smallest to largest defined as *E. s. semicaudata-E. s. palauensis-E. s. rotensis-E. s. sulcata* (Koopman 1997, Helgen and Flannery 2002). Our measurements of forearm lengths show that the Aguiguan population has overlap in body size with each of these other three subspecies, making size alone a poor criterion for subspecies definitions.

We updated summaries of museum specimen records for all subspecies of *Emballonura semicaudata* previously provided in part by Lemke (1986), Koopman (1997), and Helgen and Flannery (2002). This new summary is not exhaustive, but suggests that at least 386 specimens from wide areas of the species range are housed in the world's museums (Table VI-5). Subspecies designations made in the past (see reviews in Koopman 1997, Helgen and Flannery 2002) were based on far fewer specimens than are now known to be available, and did not include any genetic analyses. A comprehensive systematic review and new morphometric and genetic analyses would be desirable to improve our understanding of the degree of differentiation among these taxa. The current ranking of *Emballonura semicaudata rotensis* as a Category 3 candidate for listing under the U.S. Endangered Species Act is based largely on its systematic status as a subspecies of a more widely ranging species (U.S. Fish and Wildlife Service 2007).

Wing Biopsies for Genetics Studies

We obtained wing biopsies from all 12 adult bats captured during this study. These are now archived at -80° C at the USGS laboratory at Fort Collins with plans for molecular genetics studies in 2009 by USGS staff and cooperators at the Rocky Mountain Center for Conservation Genetics and Systematics. Analysis of these samples will focus on understanding the current level of genetic diversity in the isolated population on Aguiguan, as well as assessing the overall level of differentiation of this population in comparison with another, previously analyzed population of *Emballonura semicaudata semicaudata* on Fiji (Colgan and Soheili 2008). The latter analysis also might help ascertain if a subspecies designation is appropriate or if genetic divisions of sheath-tailed bats in the Mariana Islands are even deeper. To our knowledge the only genetics research involving Pacific sheath-tailed bats was the comparative analysis of *E. semicaudata* from Fiji with three other full species of *Emballonura* and a fifth emballonurid species, *Mosia nigrescens,* from the southwestern Pacific (Colgan and Soheili 2008). This study examined segments of the mitochondrial DNA genome in *E. semicaudata* from 12 bats sampled at three locations on Fiji. Objectives of the study were aimed at understanding biogeography and evolutionary processes as exemplified by the regional bat fauna rather than at estimating the genetic diversity or depth of divergences within *E. semicaudata*. However, the development of primers and data on gene sequences deposited in GenBank by Colgan and Soheili (2008) provides basic information that will expedite a preliminary analysis of variation in mtDNA of Pacific sheath-tailed bats on Aguiguan by USGS biologists. Results of the mtDNA studies may be expanded to other segments of the genome depending on preliminary findings.

Cave Temperatures and Humidities

We deployed and recovered 58 functional temperature data loggers at 31 stations: 3 stations in camp, and 28 stations at 7 caves (Tables VI-6 and VI-7). Duplicate readings were obtained at 27 of the 31 stations, with 4 other stations based on single logger records. Agreement on temperature readings between the loggers at each station was good. The distribution of differences between 5,828 hourly readings of paired loggers placed at caves was: 0.0°C (58.9 % of readings), 0.5°C(30.4 %), 1.0°C(10.4 %), 1.5°C(0.2 %), > 1.5 °C (0.0 %).

Temperatures at camp during the recording period averaged about 27 °C, fluctuating over a 10 °C range from a minimum of 22 °C to a maximum of 32.8 °C (Table VI-6). Temperatures at stations in all caves were much less variable, ranging from no variation to at most 3 °C, with mean temperatures at all stations in caves ranging narrowly from 26 °C to 27 °C. During the period when all recording stations were operating simultaneously (Table VI-7), minimum and maximum temperatures at all stations within caves varied by 0 to 2 °C; temperatures within most caves at depths of 20 m or more and heights of 1-3 m above cave floors were essentially constant, although the inner chamber at Guano Cave fluctuated by about 1 °C during this period. Slightly greater fluctuations were recorded over longer periods. Variation with height within caves was also minor in the three caves where this was measured (Guano Cave at two locations, Dangkolo Cave, and Fault Line Cave 1): means at various heights were within 1 °C or less, and differed by only fractions of degrees over a height range of 6 m directly below the roosting bats at Guano Cave. Maximum temperatures in all caves over the full recording periods also spanned a narrow range, from 26 °C to 28 °C (Table VI-6).

Overall there were no obvious major differences in thermal regimes of the caves we sampled regardless of history of occupancy by bats. Given that the manufacturer's specifications for these data loggers are ± 1 °C , the differences in mean temperatures we observed when computational averages were rounded to the nearest °C were at most 1 °C, with rounded means at all stations within caves either 26°C or 27 °C (Tables VI-6 and VI-7). Stations within two caves that had no history of occupancy by bats (Dangkolo Cave and Cave 68) averaged 26 °C and did not reach the maxima recorded in Guano Cave (most stations in Guano Cave averaged 27 °C), the only cave we sampled that was used consistently by bats on every visit from 1984 through 2008 (see Section III in this administrative report). Maxima at stations in Guano cave reached 27 °C to 28 °C. Crevice Cave, used by a very small number of bats since discovered as a roost in 1995, also averaged 27 °C and had maxima of 27 °C to 28 °C (Tables VI-6 and VI-7). Caves with inconsistent histories of use by bats varied from means of 26 °C (Fault Line Cave 1, New Cave 1) to 27 °C (Pillar Cave). Perhaps the slightly warmer caves are preferred, but it seems doubtful to us that a 1 °C difference between rounded means is biologically meaningful given this limited sampling effort to characterize the thermal environments of these caves. This is even more evident considering the low variability in temperatures in this region and the thermal characteristics of other roosts used by other emballonurids (see below).

Although additional sampling of cave temperatures at greater levels of accuracy and using a more systematic series of sampling stations might reveal some subtle differences in thermal environments among caves, subtle differences in cave temperature patterns are unlikely to limit their use as roosts by these bats. Most caves we observed (see section III of this report) do not appear to have major internal complexities that might create strong heterogeneity in internal microclimates. Cave temperatures anywhere in the world typically reflect the mean annual surface air temperatures of a region (e.g. Dwyer 1971). There are no long-term temperature data readily available for Aguiguan or neighboring islands, but the mean annual temperatures at three weather stations on Guam are 26.2 °C, 26.9 °C, and 27.7 °C (National Oceanic and Atmospheric Administration 2008), very consistent with the temperatures at the stations we sampled in caves on Aguiguan. Mean annual maxima and minima at these three weather stations on Guam varied between 22.6 °C and 30.7 °C, suggesting that even if caves were more complex the ranges of air temperatures that might occur in trapped internal air masses would be small. We did not observe any major air movement within the 41 caves we investigated in 2008 to indicate that highly complex thermal patterns might be found in these caves.

Furthermore, it is thought that the thermal environments of caves used by those species of bats that do not regularly enter torpor are less important than those of caves used by more heterothermic bats at higher latitudes (Dwyer 1971). We believe that Pacific sheath-tailed bats do not enter torpor readily and normally maintain a resting body temperature that is high enough to allow alertness and quick flight under the thermal conditions prevailing in the caves on Aguiguan. Maintenance of homeothermy under normal environmental conditions is also typical for other tropical emballonurids (Bonaccorso 1998). These bats always seemed wary, readily flew within the roost when we approached from outside, did not cluster, and did not become torpid when we placed them in cloth sacks. (Indeed, it is possible that some of the stunning and the death we observed in the first bats we captured may have been due to heat stress from struggling while held in gloves in the high humidities on Aguiguan.) The lack of regular use of torpor has been demonstrated experimentally in some (but not all) other species of emballonurids elsewhere in the world (e.g. Genoud and others 1990, Genoud and Bonaccorso 1986). Temperatures of roosts used by two of these other species of emballonurids that do not normally enter torpor also have been measured (although measurements were over shorter periods than some on Aguiguan). Two tree roosts of *Saccopteryx bilineata* (an 8.2 g emballonurid) in Costa Rica fluctuated less than 1 °C daily and had mean temperatures of 26.1 °C and 26.5 °C; temperatures at a third roost ranged 26.4 °C to 27.5 °C at noon (Genoud and Bonaccorso 1986). Temperatures in roosts used by the 5 g emballonurid *Peropteryx macrotis* in caves in Venezuela averaged 27.8 ± 1 °C (Genoud and others 1990). Temperatures in 6 caves used by a third species of small (5.3 g) emballonurid (*Balantiopteryx plicata*) in Mexico averaged 26.7 ± 3.1 (SD) °C (Avila-Flores and Medellin 2004). The similarity in temperatures of roosts used by these other emballonurids with those we measured in the Aguiguan caves is noteworthy, and is also suggestive that the thermal characteristics of caves on Aguiguan do not limit their use by Pacific sheath-tailed bats.

Relative humidity in caves was high. We recorded relative humidity at about 1.5 m height above the cave floor in five caves. Three were identical at 92 %, whereas New Cave 1 and Dangkolo Cave were slightly more humid at 96 %. The latter cave has no history of bat occupancy and was the only cave we entered that had occasional dripping water. Relative humidities taken at various times and locations outside of caves were generally lower, ranging from 74% to 92% (Table VI-8). The role of humidity in use of caves by bats on Aguiguan, if any, remains to be studied. We did not measure humidity in a large number of caves and given the lack of access to pools of freshwater for drinking, roost environments that minimize evaporative water loss may be of importance to these bats. However, given the uniformly high humidities in the caves that we measured it seems unlikely that variability in humidity among caves will be great enough to be a factor limiting sheath-tailed bat populations on Aguiguan. The humidities we observed were also within the ranges in caves utilized as roosts by many other bats in the tropics (e.g. 70-98 % in 12 species summarized by McNab 1969)

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Table VI-1. Efforts made to capture Pacific sheath-tailed bats on Aguiguan in June and July 2008, with a summary of results and observations. Locations are in Universal Transverse Mercator (UTM), Zone 55 P, WGS 84 datum; elevations and estimated location errors are available on request.

Date	Location	Number and Lengths of Nets Deployed, Other Methods	Time	Results
26 June	Vicinity of Fault Line Cave 1 (=Cave 94, across gaps in boulders and cliffs, 344804 E, 1643215 N.	1-6 m, 1-9 m; bottoms 2.5-3.0 m above ground	18:00-22:00	In the dusk from 1846 to 1913 we watched 14 bats fly to within 1-2 m of the net and turn to the side, and 8 fly directly to net and then up and over the top. No captures.
28 June	Slope about 40 m below Guano Cave (= Cave 2) 343039E, 1642089N (EPE 8, elevation 100 m); mouth of Guano Cave	2-12 m nets in forest on slope below cave; 1-2.6 m net at mouth of Guano Cave. Intent to capture bats returning rather than bats emerging	18:30-22:00	No bats captured. Some bats returned to cave but likely entered above the net,
29 June	Vicinity of Fault Line Cave 1 (=Cave 94), across gaps in boulders and cliffs, 344804 E, 1643215 N; in forest on terrace ca. 100 m inland from Cave 94	1-9 m across gap, 1-18 m in forest. Insect sweep net as bats dispersed at dusk	18:00-22:00	Watched two bats circle go over or fly parallel to 9 m net within 1 m. Captured one male in sweep net. Male appeared “stunned” during 20 mins of handling. Put it on a cliff wall about 2.5 m above ground, where it remained for 30 mins, then flew off after disturbed by light from headlamp.
30 June	Slope about 40 m below Guano Cave (= Cave 2), 343039E, 1642089N (EPE 8, elevation 100 m)	1-12 m in forest on slope below cave	18:15-20:15	One adult female captured in mist net. Held in hand for 10 mins while measuring, photographing. Bat died.
1 July	Forest on terrace above East Black Noddy Cave (= Cave 76), 343939 E, 1642819 N	1-12 m, 1-18 m in “v” under canopy, in open flat section of younger forest. Bottoms 1.5 m above ground	18:00-22:15	No bats seen approaching the nets at dusk. Only 2 bats seen under canopy, both 1840-1850. One heard at 1907h, no further bat activity noticed.
1 July	East Black Noddy Cave (=Cave 76), 344004E, 1642923N (EPE 8 m, elevation 30m)	1-9 m across mouth of the smaller of the two caves. Bottom 1 m above ground	19:50-22:30	Bats were observed exiting the cave, and circled near the rim of the cliff, then dispersed. A bat was captured exiting the cave, after mass exodus, but escaped from net. A second bat, a pregnant female,

				was captured. It appeared stunned after handling for 13 mins, was placed on a rock wall but did not fly off until 20 mins later.
2-3 July	Forest on terrace below Fault Line Cave 1 area, 344767 E, 1643240 N	1-9 m, 3-12 m, 1-18 m. Bottoms 2 m above ground	18:00-00:15	Bats were observed foraging in the area, and on multiple occasions we watched them fly within 1 m of a net and turn. No bats captured.
3-4 July	Forest on terrace below Fault Line Cave 1 area, 344767 E, 1643240 N	2-9 m, 3-12 m, 2-18 m. Bottoms 2 m above ground.	18:00-00:15	Bats were observed foraging in the area, and on multiple occasions we watched them fly within 1 m of a net and turn. No bats captured.
5 July	East Black Noddy Cave (=Cave 76), 344004E, 1642923N (EPE 8, elevation 30m), small opening	1-9 m across mouth of the smaller of the two caves. Bottom 1 m above ground	20:30-22:30	Bats observed exiting cave. Audible calls heard from bats outside of cave, after exiting. These calls were similar to audible coaxing calls made by other species of bats elsewhere (e.g., *Antrozous pallidus*). Two bats were captured at the same time, with one capture of a bat entering the cave and the other exiting.
6 July	Vicinity of Cave 94, in boulders and cliffs above fault line, 344804 E, 1643215 N.	Insect sweep net	18:00-19:10	A minimum of 17 bats dispersed past and overhead, but none was caught in the insect sweep net. No captures.
10 July	Crevice Cave (= Cave 17), 0343541 E, 1641526 N	1-2.6 m net across opening during day, sweep net inside	Day	Two bats present, evaded capture.
11 July	Vicinity of Cave 94, in boulders and cliffs above fault line, 344804 E, 1643215 N	1- 6 m net 2-5 m above rocks; insect sweep net	18:00-20:00	Multiple bats dispersed past and overhead at dusk, one male caught in the insect sweep net. Placed in bag, held for 30 min and handled for 10 min additional, flew readily on release
12 July	Guano Cave (= Cave 2), 343031 E, 1642084 N	2-2.6 m nets on 3 m poles across opening to second chamber that bats use as a refuge when disturbed during the day. Disturbance was shining light until 1-2 bats fled the main chamber, repeated at 15-30 min intervals	14:00-16:30	Five bats (including one attached young) captured in three episodes. All immediately placed in cloth bags and held for 10-30 mins, female with young for 2 hrs. None was stunned or unable to fly off readily on release.
13 July	Vicinity of fault Line Cave 1	1- 6 m net 2-5 m above rocks;	18:00-20:00	Multiple bats dispersed past and overhead at dusk.

	(=Cave 94), in boulders and cliffs above fault line, 344804 E, 1643215 N	sweep net		One male caught in mist net, stunned, was sacrificed as voucher specimen. Second male caught in the insect sweep net as it veered away from the mist net. Placed in bag, held and handled over 30 min period, flew readily on release

Table VI-2 . Records of sheath-tailed bats captured at Aguiguan, June-July 2008. See Table VI-1 for details on locations and methods of capture, Table R-1 for information about reproductive status. Abbreviations: A = adult, F= female, M= male, ND = not determined, Y = young.

Field ID	Date	General Location	Age & Sex	Forearm, Body Mass	Samples Taken	Comments
STB-1	29 June	Vicinity of Cave 94	A M	43.5 mm, ND	Wing biopsy	No visible ectoparasites. Held 21 mins without placing in bag, appeared stunned afterwards. Placed on cliff face where it remained still for 30 mins before flying off.
STB-2	30 June	Vicinity of Cave 2	A F	45.0 mm, 7.6 g	Wing biopsy	No visible ectoparasites. Held in hand 10 mins while measuring, photographing, without placing in bag. Bat died. Voucher specimen, U.S. Geological Survey Colection, Museum of Southwestern Biology, study skin and skeleton (catalog no. MSB125656), organs (heart, kidney, liver, spleen, lungs, and muscle; catalog no. NK104278) in 95% ethanol.
STB-3	1 July	Cave 76	A F	45.3 mm, 7.7 g	Wing biopsy,	No visible ectoparasites. Bat appeared stunned after handling for 13 mins without holding in bag, was placed on a rock wall but did not fly off until 20 mins later.
STB-4	5 July	Cave 76	A F	46.1 mm, 6.5 g	Wing biopsy, 1 guano pellet	No visible ectoparasites.
STB-5	5 July	Cave 76	A F	45.5 mm, 8.0 g	Wing biopsy, 3 guano pellets	No visible ectoparasites.
STB-6	11 July	Vicinity of Cave 94	A M	45.9 mm, 5.8 g	Wing biopsy	No visible ectoparasites. Held in bag about 30 mins, handled 10 mins thereafter. Flew readily on release.
STB-7	12 July	Cave 2	A F	45.3 mm, 6.5 g	Wing biopsy	No visible ectoparasites. Held in cloth bag for ca. 30 mins, handled 10 mins, placed back in bag 90 min. Flew readily on release.
STB-8	12 July	Cave 2	Y F	[24.4 mm, 2.3 g]	None	Attached nursing young of STB-7.

STB-9	12 July	Cave 2	A F	43.8 mm, 5.8 g	Wing biopsy	No visible ectoparasites. Held in cloth bag about 15 mins, 5 mins handling. Flew readily on release.
STB-10	12 July	Cave 2	A F	47.0 mm, 7.0 g	Wing biopsy	No visible ectoparasites. Held in cloth bag about 25 mins, 5 mins handling. Flew readily on release.
STB-11	12 July	Cave 2	A F	46.4 mm, 5.8 g	Wing biopsy	No visible ectoparasites. Held for 10 mins in cloth bag, about 5 mins for handling. Flew readily on release.
STB-12	13 July	Vicinity of Cave 94	A M	46.0 mm, 5.7 g	Wing biopsy	No visible ectoparasites. Stunned after 10 mins of handling. Voucher specimen, U.S. Geological Survey Colection, Museum of Southwestern Biology, study skin and skeleton (catalog no. MSB125657), organs (heart, kidney, liver, spleen, lungs, and muscle; catalog no. NK104279) in 95% ethanol
STB-13	13 July	Vicinity of Cave 94	A M	45.5 mm, 5.1 g	Wing biopsy	No visible ectoparasites. Kept in cloth bag for about 25 mins, handled about 5 mins. Flew readily on release.

Table VI-3. Published data on forearm lengths and body mass of *Emballonura semicaudata* from throughout the species distribution in comparison with measurements of bats from Aguiguan. Measurements given are ranges or individual measurements. NR = not reported. Numbers in parentheses are sample sizes if different from sample description. Subspecies names and distribution follow Koopman (1997).

Sample	Body Mass (range in g)	Forearm Length (range in mm)	Source
E. semicaudata rotensis: 8 adult females, Aguiguan, 2008	5.8-8.0	43.8-47.0	This study
E. semicaudata rotensis: 4 adult males, Aguiguan, 2008	5.1-5.8 (3)	43.5-46.0 (4)	This study
E. semicaudata rotensis: 6 adult females, Aguiguan, 2003	NR	44.5-47.3	Esselstyn (unpublished)
E. semicaudata rotensis: 2 adult females, Aguiguan, 1984	5-7	44-45	Lemke (1986)
E. semicaudata rotensis: 1 male, 1 female	NR	45, 45	Yamashina (1943); T. Yamasaki (pers. commun.)
E. semicaudata semicaudata: 3 adult males, Fiji	5.5-5.5	44.4-45.5	Flannery (1995)
E. semicaudata semicaudata : 5 adult females, Fiji	6.5-8.0	45.3-47.9	Flannery (1995)
E. semicaudata semicaudata: type specimen	NR	41.0	Tate and Archbold (1939)
E. semicaudata palauensis: 4 males, 7 females	NR	39-44.5	Tate and Archbold (1939)
E. semicaudata palauensis: 2 females	NR	42-43	Johnson (1962)
Emballonura semicaudata sulcata: 8 females, 1 male, Pohnpei	NR	48.5-52.5	Sanborn (1949)
Emballonura semicaudata sulcata: 4 adult males, Pohnpei and Chuuk	4, 4 (2)	46-49.5	Tate (1934), Tate and Archbold (1939), Bruner and Pratt (1979)
Emballonura semicaudata sulcata: 4 adult females, Pohnpei and Chuuk	4-6 (3)	43-54	Bruner and Pratt (1979)
Emballonura semicaudata sulcata: 3 adult males, Pohnpei	7.0-7.5	49-51	Johnson (1962)
E. semicaudata sulcata: 11 adults, sex or location unspecified	NR	48.4-52.5	Literature summary in Lemke (1986)

Table **VI-4**. Observations of bats dispersing in the Fault Line area in the vicinity of Cave 66 and Cave 94, during June and July 2008. Observer initials in parentheses (EM = Elvin Masga, GJW= Gary J. Wiles, PMG = P. Marcos Gorresen, GC = Greg Camacho).

Location	**Date**	**Time 1st bat seen**	**Summary of observations**
Near Cave 66 344840, 1643270	24 June	18:49	18:49-19:13 (TJO): 17 bats observed flying through the forest below canopy, most uphill but 3 noted coming downhill. Heard ultrasonic calls on bat detector in isolation 39 times, and multiple times while bats observed flying back and forth in foraging beats (including feeding "buzzes" or pursuit calls). On at least 5 instances bats were feeding rather than flying directly through the area. Audible vocalizations (social calls) were heard on 3 occasions. Most feeding seemed to be at least 3 m above ground and over the fault line fissure. 19:14- 19:45 (TJO): 1 bat seen at 1935, heard echolocation calls on bat detector in isolation 9 times, 1 seen foraging 19:38-19:42 in headlight beam over an elliptical foraging beat with accompanying feeding buzzes on bat detector. Distinctive audible vocalizations heard on 3 occasions.
Near Cave 94, near 344804 E, 1643215 N	24 June	--	18:50-19:00 (EM): 47 bats observed flying uphill below canopy at this station
Near Cave 94, near 344804 E, 1643215 N	26 June	18:41	18;41-19:13 (GJW): Counted 25-30 bats (PMG nearby saw 43) coming up hillside from lower terrace to the northwest. None seen emerging from caves. Most traveled uphill, all under canopy, early bats easily visible in fading light. Some fly 2-3 feet above ground, some stop to circle and forage briefly, continue uphill. Collared kingfishers still active. PMG counts highest at 1900-1910. GC reported seeing a few split off and fly east low over the top of the canopy. 18:46-19:13 (TJO): 27 bats observed flying uphill below canopy, did not use bat detector.
Near Cave 94, near 344804 E, 1643215 N	29 June	18:37	18:37-18:42 (TJO): 2 bats dispersed uphill below canopy, 1 made several audible calls. Observation period limited because of bat capture.
Near Cave 94, near 344804 E, 1643215 N	6 July	18:50	18:50-19:08 (TJO): 12 bats observed flying uphill below canopy, 6 ultrasonic calls on bat detector, heard > 6 audible calls. Two fed together in the same elliptical foraging beat for two minutes 18:57-18:59; another two feeding separately at 19:02-19:03, feeding buzzes on bat detector. Light drizzle may have affected activity.
Near Cave 94, near 344804 E, 1643215 N	11 July	18:31	18:31-18:53 (TJO, EWV): 18 bats observed flying uphill below canopy, 10 ultrasonic calls on bat detector, heard > 30 audible calls. One bat foraged in an elliptical beat below the canopy and 4-8 m above ground for 1-2 mins. Observation period limited because of bat capture at 18:53.
Near Cave 94, near 344804 E, 1643215 N	13 July	18:36	18:36-18:53 (TJO): 7 bats observed flying uphill below canopy, did not use bat detector. Observation period limited because of bat capture at 18:53.

Table VI-5. Summary of records of standard museum specimens (study skins and skulls, or fluid preserved whole bats) of *Emballonura semicaudata*. This summary is based primarily on published records available to us through 2008 and queries of the online database maintained by the Global Biodiversity Information Facility (GBIF). It is not exhaustive, but probably includes most of the specimens housed in museum collections. Slight overlap may occur among sources.

Collecting Locality	**Number of Specimens**	**Museum Collection**	**Source of Information**
Aguiguan	2	American Museum of Natural History	Lemke (1986)
Aguiguan	2	Museum of Southwestern Biology	This study
American Samoa	1	Museum of Vertebrate Zoology, University of California Berkeley	GBIF
American Samoa	24	Museum of Vertebrate Zoology, University of California Berkeley	Helgen and Flannery (2002)
American Samoa	2	Bernice Pauahi Bishop Museum	GBIF
American Samoa	31	United States National Museum of Natural History	GBIF
Fiji	47	Harvard University Museum of Comparative Zoology	GBIF
Fiji	1	Los Angeles County Museum	GBIF
Fiji	9	United States National Museum of Natural History	GBIF
Fiji	2	Australian Museum, Sydney	Helgen and Flannery (2002)
Fiji	8	Australian Museum, Sydney	Colgan and Soheili (2008)
Fiji	15	Institut vor Taxonomie, Amsterdam	Helgen and Flannery (2002)
Fiji	1	Academy of Natural Sciences, Philadelphia	Helgen and Flannery (2002)
Guam	6	Museum National d'Histoire Naturelle, Paris	Lemke (1986)
Palau	68	United States National Museum of Natural History	GBIF
Palau	16	Yamashina Institute for Ornithology, Chiba, Japan	Yamashina (1932) cited by Lemke (1986); T. Yamasaki (pers.

			commun.)
Pohnpei	1	Florida Museum of Natural History	GBIF
Pohnpei	2	Bernice Pauahi Bishop Museum	GBIF
Pohnpei	7	California Academy of Sciences	GBIF
Pohnpei	21	Field Museum of Natural History	GBIF
Pohnpei	5	United States National Museum of Natural History	GBIF
Rota, CNMI	14	Yamashina Institute for Ornithology, Chiba, Japan	Yamashina (1943), T. Yamasaki (pers. commun.)
Samoa	7	Harvard University Museum of Comparative Zoology	GBIF
Samoa	16	Bernice Pauahi Bishop Museum	GBIF
Samoa	1	Bell Museum of Natural History	Helgen and Flannery (2002)
Tonga	2	Burke Museum, University of Washington	GBIF
Tonga	3	Los Angeles County Museum	GBIF
Tonga	7	United States National Museum of Natural History	GBIF
Tonga	1	Western Australia Museum	Helgen and Flannery (2002)
Truk	3	Louisiana State University Museum of Natural Science	GBIF
Truk and Pohnpei	32	Yamashina Institute for Ornithology, Chiba, Japan	Yamashina (1943) cited by Lemke (1986); T. Yamasaki (pers. commun.)
Vanuatu	1	Harvard University Museum of Comparative Zoology	GBIF; see also Helgen and Flannery (2002)
Vanuatu	1	British Museum of Natural History	Dobson (1878) cited in Koopman (1997)
Unspecified	19	Museum fur Naturkunde, Berlin	GBIF
Unspecified	1	Swedish Museum of Natural History	GBIF
Unspecified	1	Los Angeles County Museum	GBIF
Pohnpei	unspecified	American Museum of Natural History	Koopman (1997)

Unspecified	6	American Museum of Natural History	Griffiths and others 1991

Table VI-6. Summary statistics for temperature data (°C) from data logger sampling stations on Aguiguan, 2008.

Station	Period	N Hourly Readings	Computational Mean (95% CI)	Rounded Mean	Range	Min	Max
Camp							
Camp 1 m above ground	6/26, 14:30 to 7/13, 13:30	408	26.8 (26.55, 26.99)	27	9.7	22.3	32
Camp 2 m above ground	6/27, 14:30 to 7/13, 13:30	408	27.0 (26.77, 27.25)	27	10.0	22	32
Camp 3 m above ground	6/26, 14:30 to 7/13, 13:30	408	27.1 (26.90, 27.37)	27	10.5	22.3	32.8
Guano Cave							
Guano Cave entrance, 2 m high	6/30, 19:00 to 7/11 18:00	264	27.05 (27.01, 27.09)	27	1.3	26.3	27.5
Guano Cave 10 m depth, 2 m high	7/7, 17:00 to 7/11 16:00	96	26.58 (26.55, 26.60	27	0.5	26.5	27.0
Guano Cave inner chamber below bats, 1 m high	6/25, 15:00 to 7/12, 14:00	408	26.75 (26.71, 26.79)	27	2.5	25.3	27.8
Guano Cave inner chamber below bats, 2 m high	6/25, 15:00 to 7/12, 14:00	408	26.84 (26.79, 26.88)	27	3.0	25	28
Guano Cave inner chamber below bats, 6 m high	6/25, 15:00 to 7/12, 14:00	408	26.48 (26.44, 26.52)	26	2.5	25	27.5
Guano cave outer chamber 2 m high	7/7, 18:00 to 7/11, 17:00	96	26.26 (26.17, 26.34)	26	1.8	25.3	27
Guano cave outer chamber 3 m high	7/7, 18:00 to 7/11, 17:00	96	26.18 (26.10, 26.27	26	2	25	27
Guano cave outer chamber 4 m high	7/7, 17:00 to 7/11, 16:00	96	26.59 (26.53, 26.66)	27	1.5	26	27.5
Guano cave outer chamber 5 m high	7/7, 17:00 to 7/11, 16:00	96	27.09 (27.03, 27.15)	27	1	26.5	27.5
Guano cave outer chamber 6 m high	7/7, 18:00 to 7/11, 17:00	96	27.16 (27.12, 27.19)	27	0.75	26.75	27.5
Crevice Cave							
Crevice Cave at entrance, 2 m high	6/27, 18:00 to 7/9, 17:00	288	26.86 (26.81, 26.91	27	2.5	25.5	28
Crevice Cave at 3 m depth, 3 m high	6/27, 18:00 to 7/9, 17:00	288	26.60 (26.57, 26.63)	27	1.5	25.75	27.25
Crevice Cave at 5 m depth, 4 m	6/27, 18:00 to 7/9, 17:00	288	27.12 (27.10, 27.14)	27	0.75	26.75	27.5

high							
Fault Line Cave 1							
Fault Line Cave at entrance, 2 m high	6/30, 17:00 to 7/13, 16:00	312	26.11 (26.05, 26.18)	26	2.5	25	27.5
Fault Line Cave 1, 8 m depth, 1 m high	6/30, 17:00 to 7/13, 16:00	312	26.05 (25.98, 26.11)	26	3.0	24.5	27.5
Fault Line Cave 1, 8 m depth, 2 m high	6/30, 17:00 to 7/13, 16:00	312	26.20 (26.14, 26.26)	26	2.75	24.5	27.25
Fault Line Cave 1, 8 m depth, 3 m high	6/30, 17:00 to 7/13, 16:00	312	26.45 (26.39, 26.51)	26	2.5	25	27.5
New Cave 1							
New Cave 1, 10 m deep, 6 m above lower chamber	7/5, 18:00 to 7/9, 17:00	96	25.80 (25.75, 25.85)	26	1	25.25	26.25
Pillar Cave							
Pillar Cave at entrance, 2 m high	7/7, 19:00 to 7/11, 18:00	96	27.32 (27.23, 27.40)	27	1.5	26.5	28
Pillar Cave, 35 m deep, 2 m high	7/7, 2:000 to 7/11, 19:00	96	27	27	0	27	27
Dangkolo Cave							
Dangkolo Cave entrance 2 m high	6/27, 17:00 to 7/9, 16:00	288	27.14 (27.09, 27.18)	27	1.75	26.25	28
Dangkolo Cave 10 m depth, 1 m high	6/27, 17:00 to 7/9, 16:00	288	26.22 (26.21, 26.23)	26	0.5	26	26.5
Dangkolo Cave 20 m depth, 1 m high	6/27, 17:00 to 7/9, 16:00	288	26	26	0	26	26
Dangkolo Cave 45 m depth, 1 m high	6/27, 17:00 to 7/9, 16:00	288	26.5	26	0	26	26
Dangkolo Cave 45 m depth, 2 m high	6/27, 17:00 to 7/9, 16:00	288	26.5	26	0.25	26.25	26.5
Dangkolo Cave 45 m depth, 3 m high	6/27, 17:00 to 7/9, 16:00	288	26.5	26	0	26.5	26.5
Cave 68							
Cave 68, rear (uphill) chamber, 5 m above ground, 3 m below opening	7/3, 17:00 to 7/13, 16:00	240	25.72 (25.66, 25.78)	26	2	24.75	26.75

Draft

Cave 68, 18 m depth from lower entrance, 2 m high	7/3, 17:00 to 7/13, 16:00	240	26.23 (26.18, 26.27)	26	1.25	25.5	26.75

Draft

Table VI-7. Summary statistics for temperature data (°C) from data logger sampling stations on Aguiguan, 2008, during the period from 7 July (19:00 h) to 10 July (15:00 h) when data were recorded simultaneously at all locations . For each station *N* = 68 hourly readings.

Station	**Computational Mean (95% CI)**	**Rounded Mean**	**Range**	**Minimum**	**Maximum**
Camp 1 m above ground	25.5 (25.14, 25.83)	26	6	23	29
Camp 2 m above ground	25.6 (25.26, 25.99)	26	6.5	23	29.5
Camp 3 m above ground	25.8 (25.41, 26.17)	26	7	23.3	30.3
Guano Cave entrance	26.8 (26.74, 26.90)	27	1.3	26.3	27.5
Guano Cave 10 m depth, 2 m high	26.60 (26.56, 26.63)	27	0.5	26.5	27.0
Guano Cave inner chamber below bats 1 m high	26.57 (26.49, 26.65)	27	1.3	25.8	27.0
Guano Cave inner chamber below bats, 2 m high	26.63 (26.55, 26.70)	27	1	26	27
Guano Cave inner chamber below bats, 6 m high	26.25 (26.18, 26.32)	26	1	25.8	26.8
Guano cave outer chamber 2 m high	26.24 (26.14, 26.35)	26	1.7	25.3	27
Guano cave outer chamber 3 m high	26.17 (26.06, 26.27)	26	2	25	27
Guano cave outer chamber 4 m high	26.58 (26.51, 26.66)	27	1	26	27
Guano cave outer chamber 5 m high	27.09 (27.01, 27.17)	27	1	26.5	27.5
Guano cave outer chamber 6 m high	27.19 (27.14, 27.23)	27	0.75	26.75	27.5
Crevice Cave					
Crevice Cave at entrance, 2 m high	26.68 (26.54, 26.82)	27	2	25.75	27.75
Crevice cave at 3 m depth, 3 m high	26.43 (26.32, 26.54)	26	2	25.75	27.75
Crevice Cave at 5 m depth, 4 m high	27.01 (26.95, 27.06)	27	1.25	26.75	28
Fault Line Cave 1					
Fault Line Cave at entrance, 2 m high	25.78 (25.68, 25.88)	26	1.5	25	26.5
Fault Line Cave 1, 8 m depth, 1 m high	25.89 (25.77, 26.01)	26	1.5	25	26.5
Fault Line Cave 1, 8 m	25.99 (25.89, 26.09)	26	1.5	25	26.5

depth, 2 m high					
Fault Line Cave 1, 8 m depth, 3 m high	26.29 (26.20, 26.38)	26	1.5	25.5	27
New Cave 1					
New Cave 1, 10 m deep, 6 m above lower chamber	25.71 (25.64, 25.78)	26	1	25.25	26.25
Pillar Cave					
Pillar Cave at entrance, 2 m high	27.35 (27.23, 27.46)	27	1.5	26.5	28
Pillar Cave, 35 m deep, 2 m high	27	27	0	27	27
Dangkolo Cave					
Dangkolo Cave entrance 2 m high	26.74 (26.66, 26.83)	27	1.5	26	27.5
Dangkolo Cave 10 m depth, 1 m high	26.09 (26.06, 26.12)	26	0.5	25.75	26.25
Dangkolo Cave 20 m depth, 1 m high	26	26	0	26	26
Dangkolo Cave 45 m depth, 1 m high	26.5	26	0	26.5	26.5
Dangkolo Cave 45 m depth, 2 m high	26.45 (26.42, 26.47)	26	0.25	26.25	26.5
Dangkolo Cave 45 m depth, 3 m high	26.5	26	0	26.5	26.5
Cave 68					
Cave 68 rear (uphill) chamber, 5 m above ground, 3 m below opening	25.65 (25.57, 25.73)	26	1.25	25	26.25
Cave 68, 18 m depth from lower entrance, 2 m high	26.16 (26.11, 26.22)	26	0.75	25.75	26.5

Table VI-8. Relative humidity at caves and other locations on Aguiguan, 2008.

Date	**Time**	**Location**	**Relative Humidity**
5 July	17:00	New Cave 1, 10 m depth	96%
6 July	13:45	Fault Line Cave 1, 18 m depth	92%
7 July	15:15	Guano Cave, 10 m depth	92%
7 July	18:20	Pillar Cave at 35 m 1 m high	92%
10 July	16:00	Dangkolo Cave at 40 m depth	96 %
6 July	13:45	Outside mouth of Fault Line Cave 1	88%
7 July	15:30	Outside mouth of Guano Cave	84%
7 July	18:25	Outside mouth of Pillar Cave	92% (drizzling)
4 July	11:15	Camp	74%
4 July	11:18	Camp	75%
5 July	09:40	Camp	81%
5 July	12:00	Camp	78%

Section VII. Reproduction of Pacific Sheath-Tailed Bats (*Emballonura semicaudata rotensis*) on Aguiguan, Commonwealth of the Northern Mariana Islands

Thomas J. O'Shea and Ernest W. Valdez

ABSTRACT

There is very little information available about reproduction in Pacific sheath-tailed bats or other species of the genus *Emballonura*. Basic information about ecological aspects of reproduction is important for understanding the population dynamics of rare mammals. We found that 7 of 8 adult females we captured at two caves on Aguiguan in June and July 2008 were reproductive (5 were pregnant and 2 were lactating). A pregnant female was reported in the literature in June 1984, but none of six adult female bats examined in September of 2003 by others were pregnant. We also observed 11 pups at roosts in June and July 2008, but captured no volant young of the year. These observations suggest that Pacific sheath-tailed bats on Aguiguan may have a diffuse seasonality in reproduction, timing the period of late gestation, lactation, and maturation of young to coincide with the late June-early November rainy season. We observed one large embryo in a female dissected in June 2008, as was also observed in a female dissected in June 1984, and each of the pups we observed in caves were singletons. These observations suggest a litter size of one. Although additional sampling is needed to fully understand patterns of reproduction in these bats on Aguiguan, findings are consistent with the scant literature on other species of *Emballonura* and with the population dynamics of many other species of bats. If reproduction occurs annually and litter size is one, then the capacity for population growth in Pacific sheath-tailed bats will be very limited.

INTRODUCTION

Basic information on ecological aspects of reproduction is essential to understanding the population dynamics of rare species of mammals. Little information is available in the literature on reproduction in Pacific sheath-tailed bats in the Mariana Islands or elsewhere. Lemke (1986) reported that one of two females captured at Guano Cave on Aguiguan on 22 June 1984 was pregnant with a single fetus. On 17 September 2003 six females were captured at Guano Cave, palpated, and released by Jake Esselstyn (personal communication) and others. None of the bats handled by Esselstyn was palpably pregnant. We are unaware of any other records describing reproduction in this species in the Mariana Islands or anywhere else in its range. Our objectives in this section are to highlight and synthesize the limited findings pertinent to this topic based on our investigations on Aguiguan in 2008 and related information.

MATERIALS AND METHODS

We employed standard field methods for assessing reproductive condition in bats. Females were palpated to determine pregnancy, the condition of the teats was assessed to determine if bats were in lactation, and males were examined to determine if testes or cauda epididymides were engorged (Racey 1988). Age classes (adult or large volant juvenile) were assigned based on the degree of closure of the phalangeal epiphyses (Anthony 1988). Reproductive condition was also assessed by examination of internal organs of two bats saved as voucher specimens. We also report on the reproductive condition of six bats examined by Jake Esselstyn and others at Guano Cave in 2003 following similar techniques. Observations of young bats in caves were made using the night vision equipment described in Section III of this administrative report.

RESULTS AND DISCUSSION

Reproductive status of adult female bats captured at two caves on Aguiguan from late June to mid-July 2008 show that most (7 of 8, or 87%) were in active reproductive condition (5 pregnant and 2 lactating). These and other records suggest a hypothesis that birthing in Pacific sheath-tailed bats on Aguiguan is diffusely seasonal and timed to coincide with the rainy season. General ecosystem productivity (including small insects) is likely to be higher in the rainy season than in the dry months. The general seasonal pattern in the region is that almost four times as much rainfall occurs in the wet season than in the dry season (Lander 2004). The lowest monthly rainfall occurs in December through May. Rainfall increases in June, is highest in July through October, and then decreases in November (Lander 2004). In other tropical areas of the world, insectivorous bats time their reproduction to coincide with rainy season productivity and are non-reproductive during dry seasons; this is thought to be due to increases in food abundance as a result of seasonably predictable rainfall (*e.g*. Bernard and Cumming 1997; Fleming and others 1972), and accompanying higher insect abundance (McWilliam 1987; Bradbury and Vehrencamp 1976).

Although sampling efforts have been very limited, several lines of evidence support a hypothesis of diffuse seasonal reproduction in Pacific sheath-trailed bats on Aguiguan. Esselstyn (pers. comm.) and others captured six adult females at Guano Cave later in the rainy season on 17 September 2003. None of these was pregnant. Using the night viewing device, we observed a pup on 23 and 27 June in the roost at Crevice Cave that also held 2-3 adults; 10 smaller bats were each observed roosting in very close association with 10 single larger adults within the colony at Guano Cave on 25 June. We assume these smaller bats at Guano Cave each were juveniles roosting with their mothers. Volant juvenile bats can be readily distinguished from adults based on epiphyseal closure and ossification for several months after birth (Anthony 1988). All of the 12 Pacific sheath-tailed bats we caught in flight at three different locations in June and July were adults (Table VII-1); the absence of readily discernible young bats in our samples suggests that reproduction was limited over the preceding few months of the late dry season. The pregnant females we handled all seemed to be in fairly advanced pregnancy based on abdominal distension, and this was supported by the presence of a large fetus (crown-rump length of 23 mm) in the museum voucher specimen taken on 30 June (see Section VI of this administrative report). The fetus observed by Lemke (1986) on 22 June 1984 was advanced but slightly smaller at 19 mm in crown-rump length. The other female he examined, however, was non-reproductive. In addition to possible seasonality in birthing, our observations of roosting pups, the single attached young caught with its mother at Guano Cave (Table VII-1, see also Table VI-2, Section VI of this administrative report), and the dissections of two females by us and Lemke (1986) all suggest a litter size of one. Very little information is available on litter size in other species in the genus *Emballonura*, but litter sizes of one seem consistent with our observations of Pacific sheath-tailed bats on Aguiguan. A litter size of one has been reported for *Emballonura tiavato* and *Emballonura atrata* on Madagascar, where reproduction may be seasonal but available data are also limited (Goodman and others 2006). Only single embryos have been reported thus far in the few samples of *Emballonura beccarii* and *Emballonura dianae* that have been taken on Papua New Guinea (Bonaccorso 1998), and single embryos have been reported for Emballonura monticola (Nowak 1999). A seasonal birthing period coinciding with the rainy season is known for other emballonurids, but the pattern in Pacific sheath-tailed bats on Aguiguan suggested by our data could be more complex and will require additional sampling to verify. For example, some Neotropical emballonurids also give birth to singletons once annually in synchrony with rainy seasons, whereas other species of emballonurids may have more than one birthing period each year (Bradbury and Vehrencamp 1976).

The single male that we dissected had no swelling of the cauda epididymides and small testes (measuring 1 x 3 mm) that were withdrawn into the inguinal canal, indicating that it was not in mating condition. The other three males we captured showed no external evidence of distended testes or epididymides. Perhaps mating occurs earlier in the year during the dry season. This would be compatible with mating systems of other emballonurids which include defending access to feeding areas (e.g. Bradbury and Emmons 1974, Bradbury and Vehrencamp 1976), if food is a more limited resource in the dry season.

Although bats are a diverse group with about 1,200 species worldwide and can show a concomitant variability in life history traits, most have limited potential for population growth based on reproduction alone (and thus require high adult survival to prevent population declines). Sexual maturity in bats is usually not reached until one year of age or older, birth typically occurs once annually (but some species of tropical bats in aseasonal environments may reproduce year-round), and litter size is small but can vary among species and habitats from one to four, with most producing one or two young at parturition (see review of ecological aspects of bat reproduction in Racey and Entwistle 2000). Our observations suggest that Pacific sheath-tailed bats on Aguiguan may be at the low range of reproductive potential for bats if they give birth once annually with litter sizes of one. This low reproductive potential will increase the time required for the population to recover and reach carrying capacity.

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Table VII-1. Summary of reproductive status of bats captured on Aguiguan, June-July 2008.

Field ID	Date	General Location	Age & Sex	Reproductive Condition
STB-1	29 June	Vicinity of Fault Line Cave 1 (Cave 94)	A M	Non-reproductive
STB-2	30 June	Vicinity of Guano Cave (Cave 2)	A F	Pregnant
STB-3	1 July	East Black Noddy Cave (Cave 76)	A F	Pregnant
STB-4	5 July	East Black Noddy Cave (Cave 76)	A F	Lactating
STB-5	5 July	East Black Noddy Cave (Cave 76)	A F	Pregnant
STB-6	11 July	Vicinity of Fault Line Cave 1 (Cave 94)	A M	Non-reproductive
STB-7	12 July	Guano Cave (Cave 2)	A F	Lactating
STB-8	12 July	Guano Cave (Cave 2)	Y F	Small nursing young attached to adult
STB-9	12 July	Guano Cave (Cave 2)	A F	Pregnant
STB-10	12 July	Guano Cave (Cave 2)	A F	Pregnant
STB-11	12 July	Guano Cave (Cave 2)	A F	Non-reproductive
STB-12	13 July	Vicinity of Fault Line Cave 1 (Cave 94)	A M	Non-reproductive
STB-13	13 July	Vicinity of Fault Line Cave 1 (Cave 94)	A M	Non-reproductive

Section VIII. Sampling Guano for Organochlorine Insecticides and Other Contaminants

Thomas J. O'Shea and Ernest W. Valdez

ABSTRACT

Past studies have shown that guano of bats can be used to assess the degree of contamination with organochlorine pesticides and the likelihood that the observed level of exposure has caused bat mortality. The scientific literature on conservation of Pacific sheath-tailed bats speculates that past organochlorine pesticide contamination may have played a role in their decline in some areas. However, Pacific sheath-tailed bats have never been assessed for organochlorine contaminants anywhere in their range. We obtained a small number of guano samples at different depths in an area of accumulation at Guano Cave on Aguiguan using chemically cleaned glass jars with teflon-lined lids. These samples are stored at our laboratory and can be made available for chemical analysis. They may be particularly useful for comparison with samples that may be taken in the future at other islands where these bats have declined, because there is no known history of organochlorine pesticide use on Aguiguan. However, our samples likely include some guano from swiftlets. Attempts to assess the degree of mixing of the two kinds of guano based on microscopic examination will be necessary prior to analysis of these and any comparative samples from other locations.

INTRODUCTION

There has been speculation that exposure to insecticides (particularly the persistent organochlorines) has been a contributing cause of the decline of Pacific sheath-tailed bats in the Mariana Islands and elsewhere (Esselstyn and others 2004, Flannery 1995, Tarburton 2002). The organochlorine insecticide DDT and the organophosphate malathion were applied in Guam, Saipan, and Tinian between the 1940s and 1970s (Baker 1946, Townes 1946, Drahos 1977, Jenkins 1983). Researchers also have speculated that declines in swiftlets and sheath-tailed bats on Guam were linked (Lemke 1986). However, there is no firm chemical or toxicological supporting evidence that the disappearance of swiftlets was a result of pesticide exposure. Concentrations of DDE (a major break-down product of DDT) in swiftlet tissues and swiftlet guano samples from Guam measured in 1981 were much less than those associated with avian mortality or reproductive failure in studies of other species of birds (Grue 1985), and an order of magnitude less than concentrations in bat guano that have been linked to mortality or population declines in other species of insectivorous bats (Clark and others, 1982, 1995; Clark and Shore 2001). Nonetheless there continue to be suspicions that swiftlet and bat declines in years past may have been a result of exposure to DDT or other pesticides (Cruz and others 2008).

Concentrations of contaminants have never been measured in sheath-tailed bat guano or tissues. DDT was used extensively in Palau in the 1940s (Baker 1946) but sheath-tailed bats have been characterized as abundant there in the recent past (Wiles and others 1997). The carbamate and organophosphate insecticides that were also widely used globally are not persistent in tissues or guano of birds or mammals, and exposure of bats or swiftlets to these compounds has not been assessed. However, it has been speculated that these additional classes of insecticides were likely responsible for deaths of bats in the United States in the 1960s (Clark and Shore 2001), so that such past poisoning also seems feasible (although only speculatively so) in the Mariana Islands. It is unknown but seemingly unlikely that there is any history of major organochlorine insecticide use on Aguiguan (most of the plantation activity of the Japanese colonists was prior to the 1940s when other substances may have been used for pest control, including elemental based compounds; recognition and introduction of DDT as an insecticide began in the 1940s (Metcalf 1973). However, count data suggest that the population of sheath-tailed bats on Aguiguan was much reduced by the early 1980s (see Section III of this administrative report).

Determining concentrations of contaminants in samples of guano from sheath-tailed bats on Aguiguan might be instructive, particularly in relation to samples from elsewhere in the CNMI or Guam where sheath-tailed bats have disappeared. Concentrations of organochlorines (particularly DDT, DDE, and dieldrin) in guano that are associated with declines or direct mortality in other species of insectivorous bats have been established (Clark and others 1982) and used to evaluate the likely impacts of exposure on bat populations (e.g., Clark and others 1988, 1995, O'Shea and others 2001). Comparison of concentrations of organochlorines in samples of guano from sheath-tailed bats on Aguiguan with samples from other colonies of sheath-tailed bats that have gone extinct (e.g. on Guam) might also be useful in evaluating the degree of any past threat associated with these substances. Therefore we also sought to use careful protocols to collect a small series of guano samples from below roosts of sheath-tailed bats in Guano Cave on Aguiguan for archival and possible future analyses.

METHODS AND MATERIALS

Samples were collected in Guano Cave directly below the high domed ceiling where the bats roost daily (see Sections III and V of this administrative report), and which does not appear to be heavily used by nesting cave swiftlets. However, mixing of swiftlet guano with sheath-tailed bat guano could have occurred, particularly over the long periods of time during which the guano pile was formed. Microscopic examination of subsamples will be required to quantify the extent of this mixing (see below). Samples were placed in chemically cleaned 120 ml glass jars with teflon-lined lids that were pre-washed following EPA procedures and specifications (Eagle Picher Lot G3255020). The samples were removed from the surface layer, and from depths at 10 and 20 cm, using a stainless steel spoon wrapped in aluminum foil, with the foil changed between each sample. Duplicate samples were taken from areas about 15 cm apart. Original teflon-lined lids were sealed to the jars using adhesive tape.

RESULT AND DISCUSSION

We obtained six samples of guano at three depths below the sheath-tailed bat roosting area in Guano cave (Table VIII-1). The amounts listed are similar to those collected in other studies of contaminants in guano of insectivorous bats (e.g. Clark and others 1995) and sufficient to allow duplicate analyses of subsamples. Given the small numbers of bats utilizing this site over the last few decades (Section III of this administrative report), we suspect the three different depths represent substantial differences in dates of deposition. However, there are no means to calibrate the layers of guano at this cave, and interpretations of differences in findings at the three depths will only be relative to each other. These samples are currently stored at room temperature at the Fort Collins Science Center and can be made available for analysis, particularly if similar material can be obtained at additional locations for comparison. Unlike animal tissues, which must be kept frozen in storage and shipment, bat guano can be stored at room temperature, but samples or subsamples should be dried in a dessicator to constant dry weight prior to any subsampling for chemical analyses (e.g. Clark and others 1982, 1995, O'Shea and others 2001). Future chemical analyses should attempt to include as many persistent contaminants as possible (e.g. metals as well as organochlorines) given the logistic difficulty of obtaining these samples. It would also be useful to examine small subsamples microscopically to verify by degree of mastication that the material taken at various depths below the surface layer are primarily of bat origin rather than from swiftlets (see Section V of this administrative report). We recommend that these samples be analyzed for a range of persistent contaminants in conjunction with samples that may be obtained from caves on Guam and from elsewhere in the CNMI where these bats formerly roosted but no longer occur.

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Table VIII-1. List of samples of guano obtained from Guano Cave for possible future analyses for contaminants.

Sample Jar Serial Number	**USGS Sample Id**	**Depth of Sample**	**Approximate Sample Mass**
A1374270	7-12-08 S-1	Surface layer at location 1	14 g
A1374275	7-12-08 S-2	Surface layer at location 2	12 g
A1374261	7-12-08 10-cm 1	10 cm at location 1	20 g
A1374287	7-12-08 10-cm 2	10 cm at location 2	16 g
A1374256	7-12-08 20-cm 1	20 cm at location 1	24 g
A1374290	7-12-08 20-cm 2	20 cm at location 2	24 g

Section IX. Assessment for Pacific Sheath-Tailed Bats (*Emballonura semicaudata rotensis*) on Tinian, Commonwealth of the Northern Mariana Islands

Thomas J. O'Shea, Ernest W. Valdez, and Frank J. Bonaccorso

ABSTRACT

Pacific sheath-tailed bats are unknown from Tinian except from prehistoric deposits in caves. We used ultrasonic detectors to sample for the presence of echolocating bats in areas of native forest on Mount Lasso and in the Kastiyu Forest on four nights. We did not detect any bats. We did not see any bats in flight during this sampling, and did not receive verbal reports from knowledgeable residents that would indicate their presence. We also found no records of specimens in museums. Native forest habitat was found to be very important in supporting the population of sheath-tailed bats on Aguiguan. However, native vegetation was impacted by Chamorro settlers prior to European contact, and by subsequent introduced ungulate grazing; thereafter most of the native forest on Tinian was cleared for sugar cane plantations by Japanese colonists in the 1920s and 1930s. If sheath-tailed bats survived this loss of foraging habitat, their roosts in caves may have been destroyed by military activities in World War II. Our lack of findings provides further negative evidence that these bats occur on Tinian, but our sampling efforts were very limited. Additional sampling with echolocation detectors across a wider area of forest and searches of caves are needed to further rule out the possibility that a relict population of these bats may remain on Tinian.

INTRODUCTION

Pacific sheath-tailed bats are not known from Tinian other than in prehistoric times. Bones of this species have been found in three caves, crevices or rock shelters in the Carolinas area of Tinian in prehistoric stratigraphic layers, at least one of which has been dated at 2,400-2,200 years before present by radiocarbon analysis (Steadman 1999). In contrast, the contemporary presence of sheath-tailed bats on Tinian has never been documented by biologists, and there are no specimens (other than zooarchaeological material) from Tinian known in museum collections (Lemke 1986, Helgen and Flannery 2002; see also Section VI of this administrative report). We had a limited amount of time available to make an assessment for the presence of Pacific sheath-tailed bats on Tinian. We arrived on Tinian during the day of 15 July 2008 and were scheduled to leave on 19 July. We decided that with 4 days and nights available the most efficient approach to identify the presence of these bats would be to use echolocation detectors in likely foraging habitat each night, rather than search caves in cliffs during the day. Stafford (2003) had previously conducted a geological inventory of 88 caves on Tinian, and did not see roosting bats in them (K. W. Stafford, personal communication 2008). Detection of even a single bat echolocation call would provide evidence to support additional survey effort in the future. We concentrated our use of echolocation detector equipment to native forest on Tinian, based on findings on Aguiguan that foraging and associated echolocation activity of Pacific sheath-tailed bats is limited primarily to this habitat (Esselstyn and others 2004; see also Section IV of this administrative report).

MATERIALS AND METHODS

We chose two widely separated stands of native forest to sample echolocation activity. One was a section of forest on Mount Lasso in the north central interior of Tinian. This area of the forest was also used during herpetological surveys in 2008 (G. Rodda, pers. comm.). The second area we sampled was 10 km to the southeast of the Mount Lasso area on the southeastern part of Tinian in the Kastiyu Forest, as recommended by CNMI Division of Fish and Wildlife staff (E. Masga and T. Castro, pers. comm.). This area was closer to sections of sea cliffs with caves than was the Mount Lasso forest, although a few small caves were also known from the Mount Lasso area.

On 15 July 2008 we activated two fixed echolocation detector stations using some of the equipment that had been used in the Aguiguan study (Section IV of this administrative report). These stations were located on a trail through the forest at Mount Lasso. Location 1 was located on Mount Lasso along the forest edge at a clearing near the trailhead, 352715E, 1663323N, elevation 196 m. Location 2 was under the canopy at an area with limited understory vegetation about 525 m NNW of Location 1, at 352609E and 1663835N, elevation 156 m. Each Anabat sampling station was programmed to sample continuously all night long (see Section IV of this administrative report for more details on the equipment and methods used at sampling stations). On 16 July 2008 we placed the echolocation detector units in the Kastiyu Forest. Location 1 in the Kastiyu Forest was at 355660E and 1653903N, elevation 161 m. The second station at the Kastiyu forest was about 400 m SSE of Location 1, at 355732E and 1653511N, elevation 158 m. Both locations where detector stations were established in the Kastiyu Forest area were below the canopy, about 30 m interior from the forest edge.

In addition to the fixed sampling stations that automatically collected echolocation activity all night long, we also sampled using *ad hoc* walking transects and hand-held Anabat II SD1 CF ultrasonic detectors at Mount Lasso and the Kastiyu Forest on 17 and 18 July 2008. These transects were sampled from dusk until about 2130 h, typically a period of peak detection of foraging bats on Aguiguan (see Section IV of this administrative report). At the Mount Lasso site we walked the interior forest trail on a path about 870 m long, beginning at a point at 352715E, 1663323N and ending at 352287E and 1663969N (travelling through the point where the second fixed station of 15 July was located). Two observers each held separate ultrasonic detectors aimed upward at the surrounding airspace with moderately high sensitivity settings and an audible broadcast setting. Detectors were deployed throughout the entire length of the transect and return. At the Kastiyu Forest area where we sampled there were no interior forest trails. Therefore we walked a route along the immediate forest edge on an overgrown road bed over a distance of 0.5 km with the detectors on continuously. An old fence line separated the forest from the old road bed, which was typically within 10 m of the canopy edge. Every 125 m we crossed the fence and entered into the forest at a perpendicular distance of about 30 m into the forest interior from the transect and stood about 15 m apart with each detector scanning upward across the air space for a 5 min fixed point sample. We walked the entire transect route and returned twice. The coordinates for each end of the transect and the locations for fixed point stations at the Kastiyu Forest are given in Table IX-1.

In addition to echolocation detector sampling we also queried employees of the CNMI Division of Wildlife and Tinian Department of Land and Natural Resources and other people for local knowledge about this bat on Tinian, and kept alert for visual observations of bats in flight when traveling at night by foot or by vehicle.

RESULTS AND DISCUSSION

We did not detect any ultrasounds in our limited sampling with echolocation detectors at two forested areas on Tinian. This is consistent with the lack of any previous historic records of Pacific sheath-tailed bats on Tinian (e.g. Lemke 1986, Helgen and Flannery 2002). We also found no records of museum specimens on Tinian in our search of museum databases (see also Section VI in this administrative report). Additionally, we saw no bats in flight at any time, and there was no apparent local knowledge of the existence of these bats on Tinian based on our limited number of conversations with residents and Tinian Department of Land and Natural Resources and CNMI Division of Fish and Wildlife employees. This is also consistent with the verbal report by Stafford (personal communication) that he saw none of these bats during his geological inventory of 88 caves on Tinian (Stafford 2003). Eleven caves specifically searched for bats in 1984-1985, failed to have evidence of occupancy by bats, although investigators suggested that additional caves should be searched in the Kastiyu area (Wiles and others 1990).

Although Pacific sheath-tailed bats are present in deposits in caves from prehistoric times (Steadman 1999), a long history of habitat degradation by human influences may have negatively impacted their foraging habitat. Tinian has a larger land mass than Aguiguan and has areas with considerable karst topography, cliffs, and caves, but the few remaining "native" forested areas on Tinian are small. As reviewed by Wiles and others (1990), the Chamorro people probably strongly modified native vegetation of Tinian prior to European contact, which was exacerbated by introduction of exotic ungulates thereafter. Thousands of cattle roamed the island and a large population of feral pigs existed between the 1700s and 1900s. During the 1920s and 1930s Japanese colonists cleared most of the island for sugar cane plantations, with very little native forest left standing. According to one estimate (Bowers 1951) as little as 2% of the island may have been left in native forest. It is likely that the extensive development and clearing, military activity, and combat operations on Tinian during and after World War II also impacted caves as roosting habitat and forests as foraging habitat. Local knowledge indicated that accessible caves were used as strongholds by soldiers, and were subject to grenade explosions and flamethrower operations during the invasion by the United States. If Pacific sheath-tailed bats were present on Tinian after loss of forest habitat to agriculture prior to World War II, it is likely that populations were severely reduced or eliminated during the war and perhaps thereafter (see Lemke 1986, and Section III of this administrative report for a history of investigations on sheath-tailed bat distribution in the Mariana Islands). If these bats currently exist on Tinian despite the absence of any historic records or contemporary evidence, then it is likely that they do so in a very small remnant population that will take considerable effort to discover. Such efforts will require additional use of ultrasonic detectors and intensive searches of caves for roosting bats. Searches of many of these caves will require specialists with technical climbing and caving skills. Additional effort at surveying forests using echolocation detectors should be devoted to a larger area of forest in the Kastiyu and Carolinas area of southeastern Tinian. This region has a significant amount of karst geology and associated caves (Stafford 2003) as well as native limestone forest, some of which may have never been cleared for agriculture because of the karst substrate. If a relict population of Pacific sheath-tailed bats exists on Tinian it would most likely be in this general location.

Similarly, the literature also reports possible sightings of small numbers of these bats on Anatahan and the east island of Maug in the late 1970s and early 1980s (Lemke 1986, 1987). These two northern islands should be surveyed more intensively for sheath-tailed bats using echolocation detectors as well as searches of caves (other subspecies of Pacific sheath-tailed bats will roost in hollow trees and overhangs in other island groups) to rule out the possibility of an established population on an island other than Aguiguan. Discovery of a second population in the Marianas Islands would help bolster the prospects for survival of this subspecies. Consideration of other management options such as translocation from Aguiguan to other locations could be deferred until further assessments on other islands are completed. Although there are 1,200 species of bats worldwide, with many species of conservation concern, with one exception translocation of insectivorous bat populations for conservation has to our knowledge never been successfully attempted. The exception involved the unusual case of the short-tailed bat (*Mystacina tuberculata*) in New Zealand. This translocation required an intermediate step of captive breeding, and has been too recent to judge its ultimate success (New Zealand Department of Conservation, 2008).

ACKNOWLEDGMENTS

We thank E. Masga, Ton Castro, and other CNMI government and mayor's office employees on Tinian for their guidance in the Field. G. Rodda suggested the location on Mt. Lasso, and the Kastiyu Forest granted after-hours access to their lands. This section of the report was improved by comments on an earlier draft by P. Cryan and G. Wiles. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Table IX-1. Coordinates (UTM, Datum: WGS 84; Zone 55P) for start point, end point, and fixed point stations using the Anabat detectors in Kastiyu Forest on 18 July 2008.

Location	**Easting Coordinate**	**Northing Coordinate**
Transect beginning	355635E	1654000N
Forest interior station 1	355660E	1653903N
Forest interior station 2	355662E	1653767N
Forest interior station 3	355692E	1653629N
Forest interior station 4 and transect end	355732E	1653511N

Section X. Considerations for Future Management, Monitoring, and Research

Thomas J. O'Shea, Ernest W. Valdez, and Gary J. Wiles

A number of considerations for future activities stem from the findings of this assessment. These are best characterized as activities related to management for conservation, monitoring, and research.

Considerations for Management for Conservation

Increasing the extent of native limestone forest, decreasing existing stands of invasive plants, and eliminating or avoiding actions that would reduce the amount of native limestone forest on Aguiguan. Results presented in Section IV of this administrative report show that Pacific sheath-tailed bats on Aguiguan forage primarily in native limestone forest, particularly in stands of taller stature. The importance of this habitat may also be reflected by some elements of their diet as reported in Section V of this administrative report. Browsing by feral goats has limited the regeneration of native forest and has likely altered tree species composition and diversity by favoring unpalatable species. Control or elimination of goats could favor forest regeneration. If such control takes place, foraging activity of sheath-tailed bats should be monitored to ensure that a developing understory provides favorable feeding habitat compared with the existing open conditions maintained by goats. A program of managing extensive areas of non-native vegetation to encourage its replacement by native forest could enhance the amount of foraging habitat available to Pacific sheath-tailed bats on Aguiguan. Similarly, new military activities that could be destructive to the remnant forest should be avoided.

Limiting disturbance and access to caves used by roosting bats. Although many caves exist on Aguiguan, only a few are used as roosts by Pacific sheath-tailed bats, despite seeming similarities among caves in structure and conditions of temperature and humidity (see Sections III and VI of this administrative report). Only two caves are known to regularly have 50 or more bats. These caves have histories of use by bats that indicate occupancy by sheath-tailed bats on every visit since first discovered by researchers. They are also occupied by endangered Mariana swiftlets. Under current levels of visitation of Aguiguan by people, activities that might disturb bats or swiftlets at caves seem minimal. However, any increase in visitation by people or increases in other activities that could disturb these colonies could have strong negative effects. Disturbance is well known to have long-lasting negative effects on other species of bats around the world that rely on caves for roosts, and a variety of techniques for protecting caves used by bats have been developed.

Considerations for Monitoring

Monitoring numbers of bats utilizing key caves on Aguiguan. Monitoring numbers of bats at caves will provide an index of population status (increasing, stable, or declining) over time, and will allow measurement of responses to habitat change (e.g. from typhoons or habitat management). Use of caves by bats could be monitored using emergence counts or internal counts with night vision equipment where possible. Counts should be made on a regular basis using a standard protocol. Caves with a history of use and past series of counts identified in Section III of this administrative report can be focal points, but new colonies that may be discovered with time could also be added. Monitoring should include some initial efforts to further assess daily and seasonal variability in counts, as well as to quantify possible observer effects. Results from variability assessments can be used to guide scheduling and levels of effort (e.g. seasons and numbers of replicate counts at a site) for monitoring.

Monitoring of the use of foraging habitat on Aguiguan using echolocation detectors and site occupancy models. Replication of sampling efforts described in Section IV of this report using echolocation detectors and site occupancy models could be carried out periodically to assess changes in the amount of activity and in habitat use by foraging sheath-tailed bats. Monitoring can detect changes in habitat use over time, changes in response to catastrophic typhoons, and changes in response to management intended to improve the population status of these bats.

Considerations for Research

Searching the more inaccessible areas on Aguiguan for the presence of additional colonies of Pacific sheath-tailed bats that may occupy caves requiring technical climbing and caving skills to reach. Pacific sheath-tailed bats on Aguiguan currently appear to roost only in caves, and occupy just a small fraction of known caves (Section III of this administrative report). Some of our observations of foraging activity and of bats dispersing early at dusk (Sections IV and VI) leave open the possibility that one or more undiscovered colonies of sheath-tailed bats may still exist on Aguiguan. If so, these are likely to be in caves that are in inaccessible sections of cliffs or caves with deep shaft-like entrances that will require technical skills at climbing and caving to search properly. Future searches for roosts should include a team of bat biologists combined with persons with good technical climbing and caving skills and appropriate safety training, dedicated exclusively to searching less accessible caves for colonies of sheath-tailed bats.

Increasing the foundation of ecological knowledge of this species pertinent to its conservation and management. The biology of Pacific sheath-tailed bats anywhere in their range is poorly known. Although we made a few new observations on the biology of these bats during the course of this assessment, determination of potentially important patterns in their ecology will require additional intensive sampling. As examples, if reproduction or foraging habitat use follows a seasonal pattern, then management needs may differ by season; understanding of vital parameters such as timing of reproduction and litter size could influence expectations for time needed for population recovery; possibilities for complexity in social behavior such as foraging territoriality (known in other emballonurid bats) could limit population density given the restricted area of native forest currently available. A focused multi-year program of research on the natural history, ecology, and biology of Pacific sheath-tailed bats on Aguiguan would provide much information of potential use for management. Development of capture techniques, analysis of cave deposits for past histories of use by these bats and other animals, analysis of fecal material for past exposure to contaminants and more in-depth assessment of diet, and further sampling to estimate genetic diversity are other areas of research that could improve biological knowledge about this population pertinent to its conservation and management.

Conducting a modern analysis of the taxonomic status of Emballonura semicaudata and its subspecies using combined quantitative morphometric and molecular genetic approaches. The management of the Aguiguan population as a subspecies of a more widely distributed Pacific sheath-tailed bat is based on a limited taxonomic understanding. The current systematic status of the subspecies in the Mariana Islands rests largely on qualitative features of skull morphology described 65 years ago after examination of a limited number of specimens. The subspecies designation was also based on size, which our measurements of bats from Aguiguan (Section VI of this administrative report) suggest may no longer be a valid criterion. Review of subspecific distinctions in 1997 was also limited in scope. There are a large number of specimens in existence in various museum collections that could be used in a systematic reassessment, and there are also a number of molecular genetic approaches that are now routinely used in the study of bat taxonomy. Modern techniques employing a variety of morphometric and molecular genetic analyses should be applied to a study of the systematics of this species throughout its range, including the Mariana Islands and American Samoa (where a different putative subspecies of *E. semicaudata* is also a Category 3 candidate for listing under the U.S. Endangered Species Act). New sampling using wing biopsy techniques like those we applied on Aguiguan may be necessary at some locations.

Further assessing for the occurrence of Pacific sheath-tailed bats on Tinian and other islands in the Commonwealth of the Northern Mariana Islands. Our negative findings on Tinian (Section IX of this administrative report) were based on very limited sampling and should be expanded to more conclusively rule out the possibility that Tinian may still be occupied by a remnant population of Pacific sheath-tailed bats. Similarly, the literature also reports possible sightings of these bats on Anatahan and the east island of Maug in the late 1970s and early 1980s. These two northern islands should be surveyed more intensively for sheath-tailed bats using echolocation detectors to rule out the possibility of an established population on an island other than Aguiguan. Discovery of a second population in the Mariana Islands would help bolster the prospects for survival of this subspecies. Consideration of other management options such as translocation from Aguiguan to other locations could be deferred until further assessments on other islands are completed. Although there are 1,200 species of bats worldwide, with many species of conservation concern, to our knowledge translocation of an insectivorous bat population for conservation has been attempted only once. This involved the short-tailed bat (*Mystacina tuberculata*) in New Zealand and required an intermediate step of captive breeding. This translocation has been too recent to judge its ultimate success.

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SYSTEMATIC RODENT MONITORING

A Study of the Introduced Small Mammals of the Mariana Islands

Final Report to the USGS Brown Treesnake Project,
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Fort Collins, CO

submitted by

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ABSTRACT OF REPORT

Introduced small mammals frequently have detrimental impacts on island ecology, including competition with or predation on native flora and fauna. Introduced small mammals may also disrupt island trophic systems and alter large-scale ecosystem processes. However, our understanding of these effects is limited by incomplete knowledge of small mammal distribution, density, and biomass on many islands. Such information is especially critical in the Mariana Islands, where introduced small mammals are keystone prey for the introduced brown treesnake (*Boiga irregularis*) and small mammal density is inversely related to the effectiveness of brown treesnake control and management tools, such as mouse-attractant traps. Despite the importance of reliable small mammal population data for numerous conservation and management applications, researchers in the Mariana Islands (and elsewhere) often use sampling and analysis methods of questionable accuracy and precision, such as snaptrapping and count-based indices of abundance, perhaps because these methods are thought to be fast and inexpensive.

In an effort to address these concerns, we developed a robust and repeatable mark-recapture livetrapping methodology to determine introduced small mammal distribution, density, and biomass at 8 sites on Guam, 4 sites on Rota, 5 sites on Saipan, and 3 sites on Tinian. On each island, we sampled at least 1 grassland, *Leucaena* forest, and native limestone forest site. In addition, we conducted snaptrapping at these sites following livetrapping, which allowed direct comparison between these sampling methods as well as estimates in indices generated from them. Livetrapping and snaptrapping occurred between April 2005 and June 2007.

In chapter 1, we present density and biomass estimates generated from mark-recapture livetrapping sampling, and speculate on potential impacts on the ecology of Mariana Islands. Of the species captured, *Rattus rattus/R. tanezumi* (morphologically similar, genetic-based differentiation in progress; hereafter *R. rattus*) was most common across all habitats and islands. In contrast, *Suncus murinus* was not captured on Rota, *Mus musculus* was rarely captured at forested sites, and *R. exulans* and *R. norvegicus* were captured infrequently. Modeling of mark-recapture data indicated that neophobia, island, sex, reproductive status and rain amount influenced *R. rattus* capture probability, whereas time, island, and capture heterogeneity influenced *S. murinus* and *M. musculus* capture probability. Introduced small mammal density and biomass estimates generated from these models were much greater on Rota,

Saipan, and Tinian than on Guam, most likely a result of brown treesnake predation pressure on the latter island. *R. rattus* and *M. musculus* density and biomass were greatest in grassland, whereas *S. murinus* density and biomass were greatest in *Leucaena* forest. The high densities documented during this research suggest that introduced small mammals (especially *R. rattus*) may be impacting the abundance and diversity of native lizards, birds, and bats in the Mariana Islands. Ecological processes such as plant regeneration may also be affected. Further, brown treesnake control and management tools that rely on mouse attractants will be less effective on Rota, Saipan, and Tinian than on Guam. If the brown treesnake becomes established on these islands, high-density introduced small mammal populations may facilitate and support a high-density brown treesnake population, even as native species are reduced or extirpated.

In chapter 2, we investigate the precision of mark-recapture and removal abundance estimates generated from livetrapping and snaptrapping data and evaluate 2 count-based indices, number of individuals captured (M_{t+1}) and captures per unit effort (CPUE), as predictors of abundance. We also evaluate the cost and time associated with implementing livetrapping and snaptrapping and compare species-specific capture rates of selected live and snap traps. For all species, mark-recapture estimates were consistently more precise based on coefficients of variation and 95% confidence intervals. The predictive utility of both M_{t+1} and CPUE was relatively poor, but improved with increasing sampling duration over occasions 1–5. More importantly, modeling of sampling data revealed that underlying assumptions critical to the application of indices of abundance, such as spatially and temporally constant capture probability, were not met. Capture probability also varied as a function of covariates (sex, age, reproductive status, body size, and rain amount) for *R. rattus*. Snaptrapping was cheaper and faster than livetrapping, although the time difference was negligible when site preparation time was considered. We documented variable capture rates in different traps: *R. rattus* captures were greatest in Haguruma live and Victor snap traps, whereas *S. murinus* and *M. musculus* captures were greatest in Sherman live and Museum Special snap traps. While snaptrapping and count-based indices may have utility after validation against more rigorous sampling or estimation procedures, validation should occur across the full range of study conditions. Resources required for this level of validation would likely be better allocated towards implementing rigorous and robust methods.

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CHAPTER 1: INTRODUCED SMALL MAMMAL DENSITY AND BIOMASS IN THE MARIANA ISLANDS: IMPLICATIONS FOR ISLAND ECOLOGY

INTRODUCTION

Introduced small mammals often have detrimental effects on island ecology (Atkinson 1985, Towns et al. 2006). Direct effects of introduced small mammals include competition with, or predation on, various amphibian (Worthy 1987, Towns and Daugherty 1994), avian (Fisher and Baldwin 1946, Wirtz 1972, Recher and Clark 1974, Atkinson 1977, Martin et al. 2000, Smith et al. 2006), invertebrate (Bremner et al. 1984; Kuschel and Worthy 1996; Brook 1999, 2000; Carlton and Hodder 2003; Priddel et al. 2003), mammalian (Daniel 1990, Goodman 1995, Pascal et al. 2005), and reptilian species (Whitaker 1973; Newman 1994; Towns 1994; Towns and Daugherty 1994; Cree et al. 1995; Hoare et al. 2007a,b), often resulting in population declines or even extirpation. Introduced small mammals may also suppress plant recruitment by consuming bark, flowers, foliage, fruits, seeds, or seedlings (Allen et al. 1994; Campbell and Atkinson 1999, 2002; McConkey et al. 2003; Wilson et al. 2003); in extreme cases this recruitment suppression can result in local extirpation (Campbell and Atkinson 1999, 2002). Less apparent but equally important indirect effects include disruption of island trophic systems (Fritts and Rodda 1998, Towns 1999) and nutrient cycling (Fukami et al. 2006), modification of vegetative community structure and successional patterns (Campbell and Atkinson 1999, 2002; Athens et al. 2002), and creation of novel vectors and reservoirs for diseases and parasites of both animals (Pickering and Norris 1996, Martina et al. 2006) and humans (Chanteau et al. 1998, Lindo et al. 2002, Bitam et al. 2006, Jiang et al. 2006).

Despite this growing body of evidence, our understanding of the effects of introduced small mammals on island ecology is far from complete. In an effort to provide a framework for future research, Parker et al. (1999) proposed that 3 factors determine the impact of introduced species on island ecosystems: their range, density or biomass, and effect per individual or per unit biomass. The authors suggest that range, density, and biomass are much easier to quantify than the per individual or unit biomass effect of introduced species (Parker et al. 1999). While this claim is valid from a procedural standpoint, in practice the range, density, and biomass of introduced small mammal species are poorly understood on many islands, severely limiting efforts to understand their effect on island ecology. This lack of knowledge is especially troubling for well-studied island systems, such as the Mariana Islands, infamous for the introduced brown treesnake (*Boiga irregularis*) and its negative impact on island ecology (Savidge 1987, Fritts and Rodda 1998, Rodda et al. 1999, Rodda and Savidge 2007). In spite of considerable research efforts associated with controlling the brown treesnake on Guam and preventing its spread to other vulnerable locations (Colvin et al. 2005), relatively little is known about the introduced small mammal community, including such basic information as the number and identity of introduced small mammal species currently present.

Based on a review of available data (Appendix 1A, Tables 1A.1 and 1A.2), the introduced small mammal community of the Mariana Islands consists of 5 or 6 species (with possible additional subspecies), ranging from the earliest introduction, *Rattus exulans*, which occurred no later than A.D. 1000–1200 (Steadman 1999) to the most recent introduction, *Suncus murinus*, first captured on Guam in 1953 (Peterson 1956). Later introductions include *Mus musculus*, first reported on Guam in 1819 (Freycinet 2003:88), and *R. norvegicus*, first reported on Saipan in the late 1800's (Kuroda 1938 cited by Wiles et al. 1990). Regarding the polytypic species *M. musculus*, it is not clear which, or how many, subspecies (*M. m. musculus*, *M. m. domesticus*, or *M. m. castaneus*; Musser and Carleton 2005:1400–1401) have been introduced. It is notable that Prager et al. (1998) found *M. m. castaneus* on Tinian, although this identification was based on genetic analysis of a single speciment. Two additional species, *R. rattus* and *R. tanezumi*, have been documented in the Mariana Islands (Baker 1946, Johnson 1962, Yosida et al. 1985), although their current status is unclear. The complex taxonomic history of these closely related species (Musser and Carleton 2005:1484–1487, 1489–1491), which were only recently separated based on karyotypic differences (*R. rattus*: 2n = 38; *R. tanezumi*: 2n = 42) as well as biochemical and morphological features (Schwabe 1979, Baverstock et al. 1983), complicates the investigation of historic introductions and current distribution. Additional confusion arises from the limited hybridization observed in both laboratory (Yosida et al. 1971) and wild (Baverstock et al. 1983) populations, which led Baverstock et al. (1983:978) to conclude that *R. rattus* and *R. tanezumi* "…are best considered as incipient species. Where they meet, they may introgress, become sympatric without interbreeding, or one may replace the other depending upon the prevailing biological conditions."

Attempts to use available historic data to investigate introduced small mammal density and distribution in the Mariana Islands are complicated by the common reliance on non-rigorous sampling techniques, such as low sampling effort and convenience sampling (Anderson 2001, 2003), and the frequent reporting of indices of density (Appendix 1A, Table 1A.2). As a result, retrospective comparisons across sites, habitats, or islands require unrealistic assumptions about the equality of detection probability across space and time (Anderson 2001, 2003), inhibiting our understanding of introduced small mammal populations as well as our ability to investigate possible effects of introduced small mammals on both the ecology of the Mariana Islands and brown treesnake control and management. Thus, our objectives were to: 1) determine the distribution of introduced small mammals across the major habitats of Guam and the nearby islands of Rota, Saipan, and Tinian and 2) generate robust estimates of introduced small mammal density and biomass in these locations using rigorous and repeatable mark-recapture livetrapping methods.

STUDY AREA

The Mariana Islands consist of 15 islands arrayed in a north-south arc between approximately 13° and 21° N and 144° and 146° E (Metteler 1986; Figure 1). The marine tropical climate of the Mariana Islands results in minimal seasonal temperature variation, with monthly averages ranging between 24° and 27° C (Mueller-Dombois and Fosberg 1998:241). Precipitation is seasonal, with a rainy season from July to October, and averages 2000–2500 mm per year (Mueller-Dombois and Fosberg 1998:241). Tropical storms and typhoons occur frequently in the Mariana Islands, especially during the rainy season (Mueller-Dombois and Fosberg 1998:241).

Introduced small mammal sampling occurred on the permanently inhabited islands of Guam, Rota, Saipan, and Tinian (Figure 1). Guam is the largest island in the Mariana chain (544 km^2) and also has the greatest human population (154,805; U.S. Census Bureau 2004). Rota (85 km^2), Saipan (115 km^2), and Tinian (101 km^2), are each much smaller and have low (Rota: 3,283; Tinian: 3,540) to moderate (Saipan: 62,392) human populations (U.S. Census Bureau 2003). Geologically, these islands consist of a mixture of upraised coral plateaus and weathered volcanic substrates, with exposed volcanic rock being least common on Tinian (Mueller-Dombois and Fosberg 1998:254). The dominant native vegetative community of the upraised coral plateaus is limestone forest, which is most common and least disturbed on Rota (Falanruw et al. 1989). Native limestone forests in the Mariana Islands have highly variable structure and species composition, primarily as a function of slope, aspect, and elevation as well as the frequency and extent of typhoon damage and human disturbance (Mueller-Dombois and Fosberg 1998:242, 270–271). Common native forest species include *Aglaia mariannensis*, *Artocarpus mariannensis*, *Cycas circinalis*, *Cynometra ramiflora*, *Elaeocarpus joga*, *Ficus prolixa*, *Guamia mariannae*, *Ochrosia mariannensis*, *Pandanus dubius* and *P. tectorius*, *Pisonia grandis*, and *Premna obtusifolia* (Falanruw et al. 1989, Mueller-Dombois and Fosberg 1998:271). Grasslands or sparsely-forested savannahs are typically found on areas of exposed volcanic substrate, especially in southern Guam, the Sabana region of Rota, and the central ridge of Saipan. These grassland/savannah habitats are generally dominated by *Dimeria chloridiformis*, *Miscanthus floridulus*, or *Pennisetum polystachyon*; other commonly encountered grassland species include *Casuarina equisetifolia*, *Dicranopteris linearis*, and *Lycopodium cernuum* (Falanruw et al. 1989, Mueller-Dombois and Fosberg 1998:259, 268, 272). On Tinian, which lacks extensive areas of exposed volcanic substrate, non-forested areas are generally covered by a mixture of invasive weeds, especially *Mimosa invisa* (Falanruw et al. 1989, Mueller-Dombois and Fosberg 1998:264). Human disturbance, including highly destructive activities during and after World War II, as well as frequent storm damage, have modified the vegetative community of large areas in the Mariana Islands. Many of these disturbed areas, especially on Guam, Saipan, and Tinian, have been recolonized by the introduced leguminous tree *Leucaena leucocephala*. This species often exists in nearly monotypic stands, but is also commonly found in association with *Flagellaria indica*, *Hibiscus tiliaceus*, *Nephrolepis biserrata* and *N. hirsutula*, and *Triphasia trifolia* (Falanruw et al. 1989, Mueller-Dombois and Fosberg 1998:264).

METHODS

For a complete description of the study site selection and small mammal sampling protocols used during this research (described below), please refer to Wiewel (2005).

Study Site Selection

We sampled 8 sites on Guam (one of which was sampled annually; Figure 2), 4 sites on Rota (Figure 3), 5 sites on Saipan (Figure 4), and 3 sites on Tinian (Figure 5) between April 2005 and June 2007 (Table 1). Study sites were identified using a combination of 1:24,000 and 1:25,000 scale topographical maps (U.S. Geological Survey 1999a,b,c; 2000) and 1:20,000 scale vegetation maps (Falanruw et al. 1989). Sites were evaluated based on habitat type, available area of relatively homogeneous habitat, and land ownership status. Selected sites represented the 3 major habitat types of the southern Mariana Islands: native limestone forest, grassland, and *L. leucocephala*-dominated secondary forest. Additional sites were selected near airports and seaports, independent of habitat type, based on a desire to better understand introduced small mammal populations in these areas. Both Johnson (1962) and Musser and Carleton (2005:1485) stated that on islands with *R. tanezumi*, *R. rattus* is restricted to ships in harbor and only rarely able to colonize onshore areas; thus, seaport (and presumably airport) areas were deemed important for understanding *R. rattus* and *R. tanezumi* distributions. Airports and seaports are also critical areas for control and management efforts aimed at preventing transport of brown treesnakes from Guam to other islands. Sites near airports and seaports generally included a mixture of habitat types (typically grassland and *L. leucocephala*-dominated secondary forest) and were classified as mixed habitat. With the exception of mixed habitat sites, potential sites contained ≥4 ha of relatively homogeneous habitat. Sites were located primarily on military and public lands because these areas generally offered larger tracts of homogeneous habitat and because information about private land ownership and permission for access were often difficult to obtain. On each island, at least 1 native limestone forest site, 1 grassland site, and 1 *L. leucocephala*-dominated secondary forest site were selected and sampled. Five sites were sampled near airports and seaports on Guam (n = 2), Rota (n = 1), and Saipan (n = 2; Table 1).

Small Mammal Sampling

Due to the uncertainty surrounding the status of *R. rattus* and *R. tanezumi* in the Mariana Islands, we collected genetic material from all captured *Rattus* to allow determination of species identification and distribution. Preliminary analysis of the cytochrome oxidase I mtDNA region of 8 specimens from northern and central Guam indicated that all were *R. diardii* (sensu Robins et al. 2007), rather than the expected *R. rattus* and *R. tanezumi*. Until samples from all islands are processed, however, we will use the more recognized term *R. rattus* to refer to the combined sample of unidentified *Rattus* species.

At each site, mark-recapture livetrapping was conducted for 5 consecutive nights on an 11 × 11 grid with 12.5 m intervals between each trap station (grid area = 1.56 ha). A single standard-length folding

Sherman live trap (229 × 89 × 76 mm; H.B. Sherman Traps, Inc., Tallahassee, FL) was placed at each trap station (*n* = 121) and a single Haguruma wire mesh live trap (approximately 285 × 210 × 140 mm; Standard Trading Co., Honolulu, HI) was placed at every other trap station (*n* = 36; Figure 6). This trapping design was based on the general home range requirements of the species most likely to be captured in each trap. For example, historic research on Guam suggests that *M. musculus* has an average home range diameter of approximately 50 m, with average female and male movements of 27 and 33 m, respectively, between captures (Baker 1946). Similarly, *S. murinus* home ranges on Guam typically range 14–60 m in diameter (Barbehenn 1974a). Thus, standard-length Sherman traps, which are more likely to capture *M. musculus* and *S. murinus* (Gragg 2004, Wiewel 2004b), were placed at 12.5 m intervals to increase the likelihood that individual *M. musculus* and *S. murinus* within the trapping grid were exposed to multiple traps. *Rattus* species typically have larger home ranges than *M. musculus* or *S. murinus*. For example, male *R. rattus* home ranges vary between approximately 0.94 ha (Dowding and Murphy 1994) and 4.2 ha (Lindsey et al. 1999), with females exhibiting slightly smaller home ranges. Spencer and Davis (1950) recorded movements between successive captures of <60 m for 66% of adult male, 77% of adult female, and 84% of juvenile *R. rattus*. *R. exulans* home ranges vary from 0.16 ha (Strecker 1962) to 2.8 ha (Lindsey et al. 1999). Thus, Haguruma traps, which are more likely to capture *Rattus* species (Gragg 2004, Wiewel 2004a) were spaced at 25 m intervals to better match the larger average home range of these species.

Closed traps were placed on the grid a minimum of 2 nights prior to the beginning of sampling to provide an opportunity for small mammals to acclimate to their presence. Traps were placed on the ground and, whenever possible, located next to or beneath clumps of grass, downed woody debris, or rocks to provide shelter from sun and rain. Traps were baited with a mixture of peanut butter, oats, and food-grade paraffin (Wiewel 2004b) and were checked beginning at 0730–0800 each day. Traps were closed during the day to minimize trap mortality. Traps were reopened at approximately 1600 and rebaited as necessary to ensure bait freshness.

Captured animals were examined and measured to determine species, sex, age, reproductive status, mass (g), head-body length (mm), tail length (mm), right hind foot length (mm), right ear length (mm), and testes length (mm; if applicable). Captured individuals were uniquely marked in each ear with numbered metal ear tags (*M. musculus* and *S. murinus*: small ear tags produced by S. Roestenburg, Riverton, UT; *Rattus* species: #1005-1, National Band and Tag Co., Newport, KY). Recaptured animals were examined to determine tag number. All capture, handling, and marking techniques followed guidelines approved by the American Society of Mammalogists (Gannon et al. 2007) and the U.S. Geological Survey Animal Care and Use Committee (Fort Collins Science Center).

Each site (except for CP05, CP06, and CP07; Table 1) was also sampled with 5 consecutive nights of snaptrapping during the week following livetrapping. Results of snaptrapping are described elsewhere (see Chapter 2); however, data collected during snaptrapping were included in the calculation of both body condition index (a covariate used in mark-recapture abundance estimation) and mean maximum distance moved (MMDM; used in density estimation).

Data Analysis

We estimated density and biomass separately for each species. First, we generated site- specific estimates of abundance using estimated capture and recapture probability modeled from livetrapping data. Because these estimates had no associated area component, our second step was to estimate the effective trapping area (ETA) for each site with reference to each species' mean maximum distance moved (MMDM) between captures. Third, we estimated density as abundance/ETA. Fourth, we determined mean body mass based on measurements of captured animals at each site. Fifth, for each site we estimated biomass as the product of site-specific density and site-specific mean body mass. Finally, we created variance-covariance matrices to separately calculate the variances of density and biomass estimates.

Data analysis generally followed an information-theoretic approach involving model selection and multi-model inference. Model selection was based on Akaike's Information Criterion (AIC; Akaike 1973) corrected for small sample size (AIC_c; Hurvich and Tsai 1989). Models were considered competitive with the top-ranked model when $\Delta AIC_c \leq 2.0$ (Burnham and Anderson 2002:131). Model-averaging was based on Akaike weights (Burnham and Anderson 2002:150) and included the entire model set except for models with nonsensical β or real parameter estimates, which were removed prior to model averaging. We defined nonsensical β estimates as those with standard error (SE) >> β (e.g., β =

16.8, SE(β) = 2084.6) and nonsensical real parameter estimates as those with SE = 0. Unless otherwise indicated, all estimates are presented as mean ± 1 SE.

Abundance Estimation.–Abundance estimates were generated from livetrapping data in Program MARK 4.3 (White and Burnham 1999) using the conditional likelihood closed capture-recapture model developed by Huggins (1989, 1991). The Huggins model uses estimates of capture probability and the number of individuals captured to estimate abundance. Encounter histories are used to estimate capture probability and can account for heterogeneity in capture probability from temporal, behavioral, and individual effects (both in the form of finite mixture distributions [Norris and Pollock 1996, Pledger 2000] and covariates [Huggins 1989, 1991]). In this context, mixture distributions are an attempt to deal with individual heterogeneity by grouping animals with similar capture probabilities into discrete classes for modeling purposes (Pledger 2000). For example, a 2-mixture distribution groups individuals into 2 classes of high and low capture probability. Similarly, covariates are variables thought to influence capture probability (and other demographic parameters) which, when added to capture probability models, may reduce unexplained heterogeneity and thereby improve parameter estimation (Pollock et al. 1984, Pollock 2002). Covariates may pertain to individual animals (e.g., age, sex, mass), in which case they are generally assumed constant over time for modeling purposes, or to the environment (e.g., temperature, precipitation), in which case they are generally assumed constant for all animals over a specified time span, such as 24 hours (Pollock et al. 1984, Pollock 2002).

In Program MARK, design matrices were coded to allow sites to be treated both individually and as groups, based on common attributes such as island or habitat. Capture and recapture probability were primarily modeled across these groups to increase statistical efficiency (i.e., reduce estimate variance) and allow abundance estimates to be generated from sites with few captures or recaptures (Bowden et al. 2003, White 2005, Conn et al. 2006, Converse et al. 2006). Models were specified using the logit link function to constrain parameter estimates to the range 0–1 and to allow the use of non-identity design matrices (Cooch and White 2005). Model building in Program MARK occurred in an iterative fashion, beginning with the traditional mark-recapture models (M_0, M_b, M_t, M_h, M_{tb}, M_{bh}, M_{th}, M_{tbh}) outlined by Otis et al. (1978), where subscripts indicate the type of capture probability variation dealt with by each model: *b* = behavioral variation, *t* = temporal variation, *h* = heterogeneity, and *0* = constant capture probability. Models incorporating heterogeneity effects were specified as 2-mixture models, based on concerns that our dataset would not support a more parameterized mixture model (Conn et al. 2006). Models were ranked based on AIC_c scores, with the top model being used for further model development. If the top ranked model included temporal variation, a set of neophobia models were fit to the dataset. Neophobia models allowed capture probability to vary during the first (neo1) or first and second (neo2) sampling occasions, while holding capture probability constant for the remaining sampling occasions. The motivation for neophobia models came both from literature accounts of neophobia for introduced small mammals (Inglis et al. 1996, Thorsen et al. 2000, Clapperton 2006), as well as observations of an increase in number of individuals captured after the first or second sampling occasion at many of our sites. As before, the top ranked model was used for further model development. The next subset of models added to the MARK analysis were parameterized to model capture probability, recapture probability, or both capture and recapture probability as a function of island, habitat, or site. This complexity was deemed necessary to investigate possible variation in capture and recapture probability across these groupings. We hypothesized that capture or recapture probability might differ between Guam (with brown treesnake predation pressure) and Rota, Saipan, and Tinian (without brown treesnake predation), so the island grouping was coded in 2 ways, with island[4] distinguishing between each island and island[2] distinguishing Guam from the combination of Rota, Saipan, and Tinian. Again, the top ranked model was used for further model development.

The final subset of models added to the MARK analysis contained combinations of 5 individual and 2 environmental covariates, beginning with the full model containing all covariates and proceeding through a series of more parsimonious models including only those covariates important for explaining capture probability. Covariate importance was assessed through examination of β values and 95% CIs, where covariates with non-zero overlapping 95% CIs were considered influential on capture probability. Model-averaged abundance estimates were then generated from this pool of models to account for model selection uncertainty, unless the top ranked model had a model weight > 0.90 (Burnham and Anderson 2002:150). Covariates under consideration included sex (male or female), age (adult or juvenile), reproductive status, body condition index, body size, rain previous night, and rain amount. Reproductive status (repstat) was a categorical variable that differentiated reproductively active adults from non-reproductive adults and juveniles; assignment of repstat class was based on mass and the presence of externally visible sexual characteristics such as descended testes for males and active lactation for females. Body condition index (bodycon) was calculated as the ratio between the observed and expected mass of an individual, where expected mass was determined from a linear regression of ln mass vs. ln head-body length. The expected mass regression was generated using mass and head-body measurements from all individuals (i.e., animals captured during both livetrapping and snaptrapping). For each species, variation in bodycon was modeled as a function of island[4], island[2], and habitat in an analysis of variance framework (Proc GLM, SAS Institute 2003; Table 2). A site-specific bodycon model was not considered because of sparse data for some sites, which might have biased bodycon estimates for individuals from those sites. Bodycon estimates from the top model (or the model-averaged bodycon estimate) for each species were included in MARK modeling. Body Size (size) was a species-specific composite variable created from a principle components analysis (Proc FACTOR, SAS Institute 2003) of mass, head-body length, tail length, hind foot length, and ear length measured for each captured individual. Rain previous night (rainprev) was a categorical measure of the presence or absence of rainfall during the night prior to each trap monitoring occasion. Finally, rain amount (rainamt) was a quantitative measure of the total rainfall (mm) at the center of the trapping grid during each 24-hour sampling occasion, with the exception of the first sampling occasion for which the rainfall measurement encompassed only a 12–16 hour period. Prior to including rainamt in MARK models, rainfall amounts for the 5 sampling occasions were examined for equality across sites. Based on overlapping 95% CIs, there was no effect of the abbreviated rainfall measurement period during the first sampling occasion (Table 3).

Density Estimation.–Species-specific density estimates were generated by dividing the model-averaged abundance estimates from Program MARK by estimates of the effective trapping area (ETA), where ETA was calculated as the total area encompassed by the trapping grid (1.56 ha) plus a boundary strip equal to ½ the mean maximum distance moved (MMDM) between captures for individuals captured ≥2 times (Wilson and Anderson 1985). For the purposes of MMDM calculation, livetrapping and snaptrapping data were combined to increase sample size, after first verifying that movements between captures were not significantly different between sampling methods. Snaptrapping movement observations occurred when animals captured and marked during livetrapping were recaptured during snaptrapping. The combination of livetrapping and snaptrapping datasets increased movement sample size by 41% for *M. musculus*, 45% for *S. murinus*, and 58% for *R. rattus*. For each species, variation in MMDM was modeled as a function of island[4], island[2], and habitat in an analysis of variance framework (Proc GLM, SAS Institute 2003; Table 4). A site-specific MMDM model was not considered because of sparse data for some sites. MMDM estimates from the top model (or model-averaged MMDM estimates) for each species were then used to calculated density. Variance-covariance matrices for density and ETA estimates were computed using the delta method (Seber 2002) and used to determine the variance of derived density estimates (Appendix 1B). We also evaluated an alternative density estimation technique implemented in Program DENSITY (Efford 2004), which avoids potential complications associated with the use of MMDM and ETA (Anderson et al. 1983, Efford 2004). Estimates from Program DENSITY were compared with our density estimates generated using Program MARK (Appendix 1C).

Biomass Estimation.—Biomass was calculated for each species as the product of site-specific density and site-specific mean body mass. For individuals captured multiple times, mean individual mass was used when estimating site-specific mean body mass. Variation in mass was modeled as a function of island[4], island[2], habitat, and site in an analysis of variance framework (Proc GLM, SAS Institute 2003; Table 5). Variance-covariance matrices for density and mass (using estimates from the top mass model or model-averaged mass estimates) were then computed using the delta method (Seber 2002) and used to determine the variance of the derived biomass estimates.

RESULTS

We captured 707 *R. rattus*, 298 *S. murinus*, 154 *M. musculus*, 16 *R. exulans*, and 5 *R. norvegicus* in 17,270 trap nights (Table 6). *R. rattus*, captured at 17 of 20 sites, was the only species captured in all sampled habitats and on all islands (Table 6). *S. murinus*, captured at 9 of 20 sites, was also captured in all sampled habitats but was not captured or observed on Rota (Table 6). In contrast, *M. musculus* was consistently captured at grassland sites only and at 8 of 20 sites overall (Table 6). *R. exulans* and *R. norvegicus* were rarely captured and were not included in density and biomass estimation. In general, captures of all species were greater on Rota, Saipan, and Tinian than on Guam.

Modeling Capture and Recapture Probability

R. rattus capture and recapture probability were best explained by an additive model (w_i = 0.871) allowing neophobic temporal variation (neo2) in capture probability for each island (island[4]; Figure 7), as well as capture probability variation by sex, repstat, and rainamt with recapture probability varying by island (island[4]), sex, repstat, and rainamt (Table 7). All plausible models contained the neo2 effect on capture probability; the best model without neo2 had no support (ΔAIC_c = 33.92). A post-hoc replacement of neo2 with neo1 in the top model reduced the parameter count by 4 but resulted in a less plausible model (ΔAIC_c = 9.81), whereas replacing neo2 with the fully parameterized time model resulted in a ΔAIC_c of 4.36. Attempts to model heterogeneity using mixture models generated nonsensical estimates for the mixture parameter (e.g., 0.52 ± 1.46, 95% CI = 0–1 for M_h or 0.98 ± 0.00, 95% CI = 0.98–0.98 for M_{tbh}). In contrast, covariates were useful for modeling heterogeneity; the addition of sex, repstat, and rainamt to capture and recapture probability greatly improved model fit compared to a model that allowed neophobic temporal variation (neo2) for each island (island[4]) without covariates (ΔAIC_c = 17.97). *R. rattus* capture and recapture probability were lower for males than for females (β_{sex} = -0.44 ± 0.15, 95% CI = -0.75– -0.14), higher for reproductively mature individuals ($\beta_{repstat}$ = 0.47 ± 0.15, 95% CI = 0.17–0.77), and positively correlated with rainfall ($\beta_{rainamt}$ = 0.02 ± 0.01, 95% CI = 0.01–0.04). Reproductively mature females were more than twice as likely to be captured and recaptured as non-mature males (Figures 8, 9). Model-averaged *R. rattus* abundance estimates generated from these models varied between sites, but were generally greatest on Tinian ($\hat{N}$ range = 86–194, n = 3) and Rota ($\hat{N}$ range = 18–186, n = 4), followed by Saipan ($\hat{N}$ range = 15–91, n = 5) and Guam ($\hat{N}$ range = 2–41, n = 9; Table 8).

S. murinus capture and recapture probability were best explained by an additive model allowing temporal variation and heterogeneity in capture probability and temporal variation for each island (island[4]) and heterogeneity in recapture probability (w_i = 0.994; Table 7). Estimated capture and recapture probability increased over time. The best model without a temporal effect had no support (ΔAIC_c = 32.43). Unexplained heterogeneity was approximated by 2 mixture classes which comprised 65% (low capture probability) and 35% (high capture probability) of the population. Thus, well over half of the population had an estimated maximum capture probability of <0.16 (Figure 10A) and a maximum recapture probability <0.19 (Figure 10B). Peak recapture probability for both mixture classes was observed on Guam (Figure 10B). In contrast to *R. rattus*, none of the covariates under consideration were useful for modeling heterogeneity in *S. murinus* capture or recapture probability; the best model containing covariates had essentially no weight (w_i = 0.006; Table 7). Due to the high level of support for the top model (w_i = 0.994), *S. murinus* abundance estimates were generated from this model alone. These estimates were varied between sites, but were generally greatest on Tinian ($\hat{N}$ range = 17–143, *n* = 3), followed by Saipan ($\hat{N}$ range = 14–71, *n* = 5) and Guam ($\hat{N}$ range = 0–20, *n* = 9; Table 8).

M. musculus capture and recapture probability were best explained by 3 additive models allowing both temporal variation and heterogeneity in these parameters (Table 7). In the top model (w_i = 0.349), temporal variation in capture probability varied between Guam and the combination of Rota, Saipan, and Tinian (island[2]). The second-ranked model (w_i = 0.331) differed only by the addition of temporal variation by island[2] on recapture probability. The third-ranked model (w_i = 0.192) differed from the top model by allowing the temporal variation in capture probability to differ for each island (island[4]). Model-averaged capture and recapture probability for Guam varied across time, whereas model-averaged capture and recapture probability for Rota, Saipan, and Tinian were relatively constant across sampling occasions (Figure 11). The best model without a temporal effect had no support (ΔAIC_c = 15.91). Unexplained heterogeneity was approximated by 2 mixture classes which comprised 67.3% (low probability) and 32.7% (high probability) of the population. On Guam, capture and recapture probabilities differed by 0.35–0.54 between the low and high probability mixtures (Figure 11). For Rota, Saipan, and Tinian, over half of the population had estimated maximum capture and recapture probabilities <0.20 and <0.12, respectively, with the remainder of the population exhibiting high capture and recapture probabilities (Figure 11). As with *S. murinus*, none of the covariates under consideration were useful for modeling *M. musculus* abundance; the best model containing covariates had essentially no weight (w_i = 0.003; Table 7). Model-averaged *M. musculus* abundance estimates generated from these models were variable between sites, but was generally greatest on Saipan ($\hat{\hat{N}}$ range = 0–81, *n* = 5) and Rota ($\hat{\hat{N}}$ range = 2–53, *n* = 4), followed by Guam ($\hat{\hat{N}}$ range = 0–18, *n* = 9) and Tinian ($\hat{\hat{N}}$ range = 0–15, *n* = 3; Table 8).

Density Estimates

R. rattus MMDM varied primarily between islands (island[4]; w_i = 0.977; Table 4), and was greatest on Guam (35.6 ± 5.4 m, 95% CI = 24.6–46.7; *n* = 33), followed by Saipan (22.8 ± 2.5 m, 95% CI = 17.8–27.9; *n* = 100), Rota (14.5 ± 1.6 m, 95% CI = 11.4–17.6; *n* = 175), and Tinian (14.5 ± 1.3 m, 95% CI = 11.9–17.1; *n* = 180). When combined with the nominal grid area of 1.56 ha, these MMDM estimates resulted in ETAs of 2.58 ha for Guam, 2.19 ha for Saipan, and 1.95 ha for Rota and Tinian and mean *R. rattus* density estimates of 73.0/ha (*n* = 3) on Tinian, 53.5/ha (*n* = 4) on Rota, 25.6/ha (*n* = 5) on Saipan, and 5.1/ha (*n* = 9) on Guam (Table 9).

S. murinus MMDM varied primarily between habitats (w_i = 0.987; Table 4), and was greatest in grassland (29.2 ± 2.7 m, 95% CI = 23.7–34.7; *n* = 48), followed by mixed habitat (19.3 ± 3.2 m, 95% CI = 12.7–25.9; *n* = 25), *Leucaena* forest (16.3 ± 1.4 m, 95% CI = 13.6–19.0; *n* = 68), and native forest (14.2 ± 3.5 m, 95% CI = 6.4–22.0; *n* = 12). When combined with the nominal grid area of 1.56 ha, these MMDM estimates resulted in ETAs of 2.38 ha for grassland, 2.08 ha for mixed habitat, 2.00 ha for *Leucaena* forest, and 1.94 ha for native forest. Because many more *S. murinus* were captured on Saipan and Tinian than on Guam, we considered habitats separately for these areas. On Saipan and Tinian, mean estimated density was 52.8/ha (*n* = 2) in *Leucaena* forest, 24.2/ha (*n* = 2) in native forest, 20.2/ha (*n* = 2) in mixed habitat, and 9.7/ha (*n* = 2) in grassland (Table 9). On Guam, estimated density was 8.6/ha (*n* = 1) in grassland and 0/ha in the other habitats (*n* = 8; Table 9).

M. musculus MMDM varied primarily between islands (island[4]; w_i = 0.718), although there was also support for the simpler island model (island[2]) differentiating only between Guam and the other islands (w_i = 0.272; Table 4). Model-averaged MMDM was greatest on Guam (31.2 ± 3.6 m, 95% CI = 22.1–38.3; *n* = 25), followed by Saipan (22.8 ± 2.5 m, 95% CI = 17.9–27.7; *n* = 77), Rota (18.2 ± 3.2 m, 95% CI = 11.9–24.5; *n* = 59), and Tinian (11.7 ± 8.7 m, 95% CI = 0–28.0; *n* = 3). When combined with the nominal grid area of 1.56 ha, these MMDM estimates resulted in ETAs of 2.44 ha for Guam, 2.18 ha for Saipan, 2.03 ha for Rota, and 1.87 ha for Tinian. These model-averaged ETAs produced mean *M. musculus* density estimates of 15.8/ha (*n* = 4) on Rota, 7.7/ha (*n* = 5) on Saipan, 2.6/ha (*n* = 3) on Tinian, and 0.8/ha (*n* = 9) on Guam (Table 9).

Biomass Estimates

R. rattus, *S. murinus*, and *M. musculus* varied dramatically in morphology (Table 10), with mean *R. rattus* mass being much greater (121.9 ± 1.8 g, 95% CI = 118.3–125.5; *n* = 707) than mean *S. murinus* mass (25.7 ± 0.4 g, 95% CI = 25.0–26.5; *n* = 298) or mean *M. musculus* mass (12.5 ± 0.2 g, 95% CI = 12.1–12.9; *n* = 154). *R. rattus* mass varied by site (w_i = 1.000), whereas *S. murinus* and *M. musculus* mass varied primarily by habitat (w_i = 0.974) and island (w_i = 0.903), respectively (Table 5). Mean *S. murinus* mass was greatest in mixed habitat (28.6 ± 0.9 g, 95% CI = 26.8–30.3; *n* = 56), followed by *Leucaena* forest (26.0 ± 0.6 g, 95% CI = 24.9–27.1; *n* = 136), native forest (25.5 ± 0.6 g, 95% CI = 24.2–26.7; *n* = 62), and grassland (21.5 ± 1.0 g, 95% CI = 19.5–23.4; *n* = 44). Mean *M. musculus* mass was greatest on Tinian (14.4 ± 1.0 g, 95% CI = 12.2–16.7; *n* = 9), followed by Rota (12.8 ± 0.2 g, 95% CI = 12.4–13.3; *n* = 77), Saipan (12.1 ± 0.3 g, 95% CI = 11.5–12.6; *n* = 53), and Guam (11.0 ± 0.7 g, 95% CI = 9.4–12.6; *n* = 15).

R. rattus biomass was markedly greater than *S. murinus* or *M. musculus* biomass across sampled habitats and islands (Table 11). In fact, there was only 1 site (SAEN) where estimated *S. murinus* biomass was similar to *R. rattus* biomass, and 1 site (ACHU) where estimated *M. musculus* biomass was >5% of *R. rattus* biomass (Table 11). Mean estimated *R. rattus* biomass was greatest on Tinian and Rota, with maximum estimates of 11.6 and 9.8 kg/ha, respectively, and was roughly 3–8 times greater at sites on Rota, Saipan, and Tinian than on Guam (Figure 12, Table 11). Similarly, mean estimated *S. murinus* biomass was greatest on Tinian and Saipan, with maximum estimates of 1.9 and 0.9 kg/ha, respectively, and mean estimated *M. musculus* biomass was greatest on Rota and Saipan, with maximum estimates of 0.3 and 0.4 kg/ha, respectively (Figure 12, Table 11).

When evaluating biomass across habitats, we separated Rota, Saipan, and Tinian from Guam due to dramatically higher *R. rattus*, *S. murinus*, and *M. musculus* biomass on these islands. On Rota, Saipan, and Tinian, mean *R. rattus* biomass was greatest in grassland (Figure 13), with a maximum estimate of 11.6 kg/ha in this habitat (Table 11). In other habitats, mean estimated *R. rattus* biomass was roughly half that estimated for grassland (Figure 13), although maximum biomass estimates exceeded 8 kg/ha in both mixed habitat and native forest (Table 11). In contrast to *R. rattus*, mean estimated *S. murinus* biomass was lowest in grassland and highest in *Leucaena* forest on Saipan and Tinian (Figure 13), with a maximum estimate of 1.9 kg/ha in this habitat (Table 11). Mean estimated *M. musculus* biomass was greatest in grassland on Rota, Saipan, and Tinian (Figure 13), with a maximum estimate of 0.4 kg/ha in this habitat (Table 11). On Guam, mean estimated biomass was greatest in grassland for all species (Figure 13, Table 11). Biologically relevant levels of *R. rattus* biomass were also observed in *Leucaena* forest on Guam, although estimates were quite variable (0–2.9 kg/ha; Table 11) in this habitat. Introduced small mammal biomass was uniformly low (or non-existent) in mixed habitat and native forest on Guam (Figure 13, Table 11).

DISCUSSION

This study provides the first robust and reliable density and biomass estimates for introduced small mammals in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian. Density and biomass were greater on Rota, Saipan, and Tinian than on Guam. Overall, density and biomass were greatest in grassland and *Leucaena* forest habitats, and on Tinian and Rota.

Three species, *R. rattus*, *S. murinus*, and *M. musculus*, were commonly captured during this study. Two additional species, *R. exulans* and *R. norvegicus*, were captured infrequently and in very low numbers. Of these species, *R. rattus* attains the greatest density and biomass in the Mariana Islands. On Rota, Saipan, and Tinian *R. rattus* density and biomass estimates ranged from 6.9–99.9/ha and 1.0–11.6 kg/ha, respectively; maximum density and biomass were observed in grasslands and on Tinian. Maximum estimates of *R. rattus* density on Rota, Saipan, and Tinian are 2–3 times greater than the highest known historic values from Guam and also greater than estimates from other tropical Pacific islands, including Pohnpei (4.0–8.5/ha; Strecker 1962), Majuro (11.3/ha; Strecker 1962), Eniwetok (19.9/ha; Jackson 1967), and the Galapagos (0.2–18.9/ha; Clark 1980). Indeed, the peak densities observed during this study, especially on Rota and Tinian, are suggestive of population irruptions. Conversely, the fact that high density *R. rattus* populations were observed across habitats, islands, and time is not indicative of an irruptive event, and instead suggests that high density *R. rattus* populations may be fairly common on Rota, Saipan, and Tinian. Comparable (and even higher) densities have been recorded for *R. exulans* on small relatively competitor- and predator-free islands. On Kure Atoll, Wirtz (1972) documented a mean *R. exulans* density of 111.2/ha during monthly sampling from March 1964 to May 1965, with monthly estimates ranging from 49.4/ha to 185.3/ha. Similarly, on Tititiri Matangi

Island, New Zealand, Moller and Craig (1987) estimated peak *R. exulans* densities of 130 ± 20/ha in grassland and 101 ± 12/ha in forest during regular sampling from February 1975 to May 1977.

Estimated *R. rattus* density (0–15.9/ha) and biomass (0–2.9 kg/ha) were considerably lower on Guam. These density estimates are slightly lower than estimates from Guam in 1945 (10.9–30.0/ha; Baker 1946) and the early 1960's (18.8/ha; Barbehenn 1969, 1974b). It is notable that our estimates of Guam *R. rattus* density are generally lower in forest than in grassland, a pattern first observed in the mid-1980's by Savidge (forest: 0–2.5/ha, grassland: 36.4/ha; 1986). Gragg et al. (in prep) also found high *Rattus* species density (combined estimates for *R. exulans* and *R. rattus*: 14.7–69.8/ha) in southern Guam grasslands in 2002–2003. This pattern is at least partially attributable to variable brown treesnake predation pressure, as brown treesnake density is generally greater in forest than grassland habitats on Guam (Savidge 1987, 1991; Rodda and Dean-Bradley 2001).

S. murinus is generally less common than *R. rattus* in the Mariana Islands, although estimated *S. murinus* density exceeded *R. rattus* density on 2 sites where both were present. Nonetheless, the low mass of *S. murinus* (in relation to *R. rattus*) resulted in *S. murinus* biomass estimates that, with one exception, were only 1–37% of the estimated *R. rattus* biomass for the same site. Overall, *S. murinus* density exceeded 30/ha at 4 of the 9 sites where this species was captured. On Saipan and Tinian, *S. murinus* density and biomass were greater in forest than grassland, with the highest values occurring in *Leucaena* forest. In contrast, we did not capture *S. murinus* in 7 forest sites on Guam, again possibly an indication of brown treesnake predation pressure in Guam forests. Although *S. murinus* was reported from Rota in 1966 (Barbehenn 1974b), we neither captured nor observed this species during approximately 9 weeks spent on the island and believe it to be absent. In general, our estimates of *S. murinus* density are comparable to historic values from Guam (25.4/ha, Barbehenn 1969, 1974b; 19.1/ha, Savidge 1986) and more recent estimates from Saipan (16.7–27.3/ha, S. Vogt unpublished data). Our estimates are also similar to values obtained for the islands of Ile aux Aigrettes (29.2/ha) and Ile de la Passe (20/ha), located off the coast of Mauritius in the Indian Ocean (Varnham et al. 2002). However, our maximum estimated *S. murinus* density of 73.7/ha greatly exceeds known values, and could indicate an irruptive potential for this species in the Mariana Islands.

M. musculus is a relatively minor component of the introduced small mammal community in the Mariana Islands from a biomass standpoint, with estimates ranging from 0.01–0.45 kg/ha. However, *M. musculus* capture probability may have been negatively influenced by *R. rattus* activity (Brown et al. 1996, Weihong et al. 1999). To investigate this possibility, we added site-specific *R. rattus* density to the top *M. musculus* model in a post-hoc MARK analysis. As anticipated, *R. rattus* density had a negative effect on *M. musculus* capture probability ($\beta = -0.008 \pm 0.006$, 95% CI = -0.019–0.003), although this effect was weak as demonstrated by the 95% CI that asymmetrically overlapped zero (Figure 14). Nonetheless, the trend of decreasing *M. musculus* capture probability with increasing *R. rattus* density suggests that this relationship warrants further investigation and should be considered during sampling design and data analysis. For example, the use of multiple trap types may decrease the likelihood of capture probability suppression of non-dominant species (Brown et al. 1996, Weihong et al. 1999, Gragg 2004). There was an indication of habitat specialization for *M. musculus*, as maximum density and biomass occurred at grassland and mixed habitat sites with patchy vegetative growth and exposed soil. Baker (1946:398) noted a similar preference for “open grass and brush land” and areas where “limestone soils are exposed” on Guam. Similar habitat preferences for this species have been noted for other tropical Pacific islands (Nicholson and Warner 1953, Berry and Jackson 1979). Overall, estimated *M. musculus* density ranged from 0.8–36.5/ha, exceeded 15/ha at 4 of the 8 sites where encountered, and was greater than *R. rattus* and *S. murinus* density at only 1 site where all 3 species were present. These estimates are comparable, though perhaps slightly lower than, historic (8.3–25.8/ha; Baker 1946) and more recent (18.5–104.0/ha; Gragg et al in prep) estimates from Guam.

When interpreting these (and other) density and biomass estimates, it is essential to recognize the potential for temporal variability in introduced small mammal populations. For example, annual sampling at a single site on Guam (CP05, CP06, CP07) demonstrated significant temporal variation in *R. rattus* density and biomass, which increased from 2.6/ha and 0.4 kg/ha in 2005 to 15.3/ha and 2.9 kg/ha in 2006. In 2007, 10 days of livetrapping (1570 trap nights) at this site yielded zero captures. Note that this sampling occurred at the same time each year (early May–early June) and therefore represents annual temporal variability. It is also possible that introduced small mammal density and biomass exhibit intra-annual temporal variability in the Mariana Islands. One slight complication is that this site is used for an ongoing, long-term brown treesnake population study (Rodda et al. 2007) and is surrounded by a snake- and ungulate-proof fence (i.e., brown treesnakes can not enter or exit and ungulates are excluded), suggesting that the site is not directly comparable with other forested areas on Guam. For example, the exclusion of introduced ungulates has resulted in rapid and dramatic shifts in vegetation structure and composition compared to the surrounding landscape (M. Christy, unpublished data). Nonetheless, the temporal variability in *R. rattus* density and biomass observed at this site suggests that introduced small mammal density and biomass may fluctuate greatly over relatively short time spans in the Mariana Islands. The potential for temporal variability should always be considered when interpreting density and biomass estimates, which are merely a snapshot of a dynamic population.

Modeling Capture and Recapture Probability

Our sampling design and data analysis approach allowed us to consider the importance of factors, including time, behavior, heterogeneity, sampling location (e.g., island, habitat), and various covariates, which can affect capture and recapture probability. By accounting for these factors during modeling, we were better able to generate robust and reliable estimates of density and biomass. Modeling identified several important sources of heterogeneity for *R. rattus* capture and recapture probability, including neophobia (capture probability only), island, sex, reproductive status, and rain amount.

We documented reduced capture probability for *R. rattus* on the first and second sampling occasion for traps placed on the grid 2 nights prior to the beginning of sampling. Neophobia has been previously documented in laboratory, commensal, and wild *Rattus* populations (Temme and Jackson 1979, Inglis et al. 1996, Thorsen et al. 2000, Priyambodo and Pelz 2003, Clapperton 2006), and should be an important consideration during sampling design. It is possible that an extended trap acclimation period (>2 nights) or trap pre-baiting could have reduced the neophobia effect, and these possibilities warrant further investigation.

R. rattus capture and recapture probability also varied between islands. Guam, Rota, Saipan, and Tinian differ in a number of biologically relevant ways, including land-use history, introduced ungulate density, and predator density, which might influence *R. rattus* populations. Each island has experienced significant but variable disturbance over the past century as a result of shifting land-use patterns and World War II. Notably, large areas of Rota, Saipan, and Tinian were converted to sugarcane production during Japanese occupation (1914–1944); these areas were largely abandoned following World War II (Bowers 2001). Wartime activities further damaged the native vegetation of these islands, such that post-war estimates of residual forest cover were only 23% for Rota, 5% for Saipan, and 2% for Tinian (Bowers 2001:206). Many disturbed areas, especially abandoned sugarcane fields and areas cleared by military activities, were recolonized by *L. leucocephala* which often persists in near-monotypic stands to the present day (Mueller-Dombois and Fosberg 1998:264). The vegetative community of the Mariana Islands has also been modified by introduced ungulates, although such effects differ between islands. Introduced feral pigs (*Sus scrofa*) and Phillipine deer (*Cervus mariannus*) are currently present on Guam, Rota, and Saipan (Stinson 1994, Vogt and Williams 2004, Wiles 2005), with possible detrimental effects on native forest species recruitment (Wiles et al. 1996, Ritter and Naugle 1999). Introduced pigs and deer once occurred on Tinian but have disappeared in recent years (Wiles et al. 1990). However, domestic cattle (*Bos taurus*) grazing over large areas of this island likely have detrimental impacts on native vegetation (Wiles et al. 1990). In addition, each island is home to a variable suite of predators capable of capturing *R. rattus*. The most obvious difference between islands, in terms of predators, is the high-density brown treesnake population on Guam (Rodda et al. 1999). Other potential predators, including feral cats (*Felis catus*; common on Rota and Tinian) and dogs (*Canis familiaris*; common on Guam), monitor lizards (*Varanus indicus*), collared kingfishers (*Halcyon chloris*; not present on Guam), Micronesian starlings (*Aplonis opaca*; uncommon on Guam), Mariana crows (*Corvus kubaryi*; Guam [rare] and Rota [uncommon] only), the introduced black drongo (*Dicrurus macrocercus*; Guam and Rota only), and the introduced cane toad (*Bufo marinus*) exist at variable densities in different habitats and on different islands (Stinson 1994, Vogt and Williams 2004, Wiles 2005). With the exception of the brown treesnake on Guam, the effect of predators on *R. rattus* in the Mariana Islands is presently unclear. It seems likely, however, that intra- and inter-island variability in predation pressure, habitat structure, and vegetative species composition influence *R. rattus* populations, suggesting that further investigation of these factors would be valuable.

Several covariates (sex, reproductive status, and rain amount) proved important for modeling *R. rattus* capture and recapture probability. Addition of these covariates improved the precision of site-specific abundance estimates by an average of 25.7% (range: 8.1–57.2%) relative to estimates produced by the same model without covariates. A secondary benefit of including covariates in models is the knowledge gained about individual or environmental factors that influence capture and recapture probability. In this case, the importance of sex and reproductive status for *R. rattus* capture and recapture probability is not surprising based on evidence of the importance of social structure and dominance hierarchies for *Rattus* species. For example, during long-term observations of a free-ranging *R. rattus* population, Ewer (1971) found that females were more aggressive than males and adults were generally dominant over juveniles. Similarly, for our data *R. rattus* capture and recapture probability were higher for females than for males, and for reproductively mature individuals than for non-reproductive individuals (both adults and juveniles). Alternatively, the high capture and recapture probability of reproductively mature females could simply be the result of increased energy requirements and foraging activity by these individuals, leading to increased encounters with traps and increased captures.

The importance of the environmental covariate rainfall amount, and the positive relationship between rainfall amount and *R. rattus* capture and recapture probability, is more difficult to interpret. Although speculative, one possible explanation is that *R. rattus* activity increased with rainfall as individuals searched for standing water. The limestone substrate of large areas of the Mariana Islands is highly permeable and available surface water is typically rare or nonexistent (Mueller-Dombois and Fosberg 1998:254). Outside of the moisture available in food items, water may be limited except immediately following a rainfall event. Unfortunately, it does not seem that *R. rattus* water requirements have been studied in detail and it is unknown if *R. rattus* in the Mariana Islands can meet daily water requirements through diet alone. Norman and Baudinette (1969) found that wild *R. rattus* collected on Green Island, Tasmania, had a mean minimum daily water requirement of only 5.95 ± 1.4 mL (representing 5.36 ± 0.8% body weight/day), although mean daily intake rose to 40.7 ± 15.0 mL (representing 21.5 ± 5.0% body weight/day) when water was provided *ad libitum*. Stomach content analysis of additional *R. rattus* collected from the same location revealed an average of 6.4 mL of free water in the diet, suggesting that individuals could meet minimum water requirements through diet alone (Norman and Baudinette 1969). The applicability of these data to *R. rattus* in the Mariana Islands is unknown, however, as conditions influencing daily water requirements (e.g., temperature, humidity, and diet) differ markedly between the Mariana Islands and Tasmania. Alternatively, rainfall amount might increase *R. rattus* activity by influencing food availability or palatability in some unknown fashion. Investigation of this speculative hypothesis would require detailed study of both the diet of *R. rattus* in the Mariana Islands and the impact of rainfall on the components of that diet. Regardless of the underlying relationship between capture and recapture probability and rainfall, the effect size was small in comparison to the effect size of sex and reproductive status. Rainfall in the Mariana Islands is highly variable, even over the spatial extent of our trapping grids, and may occur at any time. Improved rainfall measurement should incorporate more frequent recording of rainfall (minimally 12 hour intervals to differentiate daytime and nighttime rainfall) and perhaps multiple recording stations to better cover the area of the trapping grid.

In contrast to *R. rattus*, none of the covariates under consideration were important for modeling *S. murinus* and *M. musculus* capture and recapture probability. Instead, heterogeneity was accounted for through the use of 2-mixture models. This outcome was somewhat surprising, as mixture models are generally not well-supported for small datasets (Conn et al. 2006), such as our *S. murinus* (298 total individuals) and *M. musculus* (154 total individuals) datasets. Other researchers have documented apparent capture probability heterogeneity for both *S. murinus* (Seymour et al. 2005) and *M. musculus* (Drickamer et al. 1999, Conn et al. 2006). Notably, Seymour et al. (2005) found highly variable capture probabilities in a *S. murinus* population on Ile aux Aigrettes. Of the 759 *S. murinus* captured on this 25-ha island during a 7-month eradication attempt (96,613 trap nights), approximately 350 captures occurred during the first 3 nights of trapping and 89.3% of the total captures occurred by night 18. Infrequent captures (<25) occurred over the next 3.5 months, followed by a 3 month period of increasing captures across the island before the eradication attempt was abandoned. These results are suggestive of a population with at least 2 capture probability classes, with a large proportion of the population having high capture probability and a smaller proportion of the population having very low capture probability. In contrast, our results from the Mariana Islands indicated that roughly ⅓ of *S. murinus* had high capture probabilities, with the remainder having reduced capture probability.

Both *S. murinus* and *M. musculus* also exhibited temporal variation in capture and recapture probability. *S. murinus* capture and recapture probability increased over time. This pattern of reduced capture probability during early sampling occasions suggests neophobia, although this effect was not strongly supported in models. While some researchers have documented a similar response for *S. murinus* (e.g., Figure 6 in Seymour et al. 2005), the general consensus seems to be that *S. murinus* is neophilic and likely to investigate, rather than avoid, new objects (Churchfield 1990 cited by Seymour et al. 2005). Interpretation of high *S. murinus* recapture probability for Guam is difficult because of sparse data (14 animals captured at a single site) on this island. The pattern in temporal variation is less clear for *M. musculus,* although there does seem to be an indication of increasing capture and recapture probability over time for Rota, Saipan, and Tinian. Interpretation of the Guam capture and recapture probabilities is again complicated by sparse data (15 animals captured at a single site) on this island.

Modeling also indicated that *S. murinus* recapture probability varied between each island, and that *M. musculus* capture probability varied differed between Guam and the combination of Rota, Saipan, and Tinian. As with *R. rattus*, intra- and inter-island variation in habitat structure, vegetative species composition, and predator community could be biologically relevant for *S. murinus* and *M. musculus* populations and could explain these island-level differences in capture and recapture probability.

Implications for Mariana Island Ecology and Brown Treesnake Control and Management

Although little direct evidence currently exists for the Mariana Islands, it seems likely that the high-density introduced small mammal populations documented during this research have negative effects on native fauna and flora, and that introduced species (including small mammals) have modified Mariana Island ecosystems and ecosystem function (Fritts and Rodda 1998). In recent years, researchers have noted apparent declines of several avian species in the Mariana Islands, including the bridled white-eye (*Zosterops conspicillatus rotensis*; Amidon 2000, Fancy and Snetsinger 2001) and Mariana crow (*Corvus kubaryi*; Plentovich et al. 2005, U.S. Fish and Wildlife Service 2005) on Rota and the Micronesian megapode (*Megapodius laperouse*) and Mariana fruit dove (*Ptilinopus roseicapilla*) on Saipan (Craig 1999). Numerous hypotheses, including predation by introduced species (e.g., *Rattus*, black drongos, and feral cats), avian diseases or parasites, pesticides, and habitat degradation associated with land-use changes or typhoon damage, have been considered (Craig 1999, Amidon 2000, Fancy and Snetsinger 2001, Plentovich et al. 2005, U.S. Fish and Wildlife Service 2005, Ha et al. in prep). While predation by black drongos, diseases, and pesticides have largely been ruled out and habitat degradation is increasingly seen as an important factor in avian declines (e.g., Fancy and Snetsinger 2001, Ha et al. in prep), the role of introduced small mammals remains unclear. Predation by introduced *Rattus* species is often rejected as a cause of recent avian declines because ≥1 *Rattus* species have been present in the Mariana Islands for at least 1000 years. However, this rejection does not account for differential effects of various *Rattus* species on birds (Atkinson 1985, Thibault et al. 2002, Towns et al. 2006), as *R. exulans* (the earliest introduction to the Mariana Islands; Steadman 1999) is generally considered least detrimental to avian species. Perhaps more importantly, the potential impact of *R. diardii* or *R. tanezumi* on avian species is unknown, and the uncertainty surrounding the status and distribution of *R. diardii*, *R. rattus*, and *R. tanezumi* in the Mariana Islands further complicates matters. Further, temporal shifts in the presence or abundance of *Rattus* species may obscure their role in avian declines. High-density introduced small mammal populations on Rota, Saipan, and Tinian might also impact avian species through dietary competition, especially during the dry season when certain food items may become scarce. Food competition for invertebrate and reptile foods could be especially problematic for nesting birds, as these high protein prey items are required for nestlings.

Predation by introduced small mammals may also have direct negative effects on invertebrate or reptile populations in the Mariana Islands. Although *Rattus* species are often implicated in invertebrate and reptilian declines (Whitaker 1973; Bremner et al. 1984; Cree et al. 1995; Priddel et al. 2003; Hoare et al. 2007a,b), the insectivorous *S. murinus* may be more problematic for these taxa in the Mariana Islands. *S. murinus* has been implicated in the decline of native invertebrates and reptiles on Mauritius and nearby islands (Varnham et al. 2002). On Guam, Barbehenn (1974b) commented that no skinks were observed during hundreds of hours of small mammal trapping during the peak of the *S. murinus* irruption in the early 1960's, which contrasts with the current abundance and visibility of skinks on Guam. More recently, Fritts and Rodda (1998) noted large differences in mean skink density between Saipan, where *S. murinus* was common (2200 skinks/ha), areas on Guam with few *S. murinus* (8850 skinks/ha), and areas on Guam where both *S. murinus* and brown treesnakes were excluded (13,200 skinks/ha). Similarly, Rodda and Fritts (1992) implicated *S. murinus* in the decline of the pelagic gecko (*Nactus pelagicus*), when they found that this gecko was common on Rota, where *S. murinus* was absent, but highly localized (Guam) or rare or possibly extinct (Saipan and Tinian) on islands with high past or current *S. murinus* populations.

Recent research suggests that introduced small mammals have important impacts on the effectiveness of brown treesnake control efforts, which are highly dependent on traps using live, domestic mice (*M. musculus*) as attractants. These traps are placed around ports, airports, and other cargo-handling facilities on Guam, as well as in locations vulnerable to accidental brown treesnake introductions, such as Rota, Saipan, and Tinian. Mouse-attractant traps are also commonly deployed during the response to snake sightings in brown treesnake-free locations. However, research conducted on Guam suggests that brown treesnake trap capture rates are inversely related to introduced small mammal density. For example, Rodda et al. (2001) found a strong correlation ($r^2 = 0.90$) between brown treesnake trap capture rates and indices of small mammal density and documented a 7-fold increase in brown treesnake capture rates in areas of very low small mammal density on Guam. Similarly, Gragg et al. (2007) documented a 22–65% increase in brown treesnake trap capture probability after reducing rodent populations with localized rodenticide application. These findings suggest reduced effectiveness of mouse-attractant traps on Rota, Saipan, and Tinian. Further, the majority of brown treesnake control and eradication tools currently being developed and evaluated, such as various acetaminophen delivery devices (Savarie et al. 2001), also rely on mouse-based attractants and will likely be subject to the same reduction in effectiveness in areas of high introduced small mammal density.

A second, though perhaps less obvious, effect of introduced small mammals on brown treesnake control and management relates to their impact on island trophic systems and predator-prey relationships. On Guam, introduced prey species, including small mammals, skinks, and geckos, were abundant and widespread at the time of brown treesnake introduction following World War II (Baker 1946, Fritts and Rodda 1998). Because these introduced prey species evolved with various predators, they were better able to persist under brown treesnake predation than the predator-naïve native species of Guam. In so doing, introduced prey species supported a high-density brown treesnake population, even as native avian and reptilian species declined. By the time brown treesnake predation pressure began to reduce introduced prey densities and brown treesnake density also began to decline because of food limitations, many native species were already extinct. Unfortunately, the high introduced small mammal density and biomass documented on the islands of Rota, Saipan, and Tinian during this research suggests that a similar scenario could develop on these islands should a brown treesnake population become established.

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TABLES

Table 1. Introduced small mammal sampling site coordinates and dates on Guam, Rota, Saipan, and Tinian, 2005–2007. Coordinates indicate the site centroid, and are presented in decimal degrees (WGS 84, UTM Zone 55). Note that CP05, CP06, and CP07 represent a single site sampled annually.

Site	Habitat	Dates Sampled	Latitude	Longitude
Guam				
MSRG	grassland	Jun 6–10, 2005	13.542	144.912
ASMF	*Leucaena* forest	May 30–Jun 3, 2005	13.512	144.870
CP05 CP06 CP07	*Leucaena* forest	May 2–6, 2005 May 15–19, 2006 Jun 6–10, 2007	13.640	144.865
GSYF	*Leucaena* forest	Nov 6–10, 2006	13.437	144.659
PAGO	*Leucaena* forest	Jun 20–24, 2005	13.417	144.783
GAHF	mixed	Oct 23–27, 2006	13.491	144.795
NMAR	native forest	May 16–20, 2005	13.378	144.672
RITL	native forest	Apr 18–22, 2005	13.648	144.863
Rota				
SABA	grassland	Jan 23–27, 2006	14.140	145.191
GAON	*Leucaena* forest	Jan 30–Feb 3, 2006	14.115	145.199
RAPF	mixed	Apr 10–14, 2006	14.170	145.240
ASAK	native forest	Apr 3–7, 2006	14.154	145.170
Saipan				
ACHU	grassland	Sep 19–23, 2005	15.238	145.773
OBYT	*Leucaena* forest	Sep 26–30, 2005	15.108	145.729
SAEN	mixed	Aug 22–26, 2006	15.127	145.727
SPOR	mixed	Aug 15–19, 2006	15.227	145.744
LATT	native forest	Sep 12–16, 2005	15.251	145.798
Tinian				
KAST	grassland	Oct 24–28, 2005	14.951	145.651
ABLE	*Leucaena* forest	Nov 7–11, 2005	15.076	145.640
LSUS	native forest	Oct 31–Nov 4, 2005	15.043	145.629

Table 2. Model selection results from analysis of variance of multiple models explaining variation in *Rattus rattus*, *Suncus murinus*, and *Mus musculus* body condition index (bodycon) on Guam, Rota, Saipan, and Tinian, 2005–2007, as a function of island[4] (each island modeled separately), island[2] (Guam vs. Rota, Saipan, and Tinian combined), and habitat. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i).

	K	ΔAIC_c	w_i
R. rattus			
Bodycon(island[4])	6	0.00	1.000
Bodycon(island[2])	4	49.34	0.000
Bodycon(habitat)	6	70.70	0.000
S. murinus			
Bodycon(habitat)	6	0.00	0.999
Bodycon(island[4])	5	21.11	0.001
Bodycon(island[2])	4	23.90	0.000
M. musculus			
Bodycon(island[2])	6	0.00	0.656
Bodycon(island[4])	4	1.33	0.378
Bodycon(habitat)	6	9.38	0.006

Table 3. Mean ($\overline{X}$) rainfall (mm), standard error (SE), and 95% confidence intervals (95% CI) measured during livetrapping on Guam, Rota, Saipan, and Tinian, 2005–2007 (*n* = 22 sites). Average rainfall measurement period was 12–16 hours on occasion 1 and 24 hours on occasions 2–5.

	$\overline{X}$	SE	95% CI
Occasion 1	4.3	2.1	0.1–8.5
Occasion 2	4.8	1.6	1.6–7.9
Occasion 3	3.7	1.1	1.6–5.9
Occasion 4	6.1	1.8	2.5–9.7
Occasion 5	4.7	2.4	0–9.4

Table 4. Model selection results from analysis of variance of multiple models explaining variation in *Rattus rattus*, *Suncus murinus*, and *Mus musculus* mean maximum distance moved (MMDM) between captures during livetrapping on Guam, Rota, Saipan, and Tinian, 2005–2007, as a function of island[4], island[2], and habitat. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i).

	K	ΔAIC_c	w_i
R. rattus			
MMDM(island[4])	6	0.00	0.977
MMDM(island[2])	4	7.48	0.023
MMDM(habitat)	6	22.66	0.000
S. murinus			
MMDM(habitat)	6	0.00	0.986
MMDM(island[4])	5	8.88	0.012
MMDM(island[2])	4	12.62	0.002
M. musculus			
MMDM(island[4])	6	0.00	0.718
MMDM(island[2])	4	1.94	0.272
MMDM(habitat)	6	8.54	0.010

Table 5. Model selection results from analysis of variance of multiple models explaining variation in *Rattus rattus*, *Suncus murinus*, and *Mus musculus* mass observed during livetrapping on Guam, Rota, Saipan, and Tinian, 2005–2007, as a function of island[4], island[2], habitat, and site. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i).

	K	ΔAIC_c	w_i
R. rattus			
Mass(site)	20	0.00	1.000
Mass(island[2])	4	78.28	0.000
Mass(island[4])	6	79.86	0.000
Mass(habitat)	6	126.80	0.000
S. murinus			
Mass(habitat)	6	0.00	0.974
Mass(site)	11	7.24	0.026
Mass(island[2])	4	25.69	0.000
Mass(island[4])	5	26.71	0.000
M. musculus			
Mass(island[4])	6	0.00	0.903
Mass(island[2])	4	5.82	0.049
Mass(site)	10	5.88	0.048
Mass(habitat)	6	15.47	0.000

Table 6. *Mus musculus*, *Rattus exulans*, *R. norvegicus*, *R. rattus*, and *Suncus murinus* individuals captured (M_{t+1}) and total captures ($n_{.}$) during mark-recapture livetrapping in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007.

		M. musculus		*R. exulans*		*R. norvegicus*		*R. rattus*		*S. murinus*	
Site	Habitat	M_{t+1}	$n_{.}$	M_{t+1}	$n_{.}$	M_{t+1}	$n_{.}$	M_{t+1}	$n_{.}$	M_{t+1}	$n_{.}$
Guam											
MSRG	grassland	15	29	1	2			22	24	14	22
ASMF	*Leucaena* forest							5	6		
CP05				1	1			4	4		
CP06	*Leucaena* forest							22	27		
CP07											
GSYF	*Leucaena* forest							13	14		
PAGO	*Leucaena* forest										
GAHF	mixed							1	1		
NMAR	native forest										
RITL	native forest										
Rota											
SABA	grassland	25	32					88	119		
GAON	*Leucaena* forest	19	27	13	16			42	63		
RAPF	mixed	32	51					106	146		
ASAK	native forest	1	2					11	11		
Saipan											
ACHU	grassland	51	96					41	63	19	41
OBYT	*Leucaena* forest	2	2	1	2	2	2	50	58	43	63
SAEN	mixed					1	1	8	8	47	59
SPOR	mixed					1	1	29	34	9	9
LATT	native forest							24	28	19	21
Tinian											
KAST	grassland	9	12			1	1	106	132	11	11
ABLE	*Leucaena* forest							55	81	93	113
LSUS	native forest							80	92	43	43

Table 7. Model selection results for mark-recapture modeling of capture (*p*) and recapture (*c*) probability for *Rattus rattus*, *Suncus murinus*, and *Mus musculus* livetrapping data collected on Guam, Rota, Saipan, and Tinian, 2005–2007. Parenthetical terms indicate the nesting structure of the previous variable (e.g., neo2(island[4]) specifies separate neophobia effects for each island). All heterogeneity models (h) used 2 finite mixtures to approximate individual heterogeneity. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i).

	K	ΔAIC_c	w_i
Models for *R. rattus*			
p neo2(island[4]) + sex + repstat + rainamt *c* island[4] + sex + repstat + rainamt	16	0.00	0.871
p neo2(island[4]) + repstat + rainamt *c* island[4] + repstat + rainamt	15	5.72	0.050
p neo2(island[4]) + sex + age + repstat + bodycon + size + rainprev + rainamt *c* island[4] + sex + age + repstat + bodycon + size + rainprev + rainamt	20	6.97	0.027
p neo2(island[4]) + sex + rainamt *c* island[4] + sex + rainamt	15	7.12	0.025
p neo2(island[4]) + rainamt *c* island[4] + rainamt	14	7.56	0.020
p neo2(island[4]) + sex + repstat *c* island[4] + sex + repstat	15	9.61	0.007
Models for *S. murinus*			
p t + h *c* t(island[4]) + h	10	0.00	0.994
p t + h + sex + repstat + bodycon + size + rainprev + rainamt *c* t(island[4]) + h + sex + repstat + bodycon + size + rainprev + rainamt	16	10.33	0.006
Models for *M. musculus*			
p t(island[2]) + h *c* t + h	11	0.00	0.349
p t(island[2]) + h *c* t(island[2]) + h	13	0.10	0.331
p t(island[4]) + h *c* t + h	19	1.20	0.192
p t + h *c* t(island[2]) + h	9	4.36	0.039
p t(island[4]) + h *c* t(island[4]) + h	23	4.65	0.034
p t + h *c* t + h	7	5.01	0.029
p neo1 + h *c* h	4	6.79	0.012
p t + h *c* t(habitat) + h	11	7.94	0.007
p neo2 + h *c* h	5	8.82	0.004
p t(island[2]) + h + sex + repstat + bodycon + size + rainprev + rainamt *c* t + h + sex + repstat + bodycon + size + rainprev + rainamt	17	9.23	0.003

Table 8. Model-averaged closed population abundance estimates ($\hat{N}$), standard errors (SE), and 95% confidence intervals (95% CI) for *Rattus rattus*, *S. murinus*, and *Mus musculus* captured during livetrapping in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007.

		R. rattus			*S. murinus*			*M. musculus*		
Site	Habitat	$\hat{N}$	SE	95% CI	$\hat{N}$	SE	95% CI	$\hat{N}$	SE	95% CI
Guam										
MSRG	grassland	41.1	9.4	22.8–59.5	20.3	5.8	15.4–43.2	17.5	4.0	9.6–25.3
ASMF	*Leucaena* forest	6.6	1.7	3.3–9.9						
CP05		6.8	2.6	1.7–11.9						
CP06	*Leucaena* forest	39.5	8.7	22.4–56.6						
CP07										
GSYF	*Leucaena* forest	22.9	5.8	11.5–34.3						
PAGO	*Leucaena* forest									
GAHF	mixed	1.8	1.2	0–4.1						
NMAR	native forest									
RITL	native forest									
Rota										
SABA	grassland	142.4	22.8	97.6–187.1				41.5	10.1	21.6–61.3
GAON	*Leucaena* forest	70.0	12.9	44.7–95.2				32.0	8.3	15.7–48.3
RAPF	mixed	186.4	31.0	125.7–247.2				53.2	12.7	28.4–78.1
ASAK	native forest	17.8	4.3	9.4–26.3				1.7	1.2	0–4.0
Saipan										
ACHU	grassland	72.2	13.9	44.9–99.5	28.8	8.5	21.3–61.4	80.5	17.4	46.5–114.6
OBYT	*Leucaena* forest	90.6	17.4	56.4–124.7	67.7	20.0	49.1–142.3	3.2	1.6	0.2–6.3
SAEN	mixed	15.0	4.7	5.9–24.1	70.6	19.1	52.8–141.9			
SPOR	mixed	54.8	11.7	31.9–77.7	13.6	4.4	9.9–31.6			
LATT	native forest	47.1	11.1	25.4–68.8	29.9	9.4	21.5–65.8			
Tinian										
KAST	grassland	194.4	34.5	126.8–262.1	17.3	5.8	12.4–40.2	14.6	4.4	5.9–23.3
ABLE	*Leucaena* forest	85.6	14.1	58.0–113.2	143.0	39.5	105.8–288.5			
LSUS	native forest	146.1	26.3	94.6–197.6	63.7	16.9	48.1–127.0			

Table 9. *Rattus rattus*, *Suncus murinus*, and *Mus musculus* density estimates ($\hat{D}$; animals/ha), standard errors (SE), and 95% confidence intervals (95% CI) in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007. Blank entries indicate zero captures, and therefore zero estimated density.

		R. rattus			*S. murinus*			*M. musculus*		
Site	Habitat	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI
Guam										
MSRG	grassland	15.9	3.7	8.6–23.2	8.6	2.5	3.7–13.5	7.2	1.7	3.9–10.5
ASMF	*Leucaena* forest	2.6	0.7	1.2–4.0						
CP05		2.6	1.0	0.6–4.6						
CP06	*Leucaena* forest	15.3	3.5	8.4–22.2						
CP07										
GSYF	*Leucaena* forest	8.9	2.3	4.4–13.4						
PAGO	*Leucaena* forest									
GAHF	mixed	0.7	0.5	0–1.7						
NMAR	native forest									
RITL	native forest									
Rota										
SABA	grassland	73.2	11.9	49.9–96.5				20.7	5.0	10.9–30.5
GAON	*Leucaena* forest	36.0	6.7	22.9–49.1				16.0	4.1	8.0–24.0
RAPF	mixed	95.8	16.1	64.2–127.4				26.5	6.3	14.2–38.8
ASAK	native forest	9.2	2.2	4.9–13.5				0.8	0.6	0–2.0
Saipan										
ACHU	grassland	33.0	6.4	20.5–45.5	13.4	3.7	6.1–20.7	36.5	8.1	20.6–52.4
OBYT	*Leucaena* forest	41.4	8.1	25.5–57.3	31.6	10.2	11.6–51.6	1.5	0.7	0.1–2.9
SAEN	mixed	6.9	2.1	2.8–11.0	32.9	9.6	14.1–51.7			
SPOR	mixed	25.1	5.4	14.5–35.7	6.3	2.2	2.0–10.6			
LATT	native forest	21.6	5.1	11.6–31.6	14.0	5.2	3.8–24.2			
Tinian										
KAST	grassland	99.9	17.9	64.8–135.0	8.9	2.5	4.0–13.8	8.2	2.7	2.9–13.5
ABLE	*Leucaena* forest	44.0	7.3	29.7–58.3	73.7	20.1	34.3–113.1			
LSUS	native forest	75.1	13.6	48.4–101.8	32.8	9.6	14.0–51.6			

Table 10. Mean ($\bar{X}$) and standard error (SE) mass (g), head + body length (mm), tail length (mm), hind foot length (mm), and ear length (mm) of adult *Rattus rattus*, *Suncus murinus*, and *Mus musculus* captured during livetrapping on Guam, Rota, Saipan, and Tinian, 2005–2007.

	Guam		Rota		Saipan		Tinian	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
R. rattus								
n	65		263		218		277	
Mass	183.69	5.70	136.04	1.97	137.40	1.48	130.63	1.76
Head + Body Length	194.53	2.63	184.73	0.98	177.96	0.77	179.46	0.99
Tail Length[a]	205.11	2.76	195.63	1.11	189.04	1.11	194.50	1.19
Hind Foot Length	32.18	0.23	31.17	0.07	30.68	0.08	30.87	0.08
Ear Length	20.21	0.16	20.17	0.06	19.38	0.07	20.22	0.08
S. murinus								
N	30				236		208	
Mass	22.72	1.29			25.68	0.44	24.43	0.44
Head + Body Length	97.61	2.16			104.96	0.56	101.17	0.61
Tail Length[b]	63.98	1.18			67.19	0.34	66.55	0.34
Hind Foot Length	15.06	0.22			15.04	0.06	15.14	0.05
M. musculus								
N	19		98		73		10	
Mass	11.75	0.51	12.56	0.22	11.97	0.26	14.59	0.89
Head + Body Length	66.38	1.08	71.86	0.46	71.03	0.62	76.81	1.76
Tail Length[c]	77.43	0.87	75.04	0.49	76.72	0.69	79.76	1.75
Hind Foot Length	13.65	0.14	14.51	0.07	13.60	0.08	14.46	0.22
Ear Length	10.46	0.19	10.68	0.06	10.27	0.08	10.90	0.19

[a] Excludes *R. rattus* with damaged tails (corrected *n* = 62, 239, 202, and 251, respectively).
[b] Excludes *S. murinus* with damaged tails (corrected *n* = 30, 232, and 206, respectively).
[c] Excludes *M. musculus* with damaged tails (corrected *n* = 17, 85, 67, and 10, respectively).

Table 11. *Rattus rattus*, *Suncus murinus,* and *Mus musculus* biomass estimates ($\widehat{Biom}$; kg/ha), standard errors (SE), and 95% confidence intervals (95% CI) in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007. Blank entries indicate zero captures, and therefore zero estimated biomass.

		R. rattus			*S. murinus*			*M. musculus*		
Site	Habitat	$\widehat{Biom}$	SE	95% CI	$\widehat{Biom}$	SE	95% CI	$\widehat{Biom}$	SE	95% CI
Guam										
MSRG	grassland	2.42	0.58	1.28–3.56	0.20	0.06	0.08–0.32	0.08	0.02	0.04–0.12
ASMF	*Leucaena* forest	0.70	0.19	0.33–1.07						
CP05		0.39	0.16	0.08–0.70						
CP06	*Leucaena* forest	2.88	0.66	1.59–4.17						
CP07										
GSYF	*Leucaena* forest	1.36	0.37	0.63–2.09						
PAGO	*Leucaena* forest									
GAHF	mixed	0.06	0.05	0–0.16						
NMAR	native forest									
RITL	native forest									
Rota										
SABA	grassland	9.80	1.62	6.62–12.98				0.26	0.07	0.12–0.40
GAON	*Leucaena* forest	4.63	0.89	2.89–6.37				0.20	0.05	0.10–0.30
RAPF	mixed	8.85	1.54	5.83–11.87				0.34	0.08	0.18–0.50
ASAK	native forest	1.03	0.28	0.48–1.58				0.01	0.01	0–0.03
Saipan										
ACHU	grassland	4.13	0.83	2.50–5.76	0.24	0.08	0.08–0.40	0.45	0.10	0.25–0.65
OBYT	*Leucaena* forest	4.31	0.87	2.60–6.02	0.88	0.27	0.35–1.41	0.01	0.01	0–0.03
SAEN	mixed	0.96	0.32	0.33–1.59	0.98	0.28	0.43–1.53			
SPOR	mixed	3.03	0.68	1.70–4.36	0.18	0.06	0.06–0.30			
LATT	native forest	3.18	0.76	1.69–4.67	0.40	0.13	0.15–0.66			
Tinian										
KAST	grassland	11.57	2.11	7.43–15.71	0.16	0.05	0.06–0.26	0.11	0.04	0.03–0.19
ABLE	*Leucaena* forest	5.09	0.88	3.37–6.81	1.87	0.52	0.85–2.89			
LSUS	native forest	8.78	1.63	5.59–11.97	0.83	0.25	0.34–1.32			

FIGURES

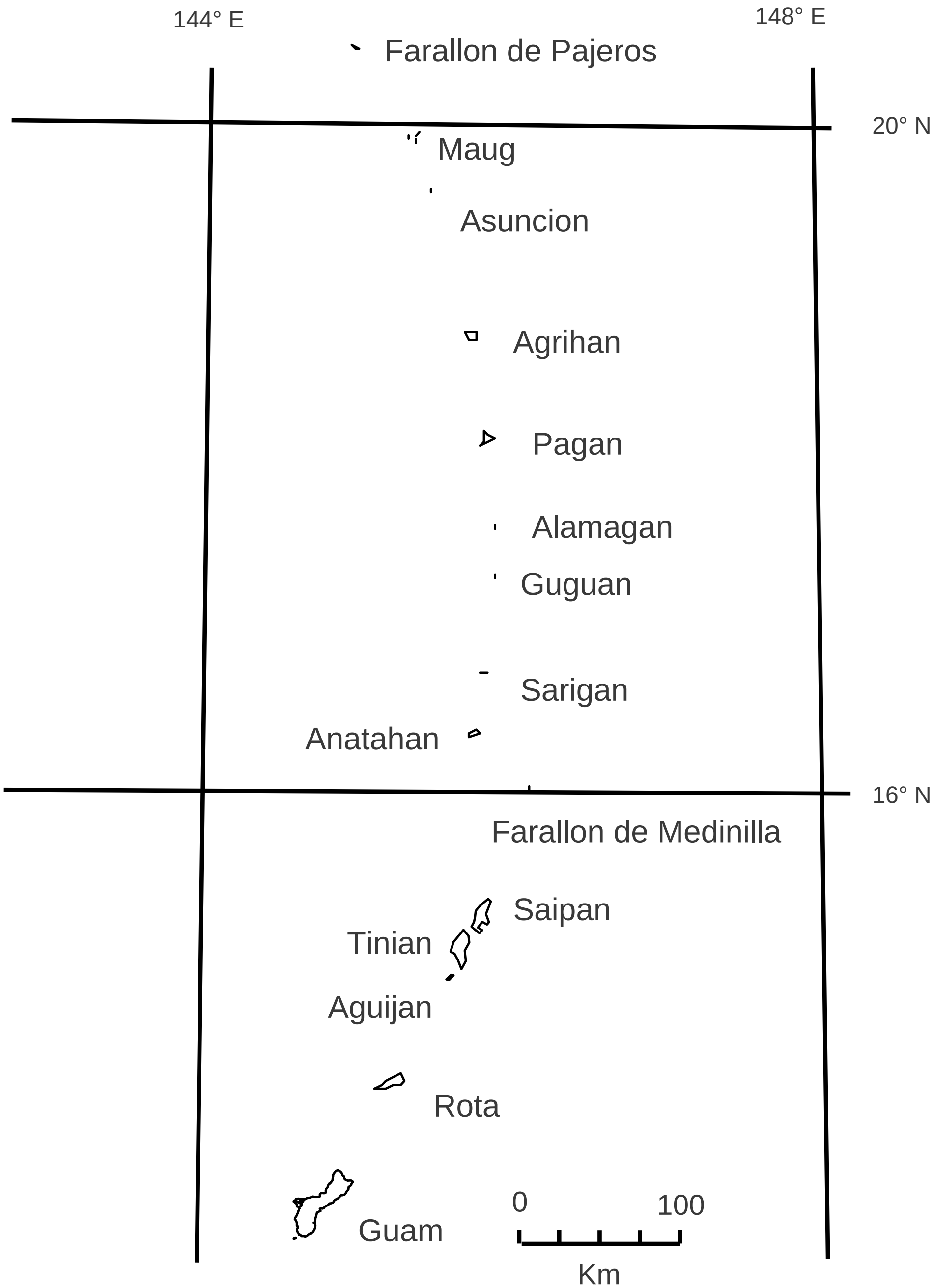

Figure 1. Map of the principal Mariana Islands.

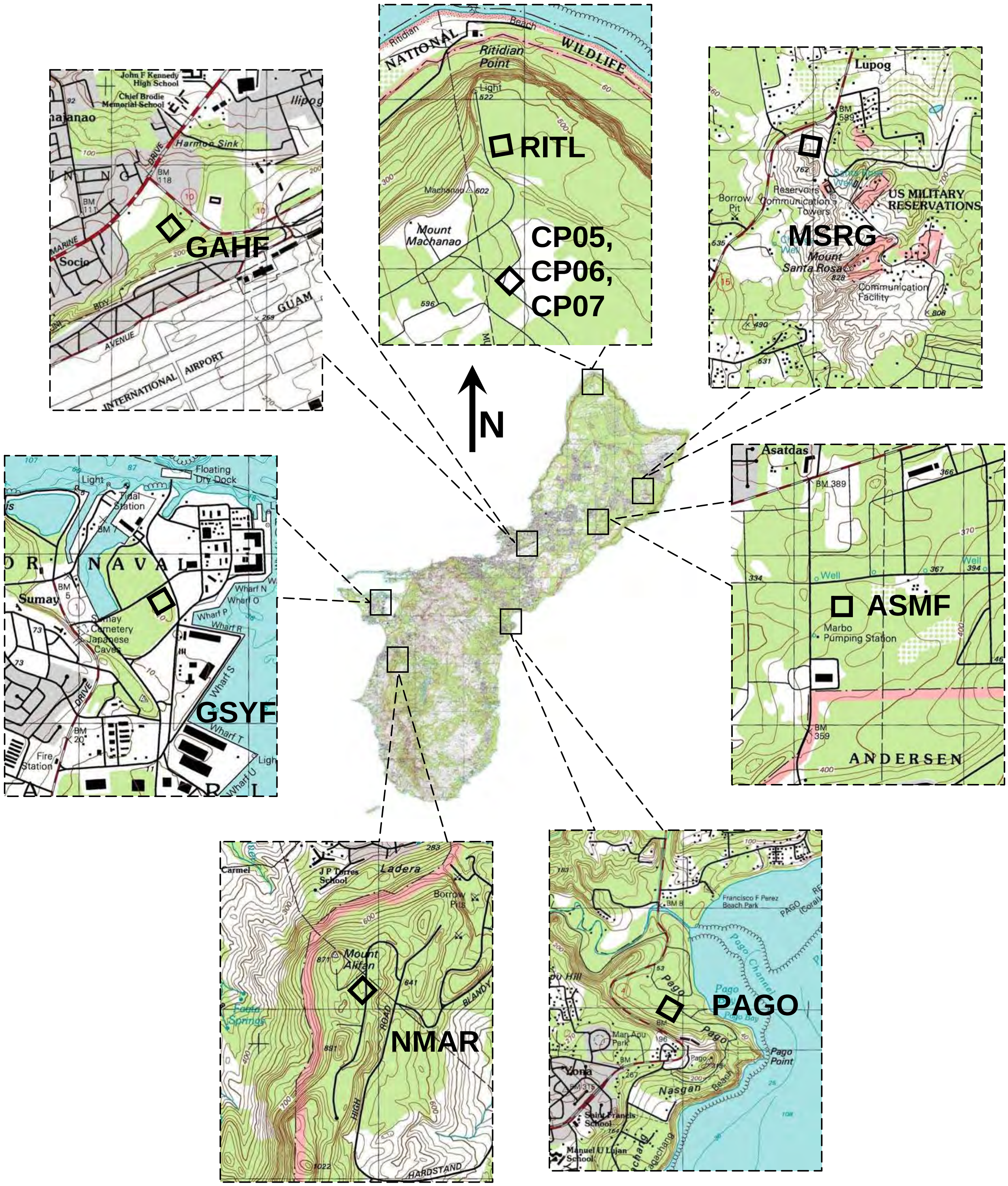

Figure 2. Introduced small mammal sampling locations on Guam, Mariana Islands, 2005–2007. Sampling grids are delineated with bold squares, which represent an area of 125 m^2 (1.56 ha). See Table 1 for site coordinates, sampling dates, and habitat classifications. Note that CP05, CP06, and CP07 represent a single site sampled annually.

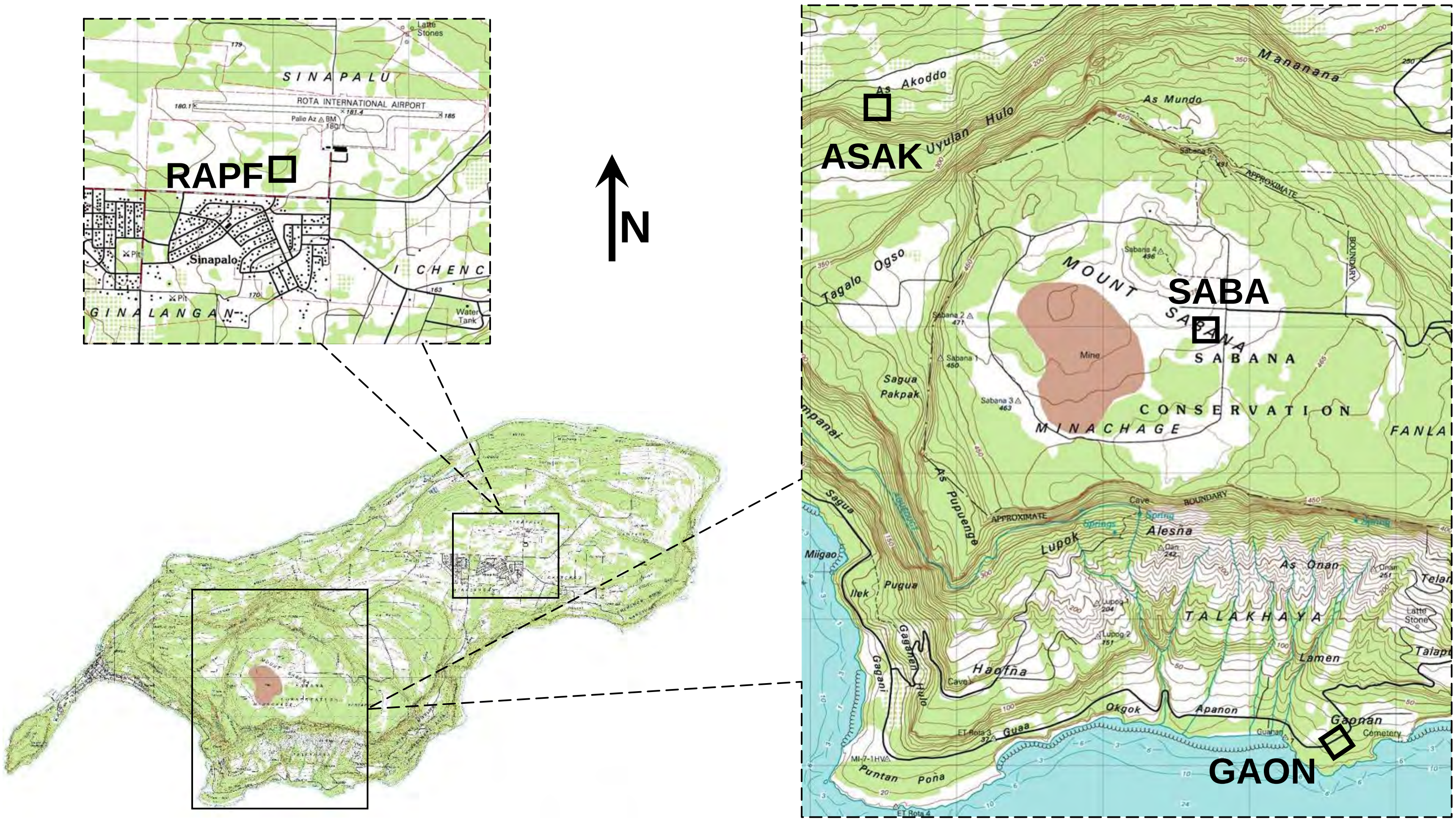

Figure 3. Introduced small mammal sampling locations on Rota, Mariana Islands, 2005–2007. Sampling grids are delineated with bold squares, which represent an area of 125 m^2 (1.56 ha). See Table 1 for site coordinates, sampling dates, and habitat classifications.

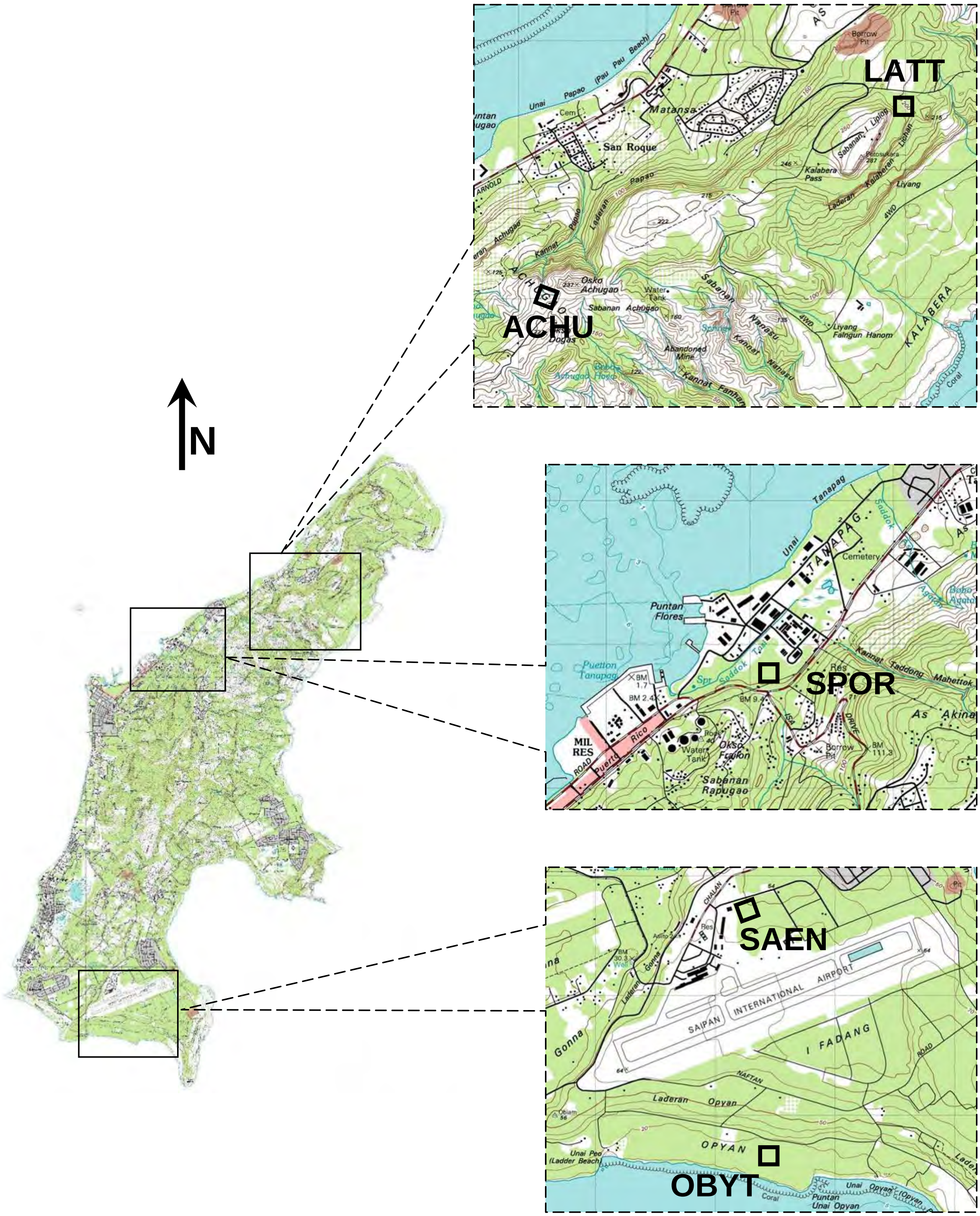

Figure 4. Introduced small mammal sampling locations on Saipan, Mariana Islands, 2005–2007. Sampling grids are delineated with bold squares, which represent an area of 125 m^2 (1.56 ha). See Table 1 for site coordinates, sampling dates, and habitat classifications.

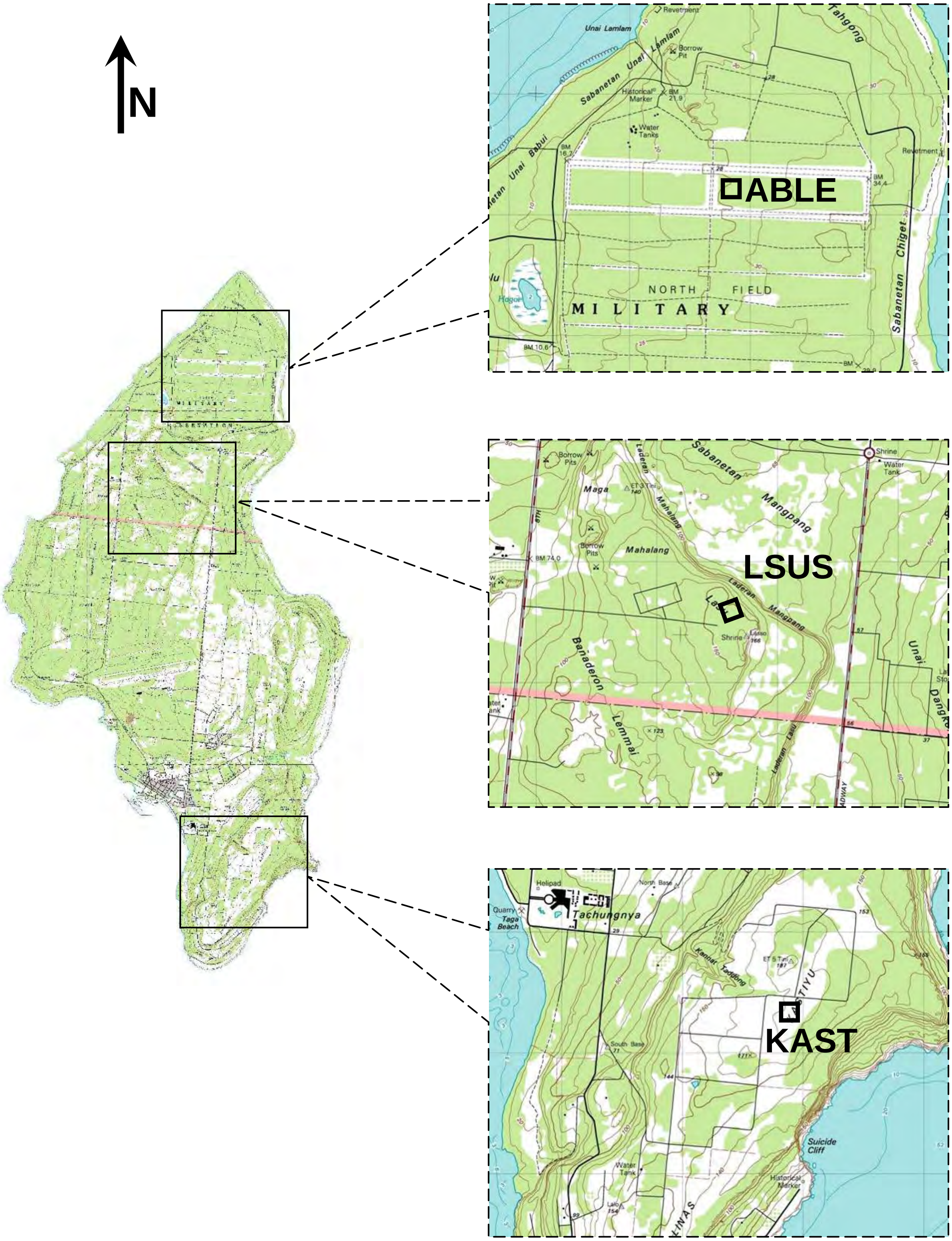

Figure 5. Introduced small mammal sampling locations on Tinian, Mariana Islands, 2005–2007. Sampling grids are delineated with bold squares, which represent an area of 125 m^2 (1.56 ha). See Table 1 for site coordinates, sampling dates, and habitat classifications.

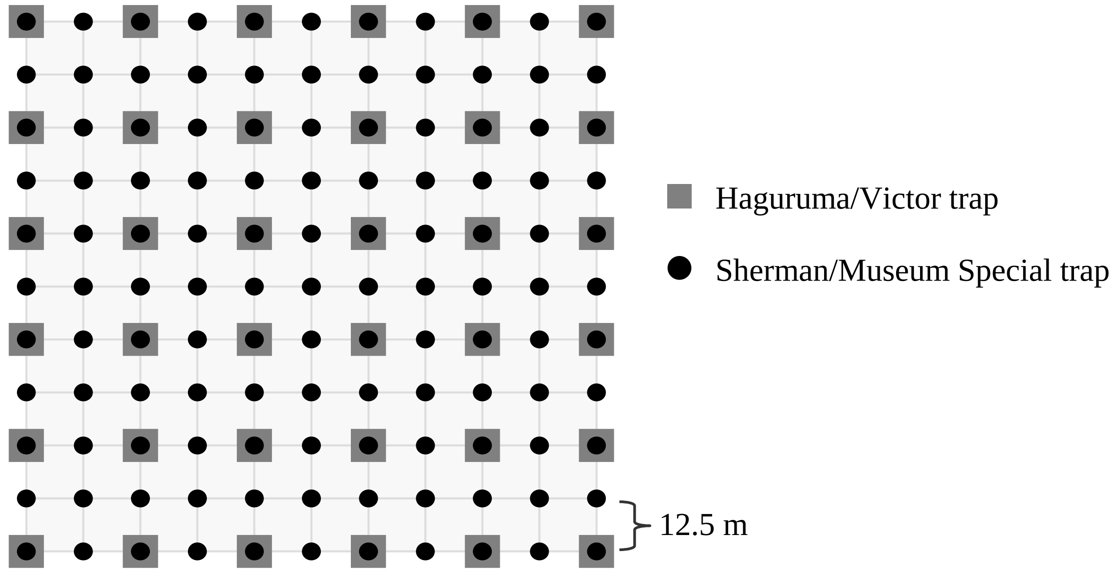

Figure 6. Schematic diagram of 11 × 11 grid (nominal area = 1.56 ha) used during mark-recapture livetrapping on Guam, Rota, Saipan, and Tinian, 2005–2007.

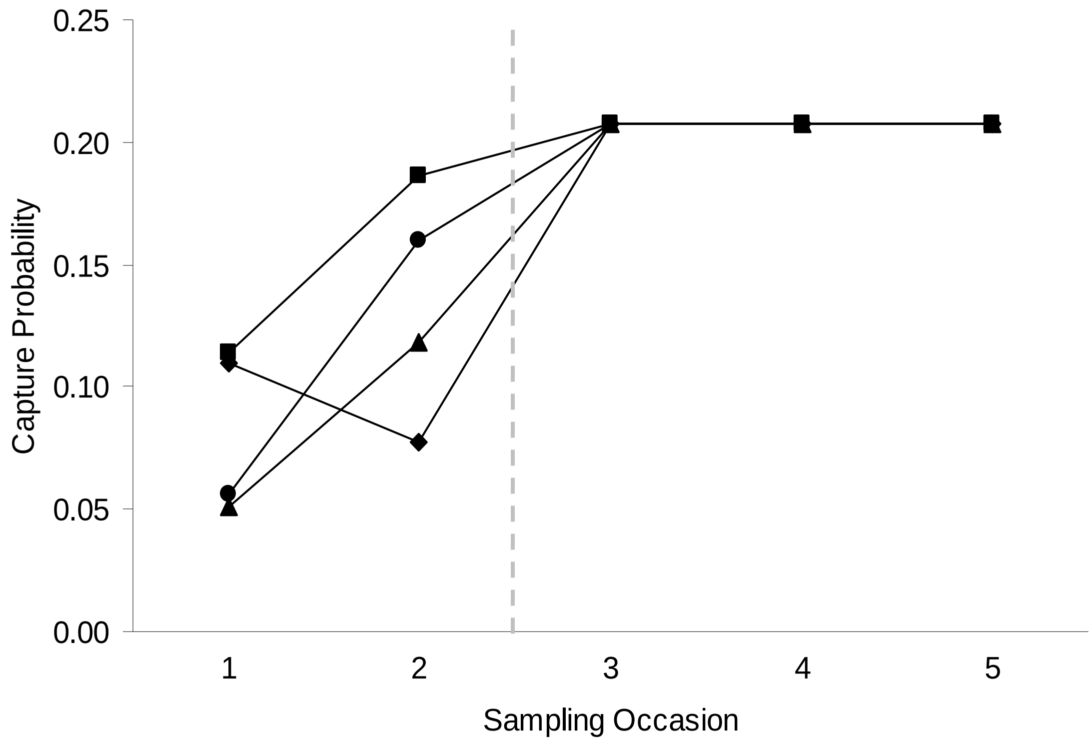

Figure 7. Island-specific neophobia effect on sampling occasion 1 and 2 *Rattus rattus* capture probabilities from mark-recapture livetrapping conducted on Guam (♦), Rota (■), Saipan (▲), Tinian (•), 2005–2007. The dashed line delineates the neophobia effect.

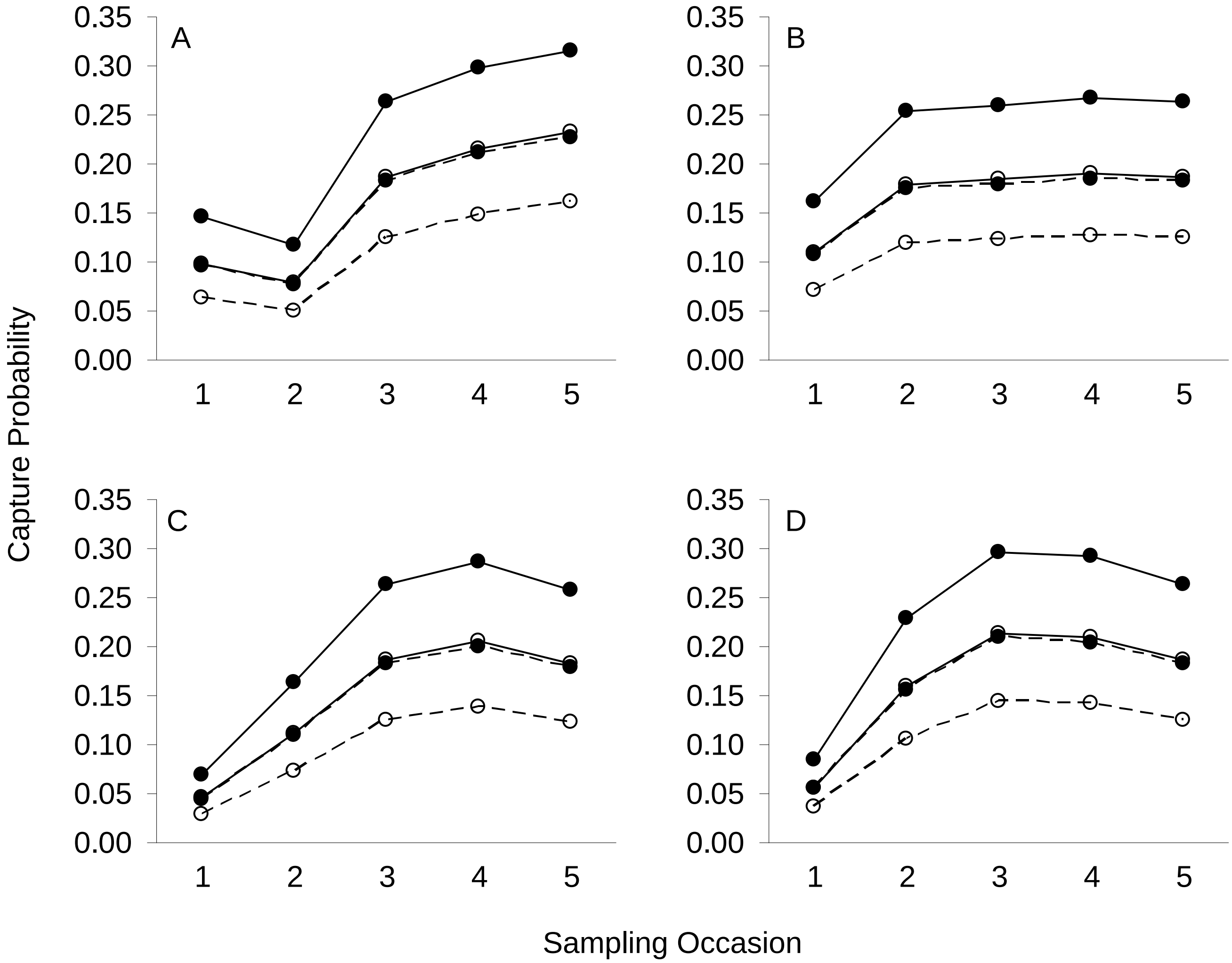

Figure 8. Effect of sex (female = •, male = ○) and reproductive status (reproductively active = solid line, non-reproductive = dashed line) on *Rattus rattus* livetrapping capture probability on Guam (A), Rota (B), Saipan (C), and Tinian (D), 2005–2007.

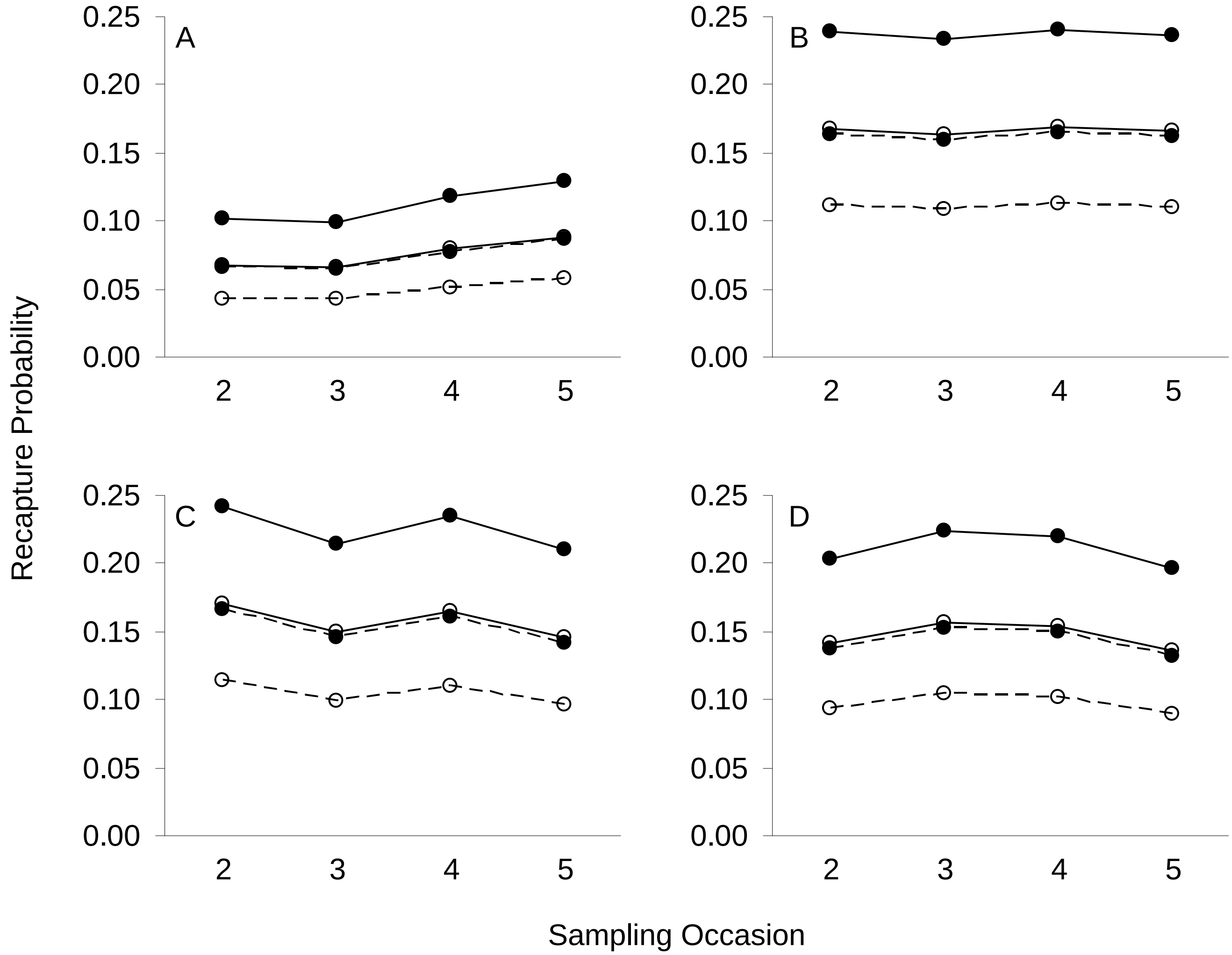

Figure 9. Effect of sex (female = •, male = ○) and reproductive condition (reproductively active = solid line, non-reproductive = dashed line) on *Rattus rattus* livetrapping recapture probability on Guam (A), Rota (B), Saipan (C), and Tinian (D), 2005–2007.

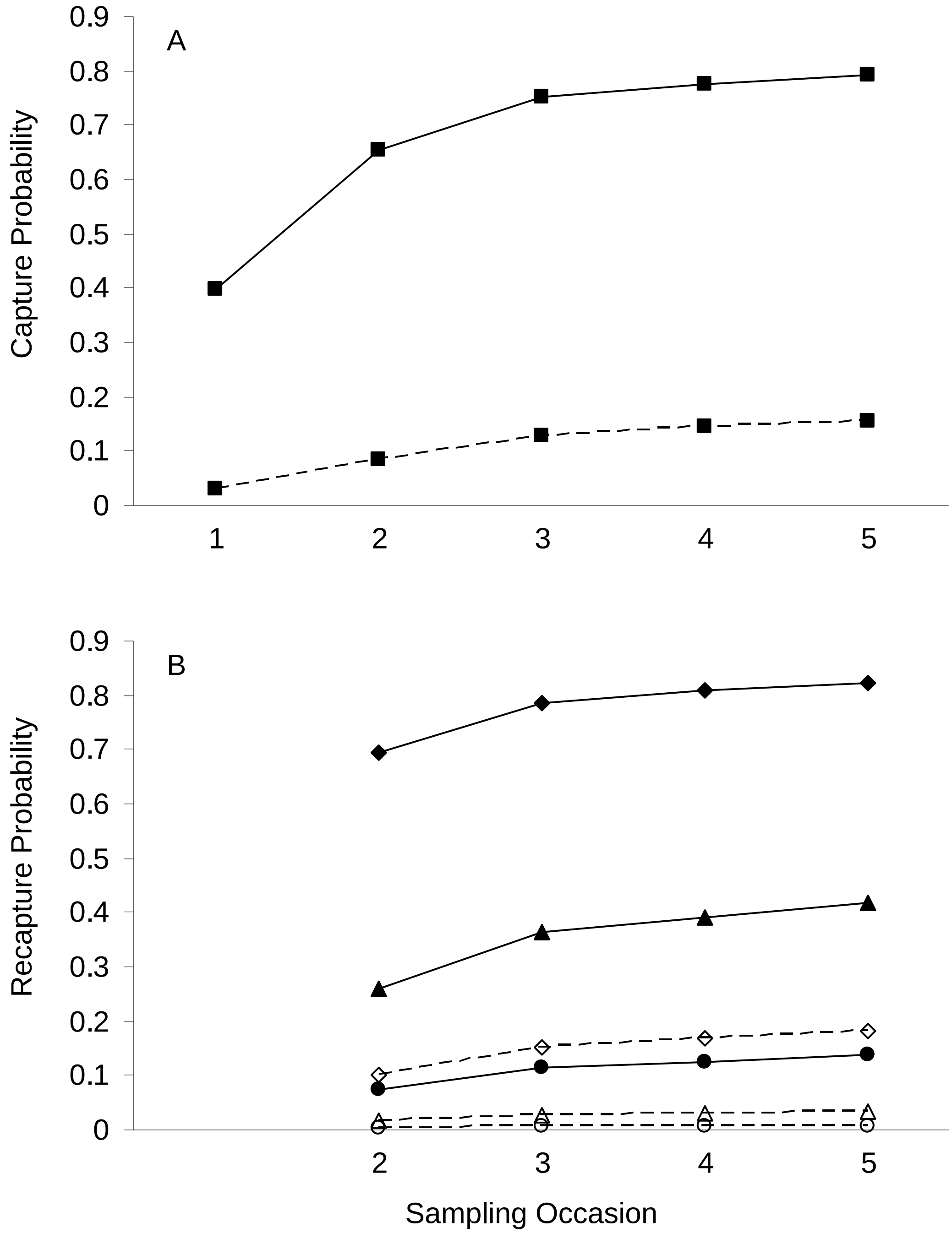

Figure 10. *Suncus murinus* livetrapping capture (A) and recapture (B) probability for high (35% of population; solid line) and low (65% of population; dashed line) mixture classes. Mixture-specific capture probabilities for all islands combined are indicated by ■ in panel A. Island-specific recapture probabilities are presented for Guam (♦), Saipan (▲), and Tinian (•) in panel B. *S. murinus* was not captured on Rota.

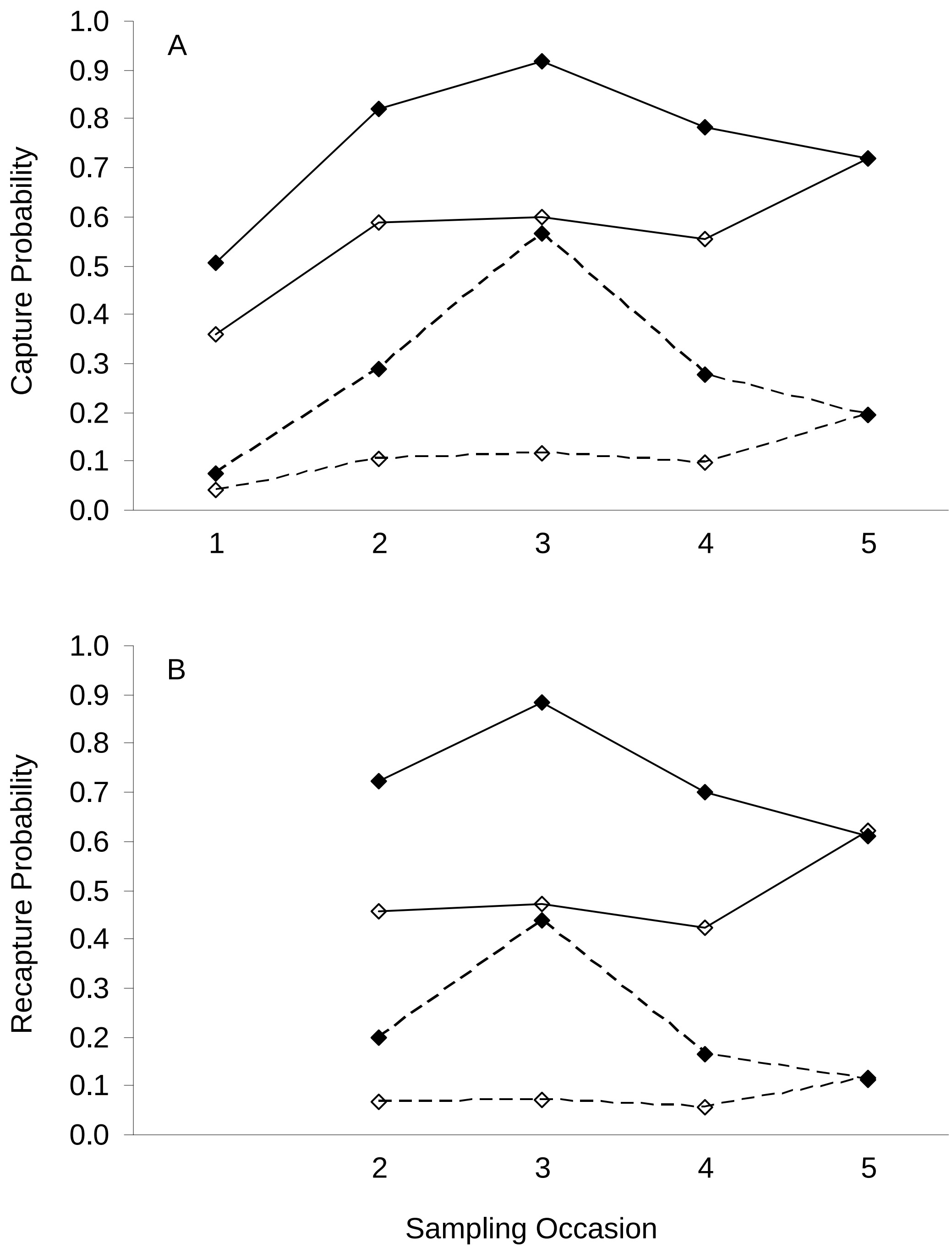

Figure 11. *Mus musculus* livetrapping capture (A) and recapture (B) probability for high (32.7% of population; solid line) and low (67.3% of population; dashed line) mixture classes. Mixture-specific capture and recapture probabilities are presented for Guam (♦) and the combination of Rota, Saipan, and Tinian (◊).

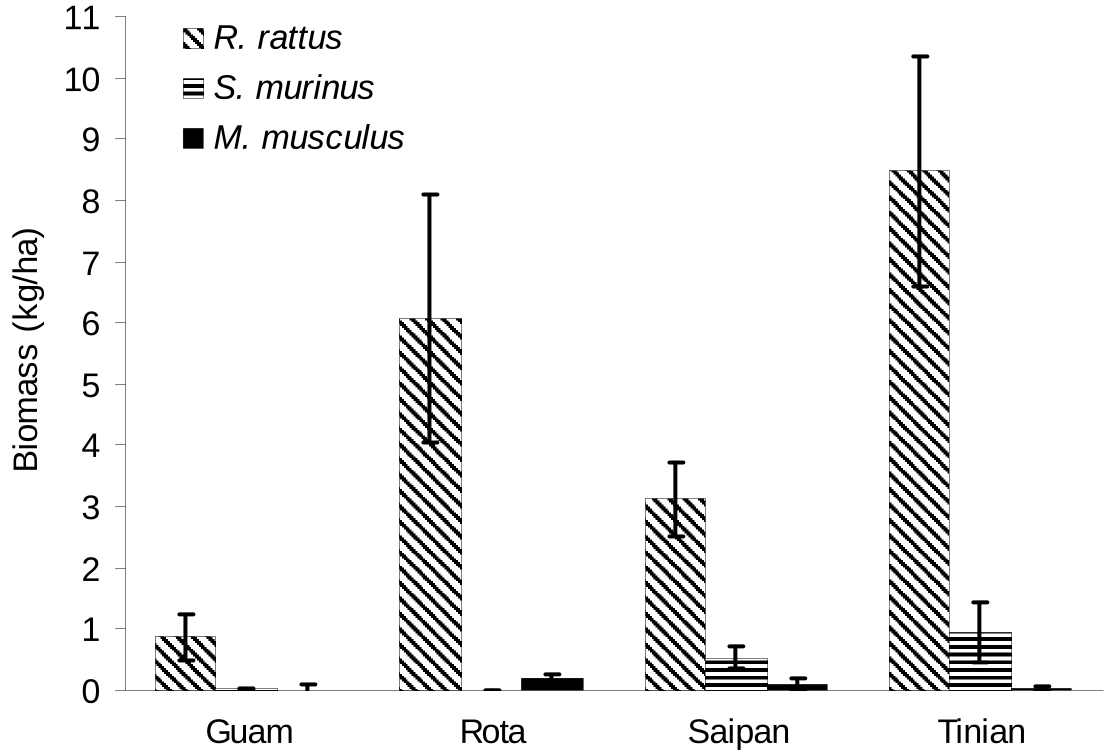

Figure 12. Mean *Rattus rattus*, *Suncus murinus*, and *Mus musculus* biomass estimates derived from mark-recapture livetrapping on Guam, Rota, Saipan, and Tinian, 2005–2007. Bars indicate ± 1 SE.

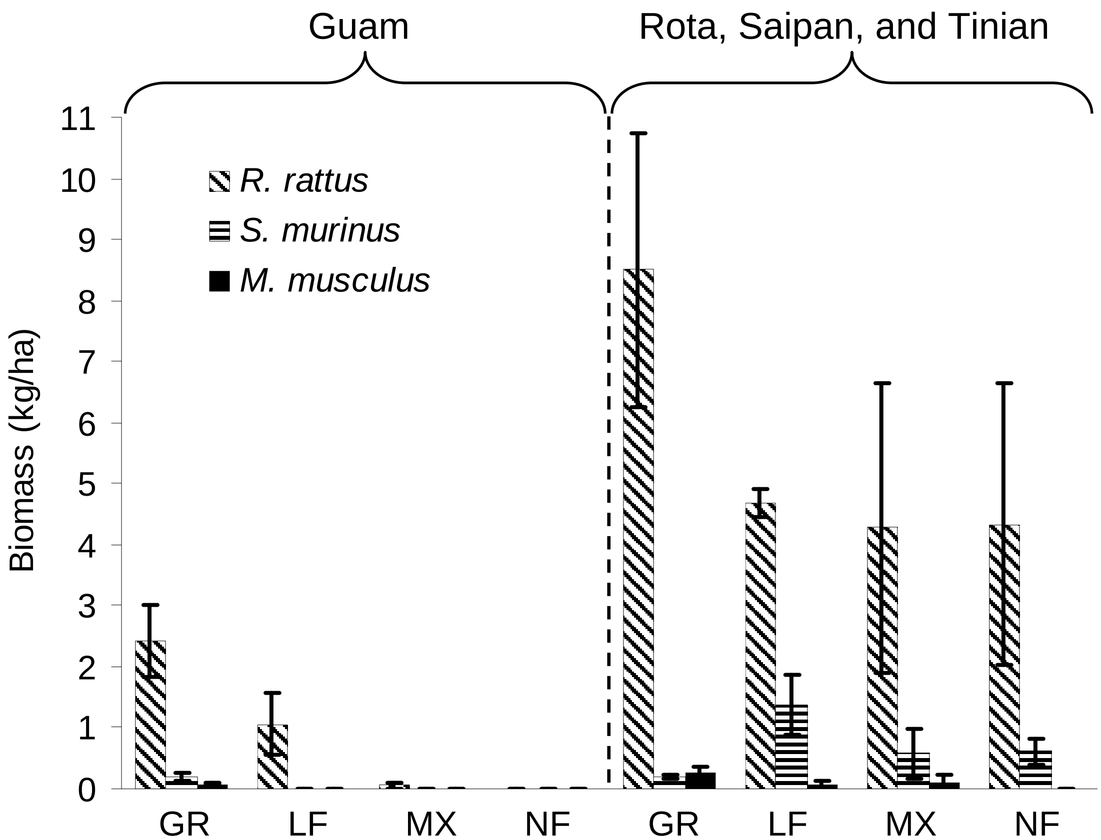

Figure 13. Mean *Rattus rattus*, *Suncus murinus*, and *Mus musculus* biomass estimates derived from mark-recapture livetrapping of grassland (GR), *Leucaena* forest (LF), mixed (MX), and native forest (NF) habitats on Guam, Rota, Saipan, and Tinian, 2005–2007. Bars indicate ± 1 SE.

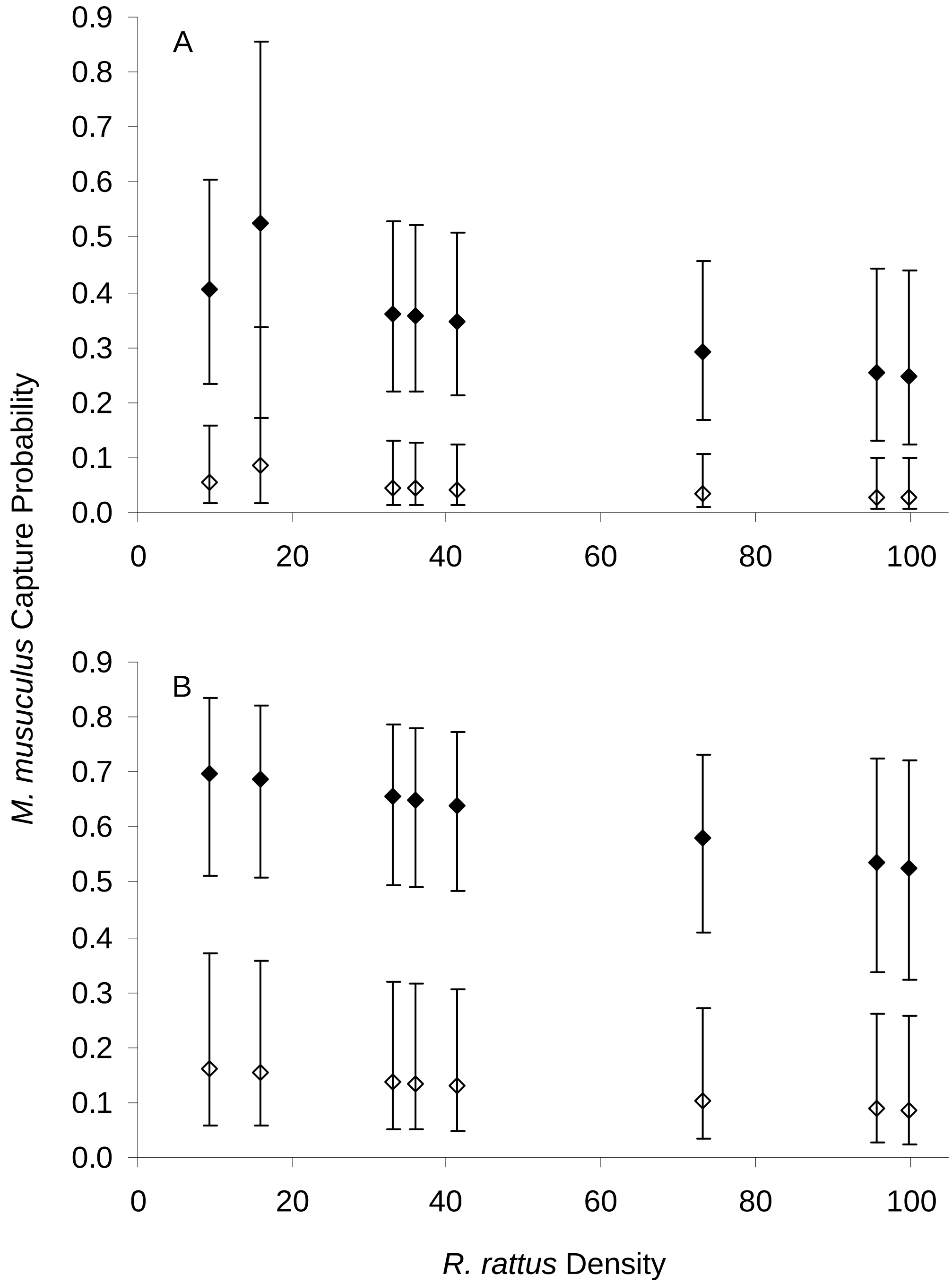

Figure 14. Effect of *R. rattus* density on *Mus musculus* livetrapping capture probability (β = -0.008 ± 0.006, 95% CI = -0.019–0.003) on Guam, Rota, Saipan, and Tinian, 2005–2007. Site-specific capture probability estimates are presented for high (32.7% of population; ♦) and low (67.3% of population; ◊) mixture classes on sampling occasion 1 (A) and sampling occasion 5 (B). Bounded bars indicate 95% CIs.

APPENDIX 1A. Review of small mammal introductions and research in the Mariana Islands

The native terrestrial mammalian fauna of the Mariana Islands is limited to the Marianas fruit bat (*Pteropus mariannus*), the little Mariana fruit bat (*Pteropus tokudae*), and the Pacific sheath-tailed bat (*Emballonura semicaudata*); all other terrestrial mammalian species historically or currently present were almost certainly introduced by humans (Stinson 1994, Wiles 2005). The Mariana Islands are somewhat unique in that they were one of the first non-continental Pacific island chains reached by both prehistoric humans (ca. 2300–1500 B.C.; Rainbird 1994, Athens and Ward 2004) and Europeans (A.D. 1521; Rogers 1995, Barratt 2003), resulting in a long history of introductions. However, attempts to determine when these introductions occurred and to identify them to the species level are complicated by limited archaeological evidence of prehistoric fauna, uncertain or unspecific identification of species (and islands) by early naturalists, and high levels of both past and present taxonomic uncertainty and revision. More importantly, the combination of extensive habitat modification, beginning with the arrival of prehistoric humans (Athens and Ward 2004), and massive movements of people and goods, especially following Spanish colonization (Russell 1998, Barratt 2003) and continuing through World War II (Bowers 2001), have likely influenced the introduced small mammal community in unknown ways. Due to these disturbances, it is likely that the composition of the introduced small mammal community in the Mariana Islands has shifted over time as newly introduced species supplanted earlier introductions or species were reintroduced to islands where they had not previously established successful population, such that a complete and accurate delineation of the history of introduced small mammals in the Mariana Islands may not be feasible. Nonetheless, there is considerable value in reviewing the available evidence of small mammal introductions and historic research, especially as this information may help researchers understand the impacts these species have had, and continue to have, on the ecology of the Mariana Islands.

History of Small Mammal Introductions

Archaeological, linguistic, and palaeoenvironmental evidence suggests that the Mariana Islands were colonized by people from the Philippines, beginning as early as ca. 2300 BC (Athens and Ward 2004) and no later than ca. 1500 BC (Rainbird 1994). These early Pacific explorers frequently transported *Rattus exulans*, either inadvertently (Tate 1935:147) or perhaps deliberately as a food resource (Roberts

1991, Matisoo-Smith and Robins 2004), suggesting that this species, native to Southeast Asia (Musser and Carleton 2005:1469–1470), was the first small mammal introduced in the Mariana Islands. While the precise date of this introduction is unknown, the earliest known *R. exulans* bone evidence in the Mariana Islands does not occur until ca. AD 1000–1200 (Steadman 1999), well after the accepted date of human colonization.

All available evidence suggests that the second small mammal introduced to the Mariana Islands was also a member of the *Rattus* genus, although there is considerable disagreement regarding both the specific identification and date of this introduction. Two of the species in question, *R. rattus* and *R. tanezumi*, are closely related species that have only recently been separated by taxonomists based on karyotype (*R. rattus*: 2n = 38; *R. tanezumi*: 2n = 42) as well as biochemical and morphological features (Schwabe 1979, Baverstock et al. 1983). The complex and evolving taxonomy of these closely related species (Musser and Carleton 2005:1484–1487, 1489–1491), and of the *Rattus* genus in general (Robins et al. 2007), complicates investigation of both historic and current distributions. Regarding *R. rattus* and *R. tanezumi*, additional confusion arises from limited hybridization observed in both laboratory (Yosida et al. 1971) and wild (Baverstock et al. 1983) populations, which led Baverstock et al. (1983:978) to conclude that they "…are best considered as incipient species. Where they meet, they may introgress, become sympatric without interbreeding, or one may replace the other depending upon the prevailing biological conditions."

Based on known historic ranges, viable introduction pathways to the Mariana Islands exist for both *R. rattus* and *R. tanezumi*. *R. rattus*, native to the Indian subcontinent (Musser and Carleton 2005:1484), was introduced to Europe as a human commensal and, beginning ca. AD 1500, transported across the globe on European ships (Atkinson 1985, Nowak 1999:1521). Thus, this species could have reached the Mariana Islands no earlier than European discovery of the islands by Ferdinand Magellan in 1521 (Atkinson 1985). In contrast, the native range of *R. tanezumi* extended into Southeast Asia, from which early introductions into island Southeast Asia, including the Malaysia and the Philippines (Musser and Carleton 2005:1489), put this species in position for potential transport by prehistoric Pacific explorers originating in this region. While a prehistoric introduction of *R. tanezumi* to the Mariana Islands is therefore possible, it seems that all scientific literature suggesting or referencing the prehistoric introduction of *R. tanezumi* can be linked back to an unpublished manuscript cited in the influential reference “Mammals of the South-West Pacific & Moluccan Islands” (Flannery 1995). This manuscript (White and Flannery unpublished manuscript) described bone evidence, dated ca. AD 1000, of a large *Rattus* species on Fais Atoll, Yap. Based on comparisons with museum specimens as well as the fact that the bones were thought older than the earliest European voyages to Micronesia the authors concluded that the bones belonged to *R. tanezumi*. White and Flannery (unpublished manuscript) also reviewed paleontological bone evidence from Guam, Rota, and Pagan in the Mariana Islands (in addition to other Micronesian islands) and speculated that these specimens were also *R. tanezumi* based on size and the estimated date of deposition. The authors concluded that *R. tanezumi* was a prehistoric introduction throughout Micronesia and, further, that the introduction of this species preceded the introduction of *R. exulans* throughout the region (White and Flannery unpublished manuscript). More recent research in the Mariana Islands, however, offers no support for this hypothesis (Steadman 1999). Further, recent advances in molecular identification of rodent skeletal remains suggests that traditional measures of bone morphology may not be adequate for differentiating between *R. exulans* and other introduced *Rattus* species, all of which have variable and overlapping size distributions on different Pacific islands (Matisoo-Smith and Allen 2001). Thus, the likelihood of a prehistoric introduction of *R. tanezumi* to the Mariana Islands remains uncertain.

If not a prehistoric introduction, it is possible that *R. tanezumi*, like *R. rattus*, was introduced following European discovery of the Mariana Islands. Attempting to date these introductions is difficult, although there is some evidence to suggest that introductions were unlikely immediately following European discovery. Most importantly, relatively few European ships visited the Mariana Islands between Magellan’s visit and 1565 when the islands were formally claimed by Spain (Driver 1988, Barratt 2003, Driver 2005). However, beginning around that time ship traffic associated with the Acapulco to Manilla galleon route began to regularly pass through the Mariana Islands (Driver 1988, Barratt 2003, Driver 2005), creating potential pathways for the introduction of both *R. rattus* (likely introduced by Europeans in Acapulco [Musser and Carleton 2005:1486] and possibly in Manilla as well) and *R. tanezumi* (likely present in Manilla; Musser and Carleton 2005:1489). Possible evidence for *R. tanezumi* transport by Spanish galleons traveling between Manila and Acapulco is provided by the recent discovery of 2n = 42 karyotype rats in western Mexico (Alonso et al. 1982). Even with increased ship traffic associated with growing trade, the introduction risk in the Mariana Islands was probably low because of the common practice of anchoring ships offshore and approaching land in small, open boats (Atkinson 1985, Barratt 2003, Driver 2005), due to the rarity of suitable inshore anchorages and apprehension of native islanders. Introduction opportunities surely increased following the establishment of a permanent Spanish settlement on Guam in 1668, which resulted in increased movements of people and goods to and from the Mariana Islands (Driver 1988, Barratt 2003, Driver 2005). Opportunities for *R. rattus* and *R. tanezumi* introduction (or reintroduction) to the Mariana Islands could have only increased further over time, as administration by Spain, Germany, Japan, and the United States brought people, goods, and ships from multiple areas to the islands (Driver 1988, Rogers 1995, Bowers 2001, Barratt 2003, Driver 2005).

An additional *Rattus* species, *R. norvegicus*, was introduced to the Mariana Islands at some point following Spanish colonization. The native range of *R. norvegicus* includes the Hondo region of Japan, southeastern Siberia, and northern China, from which the species reached Europe by ca. 1700 (Musser and Carleton 2005:1478–1480). As noted by Atkinson (1985), *R. norvegicus* replaced *R. rattus* as the common *Rattus* species in American and European ports, and consequently on American and European ships, between ca. 1700 and 1830. Indeed, most documented *Rattus* introductions during this time period were *R. norvegicus* (Atkinson 1985). Alternatively, a direct introduction from Japan to the Mariana Islands seems possible, given the native range of *R. norvegicus*. The earliest known reference for *R. norvegicus* in the Mariana Islands comes from Saipan, where the species was found by the late 1800's (Kuroda 1938 cited by Wiles et al. 1990). In contrast, Enders (1949) suggested that *R. norvegicus* was first introduced to Saipan during Japanese occupation between 1914 and 1944. Marshall (1962b) found *R. norvegicus* on Saipan in 1944–1945, and the first documented occurrence of *R. norvegicus* on Guam was not until 1962 (Barbehenn 1974). On both Guam and Saipan, *R. norvegicus* had a limited distribution and low overall abundance during extensive sampling conducted in the late 1950's and early 1960's (Barbehenn 1974), lending some support to a relatively recent introduction of this species.

Two additional species, *Mus musculus* and *Suncus murinus*, have been introduced to the Mariana Islands. As with the *Rattus* species, there is considerable uncertainty regarding both the date and identity of *M. musculus* introductions in the Mariana Islands. The taxonomy of the polytypic species *M. musculus* has been shaped by both natural and human-mediated radiation away from a presumed origin in either the northern Indian subcontinent (Boursot et al. 1996, Din et al. 1996) or west-central Asia (Prager et al. 1998). Recent research distinguishes 5 subspecific groups (*M. m. musculus*, *M. m. domesticus*, *M. m. castaneus*, *M. m. bactrianus*, and *M. m. gentilulus*) based on genetic and morphological traits, although these subspecies freely hybridize when sympatric (Boursot et al. 1993, Prager et al. 1998, Musser and Carleton 2005:1400–1402). The first 3 subspecies are the most widespread, with *M. m. musculus* ranging from Eastern Europe through Northern Asia including Japan, *M. m. domesticus* occurring throughout Western Europe, the Mediterranean including Northern Africa, and Southwest Asia, and *M. m. castaneus* extending from Central Asia through Southeast Asia and Japan (Musser and Carleton 2005:1400–1401). The remaining subspecies have more restricted ranges, possibly due to geographic constraints, with *M. m. bactrianus* occurring in mountain valleys in Afghanistan and *M. m. gentilulus* occurring in Yemen in the Southern Arabian Peninsula, although there is some speculation that this subspecies may be found throughout the Persian Gulf and Eastern Africa (Musser and Carleton 2005:1401).

Of these, *M. m. domesticus* is generally recognized as the subspecies most commonly transported (and introduced) during European colonization of North and South America, Australia, and numerous islands (Musser and Carleton 2005:1401). Nonetheless, the location of the Mariana Islands in relation to the ranges of various *M. musculus* subspecies suggests multiple potential avenues for introduction of *M. m. musculus*, *M. m. domesticus*, or *M. m. castaneus* to the Mariana Islands from Europe (*M. m. musculus* or *M. m. domesticus*), Southeast Asia (*M. m. castaneus*), or Japan (*M. m. musculus* or *M. m. castaneus*). Further, the presence of *M. m. castaneus* in Southeast Asia presents the possibility of a prehistoric introduction to the Mariana Islands, although to date no evidence of such an introduction is available. Instead, the earliest known reference for *M. musculus* in the Mariana Islands is 1819, when a French expedition to Guam noted “prodigious” rat and mice populations (Freycinet 2003:88). Although interesting, this information is not highly informative as it provides no means for discriminating between subspecies. Further, there is a possibility that the French expedition might have incorrectly identified the small (in comparison to *R. rattus* or *R. norvegicus*) *R. exulans* as mice, especially if they were unfamiliar with this species.

Additional clues about the subspecific identity of *M. musculus* in the Mariana Islands may be provided by morphological traits, such as tail length, and degree of commensalism. In general, both *M. m. domesticus* and *M. m. castaneus* have tails longer than their head and body, whereas the tail of *M. m. musculus* is shorter than its head and body (Boursot et al. 1993), suggesting that the long-tailed *M. musculus* present in the Mariana Islands (see Table 10 in main body of Chapter 1) is *M. m. domesticus* or *M. m. castaneus* (or both). Of these subspecies, *M. m. domesticus* establishes both commensal and permanent outdoor populations in warm regions, whereas *M. m. castaneus* is strictly a human commensal in tropical climates (Boursot et al. 1993). It therefore seems likely that feral populations in the Mariana Islands are *M. m. domesticus*, but the subspecific identity of commensal populations remains unclear. It is notable that Prager et al. (1998) found *M. m. castaneus* on Tinian, although this identification was based on genetic analysis of a single specimen. Clearly, additional research is necessary to clarify the subspecific identity of *M. musculus* in the Mariana Islands.

S. murinus, the most recent and best documented small mammal introduction to the Mariana Islands, was first observed on Guam in 1953 (Peterson 1956), on Saipan in 1962 and Rota in 1966 (Barbehenn 1974), and on Tinian in 1974 (Owen 1974). A single *S. murinus* was reportedly observed on Guguan in 1984 (Eldredge 1988), although no additional observations have been made since that time. Peterson (1956) suggested that the *S. murinus* on Guam were introduced from the Philippines. It is likely that other introductions in the Mariana Islands originated from the Guam population, although direct introductions from the Philippines may have occurred.

Current Distribution of Introduced Small Mammals

A review of recent accounts of faunal distribution in the Mariana Islands (Stinson 1994, Vogt and Williams 2004, Wiles 2005) and research pertaining to ≥1 islands (e.g., Pratt and Lemke 1984, Wiles et al. 1990, Rice and Stinson 1992), in addition to sampling conducted by ASW during 2005–2007 (described in the main text of Chapter 1 and 2), were summarized to determine the current distribution of introduced small mammals in the Mariana Islands (Table A.1). Not surprisingly, introduced small mammal diversity seems to be greatest in the southern, human-inhabited islands of Guam, Rota, Saipan, and Tinian. It is notable that no recent evidence exists for the presence of *R. norvegicus* or *S. murinus* on Rota or *R. exulans* on Tinian (Table A.1). *R. norvegicus* has apparently never been documented on Rota, although it is unclear if the most suitable areas for this species, such as the seaport, have been sampled. *S. murinus* was observed on Rota in 1966 (observation by R.P. Owens reported in Barbehenn 1974), but has not been documented since. Notably, this highly conspicuous species was not observed during approximately 9 weeks spent on Rota by ASW in 2005–2006. *R. exulans* was captured on Tinian following World War II (Marshall 1962a), but has not been documented since. Additional targeted sampling for *R. norvegicus* on Rota and *R. exulans* on Tinian is recommended to clarify this uncertainty.

The small, isolated, sparsely populated northern islands seem to have low introduced small mammal diversity, with *R. exulans* apparently the only species on many islands (Table A.1). *R. rattus* has been reported from 2 northern islands, Agrihan and Pagan, and unidentified *Rattus* species have been reported from Farallon de Pajaros, Maug Islands, and Asuncion Island (Table A.1). The observations from Farallon de Pajaros and Asuncion Island (Pratt and Lemke 1984) mention the presence of tunnels, which implies *R. norvegicus*. Note, however, that *R. rattus* will excavate burrows when above ground cover is scarce, a situation that may be prevalent on Farallon de Pajaros (Eldredge 1983). Stinson's (1994) suggestion that *R. norvegicus* is present (noted as uncommon) on Farallon de Pajaros is probably referencing Pratt and Lemke (1984), although the ambiguous "DFW files" (interpreted as indicating a record on file with the CNMI Division of Fish and Wildlife) is the only reference provided. Observations from Maug Islands (Eldredge et al. 1977, Eldredge 1983, Pratt and Lemke 1984, Rice and Stinson 1992) consistently mention small rats, implying *R. exulans*, although Eldredge et al. (1977) suggested that the observations may have been *R. rattus*. One additional observation, made at Naftan Rock offshore from Aguijan, requires further clarification. Here, Lemke et al. (1985) observed burrows and chewed bird bones which the authors attributed to the presence of an unidentified *Rattus* species. As noted previously, these burrows suggest, but do not confirm, the presence of *R. norvegicus*.

It should be noted that the northern islands are rarely visited and have been subject to limited terrestrial scientific investigation, such that undiscovered introduced small mammal species could be present. Although the northern islands were largely abandoned by humans during much of the Spanish administration of the Mariana Islands, activities associated with copra production, including construction of several villages and accompanying infrastructure, during German (1899–1914) and Japanese (1914–1944) administration of the northern islands (Russell 1998, C. Kessler, personal communication) certainly provided opportunities for small mammal introductions. Additional scientific visits to the northern islands, with a focus on documenting the density and distribution of introduced species, would be extremely valuable for understanding the ecology of the Mariana Islands.

Little information pertaining to habitat-specific distributions is currently available. This is not surprising, as successful introduced species are often habitat generalists. On Guam, Baker (1946) noted that *M. musculus* and *R. exulans* were rarely found in undisturbed limestone forest, and that *R. exulans* (in contrast to *M. musculus* and *R. tanezumi* [called *R. mindanensis* by Baker]) was rarely found near human habitation. Both Johnson (1962) and Musser and Carleton (2005:1485) suggested that when both species were present, *R. tanezumi* (called *R. r. mansorius* by Johnson) largely excluded *R. rattus* such that this species was found on ships in harbors but only rarely on shore. More recently, Yosida et al. (1985) collected *R. tanezumi* from houses on Guam, suggesting that this species may move freely between commensal and wild habitats. On Guam, *S. murinus* was able to colonize the entire island by 1958 (only 5 years after the first documentation; Barbehenn 1962), and was found in all available habitats during widespread sampling conducted in the early 1960's (Barbehenn 1969, 1974). Similarly, *S. murinus* was found throughout Saipan within 18 months of first documentation on the island (Barbehenn 1974). In contrast, *R. norvegicus* was much slower to colonize new areas on Guam and Saipan (Barbehenn 1974), and may be more strictly commensal than other introduced small mammals in the Mariana Islands (Marshall 1962b, Wiles et al. 1990).

Introduced Small Mammal Density in the Mariana Islands

Early, qualitative accounts of introduced small mammals in the Mariana Islands are indicative of high density populations (Table A.2). The earliest known record of introduced small mammals in the Mariana Islands is from Rota in 1602 AD, when a Spanish priest, Fray Juan Pobre de Zamora, noted that rats were so numerous they destroyed half of the planted corn crop (Russell 2002). Rats were also quite numerous on Tinian in 1742, when a British expedition led by Lord Anson stopped at the island for provisions (Thomas 1971 cited by Wiles et al. 1990). As noted previously, Freycinet (2003:88) commented on "prodigious" rat and mice populations on Guam in 1819, "whose noxious tribes here constitute a veritable scourge for the husbandman and storekeeper alike." Beginning during Spanish administration of the Mariana Islands (1668–1899), significant effort was expended in reducing introduced small mammal populations (Rogers 1995). During German administration of the Mariana Islands (1899–1914), a 5 pfennig per rat bounty was offered to encourage residents to actively reduce populations (Bowers 2001). Japanese administrators of the Mariana Islands (1914–1944) also initiated programs aimed at reducing introduced small mammal populations (Bowers 2001). A slightly different approach was taken on Guam in 1919 when the American governor passed a law requiring all male residents to deliver 5 dead rats per month or be fined $0.25 (Rogers 1995). It seems, however, that neither rewards nor penalties led to a significant population reductions in the Mariana Islands. In 1947, rats continued to "overrun the islands" of Rota, Saipan, and Tinian, causing "excessive destruction of small chickens and crops," and forcing "farmers to abandon the planting of crops for which the rats have a preference" (Bowers 2001).

Following World War II, quantitative studies of introduced small mammals began to occur in the Mariana Islands (Table A.2). Taken as a whole, however, post-World War II introduced small mammal research is relatively limited in the Mariana Islands, especially outside of the populated islands of Guam, Rota, Saipan, and Tinian. Much of the research that has been conducted is unpublished and exists only in internal agency reports (e.g., U.S. Fish and Wildlife Service, CNMI Department of Fish and Wildlife), and many of these reports contain only observational data. While useful for documenting inter-island and possibly inter-habitat distributions, these data have little utility for investigating introduced small mammal density. Interpretation of much of the available non-observational data is complicated by inconsistent documentation of sampling methodology and results, the common reliance on non-rigorous sampling techniques, such as low sampling effort and convenience sampling (Anderson 2001, 2003), and the frequent reporting of indices of density (Table A.2). These issues, while understandable given the logistical constraints imposed on research activities by the isolation and rugged nature of the Northern Mariana Islands, severely limit the utility of available data. For example, variable snaptrapping capture rates (e.g., compare sampling events on Rota; Table A.2) might reflect variable density between sites or habitats, but could also result from fluctuating capture probability associated with any number of factors, including season, habitat, weather, or sampling methodology (grid vs. transect). It is essential to consider these confounding factors when evaluating and interpreting any historic research, including the research reviewed below.

On Guam, the first known quantitative study of introduced small mammals occurred in 1945, when Baker (1946) documented relatively high, but variable, densities of *M. musculus*, *R. exulans*, and *R. tanezumi* (called *R. mindanensis* by Baker) at Mount Santa Rosa in northeastern Guam (Table A.2). Island-wide sampling conducted during the late 1950's and early 1960's on Guam suggested that *S. murinus* density equaled or exceed the combined density of other introduced small mammals, and also suggested that *R. exulans* and *R. tanezumi* (called *R. r. mansorius* by Barbehenn) density remained relatively constant in comparison to Baker's (1946) data (Barbehenn 1962, 1969, 1974). Note that this sampling occurred only 5–10 years after the proposed introduction of S. murinus to Guam in 1953 (Peterson 1956), suggesting rapid colonization and population growth. In contrast, *M. musculus* density seemed to have declined dramatically between 1945 (Baker 1946) and the early 1960's (Barbehenn 1969, 1974; Table A.2). This decline may have resulted from predation by *S. murinus* (Barbehenn 1974) as well as other factors including predation by the introduced brown treesnake (*Boiga irregularis*; Savidge 1987).

More recent sampling on Guam suggests declining introduced small mammal populations, especially in forested areas. For example, sampling conducted by King et al. (unpublished manuscript) and Savidge (1986) during the 1980's and early 1990's documented low *M. musculus*, *R. exulans*, *R. rattus*/*R. tanezumi*, and *S. murinus* density in various forest habitats (Table A.2). In contrast, introduced small mammal populations remained relatively high in sampled grasslands (King et al., unpublished manuscript; Savidge 1986). Similarly, Gragg (2004) documented high *M. musculus* and *Rattus* species (*R. exulans* and *R. rattus* were not differentiated in this study) density at 4 grassland plots in southern Guam in 2002 and 2003 (Table A.2). In contrast to previous grassland sampling, however, *S. murinus* was captured infrequently (Gragg 2004; Table A.2). It is unclear whether this result indicates a recent decline in *S. murinus* density in grasslands or if Gragg's (2004) study site encompassed an area of low *S. murinus* density not representative of the more general situation in grasslands on Guam. It is possible that the low *S. murinus* density observed by Gragg (2004) was an artifact of an unknown trap bias, as Gragg (2004) employed mark-recapture livetrapping, whereas most earlier research on Guam involved snaptrapping. The apparent long-term decline in introduced small mammal populations on Guam, especially in forest areas, is generally attributed to brown treesnake predation (Savidge 1987, Fritts and Rodda 1998). The relative persistence of introduced small mammal populations in grassland areas may result from lower brown treesnake density (and presumably lower predation pressure) in this habitat (Savidge 1987, 1991; Rodda and Dean-Bradley 2001).

Sampling data from Rota, Saipan, and Tinian suggests high-density *R. rattus*/*R. tanezumi* populations in most sampled habitats, as well as high-density *S. murinus* populations on Saipan and Tinian. *S. murinus* may no longer be present on Rota (Table A.2; J. Esselstyn and R. Ulloa, personal communication). Available data also suggest that *M. musculus*, *R. exulans*, and *R. norvegicus* occur at low densities on these islands (Table A.2), or perhaps they are sparsely distributed and have not been adequately sampled to date. It is difficult to make strong inferences about introduced small mammal populations on the remaining islands, with the possible exception of Aguijan, which is the best studied of the non-inhabited islands. On Aguijan, the available data suggests that current *R. exulans* densities may be higher than they were immediately following World War II (Table A.2), although it is not possible to make comparisons between *R. exulans* density on Aguijan and other islands based on available data.

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Table A.1. Distribution of introduced small mammal species in the Mariana Islands, where species observations are indicated with an “O,” anecdotal references (without accompanying evidence) are indicated with a “H,” and captures are indicated with a “C.” Brackets indicate uncertain species identification. Islands are listed in order from north to south.

Island	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Farallon de Pajaros[a]		|-----	--- O[d] --- H[d]	-----|	
Maug Islands[a]		|-----	--- O[d] ---	-----|	
Asuncion Island[a]		|-----	--- O[d] ---	-----|	
Agrihan[b]				C[d]	
Pagan[b]				C[d]	
Alamagan[b]		C[d]			
Guguan[a]		C[d]			H[d,f]
Sarigan[b]		C[d]			
Anatahan[b]		C[d]			
Farallon de Medinilla[a]		H[d]			
Saipan[c]	C[d,e]	C[d,e]	C[d,e]	C[d,e]	C[d,e]
Tinian[c]	C[d,e]	C[d, f]	C[e]	C[d,e]	C[d,e]
Aguijan[a]		C[d] |-----	--- H[d,f,g] ---	-----|	
Rota[c]	C[d,e]	C[d,e]		C[d,e]	H[d,f]
Guam[c]	C[d,e]	C[d,e]	C[d,e]	C[d,e]	C[d,e]

[a] Uninhabitated in modern (post-WWII) era: Farallon de Pajaros, Maug Islands, Asuncion Island, and Guguan designated as nature preserves by the constitution of the Commonwealth of the Northern Mariana Islands. Farallon de Medinilla leased as a bombing range by U.S. military.
[b] Intermittent human settlement in modern (post-WWII) era: Agrihan and Alamagan currently have 5–10 residents each, Pagan recently recolonized by 2 families (C. Kessler, personal communication).
[c] Permanent human populations in modern (post-WWII) era.
[d] See island-specific references in Table A.2.
[e] Captured by ASW during 2005–2007.
[f] No recent observations, status unknown
[g] Evidence for *R. norvegicus* pertains to Naftan Rock, located south of Aguijan.

Table A.2. Summary of known introduced small mammal records in the Mariana Islands. Islands are listed in alphabetical order. Unless otherwise indicated, all information taken directly from cited references; information modified or calculated by ASW is indicated in bold. Blanks in table indicate that information was either not present or not interpretable in the cited reference. Brackets indicate uncertain species identification or unclear reference between observations/captures and a specific sampling unit. In the Sampling Date column, “Occasions” indicate the specified duration of sampling. In the Trap Type column, “Placement” indicates the count and placement of traps for a single sampling occasion, whereas “Effort” indicates the total sampling effort in trap nights (TN). Sampling results indicate the number of individuals captured, the number of captures/100 TN or 100 corrected TN (CTN; where the correction is for traps closed without a capture, following the method described by Nelson and Clark 1973), or the number of individuals/ha. In all cases, these density estimates represent nominal densities, where the number of captured or estimated individuals is divided by the area of the sample unit (i.e., no attempt to estimate the effective trapping area).

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Agrihan										
Pratt and Lemke 1984	Feb 22–23, 1984	mid-elevation		incidental observations				| – – – – –	observed large rat in tree fern	
Cruz et al. 2000a	Aug 11–14, 2000 (4)	introduced forest (southwest coast, near anchorage)	peanut butter	225 m transect (25 m spacing)	Victor rat snap (10 ground, 10 tree; 80 TN)				5 captures **6.3/100 TN** 8.3/100 CTN	
Aguijan										
Enders 1949	1949						| – – – – –	comments that rats are hard to find	– – – – – |	
Owen 1952 (cited in Davis 1954 and Eldredge 1984)	1950 or possibly 1952						| – – – – –	reported rats extremely scarce or absent	– – – – – |	
Peterson 1954				visual searches			| – – – – –	no evidence of rats, despite extensive searching	– – – – – |	
Davis 1954	Jul 21–Aug 11, 1954	“various habitats”	coconut, bacon, and bread	trapping and visual searches	“Japanese-type”		| – – – – –	observed 2 rats	– – – – – |	
Kosaka et al. 1983	Jul 11–14, 1983			incidental observations			frequent observations			
Lemke et al. 1985	Jan 30–Feb 3, 1985	Naftan Rock		incidental observations			| – – – – –	observed sign (burrows, chewed bird bones) of unknown rat	– – – – – |	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Aguijan continued										
Reichel et al. 1988a	Jun 6–9, 1988	Guano Cave, other areas		incidental observations and specimen collection			observed single *R. exulans*; collected other rats for ID			
Stinson 1994				review of published and unpublished reports			common			
Campbell 1995 [a]	May 31–Jun 3, 1995 (4, 3)	native limestone forest	peanut butter + rolled oats	375 m transect (25 m spacing)	snap (16 ground, 16 tree; 112 TN)		10.7/100 CTN			
	Jun 2–Jun 4, 1995 (3)	savanna	peanut butter + rolled oats	325 m transect (25 m spacing)	snap (14 ground; 42 TN)		5.3/100 CTN			
Cruz et al. 2000b	Apr 2–5, 2000 (3)	introduced forest (upper plateau near camp)	peanut butter	600 m transect (25 m spacing)	snap (25 ground, 25 tree; 150 TN)		16 captures **10.7/100 TN** 12.5/100 CTN			
		native limestone forest (near or on transect 4)	peanut butter	600 m transect (25 m spacing)	snap (25 ground, 25 tree; 150 TN)		18 captures **12.0/100 TN** 16.5/100 CTN			
		savannah (upper plateau near camp)	peanut butter	600 m transect (25 m spacing)	snap (25 ground; 75 TN)		5 captures **6.7/100 TN** 9.8/100 CTN			
Esselstyn et al. 2003	Mar 14–21, 2002 (3)	*Leucaena* forest (upper plateau, south of camp)	peanut butter	275 m transect (25 m spacing)	Victor snap (12 ground, 12 tree; 72 TN)		6 captures **8.3/100 TN**			
		native limestone forest (between Transects 2 and 4)	peanut butter	275 m transect (25 m spacing)	Victor snap (12 ground, 12 tree; 72 TN)		1 capture **1.4/100 TN**			
		Cocos stand (northeast of camp)					|– – – – –	observed several unknown rats	– – – – –|	
Alamagan										
Cruz et al. 2000c [b]	Jun 11–15, 2000 (3)	mixed secondary forest (northwest slope)	peanut butter	600 m transect (25 m spacing)	Victor rat snap (25 tree; 75 TN)					
		mixed *Cocos* forest (near camp)					3 captures			

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Anatahan										
Reichel et al. 1988b	Sep 27–29, 1988			incidental observations			observed small rats			
Vogt (unpublished data)	Jul 1999 (3)	degraded native forest		700 m transect (25 m spacing)	Victor snap (29 ground; 87 TN)		2 captures **2.3/100 TN** **3.3/100 CTN**			
Cruz et al. 2000d	Jul 10–12, 2000 (3)	native forest (northwestern and southern coast)	peanut butter	675 m transect + 1000 m transect (25 m spacing)	Victor rat snap (28 ground/tree mix; 84 TN + 41 ground/tree mix; 123 TN)		12 captures **5.8/100 TN** 6.8/100 CTN			
Cruz 2002, Cruz et al. 2003 [c]	Apr 25–May 2, 2002	coastal forest dominated by *Barringtonia*	peanut butter	275 m transect (25 m spacing)	Victor snap (12 ground, 12 tree)		— | |			
		coastal scrub dominated by *Cocos*	peanut butter	275 m transect (25 m spacing)	Victor snap (12 ground, 12 tree)		2 captures (tentative identification)			
		upland forest dominated by *Hibiscus*	peanut butter	275 m transect (25 m spacing)	Victor snap (12 ground, 12 tree)		| | —			
Asuncion Island										
Pratt and Lemke 1984	Feb 28–29, 1984			incidental observations			|– – – – –	observed single rat and rat sign (tunnels)	– – – – –|	
Farallon de Medinilla										
Lusk et al. 2000 [d]	Nov 4, 1996	grass, shrubs, and isolated short trees					present (no reference)			
Farallon de Pajaros										
Pratt and Lemke 1984	Feb 27, 1984			incidental observations				unidentified large rat collected; observed extensive rat sign (scat and tunnels)	– – – – –|	
Stinson 1994				review of published and unpublished reports				uncommon		

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Guam										
Freycinet 2003	1819			incidental observations		|– – – – –	observed “prodigious” rats and mice	– – – – – – –	– – – – –|	
Baker 1946 [e]	May 8–21, 1945 (14)	grassland, modified forest (1 mile west of Mt. Santa Rosa)	rolled oats + ground coconut	~90 × 115 m site (~9 m spacing; ~1.2 ha)	Sherman live (90 ground; 1260 TN)	20 captures 8.3/ha	7 captures 6.5/ha		37 captures 30.0/ha	
	Jun 21–30, 1945 (10)	grassland, modified forest (1 mile west of Mt. Santa Rosa)	rolled oats + ground coconut	~90 × 115 m site (~9 m spacing; ~1.2 ha)	Sherman live (90 ground; 900 TN)	17 captures 10.6/ha	7 captures 5.7/ha		22 captures 18.3/ha	
	Jul 31–Aug 9, 1945 (10)	grassland, modified forest (1 mile west of Mt. Santa Rosa)	rolled oats + ground coconut	~90 × 115 m site (~9 m spacing; ~1.2 ha)	Sherman live (90 ground; 900 TN)	19 captures 13.4/ha	4 captures 3.1/ha		13 captures 12.7/ha	
	Sep 28–Oct 6, 1945 (9)	grassland, modified forest (1 mile west of Mt. Santa Rosa)	rolled oats + ground coconut	~90 × 115 m site (~9 m spacing; ~1.25 ha)	Sherman live (90 ground; 810 TN)	34 captures 25.8/ha	18 captures 15.0/ha		12 captures 10.9/ha	
	Oct 19–24, 1945 (6)	grassland, modified forest (1 mile west of Mt. Santa Rosa)	rolled oats + ground coconut	~90 × 115 m site (~9 m spacing; ~1.2 ha)	Sherman live (90 ground; 540 TN) + snap (90 ground; 540 TN)	25 captures 20.7/ha	26 captures 21.7/ha		30 captures 24.0/ha	
Marshall 1962a	~1945–1960			review of specimens deposited at U.S. National Museum		collected	collected		collected	collected
Barbehenn 1962 [f]	Jan 1–May 20, 1958 (4 nights/transect)	grassy/brushy areas near human-use areas (island-wide)		46 transects (3–3.7 m spacing)	wooden-base snap (~ 100 ground; 21876 TN)	|– – – – –	– – – – – – – –	1613 captures **7.4/100 TN**	– – – – –|	1609 captures **7.4/100 TN**
Barbehenn 1969, 1974 [g]	May 1962–May 1964 (≥ 4 nights/grid)	grassland, shrubland, *Leucaena* forest (island-wide)	fresh coconut	twenty-three 8 × 8 grids (~15 m spacing; ~1.1 ha each)	mouse snap (64–128 ground), Museum Special snap (64 ground), and rat snap (128 ground; 5888–7360 TN)	115 captures **~4.5/ha (average across grids)**	340 captures **~13.4/ha (average across grids)**	— | | |	513 captures **~20.3/ha (average across grids)**	704 captures **~27.8/ha (average across grids)**
		grassland, shrubland, *Leucaena* forest (island-wide)	fresh coconut	six 8 × 8 grids (~30 m spacing; ~4.4 ha each)	mouse snap (64–128 ground), Museum Special snap (64 ground), and rat snap (128 ground; 1536–1920 TN)	118 captures **~4.5/ha (average across grids)**	387 captures **~14.7/ha (average across grids)**	| 6 captures | | |	337 captures **~12.8/ha (average across grids)**	422 captures **~16.0/ha (average across grids)**
	(usually 4 nights/transect)	grass, scrub, and forest edge near human-use areas (island-wide)	fresh coconut	42 transects (~3.7 m spacing)	wooden-base rat snap (~100 ground; ~16800 TN)	121 captures **~0.7/100 TN**	287 captures **~1.7/100 TN**	| | | —	1324 captures **~7.9/100 TN**	2805 captures **~16.7/100 TN**

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Guam continued										
King et al. (unpublished manuscript) [h]	Jun 4–Jul 4, 1981 (1 night/transect)	limestone forest (Ritidian, Tarague)	canned dog food or peanut butter + oatmeal (alternate traps)	three 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 600 TN)	2 captures 0.3/100 TN	2 captures 0.3/100 TN			19 captures 3.2/100 TN
		second-growth forest (Andersen NE, Andersen NW)	canned dog food or peanut butter + oatmeal (alternate traps)	three 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 600 TN)	6 captures 1.0/100 TN	7 captures 1.2/100 TN			16 captures 2.7/100 TN
		mixed forest (Dededo, Ipapao, Andersen Marbo Annex)	canned dog food or peanut butter + oatmeal (alternate traps)	five 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 1000 TN)		2 captures 0.2/100 TN			7 captures 0.7/100 TN
		ravine forest (Chaot River, High Road, Almagosa Springs)	canned dog food or peanut butter + oatmeal (alternate traps)	three 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 600 TN)		1 capture 0.2/100 TN			1 capture 0.2/100 TN
		savannah (Mt. Tenjo, Sigua Falls, Roberto's, NASA Tracking Station)	canned dog food or peanut butter + oatmeal (alternate traps)	four 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 800 TN)	5 captures 0.6/100 TN				15 captures 1.9/100 TN
		swamp (Agana Swamp)	canned dog food or peanut butter + oatmeal (alternate traps)	1500 m transect (~8 m spacing)	Victor mouse snap (200 ground; 200 TN)					1 capture 0.5/100 TN
		urban (Barrigada)	canned dog food or peanut butter + oatmeal (alternate traps)	1500 m transect (~8 m spacing)	Victor mouse snap (200 ground; 200 TN)		1 capture 0.5/100 TN			8 captures 4.0/100 TN

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Guam continued										
Savidge 1986 [i]	May 1984 (5)	grassland, modified forest (Baker (1946) site)	coconut	10 × 10 grid (10 m spacing; 0.81 ha)	mouse snap (150 ground; 750 TN) + rat snap (100 ground; 500 TN)				2 captures **0.2/100 TN** **2.5/ha**	
	Feb 1985 (5)	grassland, shrubland, *Leucaena* forest (Two Lover's Point)	coconut + peanut butter (mouse snap); fresh coconut (rat snap)	8 × 8 grid (15 m spacing; 1.1 ha)	mouse snap (80 ground; 400 TN) + rat snap (128 ground; 640 TN)				2 captures **0.2/100 TN** **1.8/ha**	
	Feb–Mar 1985 (5)	grassland, shrubland, *Leucaena* forest (Northwest Field)	coconut + peanut butter (mouse snap); fresh coconut (rat snap)	8 × 8 grid (15 m spacing; 1.1 ha)	mouse snap (80 ground; 400 TN) + rat snap (128 ground; 640 TN)					
	Mar 1985 (5)	grassland, shrubland, *Leucaena* forest (Anderson South)	coconut + peanut butter (mouse snap); fresh coconut (rat snap)	8 × 8 grid (15 m spacing; 1.1 ha)	mouse snap (80 ground; 400 TN) + rat snap (128 ground; 640 TN)	11 captures **1.1/100 TN** **10.0/ha**				
	Apr 1985 (5)	savannah (NASA Tracking Station)	coconut + peanut butter (mouse snap); fresh coconut (rat snap)	8 × 8 grid (15 m spacing; 1.1 ha)	mouse snap (64 ground; 320 TN) + rat snap (128 ground; 640 TN)	96 captures **10.0/100 TN** **87.3/ha**			40 captures **4.2/100 TN** **36.4/ha**	21 captures **2.2/100 TN** **19.1/ha**
U.S. Fish and Wildlife Service 1986 [j]	Apr–May 1986	coastal strand (Haputo Beach)	fresh coconut	1 transect	mouse snap (21 ground) + rat snap (21 ground)					
	Apr–May 1986	secondary forest (Haputo Road)	fresh coconut	1 transect (~ 10 m spacing)	mouse snap (21 ground) + rat snap (21 ground)					
Fritts and Rodda 1988 [k]	Apr 29–May 8 1988 (3)	mixed forest (Northwest Field)	coconut or peanut butter + oats	490 m transect (10 m spacing)	Victor snap (50 ground; 150 TN)		3 captures **1.3/100 TN**			
		mixed forest (NCTAMS, near Haputo Beach trailhead)	coconut or peanut butter + oats	480 m transect (10 m spacing)	Victor snap (49 ground; 147 TN)					

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Guam continued										
King et al. (unpublished manuscript) [h]	Jun 3–27, 1994 (1 night/transect)	coastal strand (Ritidian, Tarague)	canned dog food or peanut butter + oatmeal (alternate traps)	two 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 400 TN)					
			fresh coconut	two 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 200 TN)				2 captures 1.0/100 TN	
		limestone forest (Ritidian, Tarague)	canned dog food or peanut butter + oatmeal (alternate traps)	five 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 1000 TN)					
			fresh coconut	two 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 200 TN)				1 capture 0.5/100 TN	
		second-growth forest (Andersen NE, Andersen NW)	canned dog food or peanut butter + oatmeal (alternate traps)	three 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 600 TN)	2 captures 0.3/100 TN				
			fresh coconut	two 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 200 TN)				3 captures 1.5/100 TN	
		mixed forest (NCTAMS, Andersen Marbo Annex)	canned dog food or peanut butter + oatmeal (alternate traps)	two 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 400 TN)					
			fresh coconut	two 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 200 TN)					
		ravine forest (Chaot River, High Road, Almagosa Springs)	canned dog food or peanut butter + oatmeal (alternate traps)	three 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 600 TN)					
			fresh coconut	three 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 300 TN)				1 capture 0.3/100 TN	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Guam continued										
King et al. (unpublished manuscript)[h] continued	Jun 3–27, 1994 (1 night/transect)	savannah (Mt. Tenjo, Sigua Falls, Roberto's, NASA Tracking Station)	canned dog food or peanut butter + oatmeal (alternate traps)	four 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 800 TN)	9 captures 1.1/100 TN	1 capture 0.1/100 TN			10 captures 1.3/100 TN
			fresh coconut	four 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 400 TN)		4 captures 1.0/100 TN		18 captures 4.5/100 TN	14 captures 3.5/100 TN
		urban (Naval Air Station Barracks, Naval Station Barracks)	canned dog food or peanut butter + oatmeal (alternate traps)	two 1500 m transects (~8 m spacing)	Victor mouse snap (200 ground; 400 TN)					15 captures 3.8/100 TN
			fresh coconut	two 750 m transects (~8 m spacing)	Victor rat snap (100 ground; 200 TN)				1 capture 0.5/100 TN	4 captures 2.0/100 TN
Stinson 1994				review of published and unpublished reports		common	uncommon	uncommon	common	uncommon
Gragg 2004[l], Gragg et al. in prep	Jul 20–25, 2002 (6)	grassland with scattered patches of trees (Ija, Inarajan, Plot 1)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	17 captures 18.5/ha			15 captures 19.5/ha	
		(Ija, Inarajan, Plot 2)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	32 captures 50.4/ha			25 captures 36.6/ha	
		(Ija, Inarajan, Plot 3)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	42 captures 53.6/ha			29 captures 41.3/ha	21 captures
		(Ija, Inarajan, Plot 4)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	52 captures 68.0/ha			13 captures 18.2/ha	

Guam continued

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Gragg 2004[I], Gragg et al. in prep continued	Sep 21–26, 2002 (6)	(Ija, Inarajan, Plot 1)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	15 captures 15.2/ha			7 captures 15.7/ha	
		(Ija, Inarajan, Plot 4)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	22 captures 31.8/ha			8 captures 14.7/ha	
	Jun 24–29, 2003 (5)	grassland with scattered patches of trees (Ija, Inarajan, Plot 1)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 140 TN), long Sherman live (25 ground; 125 TN), and standard Sherman live (28 ground; 140 TN)	40 captures 40.2/ha			15 captures 24.9/ha	
		(Ija, Inarajan, Plot 2)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 140 TN), long Sherman live (25 ground; 125 TN), and standard Sherman live (28 ground; 140 TN)	48 captures 67.0/ha			29 captures 34.2/ha	
		(Ija, Inarajan, Plot 3)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 140 TN), long Sherman live (25 ground; 125 TN), and standard Sherman live (28 ground; 140 TN)	13 captures 24.0/ha			20 captures 20.1/ha	12 captures
		(Ija, Inarajan, Plot 4)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 140 TN), long Sherman live (25 ground; 125 TN), and standard Sherman live (28 ground; 140 TN)	47 captures 61.0/ha			19 captures 23.8/ha	
	Aug 20–25, 2003 (6)	(Ija, Inarajan, Plot 2)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	63 captures 104.0/ha			24 captures 69.8/ha	
		(Ija, Inarajan, Plot 3)	fresh coconut	9 × 9 grid (12.5 m spacing; 1 ha)	Haguruma live (28 ground; 168 TN), long Sherman live (25 ground; 150 TN), and standard Sherman live (28 ground; 168 TN)	13 captures 12.6/ha			10 captures 27.8/ha	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Guguan										
Eldredge 1983		southern interior of island		incidental observations			small rats common			
Glass and Aldan 1987	May 28–Jun 4, 1987			incidental observations			observed small rats			
Eldredge 1988 [m]				incidental observations						observed single individual
Rice and Stinson 1992	May 17–18, 1992			incidental observations			found 2 small rodent skulls, probably *R. exulans*			
Stinson 1994				review of published and unpublished reports			common			
Cruz et al. 2000e	Jun 7–9, 2000 (3)	native forest (western slope)	peanut butter	550 m transect (25 m spacing)	Victor rat snap (23 tree; 69 TN)					
	(1)	savannah (near camp and large lava flow)	peanut butter	225 m transect (25 m spacing)	Victor rat snap (10 ground; 10 TN)		6 captures **60.0/100 TN** 70.6/100 CTN			
Kessler 2002 [n]				incidental observations			comment that *R. exulans* is very common			
Maug Islands										
Eldredge et al. 1977, Eldredge 1983	Jan and Jul 1975, Nov 1977, and Jul 1981	East Island (north end, abandoned cistern, Japanese weather station ruins)		incidental observations			|– – – – –	observed *R. exulans* or *R. rattus*; noted activity near *Terminalia* trees	– – – – –|	
Pratt and Lemke 1984	Feb 24–26, 1984	North Island		incidental observations			|– – – – –	observed small rat during day	– – – – –|	
		West Island		incidental observations			|– – – – –	observed 5 small rats	– – – – –|	
Rice and Stinson 1992	Jun 2–5, 1992	North and East Island		incidental observations			|– – – – –	observed small rats	– – – – –|	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Pagan										
Pratt and Lemke 1984	Feb 19–21, 1984	near abandoned buildings where unknown rats were observed during previous visit		trapping and incidental observations	"rat"			|– – – – – none captured or observed – – – – –|		
Cruz et al. 2000f [o]	Aug 4–6, 2000 (3)	near barracks	peanut butter	opportunistic placement of traps	Victor rat snap					
		introduced forest (near landing area)	peanut butter	≤ 450 m transect (25 m spacing)	Victor rat snap (≤ 19 ground; ≤ 57 TN)					
		native forest (near landing area)	peanut butter	≤ 450 m transect (25 m spacing)	Victor rat snap (≤ 19 ground; ≤ 57 TN)				8 captures **≥ 14.0/100 TN**	
Rota										
Russell 2002	1602			observations by Fray Juan Pobre de Zamora				|– – – – – observed abundant rats – – – – –|		
Marshall 1962a	~1945–1960			review of specimens deposited at U.S. National Museum			collected		collected	
Bowers 2001	1947							|– – – – – unidentified rats "overrun" island – – – – –|		
Barbehenn 1974	Sep 1966									established; cites R.P. Owen, pers. comm..
Stinson 1994 [p]				review of published and unpublished reports		uncommon	uncommon?		uncommon?	common
Amidon 1999 [q]	Apr 1999 (5)	mature limestone forest (sites: 2HA, 1HB, 1LB, 1HC, 1LC, 1HD, 2HD, 1LD)	fresh coconut + peanut butter	eight 100 m transects (25 m spacing)	"snap traps" (5 alternating tree and ground; 200 TN)				31 captures 15.5/100 TN **23.1/100 CTN**	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Rota continued										
Morton and Sharp 1997, Morton et al. 1999 [r]	Mar 25–30, 1997 (6)	coastal limestone forest with *Eugenia* understory (Mochong)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				22 captures **9.2/100 TN** **14.9/100 CTN**	
		coastal limestone forest with *Eugenia* understory (Rail-release)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				26 captures **10.8/100 TN** **17.7/100 CTN**	
		primary limestone forest (Golf Course)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				25 captures **10.4/100 TN** **15.2/100 CTN**	
		primary limestone forest (Palii)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				50 captures **20.8/100 TN** **33.8/100 CTN**	
	Aug 26–31, 1997 (6)	coastal limestone forest with *Eugenia* understory (Mochong)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				9 captures **3.8/100 TN** **6.0/100 CTN**	
		coastal limestone forest with *Eugenia* understory (Rail-release)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				26 captures **10.8/100 TN** **17.8/100 CTN**	
		primary limestone forest (Golf Course)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				14 captures **5.8/100 TN** **7.1/100 CTN**	
		primary limestone forest (Palii)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 240 TN)				11 captures **4.6/100 TN** **7.5/100 CTN**	
	Apr 1999 (5)	coastal limestone forest with *Eugenia* understory (Mochong)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 200 TN)				32 captures 16.0/100 TN **23.5/100 CTN**	
		coastal limestone forest with *Eugenia* understory (Rail-release)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 200 TN)				49 captures 24.5/100 TN **32.8/100 CTN**	
		primary limestone forest (Golf Course)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 200 TN)				23 captures 11.5/100 TN **16.9/100 CTN**	
		primary limestone forest (Palii)	fresh coconut + peanut butter	two 500 m transects (25 m spacing)	“snap traps” (20 alternating tree and ground; 200 TN)				13 captures 6.5/100 TN **11.4/100 CTN**	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Rota continued										
Esselstyn and Ulloa (unpublished data) [s]	Jul 28–30, 2002 (3)	degraded native forest (Mochong A)	coconut + peanut butter	190 m transect (10 m spacing)	Victor rat snap (20 tree; 60 TN, but traps were checked twice/day)				61 captures **50.8/100 trap checks**	
		degraded native forest (Mochong B)	coconut + peanut butter	190 m transect (10 m spacing)	Victor rat snap (20 tree; 60 TN, but traps were checked twice/day)				63 captures **52.5/100 trap checks**	
		degraded native forest (Mochong C)	coconut + peanut butter	190 m transect (10 m spacing)	Victor rat snap (20 tree; 60 TN, but traps were checked twice/day)				73 captures **60.8/100 trap checks**	
		degraded native forest (Lalayak A)	coconut + peanut butter	190 m transect (10 m spacing)	Victor rat snap (20 tree; 60 TN, but traps were checked twice/day)				67 captures **55.8/100 trap checks**	
		degraded native forest (Lalayak B)	coconut + peanut butter	190 m transect (10 m spacing)	Victor rat snap (20 tree; 60 TN, but traps were checked twice/day)				71 captures **59.2/100 trap checks**	
		degraded native forest (Lalayak C)	coconut + peanut butter	190 m transect (10 m spacing)	Victor rat snap (20 tree; 60 TN, but traps were checked twice/day)				58 captures **48.3/100 trap checks**	
	Sep 25–27, 2002 (3)	immature native forest (Pekngasu)	coconut + peanut butter	8 × 8 grid (10 m spacing; 0.49 ha)	Victor rat snap (64 tree; 192 TN)				22 captures **11.5/100 TN** **13.2/100 CTN**	
	Sep 29–Oct 4, 2002 (6)	immature native forest (Pekngasu)	coconut + peanut butter	8 × 8 grid (10 m spacing; 0.49 ha)	Victor rat snap (64 tree; 384 TN)				21 captures **5.5/100 TN** **6.1/100 CTN**	
	Oct 8–11, 2002 (4)	immature native forest (Pekngasu)	coconut + peanut butter	8 × 8 grid (10 m spacing; 0.49 ha)	Victor rat snap (64 tree; 256 TN)				21 captures **8.2/100 TN** **9.5/100 CTN**	
	Oct 15–18, 2002 (4)	immature native forest (Pekngasu)	coconut + peanut butter	8 × 8 grid (10 m spacing; 0.49 ha)	Victor rat snap (64 tree; 256 TN)				9 captures **3.5/100 TN** **3.8/100 CTN**	
	Oct 22–25, 2002 (4)	immature native forest (Pekngasu)	coconut + peanut butter	8 × 8 grid (10 m spacing; 0.49 ha)	Victor rat snap (64 tree; 256 TN)				2 captures **0.8/100 TN** **0.8/100 CTN**	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Rota continued										
Esselstyn and Ulloa (unpublished data) continued	May 2003 (3)	native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				17 captures **18.9/100 TN** 23.8/100 CTN	
		native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				17 captures **18.9/100 TN** 24.6/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				36 captures **40.0/100 TN** 50.7/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				31 captures **34.4/100 TN** 39.2/100 CTN	
	Aug 2003 (3)	native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				24 captures **26.7/100 TN** 33.1/100 CTN	
		native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				14 captures **15.6/100 TN** 19.2/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				42 captures **46.7/100 TN** 56.0/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				35 captures **35.6/100 TN** 44.8/100 CTN	
	Oct 2003 (3)	native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				7 captures **7.8/100 TN** 14.3/100 CTN	
		native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				18 captures **20.0/100 TN** 25.0/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				30 captures **33.3/100 TN** 41.4/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				49 captures **54.4/100 TN** 60.1/100 CTN	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Rota continued										
Esselstyn and Ulloa (unpublished data) continued	Feb 2004 (3)	native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				14 captures **15.6/100 TN** 19.7/100 CTN	
		native forest (< 50 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				20 captures **22.2/100 TN** 27.2/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				42 captures **46.7/100 TN** 58.3/100 CTN	
		native forest (300–350 m elevation)	coconut + peanut butter	three 225 m transects (25 m spacing)	Victor rat snap (10 tree; 90 TN)				42 captures **46.7/100 TN** 57.5/100 CTN	
Amar and Ulloa (unpublished data)	Dec 17–19, 2003 (3)	introduced forest (Aga Tasi)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				15 captures **20.8/100 TN** 33.3/100 CTN	
	Jan 21–23, 2004 (3)	native forest (Gayaugon)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				9 captures **12.5/100 TN** 13.8/100 CTN	
	Feb 19–21, 2004 (3)	introduced forest (Fruit farm 2)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				15 captures **20.8/100 TN** 38.5/100 CTN	
	Feb 26–28, 2004 (3)	native forest (As Bake)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				18 captures **25.0/100 TN** 46.2/100 CTN	
	Mar 3–5, 2004 (3)	native forest (Tetohge)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				9 captures **12.5/100 TN** 14.1/100 CTN	
	Mar 17–19, 2004 (3)	introduced forest (Fruit farm 2b)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				15 captures **20.8/100 TN** 28.3/100 CTN	
	May 5–7, 2004 (3)	native forest (Pictograph Cave)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				6 captures **8.3/100 TN** 9.5/100 CTN	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Rota continued										
Amar and Ulloa (unpublished data) continued	May 5–7, 2004 (3)	native forest (Open field 1)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				14 captures **19.4/100 TN** 23.7/100 CTN	
	May 12–14, 2004 (3)	introduced forest (Fruit farm 4)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				24 captures **33.3/100 TN** 44.4/100 CTN	
	May 19–21, 2004 (3)	native forest (Bird Sanctuary)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				18 captures **25.0/100 TN** 38.3/100 CTN	
	May 19–21, 2004 (3)	native forest (Open field 2)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				8 captures **11.1/100 TN** 13.6/100 CTN	
	May 26–28, 2004 (3)	native forest (Gayaugon B)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				13 captures **18.1/100 TN** 20.3/100 CTN	
	Jun 9–11, 2004 (3)	native forest (Quarry)	coconut + peanut butter	5 × 5 grid with empty center (25 m spacing; 1 ha)	Victor rat snap (24 tree; 72 TN)				29 captures **40.3/100 TN** 52.7/100 CTN	
Saipan										
Kuroda 1939 [t]						present		present	present	
Marshall 1962a	~1945–1960			review of specimens deposited at U.S. National Museum		collected	collected	collected	collected	
Bowers 2001	1947						|–––––	unidentified rats "overrun" island	–––––|	
Enders 1949	1949	variety of habitats and human-use areas		trapping, visual searches, and incidental observations	"standard rat traps" (both ground and tree placement)	present	captured	captured; speculated that population was in decline	captured; most abundant rat	

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Saipan continued										
Barbehenn 1974 [u]	Aug 29–Sep 3, 1962	variety of habitats across island		8 sites		|– – – – –	138 captures	— | |	– – – – –|	20 captures
	Feb 11–18, 1963	variety of habitats across island		5 sites		|– – – – –	212 captures	includes 19 *R. norvegicus*	– – – – –|	149 captures
	Aug 26–Sep 5, 1963	variety of habitats across island		14 sites		|– – – – –	151 captures	captures | |	– – – – –|	195 captures
	Feb 25–Mar 5, 1964	variety of habitats across island		13 sites		|– – – – –	240 captures	| —	– – – – –|	149 captures
Stinson 1994 [v]				review of published and unpublished reports		uncommon	uncommon	common	uncommon?	common
Vogt (unpublished data) [w]	Apr 1–3, 1997 (6 sampling occasions)	mixed secondary forest bordering wetland (American Memorial Park)	canned cat food	7 × 9 grid (15 × 10 m spacing; 0.72 ha)	minnow funnel traps with one-way flaps (63 ground; 378 trap occasions)					33 captures 27.3/ha
	Nov 17–21, 1997 (10 sampling occasions)	*Leucaena* forest (near Saipan Airport)	canned cat food	11 × 11 grid (10 m spacing; 1 ha)	minnow funnel traps with one-way flaps (121 ground; 1210 trap occasions)					50 captures 26.4/ha
	Apr 13–15, 1998 (6 sampling occasions)	native limestone forest (near Bird Island)	canned cat food	11 × 11 grid (10 m spacing; 1 ha)	minnow funnel traps with one-way flaps (121 ground; 726 trap occasions)					70 captures 16.7/ha
CNMI-DFW (unpublished data)	Apr 25–28, 2000 (4)	Airport		trapping	snap (57–64; 235 TN)		|– – – – –	27 captures **11.5/100 TN** **16.0/100 CTN**	– – – – –|	12 captures **5.1/100 TN** **7.1/100 CTN**
	May 1–2, 2000 (2)	Airport		trapping	snap (64–66; 130 TN)		|– – – – –	6 captures **4.6/100 TN** **5.6/100 CTN**	– – – – –|	14 captures **10.8/100 TN** **13.2/100 CTN**
	May 4–5, 2000 (2)	Airport		trapping	snap (61–64; 125 TN)		|– – – – –	26 captures **20.8/100 TN** **36.4/100 CTN**	– – – – –|	17 captures **13.6/100 TN** **23.8/100 CTN**
	May 11–12, 2000 (2)	Airport		trapping	snap (31–33; 64 TN)		|– – – – –	7 captures **10.9/100 TN** **16.7/100 CTN**	– – – – –|	8 captures **12.5/100 TN** **19.1/100 CTN**
	May 16–17, 2000 (2)	Airport		trapping	snap (33; 66 TN)		|– – – – –	7 captures **10.6/100 TN** **12.7/100 CTN**	– – – – –|	9 captures **13.6/100 TN** **16.4/100 CTN**

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Saipan continued										
CNMI-DFW (unpublished data)	May 22–26, 2000 (5)	Airport		trapping	snap (29–33; 161 TN)		|– – – – –	8 captures **5.0/100 TN** **5.9/100 CTN**	– – – – –|	9 captures **5.6/100 TN** **6.6/100 CTN**
continued	May 30–Jun 2, 2000 (4)	Airport		trapping	snap (33; 132 TN)		|– – – – –	7 captures **5.3/100 TN** **6.1/100 CTN**	– – – – –|	1 capture **0.8/100 TN** **0.9/100 CTN**
	Feb 29–Mar 3, 2000 (4)	Marpi		trapping	snap (97–99; 392 TN)		|– – – – –	4 captures **1.0/100 TN** **1.1/100 CTN**	– – – – –|	2 captures **0.5/100 TN** **0.6/100 CTN**
	Mar 7–10, 2000 (4)	Marpi		trapping	snap (99; 396 TN)					2 captures **0.5/100 TN** **0.6/100 CTN**
	Mar 14–16, 2000 (3)	Marpi		trapping	snap (99–102; 301 TN)		|– – – – –	2 captures **0.7/100 TN** **0.8/100 CTN**	– – – – –|	
Sachtleben (unpublished data) [x]	Jul 3–8, 2003 (6)	*Leucaena* forest (Obyan)	fresh coconut	100 m long trapping line transect	Sherman live (100 ground; 600 TN)	4 captures	4 captures		10 captures, 4 recaptures	142 captures
	Jul 14–20, 2003 (6)	*Leucaena* forest (Bird Island)	fresh coconut	100 m long trapping line transect	Sherman live (100 ground/tree mix; 600 TN)		1 capture	1 capture		25 captures, 8 recaptures
	Jul 3–8, 2003 (6)	native forest (Laolao Bay)	fresh coconut	100 m long trapping line transect	Sherman live (100 ground; 600 TN)					117 captures
	Jul 14–20, 2003 (6)	native forest (Marpi)	fresh coconut	100 m long trapping line transect	Sherman live (100 ground/tree mix; 600 TN)					31 captures, 18 recaptures
Sarigan										
Arriola et al. 1999	Jul 4–8, 1999 (4)	mixed *Cocos* forest (USFWS transect 3)	baked coconut + peanut butter	850 m transect (25 m spacing)	Victor snap (35 ground; 140 TN)		35 captures **25.0/100 TN** **33.0/100 CTN**			
	Jul 4–8, 1999 (3)	native forest (USFWS transect 5)	baked coconut + peanut butter	1075–1200 m transect (25 m spacing)	Victor snap (44–49 ground; 141 TN)		6 captures **4.3/100 TN** **4.8/100 CTN**			
Vogt (unpublished data)	Jul 1999 (3)	native forest			Victor rat snap (43 ground; 129 TN)		6 captures **4.7/100 TN** **5.6/100 CTN**			

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Sarigan continued										
Kessler 2002 [y]	Jul 1999 Jul 2000		peanut butter	two 725 m transects (25 m spacing)	"large" snap (30 ground)		< 6 captures each year			
Cruz et al. 2000g	Jul 4–6, 2000 (3)	mixed *Cocos* forest (transect 3)	peanut butter	600 m transect (25 m spacing)	Victor rat snap (25 ground; 75 TN)		3 captures **4.0/100 TN** 5.7/100 CTN			
Tinian										
Thomas 1971 (cited in Wiles et al. 1990)	1742			incidental observations by Lord Anson			|– – – – –	unidentified rats numerous	– – – – –|	
Downs 1948	May 31–Oct 17, 1945			incidental observations		|– – – – –	observed rats and mice	– – – – – – – –	– – – – –|	
Marshall 1962a	~1945–1960			review of specimens deposited at U.S. National Museum		collected	collected		collected	
Bowers 2001	1947						|– – – – –	unidentified rats "overrun" island	– – – – –|	
Owen 1974	Jan 18–25, 1974			incidental observations					3 unknown rats observed, tentative *R. rattus* identification	single observation at hotel
Wiles et al. 1990 [z]	Jan 5–12 and May 10–14, 1985 (1)	*Leucaena* forest	peanut butter, toasted coconut, or dampened oatmeal	90–590 m transect(s) (10 m spacing)	8 x 14 or 9 x 18 cm snap (10–60 ground; 198 TN)				8 captures **4.0/100 TN**	5 captures **2.5/100 TN**
		open fields	peanut butter, toasted coconut, or dampened oatmeal	90–590 m transect(s) (10 m spacing)	8 x 14 or 9 x 18 cm snap (10–60 ground; 123 TN)	1 capture **0.81/100 TN**			3 captures **2.4/100 TN**	1 captures **0.8/100 TN**
		secondary vegetation	peanut butter, toasted coconut, or dampened oatmeal	90–590 m transect(s) (10 m spacing)	8 x 14 or 9 x 18 cm snap (10–60 ground; 67 TN)				2 captures **3.0/100 TN**	2 captures **3.0/100 TN**

Reference	Sampling Date (Occasions)	Sampling Habitat (Location)	Bait	Sampling Methodology	Trap Type (Placement; Effort)	*Mus musculus*	*Rattus exulans*	*Rattus norvegicus*	*Rattus rattus/ R. tanezumi*	*Suncus murinus*
Tinian continued										
Wiles et al. 1990 [z] continued	Jan 5–12 and May 10–14, 1985 (1)	strand vegetation	peanut butter, toasted coconut, or dampened oatmeal	90–590 m transect(s) (10 m spacing)	8 x 14 or 9 x 18 cm snap (10–60 ground; 47 TN)				8 captures **17.0/100 TN**	
		native forest	peanut butter, toasted coconut, or dampened oatmeal	90–590 m transect(s) (10 m spacing)	8 x 14 or 9 x 18 cm snap (10–60 ground; 25 TN)				Observed but not captured	Observed but not captured
		municipal dump	peanut butter, toasted coconut, or dampened oatmeal	90–590 m transect(s) (10 m spacing)	8 x 14 or 9 x 18 cm snap (10–60 ground; 25 TN)				1 captures **4.0/100 TN**	Observed but not captured
Stinson 1994				review of published and unpublished reports		uncommon	rare	uncommon	common	common
Vogt (unpublished data)	Mar 2007 (3)	*Leucaena* forest (road to Puntan Tahgong)		980 m transect (20 m spacing)	Victor rat snap (50 ground; 150 TN)				67 captures **44.7/100 TN** **78.8/100 CTN**	15 captures **10.0/100 TN** **17.6/100 CTN**
		native forest (road to Lasu)		980 m transect (20 m spacing)	Victor rat snap (50 ground; 150 TN)				42 captures **28.0/100 TN** **53.8/100 CTN**	22 captures **14.7/100 TN** **28.2/100 CTN**

[a] At native limestone forest site, tree traps were active for 4 nights, ground traps were active for 3 nights. An odd trap check schedule (traps checked hourly for 3 hours in evening, then again following morning) complicates calculation of TNs for comparison to other studies. In reference, the reported captures/100 CTN is < the reported captures/100 TN, which is not possible.

[b] Results reported in reference do not agree with Methods. For example, reported TN (168 CTN) is not possible based on number of traps and sampling duration. Also, sampling conducted in mixed *Cocos* forest, where 3 *R. exulans* were captured, is not mentioned in Methods and there is no indication of sampling effort.

[c] References do not indicate sampling duration; without this information, one can not calculate sampling effort or capture rates. Reference does not indicate which transect(s) captures occurred on.

[d] Reference reports the results of an avian visual survey, but also mentioned that *R. exulans* is present, although no supporting evidence was provided.

[e] Study employed mark-recapture livetrapping, except for final sampling event (Oct 19–24) which included both live and snap traps. Traps were places somewhat systematically at an average spacing of < 10 m. Note that Baker excluded animals that died during livetrapping from his density calculations, which could affect comparison with other studies. Including these animals in density calculations can result in significantly different results. For example, 10 *M. musculus* died during the first livetrapping session; leaving these animals in the density calculation results in an estimate of 16.7/ha vs. Baker's value of 8.3/ha.

[f] Sampling conducted by Guam Sanitation Section. Reference reports 5469 traps active for 4 nights, for a total of 21876 TN. Reference reports combined capture totals for *M. musculus* and *Rattus* species.

[g] Trapping grids had 15.2 or 30.5 m spacing. Each trap station on grid contained 2 rat snap traps, 1 or 2 mouse snap traps, and 1 Museum Special snap trap. Transect sampling conducted by Guam Sanitation Section. Reference does not provide site-specific capture counts, limiting results to presentation of overall average captures/ha. Six *R. norvegicus* captured over duration of sampling, but reference does not provide indication of capture location or circumstances. Reference reports that many additional animals were captured during extended sampling (many grids were sampled > 4 nights) but offers no indication of additional sampling effort or number of additional captures.

[h] Transects located exclusively in human-made openings in vegetation (e.g., jeep trails, roadsides, utility right-of-ways). It is possible, especially for *M. musculus* and *S. murinus*

which have relatively small home ranges, that this approach sampled only "edge" habitats bordering these openings rather than the targeted habitats (e.g., native forest, ravine forest, etc.). Transects were sampled for 1 night only, except for Tarague in 1981 (alternate halves of limestone forest transect sampled on consecutive nights), Ipapao in 1981 (mixed forest transect sampled twice over consecutive nights), and Tarague in 1994 (2 limestone forest mouse trap transects each sampled twice over consecutive nights). Note that 3 *R. norvegicus* captured in 1981 and 2 *R. tanezumi* captured in 1994 are not presented in summary tables in reference. Also, reference text indicates 25 *R. tanezumi* captures in 1994, whereas reference table 2 indicates 26 *R. tanezumi* captures.

[i] Baker's (1946) site resampled with a 10 × 10 grid with trap stations spaced 10 m apart. Each trap station had 1 rat snap trap and 1–2 mouse snap traps. Other sampling events utilized 8 x 8 grids with trap stations spaced 15 m apart. Each trap station had 2 rat snap traps and 1–2 mouse snap traps. Note that nominal grid areas calculated in reference are incorrect (too large).

[j] Reference does not provide sampling duration information, so it is not possible to verify the sampling effort information (125 rat snap and 90 mouse snap TN).

[k] Note that 1 of 3 *R. exulans* was actually captured on an adhesive trap deployed for concurrent lizard surveys.

[l] Study employed mark-recapture livetrapping. Note that each trap station contained a single Haguruma, long Sherman, or standard Sherman trap. Traps allocation occurred (roughly) on an alternating row pattern. Summary data are only included here for pre-treatment and control (no rodenticide) sampling grids. Note that during Jun 24–29, 2003, sampling period data from Jun 25 had to be discarded because of a marking issue, resulting in 5 occasions for this sampling event. Reference does not separate *R. exulans* and *R. rattus* captures, but does comment that unequivocal *R. exulans* specimens made up ~3% of sample, whereas unequivocal *R. rattus* specimens made up >90% of sample. Reference does not present *S. murinus* capture information for each grid, only total captures per year.

[m] Only known record of *S. murinus* outside of Guam, Rota, Saipan, and Tinian. Status of sighting is unclear, although recent research trips to Guguan have not commented on presence of *S. murinus*.

[n] Reference reports research conducted on Sarigan, but mentions that *R. exulans* is very common and commonly observed during daylight on Guguan.

[o] Reference does not provide necessary information (number of traps) to calculate sampling effort or capture rates. Note that the value for TN presented in reference is not possible based on the maximum number of traps ($\leq$ 19) and sampling duration described.

[p] Justification for common status of *S. murinus* is unclear, as only known reference of this species for Rota (and the reference cited by Stinson) is Barbehenn 1974, which does not comment on abundance.

[q] Reference indicates uncertainty about species identification and suggest either *R. exulans* or *R. tanezumi*. Although reference provides captures/100 CTN, they were not calculated in a comparable fashion to other data in this summary and are not included here.

[r] Additional sampling (6 consecutive nights) was conducted on these study sites in March and August, 1998, although neither reference provides adequate information for summary of these data. Both references indicate uncertainty about species identification and suggest either *R. exulans* or "some variant of *R. rattus*" (possibly *R. tanezumi*?).

[s] Traps checked twice per day at Mochong A, B, and C and Lalayak A, B, and C, which complicates calculation of TN for comparison with other studies.

[t] Reference comments on presence of 2 *Mus* species on Saipan: *M. musculus momiyamai* and *M. caroli boninensis.* Validity of this claim is unclear; taxonomy of *Mus* has undergone extensive revision in recent years and the current identification of the *Mus* species in the Mariana Islands is *M. musculus castaneus* (Musser and Carleton 2005:1401).

[u] Note that captures were divided into *S. murinus* and other introduced small mammals. The other introduced small mammal category included 19 *R. norvegicus*, although no information is provided for capture location or date.

[v] Justification for common status of *R. norvegicus* is unclear. Other references for *R. norvegicus* on Saipan offer little information related to abundance; available information seems to suggest that this species is actually rare on Saipan.

[w] Study employed mark-recapture livetrapping, and was targeted specifically for *S. murinus*. Traps checked twice per day, effectively doubling sampling occasions.

[x] Study employed limited mark-recapture livetrapping. *S. murinus* was not marked during Jul 3–8 sampling events, so recaptures make up an unknown portion of the indicated captures. Traps placed in trees (Jul 14–20 sampling events) recorded zero captures.

[y] Reference provides limited methodology and results. Reference states that S. Vogt conducted sampling, so Jul 1999 sampling may be same as in the previous record (S. Vogt unpublished data), where more complete methods and results are available.

[z] Reference does not provide specific information about number of sampled transects, the number of traps per transect, or the number of each of the 2 trap types used. Note that the 8 x 14 and 9 x 18 cm snap traps are similar in dimensions to Museum Special and Victor rat snap traps, respectively.

APPENDIX 1B. Delta method procedures for calculating density and biomass variances

Density Variance Estimates

Introduced small mammal density estimates were generated using species-specific abundance estimates (Program MARK 4.3; White and Burnham 1999) and mean maximum distance moved (MMDM) estimates from mark-recapture sampling conducted on Guam, Rota, Saipan, and Tinian, 2005–2007. Variance estimates were derived using the following steps. Note that matrices created in Steps 1–5 can most easily be created in MS Excel, using values generated from SAS code provided below. Matrices and matrix algebra described in Step 6 occur in Proc IML (SAS Institute 2003).

1. Output a model-averaged variance-covariance matrix for abundance estimates ($\hat{\hat{N}}$). In Program MARK, select the "Output" tab, select "Model Averaging," and then select "Derived." In the "Model Averaging Parameter Selection" box that opens, select the parameters of interest and check the box for "Export Variance-Covariance Matrix to a dBase file." This *.dbf file includes both the model-averaged variance-covariance matrix and the model-averaged parameter estimates, of which we are interested only in the former.

2. Produce a variance-covariance matrix for MMDM model(s). Generate the variance-covariance matrix in SAS, with the "COV" option in an LSMEANS statement (see SAS Code A). Use the sum of squares error (SSE) and the sample size (corrected total *df* + 1) to estimate $\hat{\sigma}^2$ to use in calculating AIC_c values ((log(ℓ ($\hat{\theta}$)) = -*n*/2 * log($\hat{\sigma}^2$)) and weights to aid in model selection. Use the variance covariance matrix from the top model unless model selection uncertainity exists (top model AIC_c w_i < 0.90), in which case the MMDM variance-covariance matrices should be model-averaged (see SAS Code 2)).

   The MMDM variance-covariance matrix is created by taking the values and applying them to the appropriate site-specific location in an identity matrix. For example, the *Rattus rattus* identity matrix includes all sites with captures (*n* = 18). The top MMDM model (MMDM as a function of Island; see Table 4 in main body of Chapter 1) provides COV output for each island; these values are applied to each site based on its island location, such that Guam sites receive the Guam COV value, Rota sites receive the Rota COV values, etc.

3. Calculate the effective trapping area (ETA), based on the MMDMs determined from modeling. This can be done using the following equation (see Williams et al. 2002:314–315 for further explanation):

$$ETA = Area_{grid} + \left(\left(\frac{MMDM}{2}\right) * 2L\right) + \left(\left(\frac{MMDM}{2}\right) * 2W\right) + \left(4 * \left(\frac{\pi * \left(\frac{MMDM}{2}\right)^2}{4}\right)\right),$$

   which simplifies to

$$ETA = Area_{grid} + \left((MMDM) * L\right) + \left((MMDM) * W\right) + \left(\pi * \left(\frac{MMDM}{2}\right)^2\right).$$

As an example, for *R. rattus* on Guam:

$$ETA = 15625\ m + ((35.617\ m)*125\ m) + ((36.617\ m)*125\ m) + \left(\pi * \left(\frac{35.617\ m}{2}\right)^2\right)$$

$$= 25525.58\ m^2 = 2.55\ ha$$

4. Create a matrix of the partial derivative of ETA with respect to MMDM using the following equation:

$$\frac{\partial\, ETA}{MMDM} = 0 + L + W + 2(MMDM)$$

As an example, for *R. rattus* on Guam $\frac{\partial\, ETA}{MMDM} = 0 + 125\ m + 125\ m + 2(35.617\ m) = 312.39\ m$.

This value is calculated for each site, and placed in the appropriate site-specific location in an identity matrix.

5. Create a variance covariance matrix of the partial derivative of density with respect to $\hat{\hat{N}}$, and density with respect to ETA. In effect, this matrix contains 2, side-by-side identity matrices.

Because of the form of the density formula ($Density = \frac{\hat{\hat{N}}}{ETA}$), these partial derivatives are calculated using the following equations:

$$\frac{\partial\, Density}{\hat{\hat{N}}} = \frac{1}{ETA} \quad \text{and} \quad \frac{\partial\, Density}{ETA} = \frac{-(\hat{\hat{N}})}{(ETA)^2}$$

As an example, for *R. rattus* on Guam $\frac{\partial\, Density}{\hat{\hat{N}}} = \frac{1}{25525.58\ m^2}$ = 0.0000392,

and for *R. rattus* at site MSRG on Guam $\frac{\partial\, Density}{ETA} = \frac{-(41.134)}{(25525.58\ m^2)^2}$ = -0.0000000631/m^2

These values are calculated for each site, and placed in the appropriate site-specific location in an identity matrix (as noted above, this is essentially 2, side-by-side identity matrices) with $\frac{\partial\, Density}{\hat{\hat{N}}}$ on the left side of the matrix and $\frac{\partial\, Density}{ETA}$ on the right side of the matrix.

6. Perform the necessary matrix algebra to create new variance-covariance matrices using SAS Proc IML (see SAS Code 3). In the SAS code, there are a number of Proc IMPORT statements that import worksheets from an Excel spreadsheet. Imported worksheets contain the variance-covariance

matrices created in Steps 1–5 above: Program MARK $\hat{\hat{N}}$ variance-covariance, MMDM variance-covariance, $\frac{\partial ETA}{MMDM}$ variance-covariance, and $\frac{\partial Density}{\hat{\hat{N}}}$ *and* $\frac{\partial Density}{ETA}$ variance-covariance.

Imported datasets are used by Proc IML to generate new variance-covariance matrices, beginning with a variance-covariance matrix for ETA. Symbolically, this involves multiplying 3 matrices:

$$\left(Var\text{–}Cov\ of\ \frac{\partial ETA}{MMDM}\right) * \left(Var\text{–}Cov\ \ of\ \ MMDM\right) * \left(Var\text{–}Cov\ of\ \frac{\partial ETA}{MMDM}\right)^T,$$

where the T indicates that this matrix is transposed. For *R. rattus*, each of these matrices is 18 × 18; as a result of matrix algebra rules this multiplication process produces an 18 × 18 matrix.

Next, Proc IML is used to generate a variance-covariance matrix combining the Program MARK $\hat{\hat{N}}$ variance-covariance matrix and the ETA variance-covariance matrix created in the proceeding step. With the *R. rattus* data, these 18 × 18 matrices are combined to produce a 36 × 36 identity matrix, with Program MARK $\hat{\hat{N}}$ variance-covariance in the upper left quadrant and the ETA variance-covariance in the lower right, and zeros filling in the upper right and lower left quadrants of the matrix. Note that no matrix algebra or other manipulation is involved in this step; instead, existing variance-covariance matrices are combined into a new, larger variance-covariance matrix.

Finally, Proc IML is used to generate a variance-covariance matrix for the density estimates generated from Program MARK $\hat{\hat{N}}$ and MMDM. Symbolically, this involves multiplying 3 matrices:

$$\left(Var\text{–}Cov\ \ of\ \frac{\partial Density}{\hat{\hat{N}}}\ \ and\ \ \frac{\partial Density}{ETA}\right) * \left(Var\text{–}Cov\ \ of\ \ \hat{\hat{N}}\ and\ ETA\right) * \left(Var\text{–}Cov\ of\ \frac{\partial Density}{\hat{\hat{N}}}\ \ and\ \ \frac{\partial Density}{ETA}\right)^T$$

For *R. rattus*, these matrices are [18 × 36]*[36 × 36]*[36 × 18]^T which produces an 18 × 18 matrix of density estimate variances.

Values of interest (variance estimates for density by site) lie along the diagonal of the matrix. Variances are converted to standard errors by taking their square root.

Biomass Variance Estimates

Because biomass estimates were derived from density estimates, biomass variance determination builds from the density variance determination described above. Introduced small mammal biomass estimates were generated using species-specific density estimates and mass estimates from sampling conducted on Guam, Rota, Saipan, and Tinian, 2005–2007. Variance estimates were derived using the following steps:

1. Steps 1–6 above would be repeated for biomass variance determination (if not already completed for density variance determination). Many of the matrices created in these steps are carried over for biomass variance determination. Note that matrices created in Steps 2 and 3 below can most easily

be created in Excel, using data generated from SAS code provided below. Matrices and matrix algebra described in Step 4 below occur in Proc IML (SAS Institute 2003).

2. Produce a variance-covariance matrix for mass model(s). Generate the variance-covariance matrix in SAS, with the "COV" option in an LSMEANS statement (see SAS Code 4). Use the sum of squares error (SSE) and the sample size (corrected total *df* + 1) to estimate $\hat{\sigma}^2$ to use in calculating AIC_c values ((log(ℓ ($\hat{\theta}$)) = -*n*/2 * log($\hat{\sigma}^2$)) and weights for each model to aid in model selection. Use the variance covariance matrix from the top model unless model selection uncertainity exists (top model AIC_c $w_i < 0.90$), in which case the mass variance-covariance matrices should be model-averaged (follows identical procedure as in SAS Code 2)).

   The mass variance-covariance matrix is created by taking the values and applying them to the appropriate site-specific location in an identity matrix. For example, the *R. rattus* identity matrix includes all sites with captures (*n* = 18). The top mass model (mass as a function of site; see Table 5 in main body of Chapter 1) provides COV output for each site, which is entered along the main diagonal of the identity matrix.

3. Create a variance covariance matrix of the partial derivative of biomass with respect to density, and biomass with respect to mass. In effect, this matrix contains 2, side-by-side identity matrices. Because of the form of the biomass formula ($Biomass = Density\ x\ Mass$), these partial derivatives are calculated using the following equations:

   $$\frac{\partial\, Biomass}{Density} = Mass \qquad \text{and} \qquad \frac{\partial\, Biomass}{Mass} = Density$$

   As an example, for *R. rattus* at site KAST on Tinian $\frac{\partial\, Biomass}{Density} = Mass$ = 115.828 g,

   and for *R. rattus* at site RAPF on Rota $\frac{\partial\, Biomass}{Mass} = Density$ = 95.8/ha

   These values are calculated for each site, and placed in the appropriate site-specific location in an identity matrix (as noted above, this is essentially 2, side-by-side identity matrices) with $\frac{\partial\, Biomass}{Density}$ on the left side of the matrix and $\frac{\partial\, Biomass}{Mass}$ on the right side of the matrix.

4. Perform the necessary matrix algebra to create new variance-covariance matrices using SAS Proc IML (see SAS Code 3). In the SAS code, there are a number of Proc IMPORT statements that import worksheets from an Excel spreadsheet. Imported worksheets contain the variance-covariance matrix created in Step 6 from the Density variance determination procedure above, as well as Steps 2 and 3 from the Biomass determination procedure: density estimate variance-covariance, mass variance-covariance, and $\frac{\partial\, Biomass}{Density}$ *and* $\frac{\partial\, Biomass}{Mass}$ variance-covariance.

   Next, Proc IML is used to generate a variance-covariance matrix combining the density variance-covariance matrix and the mass variance-covariance matrix created in the proceeding steps. With the

R. rattus data, these 18 × 18 matrices are combined to produce a 36 × 36 identity matrix, with the density variance-covariance in the upper left quadrant and the mass variance-covariance in the lower right, and zeros filling in the upper right and lower left quadrants of the matrix. Note that no matrix algebra or other manipulation is involved in this step; instead, existing variance-covariance matrices are combined into a new, larger variance-covariance matrix.

Finally, Proc IML is used to generate a variance-covariance matrix for the biomass estimates generated from density estimates and mass estimates. Symbolically, this involves multiplying 3 matrices:

$$\left(Var\text{–}Cov\ of\ \frac{\partial\, Biomass}{Density}\ and\ \frac{\partial\, Biomass}{Mass} \right) * \left(Var\text{–}Cov\ of\ Density\ and\ Mass \right) * \left(Var\text{–}Cov\ of\ \frac{\partial\, Biomass}{Density}\ and\ \frac{\partial\, Biomass}{Mass} \right)^T$$

For *R. rattus*, these matrices are [18 × 36]*[36 × 36]*$[36 \times 18]^T$ which produces an 18 × 18 matrix of density estimate variances.

Values of interest (variance estimates for biomass by site) lie along the diagonal of the matrix. Variances are converted to standard errors by taking their square root.

Literature Cited

SAS Institute. 2003. SAS/STAT software. Version 9.1. SAS Institute, Inc., Cary, North Carolina, USA.

White, G.C., and K.P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46(Supplement):120–138.

Williams, B.K., J.D. Nichols, and M.J. Conroy. 2002. Estimating abundance for closed populations with mark-recapture methods. Pages 289–332 *in* Analysis and management of animal populations. Academic Press, San Diego, California, USA.

SAS Code 1. Code for outputting MMDM variance-covariance values – Density: Step 2 (filename: GLM – Spp MMDM.sas).

```
options formdlim = '-' ps = 80 ls = 95;
data MMDM;
input Spp $ Session $ Island $ Island2 $ Site $ Habitat $ Survey $ AnimalID MoveDis;
/*      Island2: Guam vs. CNMI
        Survey: M-R = Mark-Recapture; REM = Removal
        AnimalID: Unique ID number (assigned by site) for each animal
        MoveDis: Distance in meters between subsequent recaptures          */

cards;
MM   1    Guam     Guam     MSRG     GR   M-R      002   17.68
MM   1    Guam     Guam     MSRG     GR   REM      002   27.95
…         (many more rows of data)
SM   9    Tinian   CNMI     LSUS     NF   REM      233   0
run;

proc sort;
 by Spp;
 where Spp='RR';                    /* Select Spp */
 run;

proc sort;
 by Session;
 run;

proc glm data=MMDM;
 title '** MoveDis=Island GLM **';
 class Island;
 model MoveDis=Island /solution;
 lsmeans Island / noprint out=out1 cov;
 run;
proc print data=out1;
 run;

proc glm data=MMDM;
 title '** MoveDis=Guam vs. CNMI GLM **';
 class Island2;
 model MoveDis=Island2 /solution;
 lsmeans Island2 / noprint out=out2 cov;
 run;
proc print data=out2;
 run;

proc glm data=MMDM;
 title '** MoveDis=Habitat GLM **';
 class Habitat;
 model MoveDis=Habitat /solution;
 lsmeans Habitat / noprint out=out3 cov;
 run;
proc print data=out3;
 run;

proc glm data=MMDM;
 title '** MoveDis=Site GLM **';
 class Site;
 model MoveDis=Site /solution;
 lsmeans Site / noprint out=out4 cov;
 run;
proc print data=out4;
 run;
quit;
```

SAS Code 2. Code for obtaining variance-covariance matrix and model-averaging multiple variance-covariance matrices – Density: Step 2 (filename: IML – Mass and MMDM Var-Cov ModAvg.sas).

```
options formdlim='-' ps=80 ls=100;

/***  Model Averaging of Parameter Estimates and Variance-Covariance Matrices  ***/

Title '***  Model Averaging of MM Mass Var-Cov Matrix  ***';

Proc Import out= work.Mass_Est
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'Mass_Est$'";
  GETNAMES=No;

Proc Import out=work.Mass_Isl
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'Mass_Isl$'";
  GETNAMES=No;

Proc Import out=work.Mass_GCNMI
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'Mass_GCNMI'";
  GETNAMES=No;

Proc Import out=work.Mass_Hab
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'Mass_Hab'";
  GETNAMES=No;

Proc Import out=work.Mass_Site
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'Mass_Site'";
  GETNAMES=No;

/***  Create vectors containing parameter estimates for each Model  ***/;

Proc IML;
Use Mass_Est;
 read all var {F1} into estModel1;
 read all var {F2} into estModel2;
 read all var {F3} into estModel3;
 read all var {F4} into estModel4;

/***  Create Var-Cov matrices for each Model  ***/
/***  This corresponds to 8 columns in the Var-Cov matrix, i.e., 8 estimates of interest  ***/

Use Mass_Isl; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel1;
Use Mass_GCNMI; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel2;
Use Mass_Hab; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel3;
Use Mass_Site; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel4;

/***  Enter model weights for each model  ***/

weights={0.90278 0.04914 0.00040 0.04768};

/*** Model Average the Estimates  ***/

Mean=weights[1]*estModel1+weights[2]*estModel2+weights[3]*estModel3+weights[4]*estModel4;

/*** Model Average the Var-Cov Matrices  ***/

VarAve=weights[1]*(varModel1+(estModel1-Mean)*(estModel1-Mean)`)
+weights[2]*(varModel2+(estModel2-Mean)*(estModel2-Mean)`)
+weights[3]*(varModel3+(estModel3-Mean)*(estModel3-Mean)`)
+weights[4]*(varModel4+(estModel4-Mean)*(estModel4-Mean)`);

/***  Print the model averaged betas and Var-Cov Matrix of the betas  ***/

print Mean VarAve;
quit;

/**********************************************************************************************************************************************************/

Title '***  Model Averaging of MM MMDM Var-Cov Matrix  ***';
```

```
Proc Import out= work.MMDM_Est
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'MMDM_Est$'";
  GETNAMES=No;

Proc Import out=work.MMDM_Isl
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'MMDM_Isl$'";
  GETNAMES=No;

Proc Import out=work.MMDM_GCNMI
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'MMDM_GCNMI'";
  GETNAMES=No;

Proc Import out=work.MMDM_Hab
  DATAFILE= "C:\Documents and Settings\wiewela\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML MM ModAvg Data.xls"
  DBMS=EXCEL2000 REPLACE;
  SHEET="'MMDM_Hab'";
  GETNAMES=No;

/***  Create vectors containing parameter estimates for each Model  ***/;

Proc IML;
Use MMDM_Est;
 read all var {F1} into estModel1;
 read all var {F2} into estModel2;
 read all var {F3} into estModel3;

/***  Create Var-Cov matrices for each Model  ***/
/***  This corresponds to 8 columns in the Var-Cov matrix, i.e., 8 estimates of interest  ***/

Use MMDM_Isl; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel1;
Use MMDM_GCNMI; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel2;
Use MMDM_Hab; read all var {F1 F2 F3 F4 F5 F6 F7 F8} into varModel3;

/***  Enter model weights for each model  ***/

weights={0.71811 0.27183 0.01006};

/*** Model Average the Estimates  ***/

Mean=weights[1]*estModel1+weights[2]*estModel2+weights[3]*estModel3;

/*** Model Average the Var-Cov Matrices  ***/

VarAve=weights[1]*(varModel1+(estModel1-Mean)*(estModel1-Mean)`)
+weights[2]*(varModel2+(estModel2-Mean)*(estModel2-Mean)`)
+weights[3]*(varModel3+(estModel3-Mean)*(estModel3-Mean)`);

/***  Print the model averaged betas and Var-Cov Matrix of the betas  ***/

print Mean VarAve;
quit;
```

SAS Code 3. Code for creating new variance-covariance matrices – Density: Step 6; Biomass: Step 4 (filename: IML – Delta Method Var-Cov Matrices.sas).

```
options formdlim = '-' ps=80 ls=200;

/***  SAS Code for Delta Method Calculation of Density Estimate Variances  ***/

Title "RR Density Estimate Variance Determination by delta method";

/***  Import appropriate files  ***/

/***  Model-averaged N estimates from Program MARK  ***/

Proc Import out=work.RR_Nhat
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'RR_Nhat'";
 GETNAMES=no;

/***  Island-specific MMDM variance-covariance estimates from SAS Analysis  ***/

Proc Import out=work.RR_MMDM
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'RR_MMDM'";
 GETNAMES=no;

/***  Partial derivatives of ETA|MMDM  ***/

Proc Import out=work.RR_ETA
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'RR_Partial_A'";
 GETNAMES=no;

/***  Partial derivatives of Density|N-hat and Density|ETA  ***/

Proc Import out=work.RR_Density
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'RR_Partial_D'";
 GETNAMES=no;

/***  Site-specific Mass variance-covariance estimates from SAS Analysis  ***/

Proc Import out=work.RR_Mass_Site
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'RR_Mass_Site'";
 GETNAMES=no;

/***  Partial derivatives of Biomass|D and Biomass|Mass  ***/

Proc Import out=work.RR_Biomass
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'RR_Partial_B'";
 GETNAMES=no;

Proc IML;
 Use RR_Nhat;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into RR_Nhat_var;
 Use RR_MMDM;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into RR_MMDM_var;
 Use RR_ETA;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into RR_ETA_var;
 Use RR_Density;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18
 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F30 F31 F32 F33 F34 F35 F36} into RR_Density_var;
 Use RR_Mass_Site;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into RR_Mass_var;
 Use RR_Biomass;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18
 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F30 F31 F32 F33 F34 F35 F36} into RR_Biomass_var;

/***  Density  ***/

/***  Create Var-Cov Matrix for Effective Trapping Area (ETA)  ***/

 RR_VC_ETA=RR_ETA_var*RR_MMDM_var*RR_ETA_var`;
 print RR_VC_ETA;
```

```
/***  Create Matrix with RR_Nhat_var in the upper left of the matrix, and RR_VC_ETA in the lower right  ***/

 RR_VC_Nhat_ETA=block(RR_Nhat_var,RR_VC_ETA);
 print RR_VC_Nhat_ETA;

/***  Create Var-Cov Matrix for Density Estimates  ***/

 RR_VC_Density = RR_Density_var*RR_VC_Nhat_ETA*RR_Density_var`;
 print RR_VC_Density;

/***  Note that this is in animals/m2  Conversion to animals/ha  ***/

 C=I(18);
 Convert = C*10000;
 RR_VC_Density_ha = Convert*RR_VC_Density*Convert`;
 print RR_VC_Density_ha;

/***  Biomass  ***/

/***  Create Matrix with RR_VC_Density_ha in the upper left of the matrix, and RR_Mass_Site in the lower right  ***/

 RR_VC_Density_Mass=block(RR_VC_Density_ha,RR_Mass_var);
 print RR_VC_Density_Mass;

/***  Create Var-Cov Matrix for Biomass Estimates  ***/

 RR_VC_Biomass = RR_Biomass_var*RR_VC_Density_Mass*RR_Biomass_var`;
 print RR_VC_Biomass;

/***  Note that this is in g/ha  Conversion to kg/ha  ***/

 Convert2 = C*0.001;
 RR_VC_Biomass_kg_ha = Convert2*RR_VC_Biomass*Convert2`;
 print RR_VC_Biomass_kg_ha;
quit;

/*********************************************************************************************************************************************************/

Title "MM Density Estimate Variance Determination by delta method";

/***  Import appropriate files  ***/

/***  Model-averaged N estimates from Program MARK  ***/

Proc Import out=work.MM_Nhat
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'MM_Nhat'";
 GETNAMES=no;

/***  Model-averaged MMDM estimates from SAS Analysis  ***/

Proc Import out=work.MM_MMDM_ModAvg
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'MM_MMDM_ModAvg'";
 GETNAMES=no;

/***  Partial derivatives of ETA|MMDM  ***/

Proc Import out=work.MM_ETA
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'MM_Partial_A'";
 GETNAMES=no;

/***  Partial derivatives of Density|N-hat and Density|ETA  ***/

Proc Import out=work.MM_Density
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'MM_Partial_D'";
 GETNAMES=no;

/***  Model-averaged Mass variance-covariance estimates from SAS Analysis  ***/

Proc Import out=work.MM_Mass_ModAvg
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'MM_Mass_ModAvg'";
 GETNAMES=no;

/***  Partial derivatives of Biomass|D and Biomass|Mass  ***/
```

```
Proc Import out=work.MM_Biomass
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'MM_Partial_B'";
 GETNAMES=no;

Proc IML;
 Use MM_Nhat;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8} into MM_Nhat_var;
 Use MM_MMDM_ModAvg;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8} into MM_MMDM_var;
 Use MM_ETA;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8} into MM_ETA_var;
 Use MM_Density;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16} into MM_Density_var;
 Use MM_Mass_ModAvg;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8} into MM_Mass_var;
 Use MM_Biomass;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16} into MM_Biomass_var;

/***  Density  ***/

/***  Create Var-Cov Matrix for ETA  ***/

 MM_VC_ETA=MM_ETA_var*MM_MMDM_var*MM_ETA_var`;
 print MM_VC_ETA;

/***  Create Matrix with MM_Nhat_var in the upper left of the matrix, and MM_VC_ETA in the lower right  ***/

 MM_VC_Nhat_ETA=block(MM_Nhat_var,MM_VC_ETA);
 print MM_VC_Nhat_ETA;

/***  Create Var-Cov Matrix for Density Estimates  ***/

 MM_VC_Density = MM_Density_var*MM_VC_Nhat_ETA*MM_Density_var`;
 print MM_VC_Density;

/***  Note that this is in animals/m2  Conversion to animals/ha  ***/

 C=I(8);
 Convert = C*10000;
 MM_VC_Density_ha = Convert*MM_VC_Density*Convert`;
 print MM_VC_Density_ha;

/***  Biomass  ***/

/***  Create Matrix with MM_VC_Density_ha in the upper left of the matrix, and MM_Mass_Site in the lower right  ***/

 MM_VC_Density_Mass=block(MM_VC_Density_ha,MM_Mass_var);
 print MM_VC_Density_Mass;

/***  Create Var-Cov Matrix for Biomass Estimates  ***/

 MM_VC_Biomass = MM_Biomass_var*MM_VC_Density_Mass*MM_Biomass_var`;
 print MM_VC_Biomass;

/***  Note that this is in g/ha  Conversion to kg/ha  ***/

 Convert2 = C*0.001;
 MM_VC_Biomass_kg_ha = Convert2*MM_VC_Biomass*Convert2`;
 print MM_VC_Biomass_kg_ha;
quit;

/**********************************************************************************************************************************************************/

Title "SM Density Estimate Variance Determination by delta method";

/***  Import appropriate files  ***/

/***  Model-averaged N estimates from Program MARK  ***/

Proc Import out=work.SM_Nhat
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Nhat'";
 GETNAMES=no;

/***  Island-specific MMDM estimates from SAS Analysis  ***/

Proc Import out=work.SM_MMDM
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_MMDM'";
```

```
 GETNAMES=no;

/***  Partial derivatives of ETA|MMDM  ***/

Proc Import out=work.SM_ETA
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Partial_A'";
 GETNAMES=no;

/***  Partial derivatives of Density|N-hat and Density|ETA  ***/

Proc Import out=work.SM_Density
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Partial_D'";
 GETNAMES=no;

/***  Habitat-specific Mass variance-covariance estimates from SAS Analysis  ***/

Proc Import out=work.SM_Mass_Hab
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Mass_Hab'";
 GETNAMES=no;

/***  Partial derivatives of Biomass|D and Biomass|Mass  ***/

Proc Import out=work.SM_Biomass
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Partial_B'";
 GETNAMES=no;

Proc IML;
 Use SM_Nhat;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_Nhat_var;
 Use SM_MMDM;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_MMDM_var;
 Use SM_ETA;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_ETA_var;
 Use SM_Density;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into SM_Density_var;
 Use SM_Mass_Hab;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_Mass_var;
 Use SM_Biomass;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into SM_Biomass_var;

/***  Density  ***/

/***  Create Var-Cov Matrix for ETA  ***/

 SM_VC_ETA=SM_ETA_var*SM_MMDM_var*SM_ETA_var`;
 print SM_VC_ETA;

/***  Create Matrix with SM_Nhat_var in the upper left of the matrix, and SM_VC_ETA in the lower right  ***/

 SM_VC_Nhat_ETA=block(SM_Nhat_var,SM_VC_ETA);
 print SM_VC_Nhat_ETA;

/***  Create Var-Cov Matrix for Density Estimates  ***/

 SM_VC_Density = SM_Density_var*SM_VC_Nhat_ETA*SM_Density_var`;
 print SM_VC_Density;

/***  Note that this is in animals/m2  Conversion to animals/ha  ***/

 C=I(9);
 Convert = C*10000;
 SM_VC_Density_ha = Convert*SM_VC_Density*Convert`;
 print SM_VC_Density_ha;

/***  Biomass  ***/

/***  Create Matrix with SM_VC_Density_ha in the upper left of the matrix, and SM_Mass_Site in the lower right  ***/

 SM_VC_Density_Mass=block(SM_VC_Density_ha,SM_Mass_var);
 print SM_VC_Density_Mass;

/***  Create Var-Cov Matrix for Biomass Estimates  ***/

 SM_VC_Biomass = SM_Biomass_var*SM_VC_Density_Mass*SM_Biomass_var`;
 print SM_VC_Biomass;
```

```
/***  Note that this is in g/ha  Conversion to kg/ha  ***/

 Convert2 = C*0.001;
 SM_VC_Biomass_kg_ha = Convert2*SM_VC_Biomass*Convert2`;
 print SM_VC_Biomass_kg_ha;
quit;

/*********************************************************************************************************************************************************/

/***  The top model for SM has 99% of the weight. It may be more appropriate
      to use var-cov from this model rather than the model-averaged var-cov. ***/

Title "SM (Top Model) Density Estimate Variance Determination by delta method";

/***  Import appropriate files  ***/

/***  Model-averaged N estimates from Program MARK  ***/

Proc Import out=work.SM_Nhat_TopMod
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Nhat_TopMod'";
 GETNAMES=no;

/***  Island-specific MMDM estimates from SAS Analysis  ***/

Proc Import out=work.SM_MMDM
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_MMDM'";
 GETNAMES=no;

/***  Partial derivatives of ETA|MMDM  ***/

Proc Import out=work.SM_ETA
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Partial_A'";
 GETNAMES=no;

/***  Partial derivatives of Density|N-hat and Density|ETA  ***/

Proc Import out=work.SM_Density
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Partial_D'";
 GETNAMES=no;

/***  Habitat-specific Mass variance-covariance estimates from SAS Analysis  ***/

Proc Import out=work.SM_Mass_Hab
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Mass_Hab'";
 GETNAMES=no;

/***  Partial derivatives of Biomass|D and Biomass|Mass  ***/

Proc Import out=work.SM_Biomass
 DATAFILE= "C:\Documents and Settings\wiewela.FORT\My Documents\USGS BTS Project\Sys Rod Mon\Data Analyses\SAS\IML VarCov Data.xls"
 DBMS=EXCEL2000 REPLACE;
 SHEET="'SM_Partial_B'";
 GETNAMES=no;

Proc IML;
 Use SM_Nhat_TopMod;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_Nhat_TopMod_var;
 Use SM_MMDM;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_MMDM_var;
 Use SM_ETA;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_ETA_var;
 Use SM_Density;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into SM_Density_var;
 Use SM_Mass_Hab;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9} into SM_Mass_var;
 Use SM_Biomass;
 read all var {F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18} into SM_Biomass_var;

/***  Density  ***/

/***  Create Var-Cov Matrix for ETA  ***/

 SM_VC_ETA=SM_ETA_var*SM_MMDM_var*SM_ETA_var`;
 print SM_VC_ETA;
```

```
/***  Create Matrix with SM_Nhat_TopMod_var in the upper left of the matrix, and SM_VC_ETA in the lower right  ***/

 SM_VC_Nhat_TopMod_ETA=block(SM_Nhat_TopMod_var,SM_VC_ETA);
 print SM_VC_Nhat_TopMod_ETA;

/***  Create Var-Cov Matrix for Density Estimates  ***/

 SM_VC_Density = SM_Density_var*SM_VC_Nhat_TopMod_ETA*SM_Density_var`;
 print SM_VC_Density;

/***  Note that this is in animals/m2  Conversion to animals/ha  ***/

 C=I(9);
 Convert = C*10000;
 SM_VC_Density_ha = Convert*SM_VC_Density*Convert`;
 print SM_VC_Density_ha;

/***  Biomass  ***/

/***  Create Matrix with SM_VC_Density_ha in the upper left of the matrix, and SM_Mass_Site in the lower right  ***/

 SM_VC_Density_Mass=block(SM_VC_Density_ha,SM_Mass_var);
 print SM_VC_Density_Mass;

/***  Create Var-Cov Matrix for Biomass Estimates  ***/

 SM_VC_Biomass = SM_Biomass_var*SM_VC_Density_Mass*SM_Biomass_var`;
 print SM_VC_Biomass;

/***  Note that this is in g/ha  Conversion to kg/ha  ***/

 Convert2 = C*0.001;
 SM_VC_Biomass_kg_ha = Convert2*SM_VC_Biomass*Convert2`;
 print SM_VC_Biomass_kg_ha;
quit;
```

SAS Code 4. Code for outputting Mass variance-covariance values – Biomass: Step 2 (filename: GLM – Spp Mass for Biomass Calculations.sas).

```
options formdlim = '-' ps = 80 ls = 95;
data MASS;
input Spp $ Exclude $ Survey $ Island $ Island2 $ Habitat $ Site $ AnimalID $ Sex $ Age $ RepCond $ Mass;
/*      Exclude:    1 = all captured individuals (M-R and REM)
                    2 = marked animals recaptured during REM
        Survey: M-R = Mark-Recapture; REM = Removal
        Island2: Guam vs. CNMI
        Sex: Male = 1, Female = 0
        Age: Adult = 1, Juv = 0
        RepCond: Mature = 1, Immature = 0
        AnimalID: Unique ID number (assigned by site) for each animal      */

cards;
MM   1    M-R  Saipan    CNMI    GR    ACHU     ACHU_MM_001  0    1    0    13
MM   1    M-R  Saipan    CNMI    GR    ACHU     ACHU_MM_053  0    1    0    9.75
…         (many more rows of data)
SM   2    REM  Saipan    CNMI    HET   SPOR     SPOR_SM_406  1    1    1    32
run;

proc sort;
 by Spp;
 where Spp='RR';                  /* Select Spp */
 run;

proc sort;
 by Survey Site;
 run;

proc glm data=MASS;
 title '** M-R Mass=Island GLM **';
 where Survey='M-R';
 class Island;
 model Mass=Island /solution;
 lsmeans Island / noprint out=out1 cov;
 run;
proc print data=out1;
 run;

proc glm data=MASS;
 title '** M-R Mass=Guam vs. CNMI GLM **';
 where Survey='M-R';
 class Island2;
 model Mass=Island2 /solution;
 lsmeans Island2 / noprint out=out2 cov;
 run;
proc print data=out2;
 run;

proc glm data=MASS;
 title '** M-R Mass=Habitat GLM **';
 where Survey='M-R';
 class Habitat;
 model Mass=Habitat /solution;
 lsmeans Habitat / noprint out=out3 cov;
 run;
proc print data=out3;
 run;

proc glm data=MASS;
 title '** M-R Mass=Site GLM **';
 where Survey='M-R';
 class Site;
 model Mass=Site /solution;
 lsmeans Site / noprint out=out4 cov;
 run;
proc print data=out4;
 run;
quit;
```

APPENDIX 1C. Comparison of density estimates from Programs MARK and DENSITY

Density estimation from grid-based, mark-recapture sampling is complicated by difficulties in quantifying the true area sampled. Using the area of the grid itself (often referred to as naïve or nominal density) does not account for the unknown boundary area used by animals living along the edges of the grid, thereby underestimating the area sampled and producing a positively biased density estimate (Anderson et al. 1983, Wilson and Anderson 1985, Efford 2004). Alternative methods for determining the true area sampled by the grid, often referred to as the effective trapping area (ETA), include adding a boundary strip equal to ½ the average home range to the trapping grid (Dice 1938), using captures on nested subgrids within the grid to estimate the size of the boundary strip (Otis et al. 1978), or using a measure of animal movement, such as the mean maximum distance moved (MMDM), to determine the ETA (Wilson and Anderson 1985). A number of conceptual and procedural arguments against these ETA estimation methods have been presented in recent years (Anderson et al. 1983, Wilson and Anderson 1985). The primary objections relate to the influence of trap spacing and the number of recaptures on estimates of animal movements, and therefore estimates of ETA (Wilson and Anderson 1985). An alternative approach for determining density, using the recently developed software package Program DENSITY (Efford 2004), attempts to avoid the issue of determining ETA altogether. Instead, DENSITY uses an inverse prediction procedure to find a hypothetical density of animals, given the sampling methodology employed by the researcher, which could produce the capture and recapture results obtained during sampling.

We compared density estimates generated using the inverse prediction procedure in DENSITY to more traditional density estimates generated by dividing mark-recapture livetrapping abundance estimates generated using Program MARK by estimated ETA. Because we did not know true small mammal density on our sites, we could not directly evaluate the accuracy or precision of density estimates derived from DENSITY and MARK. Instead, our evaluation of these methods was based on species-specific comparisons of:

1. density estimates and variances, under the assumption that estimates with lower variance provide more useful information than estimates with higher variance, and

2. the ability of each method to produce density estimates from field data, including datasets with limited captures and recaptures.

Density Estimation Methods

Program DENSITY: Site- and species-specific density estimates were generated in DENSITY 3.3. DENSITY avoids issues associated with estimating the ETA by using an inverse prediction procedure to find a hypothetical density of animals, given the sampling methodology employed by the researcher, which would produce the mark-recapture trapping results obtained by the researcher. DENSITY allows the researcher to select among several estimators, including both traditional estimators such as M_0, M_t, M_b, and M_h (Otis et al. 1978, Burnham and Overton 1978) as well more recently developed estimators, including $M_{h\ Chao}$ and $M_{h\ Chao\ modified}$ (Chao 1987), $M_{h\ 2\text{-point mixture}}$ (Pledger 2000), $M_{h\ Beta\text{-binomial}}$ (Dorazio and Royle 2003), and $M_{th\ Chao\ coverage\ 1\ and\ 2}$ (Lee and Chao 1994). Efford (2004) states the choice of estimator may be relatively unimportant for density estimation, but goes on to recommend $M_{th\ Chao\ coverage\ 1}$ or $M_{th\ Chao\ coverage\ 2}$ (Lee and Chao 1994) as estimators that have proven especially robust to heterogeneity in capture probability in many field situations. However, to facilitate comparison between density estimates, we chose to select the estimator in DENSITY which most closely approximated the top model identified for each species during MARK modeling.

Program MARK: Site-and species-specific abundance estimates were generated using the Huggins (1989, 1991) conditional likelihood closed population model available in MARK 4.3 (White and Burnham 1999; see full description of modeling approach in Methods of Chapter 1). These estimates were combined with estimates of ETA to generate density estimates. ETA was calculated as the total area encompassed by the nominal trapping area (1.56 ha) plus a boundary strip equal to ½ the MMDM between captures (Wilson and Anderson 1985). MMDM was estimated separately for each species using multiple analysis of variance models (Proc GLM, SAS Institute 2003), where the candidate models allowed MMDM to vary by island, Guam and RST (Rota, Saipan, and Tinian combined), and habitat. A site-specific MMDM model was not considered because of concerns that limited movement data for several sites. Candidate MMDM models were evaluated based on AIC_c scores and MMDM estimates and variances were model-averaged as necessary to account for model selection uncertainty (Burnham and Anderson 2002:150). For each species, mark-recapture and removal sampling data were combined to increase MMDM sample size, after first verifying that movements were not significantly different between sampling methods. Removal sampling movement observations occurred when animals originally captured during mark-recapture were recaptured during removal sampling. The combination of mark-recapture and removal sampling datasets increased movement sample size by 58% for *Rattus rattus*, 45% for *Suncus murinus*, and 41% for *Mus musculus*. Variance-covariance matrices of the density and ETA estimates were computed using the delta method (Seber 2002), from which we were able to determine the variance of derived density estimates (Appendix 1B).

Evaluation of Density Estimates

Density estimates for *R. rattus*, *S. murinus*, and *M. musculus* were generated in Program DENSITY using the M_t estimator (*R. rattus*) and the $M_{th\ Chao\ coverage\ 1}$ estimator (*S. murinus* and *M. musculus*), as these estimators most closely approximated the structure of the top model for each species in our Program MARK analyses (see Table 7 in main body of Chapter 1). In contrast to modeling in MARK, which allowed us to generate density estimates for all sites where *R. rattus* (Table C.1), *S. murinus* (Table C.2), and *M. musculus* (Table C.3) were captured, DENSITY produced estimates for only 44.4% of sites with *R. rattus* captures, 55.6% of sites with *S. murinus* captures, and 37.5% of sites with *M. musculus* captures under the default inverse prediction parameters. While it was not surprising that DENSITY failed to produce estimates for sites with low captures and recaptures (e.g., most of the Guam sites), it also failed to produce estimates for several sites with large numbers of captures and recaptures such as RAPF (*R. rattus* M_{t+1} = 106, $n_{.}$ = 146) and KAST (*R. rattus* M_{t+1} = 106, $n_{.}$ = 132). Modification of inverse prediction parameters, including increasing the number of simulation replicates, decreasing the required precision, and excluding “extreme” movement observations (as recommended in the DENSITY Help file) improved the success rate of the inverse prediction procedure, such that density estimates were generated for 2 additional sites for both *R. rattus* (Table C.1) and *M. musculus* (Table C.3), including all sites with seemingly adequate numbers of captures and recaptures. Modification of inverse prediction procedures did not result in additional successful *S. murinus* density estimates (Table C.2).

Site-specific comparisons between DENSITY (for sites with estimates) and MARK revealed essentially equivalent density estimates (Tables C.1, C.2, C.3). Discrepancies between density estimates were generally small, with no apparent pattern to which method produced the greater estimate or variance. More importantly, on a site-specific basis, the 95% CIs overlapped for all estimates, and in all but 4 occasions (1 *R. rattus*, 2 *M. musculus*, and 1 *S. murinus*) the density estimate from DENSITY was included in the 95% CI from MARK, and vice versa (Tables C.1, C.2, C.3). However, DENSITY could not generate estimates for sites with sparse capture or recapture data, limiting the utility of this software. This limitation is thought to be addressed in the updated version of the software (Version 4.0) to be released in Fall 2007.

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Table C.1. *Rattus rattus* density estimates ($\hat{D}$), standard errors (SE), and 95% confidence intervals (95% CI) generated from mark-recapture livetrapping of grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007, using Program MARK 4.3 and Program DENSITY 3.3. For Program DENSITY, "Failed" indicates that the program could not generate a density estimate.

		Program MARK			Program DENSITY		
Site	Habitat	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI
Guam[a]							
MSRG	grassland	15.9	3.7	8.6–23.2	Failed		
ASMF	*Leucaena* forest	2.6	0.7	1.2–4.0	Failed		
CP05	*Leucaena* forest	2.6	1.0	0.6–4.6	Failed		
CP06		15.3	3.5	8.4–22.2	12.7	5.7	5.5–29.6
GSYF	*Leucaena* forest	8.9	2.3	4.4–13.4	Failed		
GAHF	mixed	0.7	0.5	0–1.7	Failed		
Rota							
SABA	grassland	73.2	11.9	49.9–96.5	71.1	15.1	47.1–107.3
GAON	*Leucaena* forest	36.0	6.7	22.9–49.1	23.2	5.7	14.5–37.2
RAPF	mixed	95.8	16.1	64.2–127.4	80.2	11.2	61.1–105.3
ASAK	native forest	9.2	2.2	4.9–13.5	Failed		
Saipan							
ACHU	grassland	33.0	6.4	20.5–45.5	18.3	4.8	11.1–30.3
OBYT	*Leucaena* forest	41.4	8.1	25.5–57.3	60.0	28.6	24.7–145.8
SAEN	mixed	6.9	2.1	2.8–11.0	Failed		
SPOR	mixed	25.1	5.4	14.5–35.7	31.0	15.1	12.5–76.6
LATT	native forest	21.6	5.1	11.6–31.6	Failed		
Tinian							
KAST	grassland	99.9	17.9	64.8–135.0	92.7	17.7	64.0–134.1
ABLE	*Leucaena* forest	44.0	7.3	29.7–58.3	30.6	5.8	21.3–44.1
LSUS	native forest	75.1	13.6	48.4–101.8	103.3	32.0	57.0–187.0

[a] Zero *R. rattus* captured at 4 sites (2 *Leucaena* forest, 2 native forest).

Table C.2. *Suncus murinus* density estimates ($\hat{D}$), standard errors (SE), and 95% confidence intervals (95% CI) generated from mark-recapture livetrapping of grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Saipan, and Tinian, 2005–2007, using Program MARK 4.3 and Program DENSITY 3.3. For Program DENSITY, "Failed" indicates that the program could not generate a density estimate. *S. murinus* was not captured on Rota.

		Program MARK			Program DENSITY		
Site	Habitat	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI
Guam[a]							
MSRG	grassland	8.5	2.5	3.6–13.4	6.0	4.4	1.7–21.6
Saipan							
ACHU	grassland	13.4	3.7	6.1–20.7	5.8	2.3	2.8–12.2
OBYT	*Leucaena* forest	31.6	10.2	11.6–51.6	29.4	10.3	15.1–57.2
SAEN	mixed	32.9	9.6	14.1–51.7	29.5	9.3	16.2–57.7
SPOR	mixed	6.3	2.2	2.0–10.6	Failed		
LATT	native forest	14.0	5.2	3.8–24.2	Failed		
Tinian							
KAST	grassland	8.9	2.5	4.0–13.8	Failed		
ABLE	*Leucaena* forest	73.7	20.1	34.3–113.1	99.5	26.4	59.7–165.9
LSUS	native forest	32.8	9.6	14.0–51.6	Failed		

[a] Zero *S. murinus* captured at 9 sites (6 *Leucaena* forest, 1 mixed habitat, and 2 native forest).

Table C.3. *Mus musculus* density estimates ($\hat{D}$), standard errors (SE), and 95% confidence intervals (95% CI) generated from mark-recapture livetrapping of grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007, using Program MARK 4.3 and Program DENSITY 3.3. For Program DENSITY, "Failed" indicates that the program could not generate a density estimate.

		Program MARK			Program DENSITY		
Site	Habitat	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI
Guam[a]							
MSRG	grassland	7.2	1.7	3.9–10.5	3.8	1.9	1.5–9.4
Rota							
SABA	grassland	20.7	5.0	10.9–30.5	21.8	17.5	5.5–86.9
GAON	*Leucaena* forest	16.0	4.1	8.0–24.0	19.9	16.1	5.0–80.1
RAPF	mixed	26.5	6.3	14.2–38.8	24.6	8.4	12.8–47.1
ASAK	native forest	0.8	0.6	0–2.0	Failed		
Saipan[b]							
ACHU	grassland	36.5	8.1	20.6–52.4	25.4	4.1	18.5–34.9
OBYT	*Leucaena* forest	1.5	0.7	0.1–2.9	Failed		
Tinian[c]							
KAST	grassland	8.2	2.7	2.9–13.5	Failed		

[a] Zero *M. musculus* captured at 9 sites (6 *Leucaena* forest, 1 mixed habitat, and 2 native forest).
[b] Zero *M. musculus* captured at 3 sites (2 mixed habitat and 1 native forest).
[c] Zero *M. musculus* captured at 2 sites (1 *Leucaena* forest and 1 native forest).

CHAPTER 2: EVALUATING ABUNDANCE ESTIMATES AND THE ASSUMPTIONS OF A COUNT-BASED INDEX OF ABUNDANCE FOR SMALL MAMMALS

INTRODUCTION

One of the most common questions in ecological research or management is: "How many are there?" Ideally, this question would be answered with a complete count, or census, of the population of interest. In practice, many species have life history traits which complicate population censuses. For example, most small mammal species are cryptic, nocturnal, and have spatially and temporally variable densities which generally preclude the use of a population census. Thus, small mammal researchers are often able to sample only a portion of the population, from which they make inference about the entire population of interest (Lancia et al. 2005). This approach requires that researchers select the most appropriate and reliable sampling and data analysis method(s) available, based on research objectives and the ecology of target species (Pollock et al. 2002, Witmer 2005).

Two of the most commonly used small mammal sampling methods are livetrapping and snaptrapping (Lancia et al. 2005). The primary difference between these methods is that livetrapping yields live animal captures, whereas captured animals are killed during snaptrapping. The usefulness of snaptrapping for long-term monitoring of small mammal abundance, distribution, or diversity is questionable, as the sampling method is highly disruptive to the study population (Sullivan et al. 2003) and could confound effects of interest. Further, direct comparisons between livetrapping and snaptrapping (or analogous methods such as seining and electrofishing) have produced equivocal or conflicting results, leading to uncertainty about the utility of methods which removal animals from the study population (Stickel 1946a, Yang et al. 1970, Bohlin and Sundstrom 1977, Rodgers et al. 1992, Sullivan et al. 2003, Rosenberger and Dunham 2005). Despite these potential issues, snaptrapping is often used alone or in conjunction with other methods such as pitfall sampling to study small mammal demography, habitat preferences, or response to management activities (e.g., Roberts and Craig 1990, Mitchell et al. 1995, Christian et al. 1997, Bellows et al. 2001, Ecke et al. 2002), perhaps because the method is thought to be faster and cheaper than livetrapping.

Both livetrapping and snaptrapping can provide data suitable for abundance estimation, although the removal of animals from the population during snaptrapping limits applicable estimation methods (Otis et al. 1978, White et al. 1982). During livetrapping, captured animals can be uniquely marked and released back into the study population, where they are available for recapture during subsequent sampling occasions, a process commonly referred to as mark-recapture (also capture-recapture or capture-mark-recapture) sampling. If continued over multiple sampling occasions, the capture history of marked and unmarked individuals on each sampling occasion can be used to generate a mark-recapture abundance estimate ($\hat{N}_{\mathrm{M-R}}$). For example, over 2 sampling occasions

$$\hat{N}_{\mathrm{M-R}} = \frac{n_1 n_2}{m_2},$$

where n_1 is the number of individuals captured and marked on occasion 1, n_2 is the number of individuals captured on occasion 2, and m_2 is the number of marked individuals recaptured on occasion 2 (Pollock et al. 1990). This most basic mark-recapture abundance estimator (the Lincoln-Petersen estimator) is subject to several assumptions: population closure (no births, deaths, emigration or immigration during sampling), no loss or misidentification of unique animal identifiers, and equal probability of capture for all animals on each sampling occasion (Williams et al. 2002). While the first assumption, population closure, can be relaxed if open population models are considered (Jolly 1965, Seber 1965), the scope of this paper is restricted to closed populations. Extending sampling over additional occasions allows the use of more sophisticated mark-recapture abundance estimators which relax the assumption of equal capture probability, which is unlikely to hold for wild populations and can cause bias in Lincoln-Peterson abundance estimates (Carothers 1973, Otis et al. 1978). These estimators have the general form

$$\hat{N}_{\mathrm{M-R}} = \frac{M_{\mathrm{t+1}}}{\hat{p}},$$

where $M_{\mathrm{t+1}}$ is the count of unique animals captured during sampling and $\hat{p}$ is the estimated cumulative capture probability, defined as the proportion of the total population captured and estimated from the relationship between new captures and recaptures over multiple sampling occasions (Nichols 1992). Like the Lincoln-Petersen estimator, these estimation methods are subject to the assumption of population closure and no tag loss or misidentification, but also add the assumption that capture probability is appropriately modeled (Williams et al. 2002). Following the nomenclature of Otis et al. (1978), capture probability can be modeled as being constant (M_0) or allowed to vary over time (M_t), between marked and unmarked individuals (i.e., behavioral response to capture; M_b), between all individuals (i.e., individual heterogeneity; M_h), or combinations of these factors (M_{tb}, M_{bh}, M_{th}, M_{tbh}). Recent advances in estimator development permit even more complex models, such as those incorporating mixture models (Norris and Pollock 1996, Pledger 2000) or covariates (Pollock et al. 1984; Huggins 1989, 1991). For a complete discussion of the history and development of mark-recapture abundance estimation methods, refer to Otis et al. 1978, White et al. 1982, Nichols 1992, Williams et al. 2002, and Lancia et al. 2005.

In contrast to livetrapping, the removal of captured animals from the population during snaptrapping eliminates the possibility of recaptures. This constraint limits suitable abundance estimation methods, as fewer data are available to model capture probability relative to mark-recapture sampling (Otis et al. 1978, White et al. 1982). Over 2 sampling occasions, snaptrapping can be used to generate removal abundance estimates ($\hat{N}_{\text{REM}}$) of the general form

$$\hat{N}_{\text{REM}} = \frac{n_1^2}{n_1 - n_2},$$

where n_1 is the number of individuals removed on occasion 1 and n_2 is the number of individuals removed on occasion 2 (Pollock 1991). Note that the form of this estimator requires that $n_1 > n_2$ (i.e., captures must decline from the first to the second sampling occasion to produce a viable estimate). Sampling over additional occasions allows $\hat{N}_{\text{REM}}$ to be generalized as

$$\hat{N}_{\text{REM}} = \frac{M_{t+1}}{\hat{p}},$$

where p is now estimated from the change in number of animals captured over successive sampling occasions (Pollock 1991). The generalized estimator does not relax the requirement that captures decline over successive sampling occasions; in fact, without this decline one cannot accurately estimate p or generate robust and unbiased $\hat{N}_{\text{REM}}$ from snaptrapping data (Otis et al. 1978, White et al. 1982, Pollock 1991). Early removal estimation methods assumed that capture probability was constant for all animals and across all sampling occasions (Zippin 1956, 1958). More recent estimation methods relax this assumption somewhat, but all removal abundance estimation methods assume population closure (outside of known removals associated with sampling) and that capture probability is modeled correctly. Recommended removal abundance estimators include M_b and M_{bh} (Otis et al. 1978), where the removal of animals is considered an extreme behavioral response to initial capture (i.e., recapture probability = 0). As with mark-recapture abundance estimation methods, recent advances allow more sophisticated models incorporating mixture models (Norris and Pollock 1996, Pledger 2000) or covariates (Pollock et al. 1984; Huggins 1989, 1991). The applicability of various estimators (M_b and M_{bh}) to both livetrapping and snaptrapping data illustrates an important and sometimes unrecognized point: livetrapping data can also be used to generate $\hat{N}_{\mathrm{REM}}$ if recaptures are not considered during the estimation process (Otis et al. 1978). For a more thorough discussion of the history and development of removal abundance estimation methods, refer to Otis et al. 1978, White et al. 1982, and Williams et al. 2002.

Many researchers using either livetrapping or snaptrapping choose to forgo abundance estimation altogether and instead report only count-based indices of abundance, such as the number of individuals captured (M_{t+1}; Otis et al. 1978) or the captures per unit effort (CPUE; White et al. 1982). Index proponents suggest that indices require less analytical expertise and are subject to fewer or less restrictive assumptions than abundance estimation methods (Engeman 2005), while providing data suitable for relative comparisons between populations across space and time (Engeman 2003, 2005). Careful consideration of conditions surrounding the application of indices, however, suggests that they are not without potentially restrictive assumptions. For example, the assumption of population closure is critical for any comparison between populations, regardless of the metric the comparison is based on. More importantly, the inherent assumption of any index is that the relationship between the index and true abundance is monotonic, proportional, and constant across space and time (Nichols 1992; Anderson 2001, 2003). Unfortunately, few researchers test this assumption, either by evaluating indices against known populations (Conn et al. 2006), double sampling using both an index and a more rigorous sampling technique (Eberhardt and Simmons 1987, Slade and Blair 2000), or through simulation (McKelvey and Pearson 2001). Failure to validate indices limits their utility for making inference about animal populations (Nichols 1992; Anderson 2001, 2003).

As part of a larger study of introduced small mammal populations in the Mariana Islands, we evaluated livetrapping and snaptrapping in terms of sampling efficiency (the cost and time associated with implementing each method) and numerical estimation. Based on experience with these sampling methods, our *a priori* expectation was that snaptrapping would be both cheaper and faster than livetrapping. To evaluate numerical estimates, we compared site- and species-specific abundance estimates and count-based indices of abundance (M_{t+1} and CPUE) generated from each sampling method. *A priori*, we expected mark-recapture abundance estimates generated from livetrapping data to be more precise (i.e., have a smaller coefficient of variation and narrower 95% confidence intervals) than removal abundance estimates or count-based indices generated from either livetrapping or snaptrapping data. We based this hypothesis on the amount of information used to generate each estimate or index ($\hat{N}_{\text{M}-\text{R}} > \hat{N}_{\text{REM}}$ > CPUE > M_{t+1}) as discussed above, as well as the anticipated robustness of each metric to violations of critical assumptions, such as population closure, and sources of variation in capture probability. For example, temporal variation in capture probability would invalidate both M_{t+1} and CPUE, as the relationship between the indices and true abundance would no longer be constant across time. More importantly, these indices provide no means of recognizing temporal variation in capture probability, and therefore no criteria for determining the validity of the index. Removal abundance estimate methods are more robust to temporal variation in capture probability than indices, although such variation is likely to reduce the accuracy and precision of these estimates (Otis et al. 1978); if captures do not decline over time, however, removal abundance estimation methods will produce inaccurate and imprecise estimates. In contrast, mark-recapture abundance estimation methods are well suited for identifying and accounting for temporal variation in capture probability if sufficient data are available for modeling (Otis et al. 1978). Further discussion of the robustness of each metric to various sources of capture probability variation is provided in Table 1. Finally, because indices are frequently generated from short duration sampling events, we investigated the effects of sampling duration on index performance by evaluating M_{t+1} and CPUE generated from 1, 3, and 5 days of livetrapping and snaptrapping data, with the *a priori* expectation that the precision of these indices would increase with increased sampling duration.

METHODS

For a complete description of the study site selection and small mammal sampling protocols used during this research (described below), please refer to Wiewel (2005).

Study Site Selection

Sampling was conducted during 2005–2006 on Guam, Rota, Saipan, and Tinian in the Mariana Islands, an archipelago of 15 islands arrayed in a north-south arc between approximately 13° and 21° N and 144° and 146° E (Metteler 1986; Figure 1). Potential study sites were identified using a combination of 1:24,000 and 1:25,000 scale topographical maps (U.S. Geological Survey 1999a,b,c; 2000) and 1:20,000 scale vegetation maps (Falanruw et al. 1989). These sites were then evaluated based on habitat type, available area of relatively homogeneous habitat, and land ownership status. Selected sites represented the 3 major habitat types of the southern Mariana Islands: grassland, native limestone forest, and secondary forest dominated by *Leucaena leucocephala*, an introduced leguminous tree (Mueller-Dombois and Fosberg 1998). Additional sites were selected near airports and seaports, independent of habitat type, to better understand introduced small mammal populations in these areas which are important for brown treesnake (*Boiga irregularis*) control and management in the Mariana Islands. These sites generally included several habitat types (typically grassland and *L. leucocephala*-dominated secondary forest) and are classified as mixed habitat. With the exception of mixed habitat sites, potential sites contained ≥4 ha of relatively homogeneous habitat. Selected sites were located primarily on military and public lands because these areas frequently offered larger tracts of homogeneous habitat and because accurate information about private land ownership was often difficult to obtain. Sampling occurred at 7 sites on Guam, 4 on Rota, 5 on Saipan, and 3 on Tinian (Table 2). On each island, at least 1 grassland site, 1 native limestone forest site, and 1 *L. leucocephala*-dominated secondary forest site were selected and sampled. Five sites were sampled near airports and seaports on Guam (n = 2), Rota (n = 1), and Saipan (n = 2; Table 2).

Small Mammal Sampling

At each selected site, sampling activities occurred over 2 weeks and consisted of (in chronological order) a 2-day live trap acclimation period, a 5-day livetrapping period, a 2-day snap trap acclimation period, and a 5-day snaptrapping period. During acclimation periods traps were placed on the trapping grid but not baited. Species targeted during sampling include *Mus musculus*, *Rattus exulans*, *R. norvegicus*, *R. rattus,* and *Suncus murinus,* all of which are introduced in the Mariana Islands. There is uncertainty regarding the status of *R. rattus* and a closely related and morphologically similar species, *R.*

tanezumi (Musser and Carleton 2005:1484–1487, 1489–1491), in the Mariana Islands. Due to this uncertainty, we collected genetic material from all captured *Rattus* and are in the process of confirming species identification and distribution. Analysis of the cytochrome oxidase I mtDNA region of 8 specimens from northern and central Guam indicated that all were *R. diardii* (sensu Robins et al. 2007), rather than the expected *R. rattus* and *R. tanezumi*. Until samples from all islands are processed, however, we will use the more recognized term *R. rattus* to refer to the combined sample of unidentified *Rattus* species.

Sampling was conducted on an 11 × 11 grid with 12.5 m intervals between each trap station (nominal area = 1.56 ha). During livetrapping, a single standard-length folding Sherman live trap (229 × 89 × 76 mm; H.B. Sherman Traps, Inc., Tallahassee, FL) was placed at each trap station (*n* = 121) and a single Haguruma wire mesh live trap (approximately 285 × 210 × 140 mm; Standard Trading Co., Honolulu, HI) was placed at every other trap station (*n* = 36; Figure 2). Immediately following the final check of live traps, each Sherman trap was replaced with a single Museum Special snap trap (141 × 70 × 15 mm; Woodstream Corporation, Lititz, PA) and each Haguruma trap was replaced with a single Victor rat snap trap (175 × 84 × 28 mm; Model M201, Woodstream Corporation, Lititz, PA).

Trap selection and spacing were determined based on a combination of literature review and preliminary testing of these sampling parameters. Two types of live and snap traps were used to maximize captures of target species, based on preliminary trap evaluations in the Mariana Islands (Gragg 2004, Wiewel 2004a,b). Trap spacing was selected based on review of target species' home range and movement patterns. Thus, Sherman and Museum Special traps, which we believed would best capture *M. musculus* and *S. murinus* (Gragg 2004, Wiewel 2004b), were spaced at 12.5 m intervals to match the relatively small average home ranges of these species (Baker 1946; Barbehenn 1969, 1974). Similarly, Haguruma and Victor traps, which we believed would be more appropriate for capturing *Rattus* species (Gragg 2004, Wiewel 2004a), were spaced at 25 m intervals to better match the larger average home ranges of these species (Baker 1946, Strecker 1962, Barbehenn 1974, Dowding and Murphy 1994, Lindsey et al. 1999).

Traps were placed on the ground and, whenever possible, located next to or beneath clumps of grass, downed woody debris, or rocks to provide shelter from sun and rain. Traps were baited with a mixture of peanut butter, oats, and food-grade paraffin (Wiewel 2004a) and were checked beginning around 0730–0800 each day. Traps were closed throughout the day to minimize trap mortality, reopened at approximately 1600, and rebaited as necessary to ensure bait freshness. We recorded the time required to complete daily activities associated with each sampling method, including trap baiting, trap monitoring, and captured animal processing, for comparative purposes.

Animals captured during livetrapping were uniquely marked in each ear with appropriately sized numbered metal ear tags (*M. musculus* and *S. murinus*: small ear tags produced by S. Roestenburg, Riverton, UT; *Rattus* species: #1005-1, National Band and Tag Co., Newport, KY), allowing us to identify recaptured individuals. During both livetrapping and snaptrapping, captured animals were examined and measured to determine species, sex, age, and reproductive status, mass (g), head-body length (mm), tail length (mm), right hind foot length (mm), right ear length (mm), and testes length (mm; if applicable). All capture, handling, and marking techniques followed guidelines approved by the American Society of Mammalogists (Gannon et al. 2007) and the U.S. Geological Survey Animal Care and Use Committee (Fort Collins Science Center). Animals captured during snaptrapping were disposed of away from study sites and human-use areas.

Data Analysis

Data analysis generally followed an information-theoretic approach involving model selection and multi-model inference. Model selection was based on Akaike's Information Criterion (AIC; Akaike 1973) corrected for small sample size (AIC_c; Hurvich and Tsai 1989). Models were considered competitive with the top-ranked model when $\Delta AIC_c \leq 2.0$ (Burnham and Anderson 2002:131). Model-averaging was based on Akaike weights (Burnham and Anderson 2002:150) and included the entire model set except for models with nonsensical β or real parameter estimates, which were removed prior to model averaging. We defined nonsensical β estimates as those with standard error (SE) >> β (e.g., β = -18.6, SE(β) = 475.6) and nonsensical real parameter estimates as those with SE = 0. Unless otherwise indicated, all estimates are presented as mean ± 1 SE.

Data collected during livetrapping and snaptrapping were used to generate 3 distinct site- and species-specific abundance estimates. Mark-recapture abundance estimates were generated from livetrapping data and removal abundance estimates were generated from both livetrapping data (after excluding recapture information from the dataset) and snaptrapping data. Livetrapping and snaptrapping data were treated similarly during abundance estimation, with the exception that the modeling of removal abundance estimates required that recapture probability be constrained to 0 (i.e., no possibility of recapture), which precluded the creation of models allowing a behavioral response to initial capture or any variation in recapture probability. All abundance estimates were generated in Program MARK 4.3 (White and Burnham 1999) using the conditional likelihood closed capture-recapture model developed by Huggins (1989, 1991). The Huggins model uses estimates of capture probability and the number of individuals captured to estimate abundance. Encounter histories are used to estimate capture probability and can account for heterogeneity in capture probability from temporal, behavioral, and individual effects (both in the form of mixture distributions [Norris and Pollock 1996, Pledger 2000] and individual covariates [Huggins 1989, 1991]). In this context, mixture distributions are an attempt to deal with individual heterogeneity by grouping animals with similar capture probabilities into discrete classes for modeling purposes (Pledger 2000). For example, a 2-mixture distribution could group individuals into high and low capture probability classes. Similarly, covariates are variables thought to influence capture probability (and other demographic parameters) which, when added to capture probability models, may reduce unexplained heterogeneity and thereby improve parameter estimation (Pollock et al. 1984, Pollock 2002). Covariates may pertain to individual animals (e.g., age, sex, mass), in which case they are generally assumed constant over time for modeling purposes, or to the environment (e.g., temperature, precipitation), in which case they are generally assumed constant for all animals over a specified time span, such as 24 hours, for modeling purposes (Pollock et al. 1984, Pollock 2002).

In Program MARK, design matrices were coded to allow sites to be treated both individually and as groups, based on common attributes such as island or habitat. Capture and recapture probability were primarily modeled across these groups to increase statistical efficiency (i.e., reduce estimate variance) and allow abundance estimates to be generated from sites with few captures or recaptures (Bowden et al. 2003, White 2005, Conn et al. 2006, Converse et al. 2006). Models were specified using the logit link function to constrain parameter estimates to the range 0–1 and to allow the use of non-identity design matrices (Cooch and White 2005). Model building in Program MARK occurred in an iterative fashion, beginning with the traditional models (M_0, M_b, M_t, M_h, M_{tb}, M_{bh}, M_{th}, M_{tbh}) outlined in Otis et al. (1978), where subscripts indicate the type of capture probability variation dealt with by each model: *b* = behavioral variation, *t* = temporal variation, *h* = heterogeneity, and M_0 = constant capture probability. Models incorporating heterogeneity were specified as 2-mixture models, based on concerns that our dataset would not support a more parameterized model (Norris and Pollock 1996, Pledger 2000, Conn et al. 2006). Models were ranked based on AIC_c scores, with the top model being considered for further model development. If the top ranked model included a temporal component, a set of neophobia models were fit to the dataset. Neophobia models allowed capture probability to vary during the first (neo1) or first and second (neo2) sampling occasions, while holding capture probability constant for the remaining sampling occasions. The motivation for neophobia models came both from literature accounts of neophobia for introduced small mammals (Inglis et al. 1996, Thorsen et al. 2000, Clapperton 2006), as well as observations of an increase in captured individuals after the first or second sampling occasion at many of our sites. As before, the top ranked model was considered for further model development. The next subset of models added to the MARK analysis were parameterized to model capture probability, recapture probability, or both capture and recapture probability as a function of island, habitat, or site. This complexity was deemed necessary to investigate possible variation in capture and recapture probability across these groupings. We hypothesized that capture or recapture probability might differ between Guam (with brown treesnake predation pressure) and Rota, Saipan, and Tinian (without brown treesnake predation), so the island grouping was coded in 2 ways, with island[4] distinguishing between each island and island[2] distinguishing Guam from the combination of Rota, Saipan, and Tinian. Again, the top ranked model was used for further model development.

The final subset of models added to the MARK analysis contained combinations of 5 individual and 2 environmental covariates, beginning with the full model containing all covariates and proceeding through a series of more parsimonious models including only covariates important for explaining capture probability. Covariate importance was assessed by examining β values and 95% CIs, where covariates with non-zero overlapping 95% CIs were considered influential on capture probability. Model-averaged abundance estimates were then generated from this pool of models to account for model selection uncertainty, unless the top ranked model had a model weight > 0.90 (Burnham and Anderson 2002:150). Covariates under consideration included sex (male or female), age (adult or juvenile), reproductive status, body condition index, body size, rain previous night, and rain amount. Reproductive status (repstat) was a categorical variable that differentiated reproductively active adults from non-reproductive adults and juveniles; assignment of repstat class was based on mass and the presence of externally visible sexual characteristics such as descended testes for males and active lactation for females. Body condition index (bodycon) was calculated as the ratio between the observed and expected mass of an individual, where expected mass was determined from a linear regression of ln mass vs. ln head-body length. The expected mass regression was generated using mass and head-body measurements from all individuals (i.e., animals captured during both livetrapping and snaptrapping). For each species, variation in bodycon was modeled as a function of island[4], island[2], and habitat in an analysis of variance framework (Proc GLM, SAS Institute 2003; Table 3). A site-specific bodycon model was not considered because of sparse data for some sites, which might have biased bodycon estimates for individuals from those sites. Bodycon estimates from the top model (or the model-averaged bodycon estimate) for each species were included in MARK modeling. Body Size (size) was a species-specific composite variable created from a principle components analysis (Proc FACTOR, SAS Institute 2003) of mass, head-body length, tail length, hind foot length, and ear length measured for each captured individual. Rain previous night (rainprev) was a categorical measure of the presence or absence of rainfall during the night prior to each trap monitoring occasion. Finally, rain amount (rainamt) was a quantitative measure of the total rainfall (mm) at the center of the trapping grid during each 24-hour sampling occasion, with the exception of the first sampling occasion for which the rainfall measurement encompassed only a 12–16 hour period. Prior to including rainamt in MARK models, rainfall amounts for the 5 sampling occasions were examined for equality across sites. Based on overlapping 95% CIs, there was no effect of the abbreviated rainfall measurement period during the first sampling occasion (Table 4).

Because we did not know true abundance, mark-recapture and removal abundance estimates were compared against each other on a site-specific basis. Abundance estimates were evaluated based on the magnitude of coefficients of variation (CV) and the width of 95% confidence intervals (95% CI). We considered estimates with small CVs and narrow 95% CIs to be more informative than estimates with large CVs and wide 95% CIs. The sampling method producing the greatest proportion of informative site-specific estimates was then used to evaluate 2 common count-based indices of abundance generated from the livetrapping and snaptrapping data: the number of unique individuals captured (M_{t+1}; Otis et al. 1978) and the captures per unit effort (CPUE; White et al. 1982). We used the method described by Nelson and Clark (1973) to account for sprung traps when calculating sampling effort, and present CPUE as captures/100 corrected trap nights, where a trap night is defined as 1 trap active for 1 night. The relationship between the most informative abundance estimate and M_{t+1} or CPUE was investigated using regression analyses (Proc REG, SAS Institute 2003), with regressions constrained to pass through the origin. When evaluating constrained regressions, we calculated r^2 using the formula

$$r^2 = 1 - \frac{\text{SSE}}{\text{SST}_c},$$

where SSE = the sum of squared residuals and SST_c = the corrected total sum of squared deviations (Kvålseth 1985). This correction is necessary because many statistical packages (including SAS) calculate r^2 for constrained regressions by replacing SST_c in the previous equation with SST_u, the uncorrected total sum of squares, resulting in artificially high r^2 values that are not directly comparable to r^2 values generated for unconstrained regressions (Kvålseth 1985, Cade and Terrell 1997). Because M_{t+1} and CPUE are frequently generated from short duration sampling events, we used indices from the first day of sampling, the first 3 days of sampling, and the full 5 day sampling period to investigate the effects of sampling duration on index performance. Indices were evaluated by comparing the width of 95% prediction intervals (95% PI), which are confidence intervals for an individual predicted value (Ott 1992:519). We considered indices with narrow 95% PIs to be better predictors of small mammal abundance.

We also compared livetrapping and snaptrapping based on the effectiveness of each method for capturing target species as well as the cost of implementing each sampling method. We evaluated trap effectiveness by comparing species-specific capture rates (captures/100 corrected trap nights) during livetrapping (Haguruma and Sherman live traps) and snaptrapping (Victor and Museum Special snap traps). Capture rate calculations included only sites where a species was captured. We investigated the cost of each sampling method by comparing the initial cost of supplies required to implement our sampling protocol, the mass and volume of those supplies, and the time required for site preparation and activities directly associated with sampling: trap baiting, trap monitoring, and the processing of captured animals. For comparative purposes, time requirements were standardized to person-hours to avoid possible bias resulting from unequal numbers of personnel participating in various activities.

RESULTS

We captured 681 *R. rattus*, 298 *S. murinus*, 154 *M. musculus*, 15 *R. exulans*, and 5 *R. norvegicus* in 14,915 trap nights (12,011.5 corrected trap nights) during livetrapping and 642 *R. rattus*, 255 *S. murinus*, 122 *M. musculus*, 14 *R. exulans*, and 3 *R. norvegicus* in 14,915 trap nights (8,952 corrected trap nights) during snaptrapping (Table 5). *S. murinus* was not captured or observed during 9 weeks spent on Rota, and is believed absent from that island. *R. exulans* and *R. norvegicus* were rarely captured with either sampling method, and are not considered further.

Modeling Capture and Recapture Probability

Modeling of *R. rattus* livetrapping and snaptrapping data revealed several common factors important for understanding capture probability, including temporal variation and the individual covariates sex and repstat. The top mark-recapture model for livetrapping data (w_i = 0.871) allowed neophobic temporal variation in capture probability (neo2) for each island (island[4]) as well as capture probability variation by sex, repstat, and rainamt, with recapture probability variation by island (island[4]), sex, repstat, and rainamt (Table 6). The top removal model for livetrapping data (w_i = 0.860) specified an identical parameter set to explain capture probability variation (Table 6). Model selection uncertainty increased for snaptrapping data; the top removal model (w_i = 0.375) allowed capture probability to vary by island[2], sex, age, repstat, and size (Table 6). All attempts to model unexplained heterogeneity in *R. rattus* sampling data using mixture models resulted in nonsensical parameter estimates. In contrast, individual and environmental covariates were useful for modeling unexplained heterogeneity; the top model without covariates had little support during either mark-recapture (ΔAIC_c = 17.97) or removal modeling (ΔAIC_c = 19.98) of livetrapping data or removal modeling of snaptrapping data (ΔAIC_c = 12.08). Based on the top mark-recapture and removal models from livetrapping data described above, *R. rattus* capture probability was lower for males than for females, higher for reproductively mature individuals, and positively correlated with rainfall amount (Figures 3, 4; Table 7). The top removal model from snaptrapping data also indicated that capture probability was lower for males than for females and higher for reproductively mature individuals, while also suggesting that capture probability was higher for adults than juveniles, but lower for the largest individuals within age classes (Figure 5, Table 7).

There were fewer common factors in models of *S. murinus* livetrapping and snaptrapping data, although temporal variation in capture probability was always important. The top mark-recapture model for livetrapping data (w_i = 0.994) allowed both temporal variation and heterogeneity (2 mixtures) in capture and recapture probability, with the temporal recapture probability variation differing by island (island[4]; Table 8). Model selection uncertainty increased for removal modeling of livetrapping data; each of the closely ranked top models allowed neophobic temporal variation in capture probability (neo1; Table 8), with the top model (w_i = 0.254) also allowing capture probability variation by bodycon. *S. murinus* capture probability tended to increase with increasing bodycon ($\beta_{bodycon}$ = 4.33 ± 2.96, 95% CI = -1.47–10.13), although this relationship was weak as demonstrated by the 95% CI that asymmetrically overlapped zero. For snaptrapping data, the top removal model (w_i = 0.836) allowed neophobic temporal variation in capture probability (neo1) for each habitat (Table 8). Although heterogeneity was an important factor for mark-recapture modeling of livetrapping data, attempts to account for unexplained heterogeneity with mixture models during removal modeling of both livetrapping and snaptrapping data resulted in nonsensical parameter estimates. With the exception of bodycon, none of the covariates under consideration were useful for modeling *S. murinus* capture probability.

As with *S. murinus*, modeling of *M. musculus* livetrapping and snaptrapping data indicated that temporal variation was always an important factor for understanding capture probability. For livetrapping data there was considerable model selection uncertainty for both mark-recapture and removal models. The top mark-recapture model (w_i = 0.349) allowed both temporal variation and heterogeneity (2 mixtures) in capture and recapture probability, with the temporal variation in capture probability differing between Guam and the other islands (island[2]; Table 9). The top removal model for livetrapping data (w_i = 0.414) allowed neophobic temporal variation in capture probability (neo1; Table 9). For snaptrapping data, the top removal model (w_i = 0.745) allowed neophobic temporal variation in capture probability (neo1), with this temporal variation differing by island[2] (Table 9).

Although heterogeneity was an important factor for mark-recapture modeling of livetrapping data, attempts to account for unexplained heterogeneity with mixture models during removal modeling of both livetrapping and snaptrapping data resulted in nonsensical parameter estimates. Similarly, none of the covariates under consideration were useful for modeling *M. musculus* capture probability.

Abundance Estimates

In spite of differences in model structure, model-averaged mark-recapture and removal abundance estimates from livetrapping ($\hat{\hat{N}}_{\text{M-R Live}}$ and $\hat{\hat{N}}_{\text{REM Live}}$, respectively) and removal abundance estimates from snaptrapping ($\hat{\hat{N}}_{\text{REM Snap}}$) were correlated for each species. It should be noted that mark-recapture abundance estimates from livetrapping data were not model-averaged for *S. murinus* (top model w_i = 0.994; Table 8); however, the symbol $\hat{\hat{N}}_{\text{M-R Live}}$ will also be used for this species to avoid confusing notation. The strongest relationship was between $\hat{\hat{N}}_{\text{M-R Live}}$ and $\hat{\hat{N}}_{\text{REM Live}}$ for each species (*M. musculus*: r^2 = 0.99, *R. rattus*: r^2 = 0.97, and *S. murinus*: r^2 = 0.99). Weaker correlations were observed between $\hat{\hat{N}}_{\text{M-R Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ (*M. musculus*: r^2 = 0.86, *R. rattus*: r^2 = 0.79, and *S. murinus*: r^2 = 0.58) and between $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ (*M. musculus*: r^2 = 0.88, *R. rattus*: r^2 = 0.82, and *S. murinus*: r^2 = 0.56). On a site-specific basis, abundance estimates were often qualitatively similar, although there was an overall trend of $\hat{\hat{N}}_{\text{REM Snap}}$ and $\hat{\hat{N}}_{\text{REM Live}} > \hat{\hat{N}}_{\text{M-R Live}}$ for *R. rattus* (Table 10) and $\hat{\hat{N}}_{\text{REM Snap}} >$ $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{M-R Live}}$ for *S. murinus* (Table 11). $\hat{\hat{N}}_{\text{M-R Live}}$, $\hat{\hat{N}}_{\text{REM Live}}$, and $\hat{\hat{N}}_{\text{REM Snap}}$ were relatively analogous across most sites for *M. musculus* (Table 12).

In addition to these discrepancies in the magnitude of abundance estimates, we found that $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ were generally less informative than $\hat{\hat{N}}_{\text{M-R Live}}$ based on comparison of CVs and 95% CIs. For *R. rattus*, the mean $\hat{\hat{N}}_{\text{M-R Live}}$ CV (0.24 ± 0.03, 95% CI = 0.17–0.30; *n* = 16) was lower than the mean CV for $\hat{\hat{N}}_{\text{REM Live}}$ (0.59 ± 0.04, 95% CI = 0.50–0.67; *n* = 16) or $\hat{\hat{N}}_{\text{REM Snap}}$ (0.40 ± 0.04, 95% CI = 0.32–0.48; *n* = 17). Further, 95% CIs were notably wider for $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ than for $\hat{\hat{N}}_{\text{M-R Live}}$, and frequently overlapped zero (Table 10). For *S. murinus*, mean $\hat{\hat{N}}_{\text{M-R Live}}$ and $\hat{\hat{N}}_{\text{REM Live}}$ CVs were similar (0.30 ± 0.01, 95% CI = 0.28–0.32; *n* = 9 and 0.26 ± 0.01, 95% CI = 0.23–0.29; *n* = 9, respectively), with both being much lower than the mean $\hat{\hat{N}}_{\text{REM Snap}}$ CV (1.26 ± 0.01, 95% CI = 1.24–1.29; *n* = 10). $\hat{\hat{N}}_{\text{REM Snap}}$ 95% CIs were notably wider than 95% CIs for $\hat{N}_{\text{M-R Live}}$ or $\hat{\hat{N}}_{\text{REM Live}}$, and all $\hat{\hat{N}}_{\text{REM Snap}}$ 95% CIs overlapped zero (Table 11). For *M. musculus*, mean $\hat{\hat{N}}_{\text{M-R Live}}$ CV (0.34 ± 0.06, 95% CI = 0.19–0.48; n = 8) was lower than the mean CV for $\hat{\hat{N}}_{\text{REM Live}}$ (0.60 ± 0.05, 95% CI = 0.49–0.72; n = 8) or $\hat{\hat{N}}_{\text{REM Snap}}$ (0.75 ± 0.05, 95% CI = 0.62–0.88; n = 7). Again, 95% CIs were notably wider for $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ than for $\hat{\hat{N}}_{\text{M-R Live}}$, and all $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ 95% CIs overlapped zero (Table 12).

Evaluation of Count-Based Indices

Count-based indices of abundance generated from livetrapping and snaptrapping data were evaluated against our most information-rich abundance estimate, $\hat{\hat{N}}_{\text{M-R Live}}$. $M_{\text{t+1}}$ and CPUE from 1, 3, and 5 days of both livetrapping ($M_{\text{t+1 Live}}$ and $\text{CPUE}_{\text{Live}}$) and snaptrapping ($M_{\text{t+1 Snap}}$ and $\text{CPUE}_{\text{Snap}}$) were strong correlates ($r^2 \geq 0.8$) with $\hat{\hat{N}}_{\text{M-R Live}}$ in 10 of 12 comparisons (83%) for *R. rattus* and 9 of 12 comparisons (75%) for *M. musculus* (Table 13). In contrast, strong correlations were observed between indices and $\hat{\hat{N}}_{\text{M-R Live}}$ in only 6 of 12 comparisons (50%) for *S. murinus* (Table 13). In all cases, regression slope coefficients were > 1.0 (Table 13).

The utility of $M_{\text{t+1}}$ and CPUE as predictors of small mammal abundance differed depending on the sampling method and sampling duration the index was generated from. For *R. rattus*, $M_{\text{t+1 Live}}$ 95% PIs improved with additional sampling occasions (Figure 6). For example, a mid-range $M_{\text{t+1 Live}}$ value from 1 day of sampling (10 individuals) predicts $\hat{\hat{N}}_{\text{M-R Live}}$ of approximately 20–185 individuals, whereas a mid-range $M_{\text{t+1 Live}}$ value from 5 days of sampling (55 individuals) predicts $\hat{\hat{N}}_{\text{M-R Live}}$ of approximately 85–110 individuals (Figure 6). In contrast, there was little improvement in 95% PIs between a mid-range $M_{\text{t+1 Snap}}$ value from 1 day of sampling (15 individuals; 95% PI $\approx$ 45–150 individuals) and a mid-range $M_{\text{t+1 Snap}}$ value from 5 days of sampling (50 individuals; 95% PI $\approx$ 30–130 individuals; Figure 6). Similar patterns were evident for the 95% PIs of $\text{CPUE}_{\text{Live}}$ and $\text{CPUE}_{\text{Snap}}$ (Figure 7). For example, a mid-range $\text{CPUE}_{\text{Live}}$ value from 1 day of sampling (7 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{\text{M-R Live}}$ of approximately 5–170 individuals, whereas a mid-range $\text{CPUE}_{\text{Live}}$ value from 5 days of sampling (10 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{\text{M-R Live}}$ of approximately 75–125 individuals (Figure 7). In comparison, there was little improvement in predictive value between a mid-range $\text{CPUE}_{\text{Snap}}$ value (20 captures/100 corrected trap nights) from 1 day of sampling (95% PI $\approx$ 50–150 individuals) or 5 days of sampling (95% PI $\approx$ 85–190 individuals; Figure 7).

For *S. murinus*, $M_{t+1\ Live}$ and CPUE $_{Live}$ 95% PIs improved with additional sampling occasions, whereas the width of $M_{t+1\ Snap}$ and CPUE $_{Snap}$ 95% PIs was relatively independent of sampling duration, and quite poor overall (Figures 8, 9). For example, a mid-range CPUE $_{Live}$ value from 1 day of sampling (8 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 60–100 individuals, whereas the same mid-range CPUE $_{Live}$ value from 5 days of sampling predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 70–80 individuals (Figure 9). In contrast, there was little improvement in $M_{t+1\ Snap}$ and CPUE $_{Snap}$ 95% PIs with increasing sampling duration (Figures 8, 9). For example, a mid-range CPUE $_{Snap}$ value of 7 captures/100 corrected trap nights from 1 day of sampling predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 0–120 individuals, whereas the same CPUE $_{Snap}$ value from 5 days of sampling predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 0–110 individuals (Figure 9).

As with *R. rattus* and *S. murinus*, *M. musculus* $M_{t+1\ Live}$ and CPUE $_{Live}$ 95% PIs improved with additional sampling occasions (Figures 10, 11). In contrast to both *R. rattus* and *S. murinus*, however, there was also improvement $M_{t+1\ Snap}$ and CPUE $_{Snap}$ 95% PIs as sampling occasions increased, although they remained wider than those for $M_{t+1\ Live}$ and CPUE $_{Live}$ (Figures 10, 11). For example, a 1 day CPUE $_{Live}$ value of 5 captures/100 corrected trap nights predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 20–60 individuals, whereas the same CPUE $_{Live}$ value from 5 days of sampling predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 45–55 individuals (Figure 11). In comparison, a 1 day CPUE $_{Snap}$ value of 5 captures/100 corrected trap nights predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 0–50 individuals, whereas the same CPUE $_{Snap}$ value from 5 days of sampling predicts $\hat{\hat{N}}_{M-R\ Live}$ of approximately 35–60 individuals (Figure 11).

Comparison of Livetrapping and Snaptrapping Capture Rates

R. rattus, *S. murinus*, and *M. musculus* were each captured in both available trap types during livetrapping and snaptrapping. However, the effectiveness (mean captures/100 corrected trap nights) of live and snap traps differed for each species, after controlling for the number of sites where each species was captured (Figure 12). During livetrapping, Haguruma traps were much more effective for capturing *R. rattus* (27.35 ± 6.35, 95% CI = 13.88–40.82; *n* = 17) than were Sherman traps (1.85 ± 0.87, 95% CI = 0.01–3.69; *n* = 17). In contrast, *S. murinus* captures were greater in Sherman traps (5.69 ± 1.73, 95% CI = 1.77–9.61; *n* = 10) than in Haguruma traps (0.60 ± 0.23, 95% CI = 0.08–1.12; *n* = 10). *M. musculus* captures were also greater in Sherman traps (3.37 ± 1.06, 95% CI = 0.92–5.82; *n* = 9) than in Haguruma traps (0.93 ± 0.61, 95% CI = 0–2.34; *n* = 9), although this difference was not significant based on overlapping 95% CIs. During snaptrapping, Victor traps were much more effective for capturing *R. rattus* (27.92 ± 7.13, 95% CI = 12.81–43.02; *n* = 17) than were Museum Special traps (2.63 ± 0.93, 95% CI = 0.67–4.60; *n* = 17). In contrast, *M. musculus* captures were generally greater in Museum Special traps (3.24 ± 1.22, 95% CI = 0.43–6.05; *n* = 9) than in Victor traps (0.33 ± 0.18, 95% CI = 0–0.73; *n* = 9), although this difference was not significant based on overlapping 95% CIs. Victor (4.81 ± 1.49, 95% CI = 1.44–8.18; *n* = 10) and Museum Special traps (5.84 ± 2.13, 95% CI = 1.02–10.66; *n* = 10) were equally effective for capturing *S. murinus*.

Comparison of Livetrapping and Snaptrapping Cost and Effort

The total cost of any sampling method is the sum of the cost of necessary supplies, the cost of transporting those supplies, and the labor costs associated with conducting sampling, including site preparation. Based on our sampling protocol, minimum initial supply cost was much lower for snaptrapping than for livetrapping (Table 14). Victor and Museum Special snap traps were also smaller and lighter than Haguruma and Sherman live traps (Table 15). More importantly, snaptrapping activities required less time (19.7 ± 0.9 person-hours, 95% CI = 17.8–21.5; *n* = 19) than activities associated with livetrapping (31.8 ± 2.4 person-hours, 95% CI = 26.7–36.8; *n* = 19; Table 16). Closer examination of these data revealed a more complex relationship, however, as time requirements increased with increasing small mammal captures for livetrapping, but not for snaptrapping. For example, livetrapping required nearly twice as much time on Rota, Saipan, and Tinian (37.7 ± 2.1 person-hours, 95% CI = 33.1–42.4; *n* = 12) as on Guam (21.5 ± 2.4 person-hours, 95% CI = 15.6–27.4; *n* = 7), whereas snaptrapping time requirements varied little between Rota, Saipan, and Tinian (19.7 ± 1.1 person-hours, 95% CI = 17.3–22.0; *n* = 12) and Guam (19.6 ± 1.6 person-hours, 95% CI = 15.7–23.5; *n* = 7; Table 16). Further, the time required for sampling activities was generally less than the time required to prepare sampling grids in the dense vegetation and rugged terrain of the Mariana Islands (48.6 ± 6.3 person-hours, 95% CI = 35.2–62.0; *n* = 18). Overall, the time required for site preparation and sampling activities was not markedly different between livetrapping (81.0 ± 6.3 person-hours, 95% CI = 67.8–97.2; *n* = 18) and snaptrapping (67.9 ± 6.4 person-hours, 95% CI = 54.3–81.4; *n* = 18; Table 16).

DISCUSSION

Comparison of Mark-Recapture and Removal Abundance Estimates

Using data collected during consecutive livetrapping and snaptrapping events, we demonstrate that mark-recapture abundance estimates generated from livetrapping data ($\hat{\hat{N}}_{\text{M-R Live}}$) were more precise than removal abundance estimates generated from either livetrapping ($\hat{\hat{N}}_{\text{REM Live}}$) or snaptrapping ($\hat{\hat{N}}_{\text{REM Snap}}$) data. On a site-specific basis, $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ were generally greater (often much greater) than $\hat{\hat{N}}_{\text{M-R Live}}$, especially for *R. rattus* and *S. murinus*. Unfortunately, without knowledge of true abundance, we can not evaluate the accuracy or precision of these estimates. In practice, true abundance is rarely known and researchers must rely on abundance estimates to make conservation and management decisions. In that framework, the generally high variance of $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$, as demonstrated by large CVs (e.g., >0.30) and wide 95% CIs, would severely limit the utility of these estimates for any foreseeable conservation or management purpose. In fact, many of our $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ had little or no informational value based on 95% CIs spanning or exceeding the plausible range of abundance we might encounter during sampling of wild populations of these species (e.g., 0–1000 *R. rattus* or 0–400 *S. murinus*). In contrast, the majority of $\hat{\hat{N}}_{\text{M-R Live}}$ had reasonable CVs (e.g., ≤0.30) and 95% CIs, such that these estimates could be used to detect biologically significant differences in small mammal abundance across space or time.

We suspect that the high variance of $\hat{\hat{N}}_{\text{REM Live}}$ and $\hat{\hat{N}}_{\text{REM Snap}}$ is largely attributable to non-declining captures over successive sampling occasions. For example, livetrapping captures of new individuals declined over successive sampling occasions at only 1 of 16 sites with >5 *R. rattus* captures, 0 of 9 sites with >5 *S. murinus* captures, and 1 of 6 sites with >5 *M. musculus* captures. Similarly, snaptrapping captures of new individuals declined at only 4 of 14 sites with >5 *R. rattus* captures, 1 of 9 sites with >5 *S. murinus* captures, and 2 of 5 sites with >5 *M. musculus* captures. The most obvious explanation for non-declining captures over time is a failure of population closure (i.e., births, deaths, emigration, or immigration occurring during sampling). Of these possibilities, neither deaths nor emigration can explain non-declining captures over successive sampling occasions, as each would decrease the number of animals on the sampling area over time. In contrast, both births and immigration would add animals to the sampling area and contribute to non-declining captures over time. While births themselves are probably unimportant for short-duration sampling events, the maturation of juvenile animals could be important. Indeed, *R. rattus* juvenile captures increased from 17% of total captures during livetrapping to 35% of total captures during snaptrapping. Similarly, *M. musculus* juvenile captures increased from just 2% of total captures during livetrapping to 12.5% of total captures during snaptrapping. These increases could result from recently born individuals maturing and becoming available for capture, although it seems unlikely that this would be an important factor across multiple sites, habitats, and islands sampled at different times.

A more plausible explanation is that the removal of dominant adults during snaptrapping altered the behavior of non-dominant juveniles, thereby increasing their capture probability (Summerlin and Wolfe 1973). The removal of animals during snaptrapping also increases the likelihood of immigration, as territorial vacancies are created which may attract animals from outside the sampling area (Stickel 1946b, Fitzgerald et al. 1981, White et al. 1982). Immigration seems less probable during livetrapping, although it is possible that the use of bait in traps might attract animals into the sampling area (White et al. 1982). If immigration were occurring, we might expect the majority of new individuals to be captured on the perimeter of the sampling area, especially during later sampling occasions. However, a post-hoc analysis of captures in perimeter (defined as the 2 outer “rings” of traps) and interior traps revealed little evidence of immigration during either livetrapping or snaptrapping. Observed captures in perimeter and interior traps were generally within 5–10% of expected captures in each segment of the sampling area, and never exceeded expected captures by >13% during sampling occasions 3–5 (Appendix 2A).

Evaluation of Count-Based Indices

Using $\hat{\bar{N}}_{\text{M}-\text{R Live}}$ as our best measure of small mammal abundance, we found that count-based indices generated from livetrapping data ($M_{\text{t+1 Live}}$ and CPUE $_{\text{Live}}$) generally had narrower 95% PIs than indices generated from snaptrapping data ($M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$). The predictive value of $M_{\text{t+1 Live}}$ and CPUE $_{\text{Live}}$ increased with increasing sampling duration for all species. In contrast, there was little apparent benefit to increased sampling duration on the predictive value of $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$, except for *M. musculus*. *M. musculus* snaptrapping captures may have been suppressed by *R. rattus* or *S. murinus* during early sampling occasions (Brown et al. 1996, Weihong et al. 1999) at some sites, such that indices derived from short-duration sampling had inflated 95% PIs. There was little difference between the predictive value of $M_{t+1\ Live}$ vs. CPUE $_{Live}$ or $M_{t+1\ Snap}$ vs. CPUE $_{Snap}$, perhaps not surprising as CPUE is an extension of M_{t+1}. Nonetheless, M_{t+1} has limited utility because it provides no information about sampling effort and therefore does not facilitate comparisons between samples.

Indices such as M_{t+1} and CPUE are commonly used when relative, rather than absolute, measures of abundance are thought to be adequate to answer conservation or management questions, under the assumption that these methods require less costly data collection and analysis methods than those required for abundance estimation (Engeman 2003, 2005). Further, proponents of indices frequently reference the restrictive assumptions of abundance estimation methods as the primary argument for the use of indices (Engeman 2003, 2005) and, in effect, imply that indices are subject to fewer or less restrictive assumptions. It is important to note, however, that when an index is used to monitor populations across space or time, an assumption is made that the relationship between the index and true abundance is monotonic and spatially and temporally constant (Nichols 1992; Anderson 2001, 2003); in classic population modeling terminology this assumption is analogous to the constant capture probability ($p_{.}$) model (M_0; Otis et al. 1978). Without knowledge of true abundance, we can not directly evaluate this relationship, but we can use information provided by our modeling of livetrapping and snaptrapping data to evaluate the validity of the underlying assumption of constant capture probability. Although we observed a monotonic relationship, modeling of livetrapping ($\hat{\hat{N}}_{\text{M}-\text{R Live}}$ and $\hat{\hat{N}}_{\text{REM Live}}$) and snaptrapping ($\hat{\hat{N}}_{\text{REM Snap}}$) data indicated no support for the $p_{.}$ model for *R. rattus* (ΔAIC_c = 105.12, 51.71, and 15.09, respectively) and at best limited support for the $p_{.}$ model for *S. murinus* (ΔAIC_c = 49.30, 4.08, and 11.90, respectively) and *M. musculus* (ΔAIC_c = 35.91, 4.04, and 3.85, respectively). Instead, capture probability varied over time and between habitats or islands for each species. Further, modeling of *R. rattus* sampling data identified several covariates (sex, age, reproductive status, size, and rainfall amount) that influenced capture probability. Similarly, capture probability heterogeneity (in the form of mixture models) was also found during mark-recapture modeling of *S. murinus* and *M. musculus* livetrapping data. As noted in Table 1, count-based indices of abundance are invalid when capture probability varies over space, time, or between individuals (heterogeneity). Thus, for these data, the assumptions intrinsic to the application of indices were clearly not met.

In practice, spatial, temporal, or individual variation in capture probability seem likely during any population study. Nonetheless, many have argued that when data are sparse or capture probabilities are low, the known negative bias (unless capture probability = 1) of count-based indices of abundance may be preferred (McKelvey and Pearson 2001, Engeman 2005) over the instability of model selection procedures, unknown bias, and large standard errors associated with abundance estimates derived under these conditions (Otis et al. 1978, Menkens and Anderson 1988, Pollock et al. 1990, Manning et al. 1995, Stanley and Burnham 1998, McKelvey and Pearson 2001). While this may have been true in the past, recent advances in population modeling procedures address many of these concerns. For example, Program MARK allows sites to be grouped based on common characteristics such as island or habitat to increase sample size for capture probability estimation, thereby lessening the negative impacts of sparse data or low capture probability at some sites (Bowden et al. 2003, White 2005, Conn et al. 2006, Converse et al. 2006). Information theoretic-based model selection procedures offer vast improvements over earlier techniques (Burnham and Anderson 2002), such as the much-maligned model selection procedure implemented in Program CAPTURE (Otis et al. 1978, White et al. 1982). Further, information theoretic-based model selection allows the generation of model-averaged abundance and variance estimates (Burnham and Anderson 2002). The ability to incorporate covariates into population modeling procedures has also improved the flexibility and biological relevancy of models, and can result in improved parameter estimation accuracy and precision (White 2005).

We were concerned that these results might be an artifact of our use of $\hat{\hat{N}}_{\text{M}-\text{R Live}}$ as a proxy for true abundance, rather than being representative of the true predictive value of indices. If this were the case, then we might expect contradictory results from a comparison of count-based indices with $\hat{\hat{N}}_{\text{REM Snap}}$. Indeed, a post-hoc investigation revealed that $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$ had narrower 95% PIs than $M_{\text{t+1 Live}}$ and CPUE $_{\text{Live}}$ when regressed against $\hat{\hat{N}}_{\text{REM Snap}}$ (Appendix 2B). It is notable that 95% PIs were generally greater in these regressions than for our original $\hat{\hat{N}}_{\text{M}-\text{R Live}}$ regressions, especially for indices generated from 1 or 3 days of sampling data (Appendix 2B). Regardless of which estimate we used, 95% PI width tended to decrease with increasing sampling duration.

Our evaluation of abundance estimates and index performance is somewhat limited because we did not know the true abundance of the small mammal populations we sampled. We note, however, that few comparisons of estimator or index performance involving known-abundance small mammal populations exist (e.g., Manning et al. 1995, Parmenter et al. 2003, Conn et al. 2006). These controlled studies, in turn, may have reduced applicability towards field-based sampling of small mammal populations. For example, it is not clear that populations of a single species in small enclosures (e.g., 0.02 ha: Conn et al. 2006; 0.2 ha: Manning et al. 1995), provided with supplemental food (Conn et al. 2006), are analogous to wild small mammal populations. Further, the effort involved in studying enclosed populations necessarily limits sample size, such that the range of observed population size (e.g., 2,700–14,700 *M. musculus*/ha: Conn et al. 2006; 0–20.6/ha across 12 species: Parmenter et al. 2003) may not be comparable to the potential density range of the same species in wild situations. Similarly, simulation-based evaluations (e.g., Otis et al. 1978, Menkens and Anderson 1988, McKelvey and Pearson 2001, Conn et al. 2004) of estimator or index performance, while valuable for testing robustness to violations of major assumptions, may not represent the full suite of conditions encountered during sampling of wild small mammal populations.

Comparison of Livetrapping and Snaptrapping Capture Rates

We found variable capture rates in our live and snap traps. During livetrapping, *R. rattus* capture rates were much greater in Haguruma traps than in Sherman traps. It is possible that the relatively open, wire mesh design of the Haguruma trap elicits a lesser avoidance response than the enclosed Sherman trap for *Rattus* species, which are commonly thought to be neophobic (Temme and Jackson 1979, Inglis et al. 1996, Thorsen et al. 2000, Priyambodo and Pelz 2003, Clapperton 2006). In contrast, both *S. murinus* and *M. musculus* were captured infrequently in Haguruma traps. Based on limited observations, we believe the mixed effectiveness of Haguruma traps results from a combination of body size and feeding behavior. Unlike *R. rattus*, which often attempted to remove bait from the trap, thereby triggering Haguruma traps, *S. murinus* and *M. musculus* tended to nibble at the bait without attempting to remove it. This behavior, coupled with the low mass of these species, might allow *S. murinus* and *M. musculus* to enter a Haguruma trap, sample the bait without disturbing the trigger, and then exit the trap without releasing the door. In contrast, the design of Sherman traps, which requires an animal to walk across the treadle to reach the bait, is more suitable for capturing these small, low mass species. Several other studies comparing wire mesh traps (Haguruma or others) with box-type traps (Sherman or Elliot traps) have noted similar results, with wire mesh traps being more effective for *Rattus* and other large species and box-type traps being more effective for small species (O'Farrell et al. 1994, Gragg 2004, Wilson et al. 2007). During snaptrapping, *R. rattus* capture rates were much greater in Victor traps than in Museum Special traps, most likely because the smaller Museum Special traps do not consistently kill captured *R. rattus,* some of which may then escape from the trap. The variable capture rate of *M. musculus* in Victor and Museum Special traps may again be related to the small size of this species. There is significant tension on Victor trap treadles, such that *M. musculus* may not consistently trigger these traps, even if they disturb the bait. Further, if *M. musculus* does trigger a Victor trap, it may be missed by the trap bale (or perhaps captured by only the tail). The relatively equivalent captures of *S. murinus* in Victor and Museum Special snap traps indicates that that this species, intermediate in size and mass between *R. rattus* and *M. musculus*, is efficiently captured in either trap. Other studies comparing various snap traps have noted similar results, with Victor rat traps being most effective for large species, and Museum Special (or Victor mouse traps) being effective for smaller species (Wiener and Smith 1972, Pendleton and Davison 1982, Perry et al. 1996). The mixed effectiveness of live and snap traps suggests that trap effectiveness for target species should be assessed prior to large-scale sampling activities; in many situations the use of multiple trap types may be beneficial, especially if resident small mammal species vary greatly in foraging behavior or size. As an added benefit, the use of multiple trap types with mixed effectiveness for target species may decrease the risk of capture suppression of non-dominant species (e.g., suppression of *M. musculus* by *Rattus* species; Brown et al. 1996, Weihong et al. 1999, Gragg 2004).

Comparison of Livetrapping and Snaptrapping Cost and Effort

We found that initial supply cost was approximately 4 times lower for snaptrapping than for livetrapping, based on our protocol. Victor and Musuem Special snap traps were smaller (~ 15 times less volume) and lighter (~ 5 times lighter) than Haguruma and Sherman live traps, which could provide a definite advantage for research conducted in remote areas, rugged terrain, or dense vegetation. Trap baiting, trap monitoring, and animal processing required less time during snaptrapping, although this difference was only pronounced at sites with abundant small mammal populations. In other words, there was no time penalty for livetrapping relative to snaptrapping at sites with few small mammal captures.

More importantly, when we included site preparation in time calculations, there was on average only a 16% time savings for snaptrapping relative to livetrapping. This difference is relatively small in comparison to the observed difference in the informational value between $\hat{\bar{N}}_{\text{M}-\text{R Live}}$ and $\hat{\bar{N}}_{\text{REM Snap}}$ generated from our sampling. It is important to note, however, that dense vegetation and rugged terrain at many of our sites increased site preparation time. The contribution of site preparation time to total time requirements would likely be much lower in other locations, increasing the time differential between livetrapping and snaptrapping.

Management Implications

Knowledge of small mammal population size is often necessary for implementation and evaluation of conservation and management practices (Lancia et al. 2005). Limited resources are available for collecting small mammal population data (Witmer 2005), and researchers frequently rely on sampling and data analysis methods assumed to be fast and cheap (Slade and Blair 2000, McKelvey and Pearson 2001), such as snaptrapping and count-based indices of abundance. We demonstrate, however, that there is limited utility in methods that typically produce unreliable and non-informative results (Nichols 1992; Anderson 2001, 2003), especially when they may not offer significant cost or time savings. Nonetheless, these methods may have value after validation against a more rigorous sampling or estimation procedure (Eberhardt and Simmons 1987). To be effective, however, validation should occur across the full breadth of conditions from which index data will be collected. We suggest that the resources required for thorough and repeated validation efforts might be better invested in implementing rigorous and robust sampling methods and population abundance estimation procedures.

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TABLES

Table 1. Comparison of the robustness of selected count-based indices and closed population abundance estimates to violation of population closure and potential forms of capture probability variation.

	Count-based Index		Abundance Estimate	
	M_{t+1}	CPUE	Removal	Mark-Recapture
population closure violation	invalid; unclear how violation would be recognized	invalid; unclear how violation would be recognized	invalid; difficult to recognize violation	problematic; possible to recognize violation
capture probability variation by:				
space	invalid across space	invalid across space	valid if modeled	valid if modeled
time	invalid across time	invalid across time	problematic; reduced accuracy and precision	valid if modeled
behavior	valid; only first capture data are utilized	valid; only first capture data are utilized	valid; only first capture data are utilized	valid if modeled
individual heterogeneity	invalid unless stratified	invalid unless stratified	problematic; reduced accuracy and precision	valid if modeled

Table 2. Introduced small mammal sampling site coordinates and dates on Guam, Rota, Saipan, and Tinian, 2005–2006. Coordinates indicate the site centroid, and are presented in decimal degrees (WGS 84, UTM Zone 55).

Site	Habitat	Dates Sampled	Latitude	Longitude
Guam				
MSRG	grassland	Jun 6–17, 2005	13.542	144.912
ASMF	*Leucaena* forest	May 30–Jun 10, 2005	13.512	144.870
GSYF	*Leucaena* forest	Nov 6–17, 2006	13.437	144.659
PAGO	*Leucaena* forest	Jun 20–Jul 1, 2005	13.417	144.783
GAHF	mixed	Oct 23–Nov 3, 2006	13.491	144.795
NMAR	native forest	May 16–27, 2005	13.378	144.672
RITL	native forest	Apr 18–29, 2005	13.648	144.863
Rota				
SABA	grassland	Jan 23–Feb 3, 2006	14.140	145.191
GAON	*Leucaena* forest	Jan 30–Feb 10, 2006	14.115	145.199
RAPF	mixed	Apr 10–21, 2006	14.170	145.240
ASAK	native forest	Apr 3–14, 2006	14.154	145.170
Saipan				
ACHU	grassland	Sep 19–30, 2005	15.238	145.773
OBYT	*Leucaena* forest	Sep 26–Oct 7, 2005	15.108	145.729
SAEN	mixed	Aug 22–Sep 2, 2006	15.127	145.727
SPOR	mixed	Aug 15–26, 2006	15.227	145.744
LATT	native forest	Sep 12–23, 2005	15.251	145.798
Tinian				
KAST	grassland	Oct 24–Nov 4, 2005	14.951	145.651
ABLE	*Leucaena* forest	Nov 7–18, 2005	15.076	145.640
LSUS	native forest	Oct 31–Nov 11, 2005	15.043	145.629

Table 3. Model selection results from analysis of variance of multiple models explaining variation in *Rattus rattus*, *Suncus murinus*, and *Mus musculus* body condition index (bodycon) on Guam, Rota, Saipan, and Tinian, 2005–2006, as a function of island[4] (each island modeled separately), island[2] (Guam vs. Rota, Saipan, and Tinian combined), and habitat. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i).

	K	ΔAIC_c	w_i
R. rattus			
Bodycon(island[4])	6	0.00	1.000
Bodycon(island[2])	4	49.34	0.000
Bodycon(habitat)	6	70.70	0.000
S. murinus			
Bodycon(habitat)	6	0.00	0.999
Bodycon(island[4])	5	21.11	0.001
Bodycon(island[2])	4	23.90	0.000
M. musculus			
Bodycon(island[2])	6	0.00	0.656
Bodycon(island[4])	4	1.33	0.378
Bodycon(habitat)	6	9.38	0.006

Table 4. Mean ($\bar{X}$) rainfall (mm), standard error (SE), and 95% confidence intervals (95% CI) measured during livetrapping and snaptrapping on Guam, Rota, Saipan, and Tinian during 2005–2006 (*n* = 19 sites). Average rainfall measurement period was 12–16 hours on Occasion 1 and 24 hours on Occasions 2–5.

	Livetrapping			Snaptrapping		
	$\bar{X}$	SE	95% CI	$\bar{X}$	SE	95% CI
Occasion 1	3.8	2.3	0–8.3	3.9	1.7	0.5–7.3
Occasion 2	5.5	1.8	2.0–9.1	3.5	1.4	0.7–6.2
Occasion 3	4.1	1.2	1.6–6.5	3.7	1.7	0.3–7.1
Occasion 4	6.9	2.1	1.6–10.9	4.2	1.7	0.9–7.5
Occasion 5	5.4	2.7	0–10.8	2.3	0.6	1.1–3.5

Table 5. Number of individual *Mus musculus*, *Rattus exulans*, *R. norvegicus*, *R. rattus*, and *Suncus murinus* captured (M_{t+1}) and captures per unit effort (CPUE) during livetrapping (Live) and snaptrapping (Snap) of grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2006.

		M. musculus		*R. exulans*		*R. norvegicus*		*R. rattus*		*S. murinus*	
Site	Habitat	Live	Snap	Live	Snap	Live	Snap	Live	Snap	Live	Snap
Guam											
MSRG	grassland	15 (2.2)	19 (2.8)	1 (0.2)	1 (0.2)			22 (3.2)	14 (2.1)	14 (2.0)	19 (2.8)
ASMF	*Leucaena* forest							5 (0.7)	1 (0.2)		
GSYF	*Leucaena* forest							13 (2.5)	3 (0.7)		
PAGO	*Leucaena* forest										
GAHF	mixed							1 (0.1)	1 (0.2)		5 (1.0)
NMAR	native forest										
RITL	native forest								1 (0.2)		
Rota											
SABA	grassland	25 (4.1)	24 (4.9)					88 (14.3)	82 (16.9)		
GAON	*Leucaena* forest	19 (3.6)	9 (2.2)	13 (2.5)	12 (3.0)			42 (7.9)	20 (5.0)		
RAPF	mixed	32 (6.1)	15 (3.8)					106 (20.3)	79 (19.9)		
ASAK	native forest	1 (0.2)						11 (1.9)	4 (1.0)		
Saipan											
ACHU	grassland	51 (8.1)	52 (8.4)					41 (6.5)	32 (5.2)	19 (3.0)	12 (1.9)
OBYT	*Leucaena* forest	2 (0.3)		1 (0.2)	1 (0.2)	2 (0.3)	1 (0.2)	50 (7.9)	63 (14.7)	43 (6.8)	80 (18.7)
SAEN	mixed		1 (0.2)			1 (0.1)		8 (1.1)	15 (2.6)	47 (6.6)	20 (3.4)
SPOR	mixed					1 (0.2)	1 (0.2)	29 (4.8)	34 (8.3)	9 (1.5)	14 (3.4)
LATT	native forest							24 (4.0)	28 (7.0)	19 (3.2)	27 (6.7)
Tinian											
KAST	grassland	9 (1.4)	2 (0.5)			1 (0.2)	1 (0.2)	106 (16.5)	145 (35.4)	11 (1.7)	6 (1.5)
ABLE	*Leucaena* forest							55 (9.0)	41 (9.1)	93 (15.2)	62 (13.7)
LSUS	native forest							80 (12.8)	79 (19.7)	43 (6.9)	10 (2.5)

Table 6. Model selection results for mark-recapture and removal modeling of capture (*p*) and recapture (*c*) probability for *Rattus rattus* livetrapping and snaptrapping data collected on Guam, Rota, Saipan, and Tinian, 2005–2006. Parenthetical terms indicate the nesting structure of the previous variable (e.g., neo2(island[4]) specifies separate neophobia effects for each island). All heterogeneity models (h) used 2 finite mixtures to approximate individual heterogeneity. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i). Note that the exclusion of recapture data constrains $c = 0$ during removal modeling of livetrapping and snaptrapping data.

	K	ΔAIC_c	w_i
Mark-recapture modeling of *R. rattus* livetrapping data			
p neo2(island[4]) + sex + repstat + rainamt *c* island[4] + sex + repstat + rainamt	16	0.00	0.871
p neo2(island[4]) + repstat + rainamt *c* island[4] + repstat + rainamt	15	5.72	0.050
p neo2(island[4]) + sex + age + repstat + bodycon + size + rainprev + rainamt *c* island[4] + sex + age + repstat + bodycon + size + rainprev + rainamt	20	6.97	0.027
p neo2(island[4]) + sex + rainamt *c* island[4] + sex + rainamt	15	7.12	0.025
p neo2(island[4]) + rainamt *c* island[4] + rainamt	14	7.56	0.020
p neo2(island[4]) + sex + repstat *c* island[4] + sex + repstat	15	9.61	0.007
Removal modeling of *R. rattus* livetrapping data			
p neo2(island[4]) + sex + repstat + rainamt	12	0.00	0.860
p neo2(island[4]) + sex + age + repstat + bodycon + size + rainprev + rainamt	16	4.58	0.087
p neo2(island[4]) + sex + repstat	11	5.70	0.050
p neo2(island[4]) + sex + rainamt	11	12.18	0.003
Removal modeling of *R. rattus* snaptrapping data			
p(island[2]) + sex + age + repstat + size	6	0.00	0.375
p(island[2]) + age + repstat + size	5	2.24	0.122
p(island[2]) + sex + repstat	4	2.35	0.116
p(island[2]) + sex + age + repstat	5	2.77	0.094
p(island[2]) + sex + age + repstat + bodycon + size + rainprev + rainamt	9	2.86	0.090
p(island[2]) + sex	3	3.94	0.052
p(island[2]) + sex + repstat + size	5	4.09	0.049
p(island[2]) + age + repstat	4	4.55	0.038
p(island[2]) + repstat + size	4	5.44	0.025
p(island[2]) + age	3	6.50	0.015
p(island[2]) + sex + age	4	7.78	0.008
p(island[2]) + age + size	4	8.23	0.006
p(island[2]) + size	3	9.40	0.003
p(island[2]) + sex + age + size	5	9.69	0.003
p(island[2]) + sex + size	4	10.39	0.002
p(island[2])	2	12.08	0.001
p(island[4])	4	13.18	0.001

Table 7. Covariate effect sizes (β), standard errors (SE), and 95% confidence intervals (95% CI) from the top-ranked *Rattus rattus* models identified by mark-recapture and removal modeling of livetrapping data and snaptrapping data (Table 6) collected on Guam, Rota, Saipan, and Tinian, 2005–2006. Missing entries indicate that a particular covariate was not present in the top model.

	Livetrapping Data						Snaptrapping Data		
	Mark-Recapture Analysis			Removal Analysis			Removal Analysis		
Covariate	β	SE	95% CI	β	SE	95% CI	β	SE	95% CI
sex	-0.44	0.15	-0.75– -0.14	-1.69	0.61	-2.89– -0.50	-0.73	0.35	-1.41– -0.05
age							2.33	0.99	0.38–4.28
repstat	0.47	0.15	0.17–0.77	1.47	0.52	0.45–2.48	1.66	0.61	0.46–2.85
size							-0.92	0.40	-1.71– -0.13
rainamt	0.02	0.01	0.01–0.04	0.02	0.01	0.01–0.04			

Table 8. Model selection results for mark-recapture and removal modeling of capture (*p*) and recapture (*c*) probability for *Suncus murinus* livetrapping and snaptrapping data collected on Guam, Saipan, and Tinian, 2005–2006. Parenthetical terms indicate the nesting structure of the previous variable (e.g., neo2(island[4]) specifies separate neophobia effects for each island). All heterogeneity models (h) used 2 finite mixtures to approximate individual heterogeneity. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i). Note that the exclusion of recapture data constrains $c = 0$ during removal modeling of livetrapping and snaptrapping data.

	K	ΔAIC_c	w_i
Mark-recapture modeling of *S. murinus* livetrapping data			
$p_{\text{t + h}}$ $c_{\text{t(island[4]) + h}}$	10	0.00	0.994
$p_{\text{t + h + sex + repstat + bodycon + size + rainprev + rainamt}}$ $c_{\text{t(island[4]) + h + sex + repstat + bodycon + size + rainprev + rainamt}}$	16	10.33	0.006
Removal modeling of *S. murinus* livetrapping data			
$p_{\text{neo1 + bodycon}}$	3	0.00	0.254
p_{neo1}	2	0.17	0.233
$p_{\text{neo1(island[2])}}$	3	0.26	0.223
$p_{\text{neo1(island[4])}}$	4	1.24	0.137
p_{neo2}	3	2.15	0.087
$p_{.}$	1	4.08	0.033
$p_{\text{neo1(habitat)}}$	5	4.58	0.025
$p_{\text{neo1 + sex + repstat + bodycon + size + rainprev + rainamt}}$	8	7.00	0.008
Removal modeling of *S. murinus* snaptrapping data			
$p_{\text{neo1(habitat)}}$	5	0.00	0.836
$p_{\text{neo1(island[2])}}$	3	4.16	0.105
$p_{\text{neo1(island[4])}}$	4	5.94	0.043
p_{neo1}	2	7.94	0.016

Table 9. Model selection results for mark-recapture and removal modeling of capture (*p*) and recapture (*c*) probability for *Mus musculus* livetrapping and snaptrapping data collected on Guam, Rota, Saipan, and Tinian, 2005–2006. Parenthetical terms indicate the nesting structure of the previous variable (e.g., neo2(island[4]) specifies separate neophobia effects for each island). All heterogeneity models (h) used 2 finite mixtures to approximate individual heterogeneity. Results include the number of model parameters (*K*), relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i). Note that the exclusion of recapture data constrains $c = 0$ during removal modeling of livetrapping and snaptrapping data.

	K	ΔAIC_c	w_i
Mark-recapture modeling of *M. musculus* livetrapping data			
p t(island[2]) + h c t + h	11	0.00	0.349
p t(island[2]) + h c t(island[2]) + h	13	0.10	0.331
p t(island[4]) + h c t + h	19	1.20	0.192
p t + h c t(island[2]) + h	9	4.36	0.039
p t(island[4]) + h c t(island[4]) + h	23	4.65	0.034
p t + h c t + h	7	5.01	0.029
p neo1 + h c h	4	6.79	0.012
p t + h c t(habitat) + h	11	7.94	0.007
p neo2 + h c h	5	8.82	0.004
p t(island[2]) + h + sex + repstat + bodycon + size + rainprev + rainamt c t + h + sex + repstat + bodycon + size + rainprev + rainamt	17	9.23	0.003
Removal modeling of *M. musculus* livetrapping data			
p neo1	2	0.00	0.414
$p_.$	1	0.90	0.264
p neo1(island[4])	5	1.79	0.170
p neo1(island[2])	3	2.01	0.152
Removal modeling of *M. musculus* snaptrapping data			
p neo1(island[2])	3	0.00	0.745
p neo1	2	3.61	0.123
$p_.$	1	3.85	0.109
p neo1(habitat)	4	6.98	0.023

Table 10. *Rattus rattus* model-averaged mark-recapture and removal abundance estimates, standard errors (SE), coefficients of variation (CV), and 95% confidence intervals (95% CI) generated from livetrapping ($\hat{\hat{N}}_{\text{M-R Live}}$ and $\hat{\hat{N}}_{\text{REM Live}}$, respectively) and snaptrapping ($\hat{\hat{N}}_{\text{REM Snap}}$) data collected in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2006.

Site	Habitat	$\hat{\hat{N}}_{\text{M-R Live}}$	SE	CV	95% CI	$\hat{\hat{N}}_{\text{REM Live}}$	SE	CV	95% CI	$\hat{\hat{N}}_{\text{REM Snap}}$	SE	CV	95% CI
Guam[a]													
MSRG	grassland	41.1	9.4	0.23	22.8–59.5	76.6	45.9	0.60	0–166.5	17.5	5.2	0.30	7.3–27.7
ASMF	*Leucaena* forest	6.6	1.7	0.26	3.3–9.9	8.2	3.3	0.40	1.8–14.6	1.1	0.5	0.45	0.2–2.1
GSYF	*Leucaena* forest	22.9	5.8	0.25	11.5–34.3	34.6	19.8	0.57	0–73.3	3.7	1.4	0.38	1.1–6.4
GAHF	mixed	1.8	1.2	0.67	0–4.1	2.6	2.4	0.92	0–7.3	1.0	0.1	0.10	0.8–1.2
RITL	native forest									1.1	0.2	0.18	0.6–1.5
Rota													
SABA	grassland	142.4	22.8	0.16	97.6–187.1	229.8	114.2	0.50	6.0–453.7	210.0	107.0	0.51	0.3–419.6
GAON	*Leucaena* forest	70.0	12.9	0.18	44.7–95.2	100.9	45.4	0.45	11.9–189.9	34.9	9.2	0.26	16.9–52.9
RAPF	mixed	186.4	31.0	0.17	125.7–247.2	387.6	252.0	0.65	0–881.5	237.0	115.6	0.49	10.5–463.6
ASAK	native forest	17.8	4.3	0.24	9.4–26.3	24.3	10.8	0.44	3.1–45.4	9.1	5.2	0.57	0–19.3
Saipan													
ACHU	grassland	72.2	13.9	0.19	44.9–99.5	98.1	36.4	0.37	26.7–169.4	65.0	25.4	0.39	15.1–114.8
OBYT	*Leucaena* forest	90.6	17.4	0.19	56.4–124.7	180.9	115.2	0.64	0–406.6	151.5	53.0	0.35	47.6–255.4
SAEN	mixed	15.0	4.7	0.31	5.9–24.1	31.1	25.9	0.83	0–81.8	26.3	8.5	0.32	9.6–42.9
SPOR	mixed	54.8	11.7	0.21	31.9–77.7	134.8	100.4	0.74	0–331.5	82.5	38.6	0.47	6.8–158.1
LATT	native forest	47.1	11.1	0.24	25.4–68.8	77.0	44.0	0.57	0–163.3	55.4	16.6	0.30	22.8–87.9
Tinian													
KAST	grassland	194.4	34.5	0.18	126.8–262.1	374.3	230.7	0.62	0–826.5	474.8	268.6	0.57	0–1001.2
ABLE	*Leucaena* forest	85.6	14.1	0.16	58.0–113.2	131.5	59.8	0.45	14.4–248.6	122.8	79.3	0.65	0–278.2
LSUS	native forest	146.1	26.3	0.18	94.6–197.6	288.1	178.2	0.62	0–637.3	230.6	120.6	0.52	0–467.1

[a] Zero *R. rattus* captured at 2 sites (1 *Leucaena* forest and 1 native forest).

Table 11. *Suncus murinus* mark-recapture and model-averaged removal abundance estimates, standard errors (SE), coefficients of variation (CV), and 95% confidence intervals (95% CI) generated from livetrapping ($\hat{N}_{\text{M-R Live}}$ and $\hat{\bar{N}}_{\text{REM Live}}$, respectively) and snaptrapping ($\hat{\bar{N}}_{\text{REM Snap}}$) data collected in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2006. Note that mark-recapture estimates from livetrapping were not model-averaged (Table 8.). *S. murinus* was not captured or observed on Rota and is believed absent from that island.

Site	Habitat	$\hat{N}_{\text{M-R Live}}$	SE	CV	95% CI	$\hat{\bar{N}}_{\text{REM Live}}$	SE	CV	95% CI	$\hat{\bar{N}}_{\text{REM Snap}}$	SE	CV	95% CI
Guam[a]													
MSRG	grassland	20.3	5.8	0.29	8.9–31.7	23.3	6.5	0.28	10.6–35.9	80.9	97.0	1.20	0–271.0
GAHF	mixed									27.9	37.2	1.33	0–100.7
Saipan													
ACHU	grassland	28.8	8.5	0.30	12.1–45.5	32.3	8.7	0.27	15.2–49.4	53.1	65.7	1.24	0–181.8
OBYT	*Leucaena* forest	67.8	20.1	0.30	28.4–107.2	72.8	17.4	0.24	38.7–106.9	436.8	550.0	1.26	0–1514.7
SAEN	mixed	70.6	19.2	0.27	33.0–108.3	78.3	17.9	0.23	43.1–113.4	114.8	147.5	1.28	0–403.9
SPOR	mixed	13.6	4.5	0.33	4.9–22.4	15.5	5.1	0.33	5.6–25.4	80.3	103.8	1.29	0–283.8
LATT	native forest	30.0	9.4	0.31	11.5–48.4	31.0	7.9	0.25	15.5–46.5	135.4	168.8	1.25	0–466.2
Tinian													
KAST	grassland	17.3	5.8	0.34	5.9–28.7	18.5	5.4	0.29	7.9–29.0	26.6	33.6	1.26	0–92.5
ABLE	*Leucaena* forest	143.1	39.7	0.28	65.4–220.8	152.7	33.2	0.22	87.6–217.8	338.9	427.2	1.26	0–1176.3
LSUS	native forest	63.7	17.0	0.27	30.5–97.0	71.4	16.5	0.23	39.0–103.8	49.9	63.2	1.27	0–173.7

[a] Zero *S. murinus* captured at 5 sites (3 *Leucaena* forest and 2 native forest).

Table 12. *Mus musculus* model-averaged mark-recapture and removal abundance estimates, standard errors (SE), coefficients of variation (CV), and 95% confidence intervals (95% CI) generated from livetrapping ($\hat{\hat{N}}_{\text{M-R Live}}$ and $\hat{\hat{N}}_{\text{REM Live}}$, respectively) and snaptrapping ($\hat{\hat{N}}_{\text{REM Snap}}$) data collected in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2006.

Site	Habitat	$\hat{\hat{N}}_{\text{M-R Live}}$	SE	CV	95% CI	$\hat{\hat{N}}_{\text{REM Live}}$	SE	CV	95% CI	$\hat{\hat{N}}_{\text{REM Snap}}$	SE	CV	95% CI
Guam[a]													
MSRG	grassland	17.5	4.0	0.23	9.6–25.3	30.8	16.7	0.54	0–63.5	35.2	20.7	0.59	0–75.7
Rota													
SABA	grassland	41.5	10.1	0.24	21.6–61.3	51.6	27.1	0.53	0–104.7	54.4	37.8	0.69	0–128.4
GAON	*Leucaena* forest	32.0	8.3	0.26	15.7–48.3	39.2	20.9	0.53	0–80.1	20.5	14.8	0.72	0–49.5
RAPF	mixed	53.2	12.7	0.24	28.4–78.1	66.0	34.4	0.52	0–133.5	34.0	23.9	0.70	0–80.9
ASAK	native forest	1.7	1.2	0.71	0–4.0	2.1	1.9	0.90	0–5.7				
Saipan[b]													
ACHU	grassland	80.5	17.4	0.22	46.5–114.6	104.1	54.2	0.52	0–210.3	117.9	80.7	0.68	0–276.1
OBYT	*Leucaena* forest	3.2	1.6	0.50	0.2–6.3	4.1	3.0	0.73	0–10.0				
SAEN	mixed									2.3	2.3	1.00	0–6.8
Tinian[c]													
KAST	grassland	14.6	4.4	0.30	5.9–23.3	18.6	10.5	0.56	0–39.1	4.5	3.9	0.87	0–12.2

[a] Zero *M. musculus* captured at 6 sites (3 *Leucaena* forest, 1 mixed habitat, and 2 native forest).
[b] Zero *M. musculus* captured at 2 sites (1 mixed habitat and 1 native forest).
[c] Zero *M. musculus* captured at 2 sites (1 *Leucaena* forest and 1 native forest).

Table 13. Linear regression slope coefficients (β), standard errors (SE), and squared correlation coefficients[a] (r^2) relating the number of individuals captured (M_{t+1}) and captures/100 corrected trap nights (CPUE) derived from 1-, 3-, and 5-days of livetrapping ($M_{t+1\ Live}$, $CPUE_{Live}$) and snaptrapping ($M_{t+1\ Snap}$, $CPUE_{Snap}$) to model-averaged mark-recapture abundance estimates generated from 5-day livetrapping data ($\hat{\hat{N}}_{M-R\ Live}$) or, for S. murinus, non-model-averaged mark-recapture estimates from livetrapping ($\hat{N}_{M-R\ Live}$;Table 8). All regressions were constrained to pass through the origin.

	1 Day			3 Day			5 Day		
	β	SE	r^2	β	SE	r^2	β	SE	r^2
R. rattus (*n* = 19)									
$\hat{\hat{N}}_{M-R\ Live}$ vs. $M_{t+1\ Live}$	10.41	1.09	0.66	2.70	0.11	0.94	1.76	0.02	0.99
$\hat{\hat{N}}_{M-R\ Live}$ vs. $M_{t+1\ Snap}$	6.50	0.42	0.86	2.43	0.12	0.91	1.67	0.10	0.88
$\hat{\hat{N}}_{M-R\ Live}$ vs. $CPUE_{Live}$	13.22	1.48	0.63	9.74	0.46	0.92	10.36	0.27	0.98
$\hat{\hat{N}}_{M-R\ Live}$ vs. CPUE	5.32	0.31	0.89	5.97	0.32	0.90	7.01	0.45	0.86
S. murinus (*n* = 15)									
$\hat{N}_{M-R\ Live}$ vs. $M_{t+1\ Live}$	7.24	0.30	0.96	2.21	0.05	0.99	1.53	0.01	0.99
$\hat{N}_{M-R\ Live}$ vs. $M_{t+1\ Snap}$	7.86	1.64	0.40	2.37	0.41	0.53	1.49	0.24	0.58
$\hat{N}_{M-R\ Live}$ vs. $CPUE_{Live}$	9.78	0.44	0.96	8.47	0.23	0.98	9.64	0.12	0.99
$\hat{N}_{M-R\ Live}$ vs. CPUE	7.10	1.34	0.47	5.97	1.10	0.49	6.41	1.12	0.52
M. musculus (*n* = 19)									
$\hat{\hat{N}}_{M-R\ Live}$ vs. $M_{t+1\ Live}$	6.32	0.59	0.82	2.25	0.11	0.94	1.60	0.02	0.99
$\hat{\hat{N}}_{M-R\ Live}$ vs. $M_{t+1\ Snap}$	3.64	0.59	0.57	2.04	0.23	0.75	1.68	0.14	0.84
$\hat{\hat{N}}_{M-R\ Live}$ vs. $CPUE_{Live}$	8.43	0.72	0.84	8.35	0.32	0.97	9.49	0.16	0.99
$\hat{\hat{N}}_{M-R\ Live}$ vs. CPUE	3.79	0.54	0.65	7.02	0.59	0.85	9.88	0.54	0.93

[a] Squared correlation coefficients for constrained regressions were calculated as $r^2 = 1 - \frac{SSE}{SST_c}$, where SSE = the sum of squared residuals and SST_c = the corrected total sum of squared deviations.

Table 14. Initial cost (US$) of livetrapping and snaptrapping conducted on Guam, Rota, Saipan, and Tinian, 2005–2006, based on the purchase of minimal supplies necessary for sampling activities.

	n	Unit Cost	Total Cost
Livetrapping			
Haguruma trap [a]	36	14.99	539.64
Sherman trap [b]	121	16.15–17.65 [c]	1954.15–2135.65 [c]
1005-1 ear tags (*Rattus* species) [d]	1400	0.077–0.133 [e]	107.80–186.20 [e]
Application pliers for 1005-1 tags	1	25.00	25.00
Roestenburg ear tags (*Mus* and *Suncus*) [f]	900	0.33	297.00
Application pliers for Roestenburg tags	1	40.00	40.00
Total			2963.59–3223.49
Snaptrapping			
Victor trap [g]	36	1.63	58.68
Museum Special trap [h]	121	5.26	636.46
Total			695.14

[a] Standard Trading Co., Honolulu, HI
[b] Models LFG, LFAHD, and LFATDG, H.B. Sherman Traps, Inc., Tallahassee, FL
[c] Sherman cost varies depending on the metal (aluminum or galvanized) chosen for trap construction.
[d] National Band and Tag Co., Newport, KY
[e] Ear tag cost dependent on quantity ordered.
[f] S. Roestenberg, Riverton, UT
[g] Model M201, Woodstream Corporation, Lititz, PA
[h] Woodstream Corporation, Lititz, PA

Table 15. Volume (m^3) and mass (kg) of live and snap traps used during small mammal sampling on Guam, Rota, Saipan, and Tinian, 2005–2006.

	n	Unit Volume	Total Volume [a]	Unit Mass	Total Mass
Livetrapping					
Haguruma trap [b]	36	~ 0.0084	~ 0.302	0.460	16.6
Sherman trap [c]	121	~ 0.0015	~ 0.187	0.227–0.363 [d]	27.5–43.9 [d]
Total			~ 0.489		44.1–60.5
Snaptrapping					
Victor trap [e]	36	~ 0.00041	~ 0.015	0.132	4.8
Museum Special trap [f]	121	~ 0.00015	~ 0.018	0.049	5.9
Total			~ 0.033		10.7

[a] Represents minimum estimate of total volume; realized volume is greater due to inefficiency when packing traps for transport.
[b] Standard Trading Co., Honolulu, HI
[c] Models LFG, LFAHD, and LFATDG, H.B. Sherman Traps, Inc., Tallahassee, FL
[d] Sherman trap mass dependent on metal choice: aluminum (light weight) or galvanized (heavy weight).
[e] Model M201, Woodstream Corporation, Lititz, PA
[f] Woodstream Corporation, Lititz, PA

Table 16. Total time (person-hours) required for site preparation, 5-day livetrapping activites, and 5-day snaptrapping activities in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2006. Livetrapping and snaptrapping times include time required for trap baiting, trap monitoring, and processing of captured animals.

		Time Required		
	Habitat	Site Preparation	Livetrapping	Snaptrapping
Guam				
MSRG	grassland	19.0	34.4	22.5
ASMF	*Leucaena* forest	40.5	16.7	13.3
GSYF	*Leucaena* forest	52.1	21.5	16.3
PAGO	*Leucaena* forest	37.3	24.3	21.3
GAHF	mixed	60.5	17.5	18.3
NMAR	native forest	41.8	16.5	19.5
RITL [a]	native forest		19.5	26.2
Rota				
SABA	grassland	17.0	41.5	18.8
GAON	*Leucaena* forest	63.2	34.7	16.4
RAPF	mixed	64.2	50.3	21.5
ASAK	native forest	76.5	27.3	17.9
Saipan				
ACHU	grassland	8.5	48.3	15.0
OBYT	*Leucaena* forest	34.0	37.0	28.3
SAEN	mixed	67.5	27.0	15.3
SPOR	mixed	119.0	33.4	23.3
LATT	native forest	51.0	32.5	19.3
Tinian				
KAST	grassland	13.5	42.7	20.3
ABLE	*Leucaena* forest	41.0	38.8	21.6
LSUS	native forest	67.8	39.4	18.3

[a] Site preparation time not recorded.

FIGURES

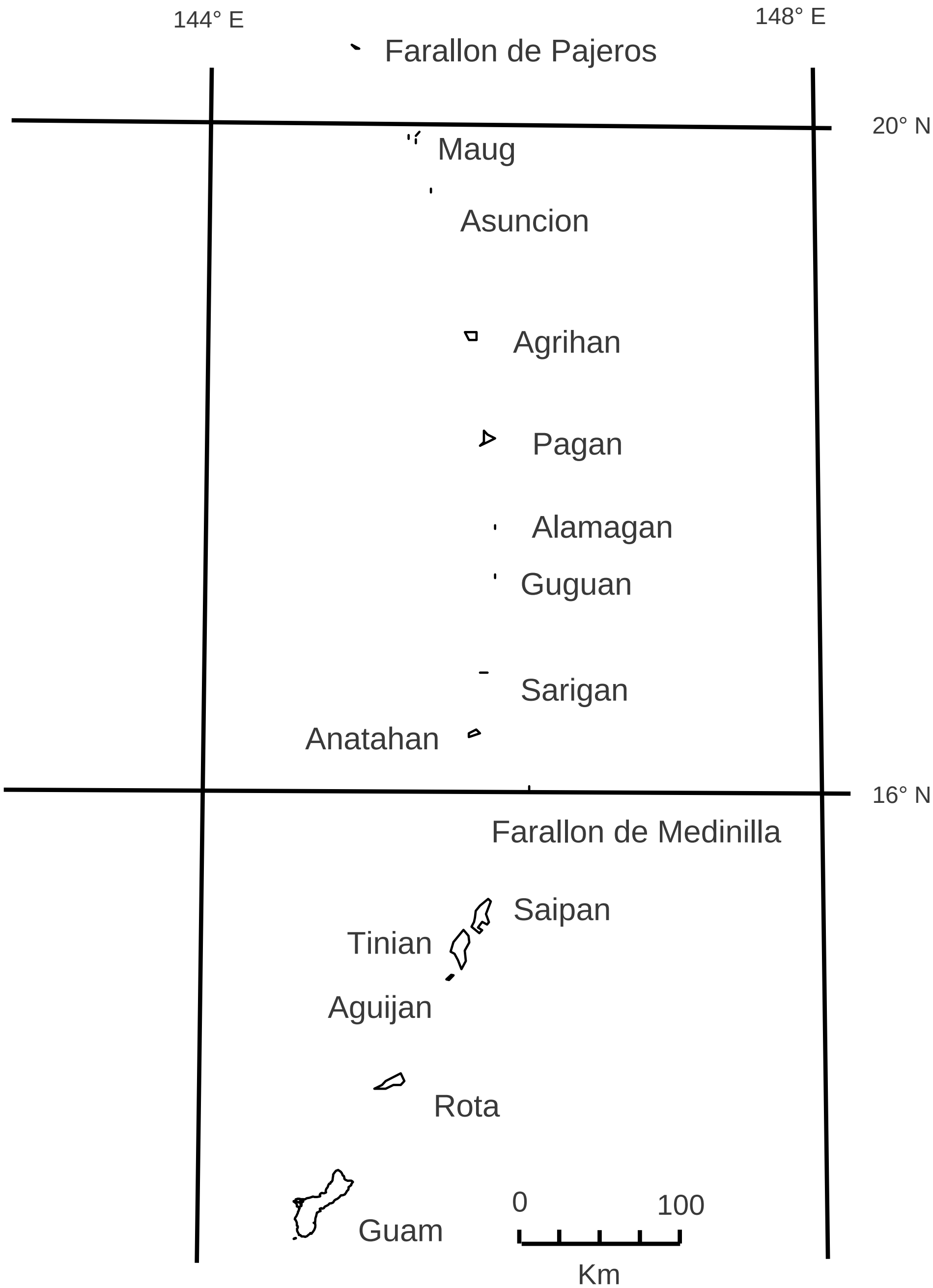

Figure 1. Map of the principal Mariana Islands.

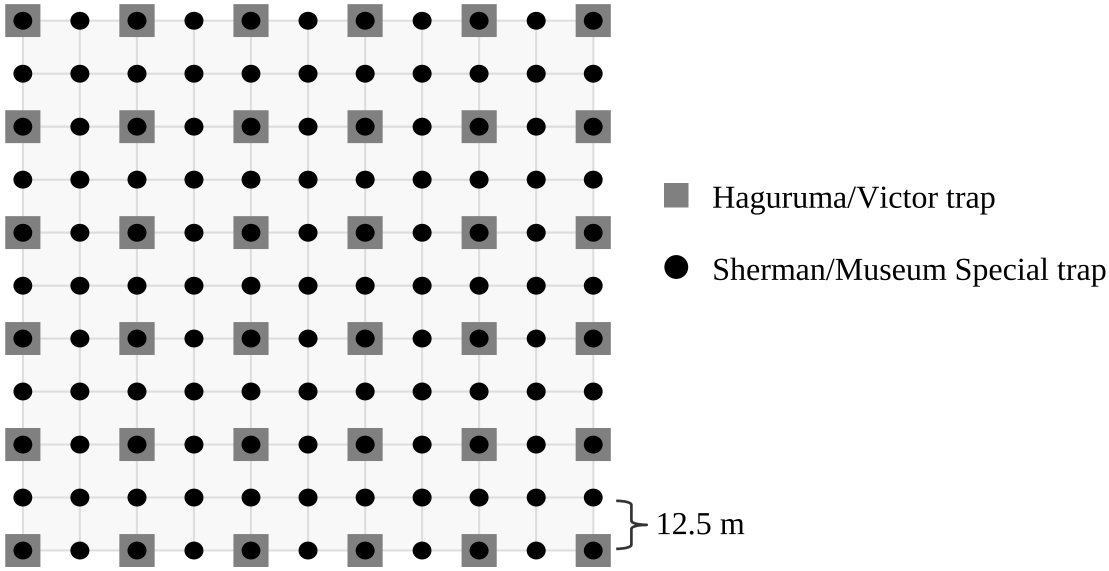

Figure 2. Schematic diagram of 11 x 11 grid (nominal area = 1.56 ha) used during livetrapping (Haguruma and Sherman traps) and snaptrapping (Victor and Museum Special traps) on Guam, Rota, Saipan, and Tinian, 2005–2006.

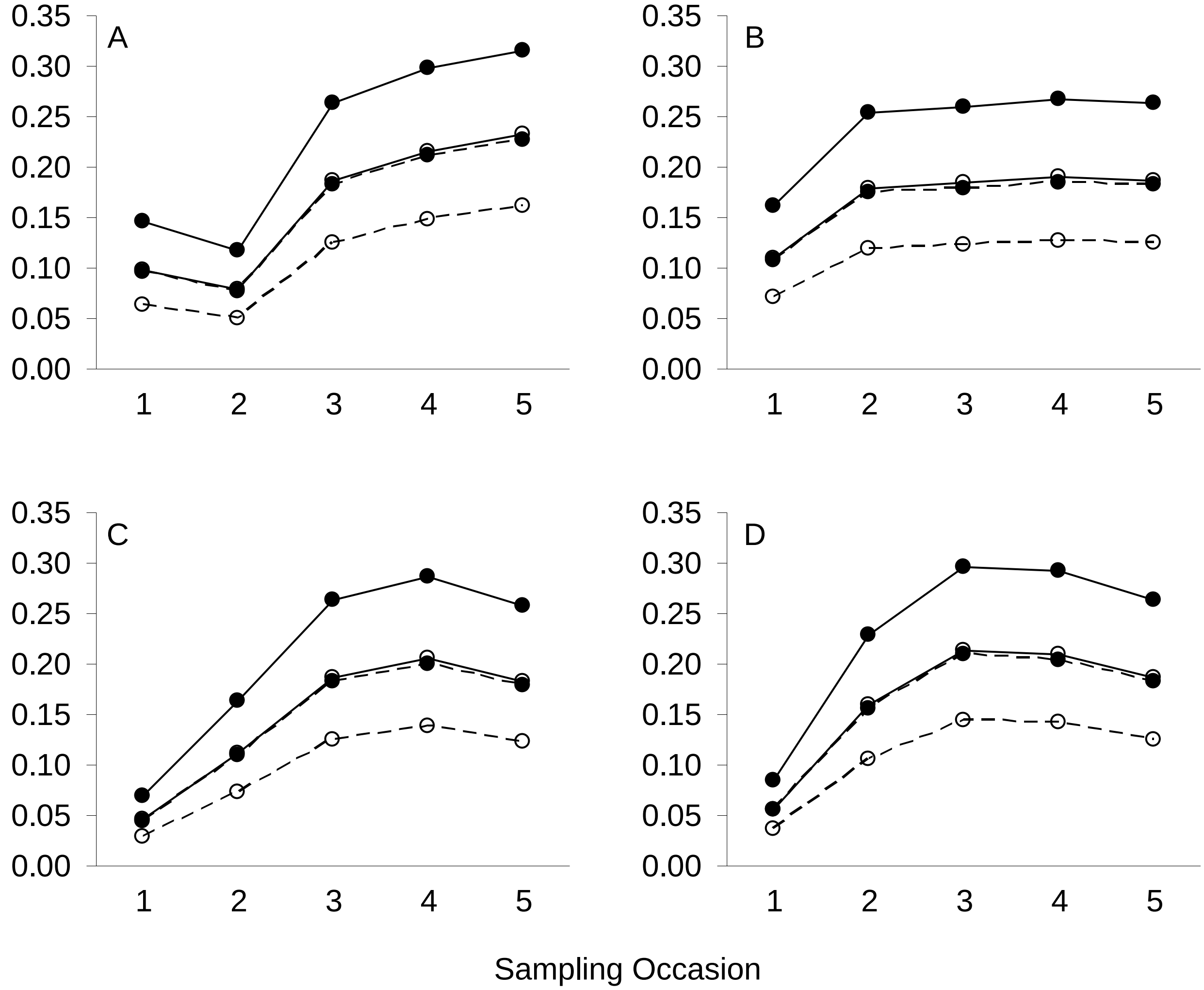

Figure 3. Effect of sex (female = •, male = ○) and reproductive status (reproductively active = solid line, non-reproductive = dashed line) on *Rattus rattus* capture probability generated from mark-recapture modeling of livetrapping data collected on Guam (A), Rota (B), Saipan (C), and Tinian (D), 2005–2006.

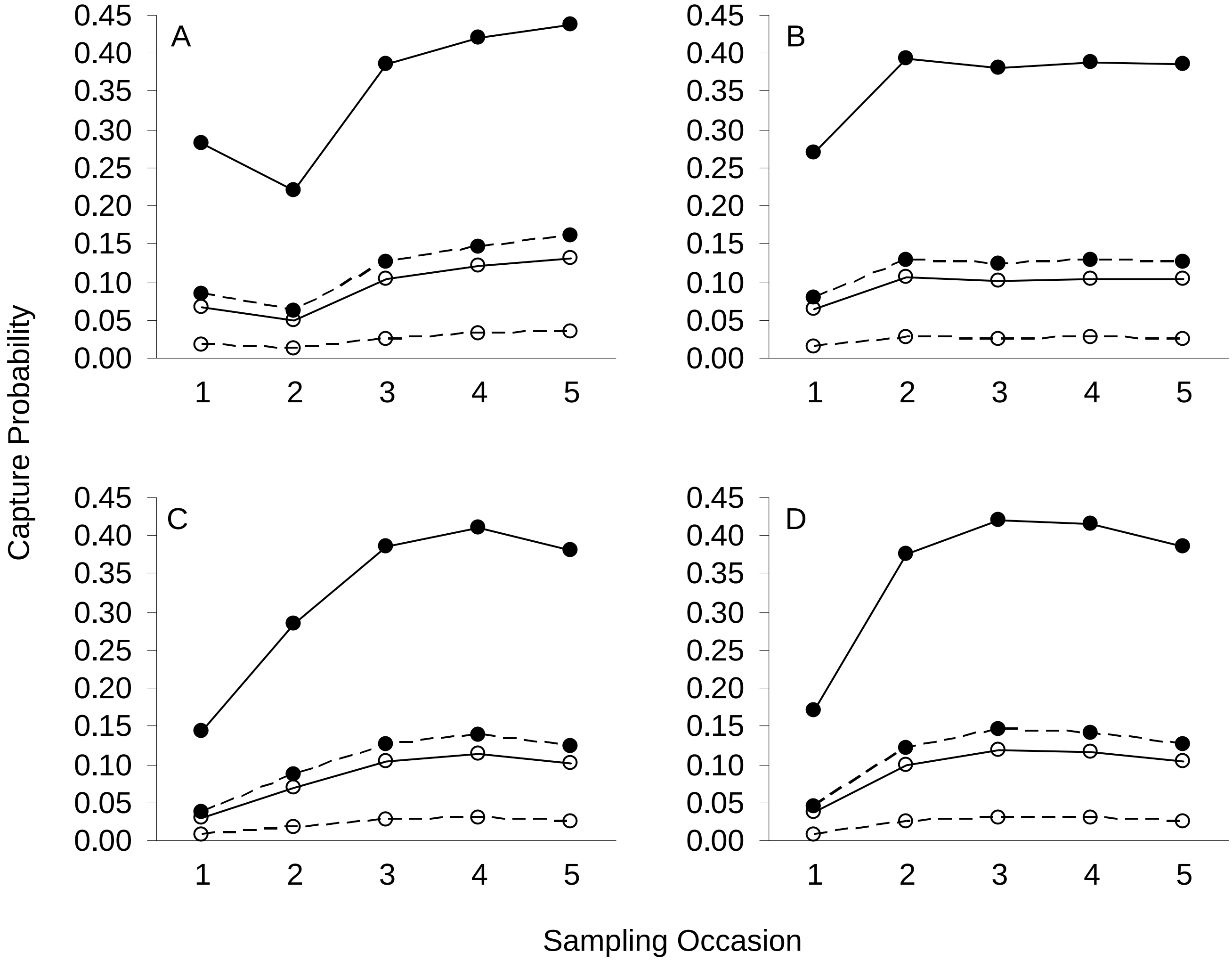

Figure 4. Effect of sex (female = •, male = ○) and reproductive status (reproductively active = solid line, non-reproductive = dashed line) on *Rattus rattus* capture probability generated from removal modeling of livetrapping data collected on Guam (A), Rota (B), Saipan (C), and Tinian (D), 2005–2006.

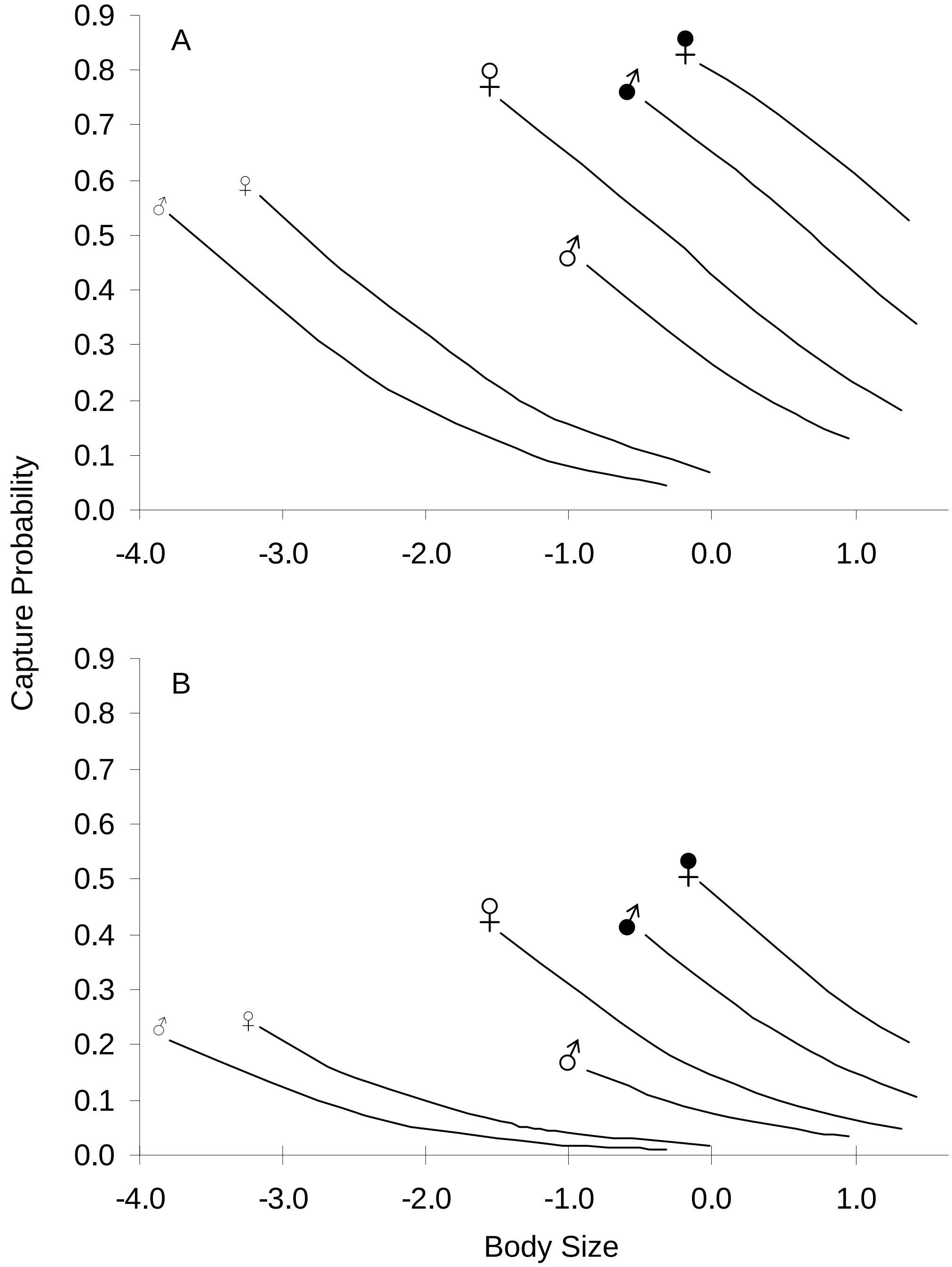

Figure 5. *Rattus rattus* snaptrapping capture probability as a function of sex, age (adult = large symbol, juvenile = small symbol), reproductive status (reproductively active = closed symbol, non-reproductive = open symbol), and body size (a composite variable created from a principle components analysis of mass, head-body length, tail length, hind foot length, and ear length, where size increases from left to right on the x-axis) for Guam (A) and the combination of Rota, Saipan, and Tinian (B).

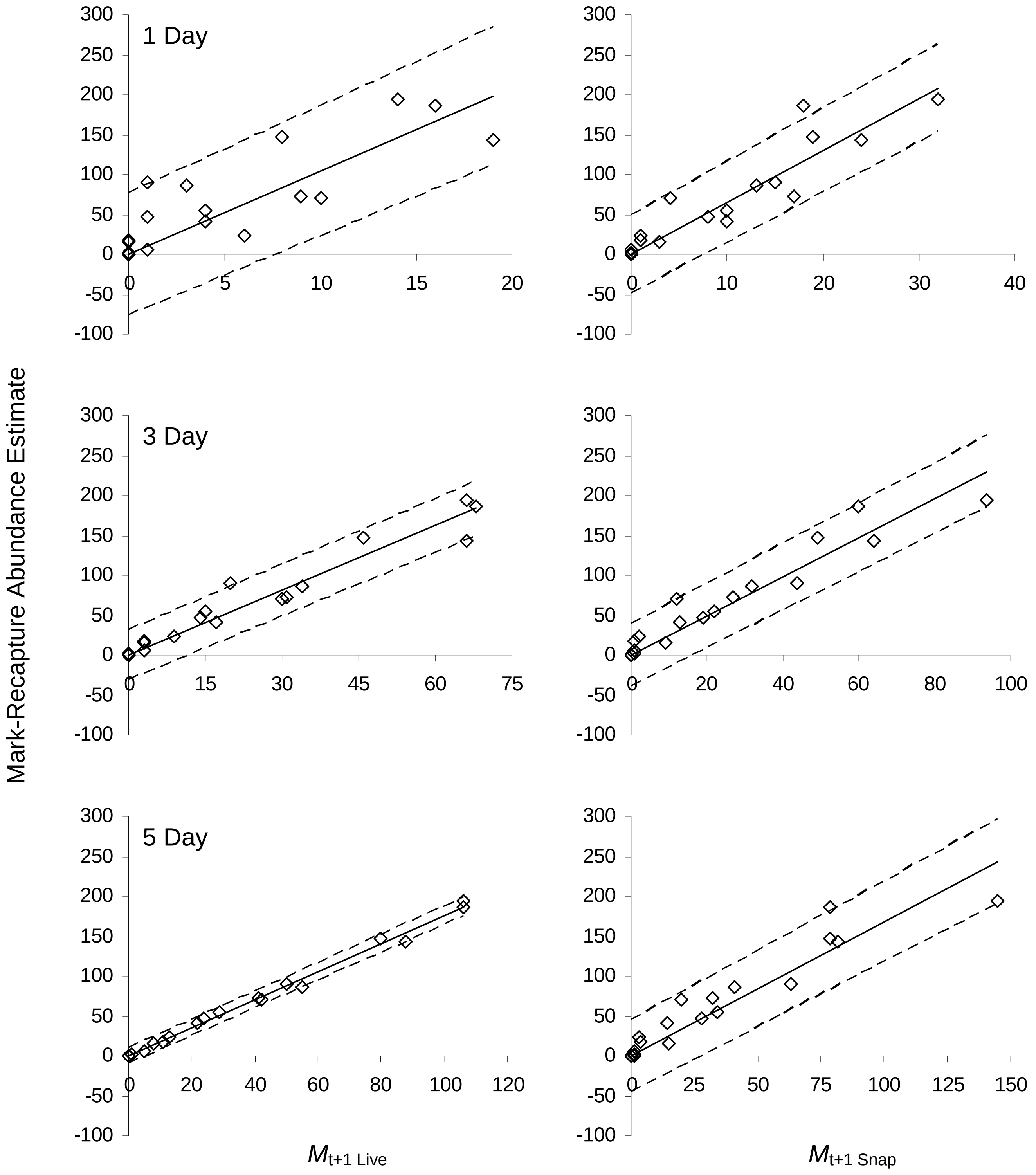

Figure 6. Relationship between *Rattus rattus* mark-recapture abundance estimates generated from livetrapping data and M_{t+1} from 1 day, 3 days, and 5 days of livetrapping ($M_{t+1\ Live}$) and snaptrapping ($M_{t+1\ Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value. Note the change in M_{t+1} scale as sampling duration increases.

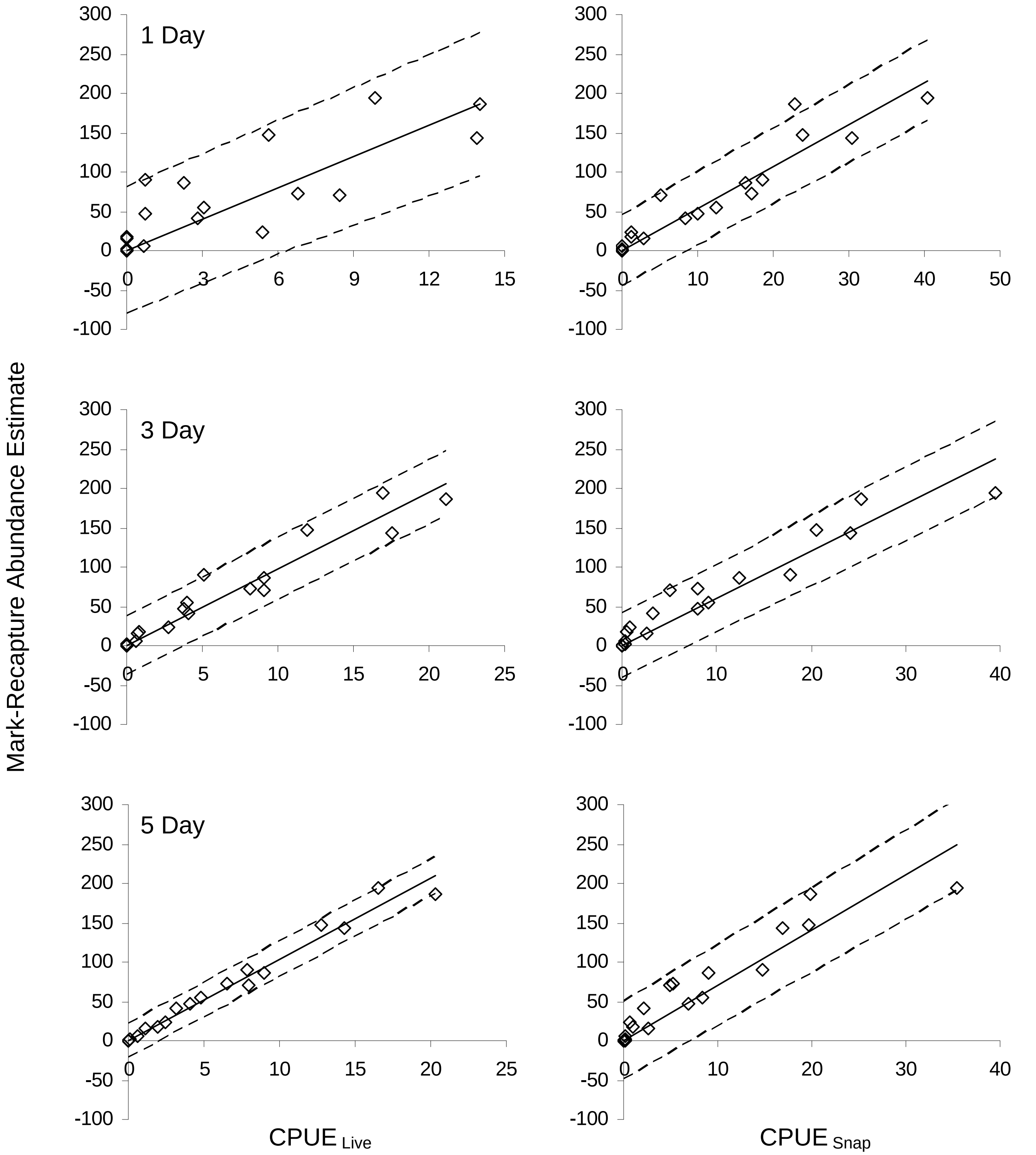

Figure 7. Relationship between *Rattus rattus* mark-recapture abundance estimates generated from livetrapping data and CPUE (captures / 100 corrected trap nights) from 1 day, 3 days, and 5 days of livetrapping ($CPUE_{Live}$) and snaptrapping ($CPUE_{Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value.

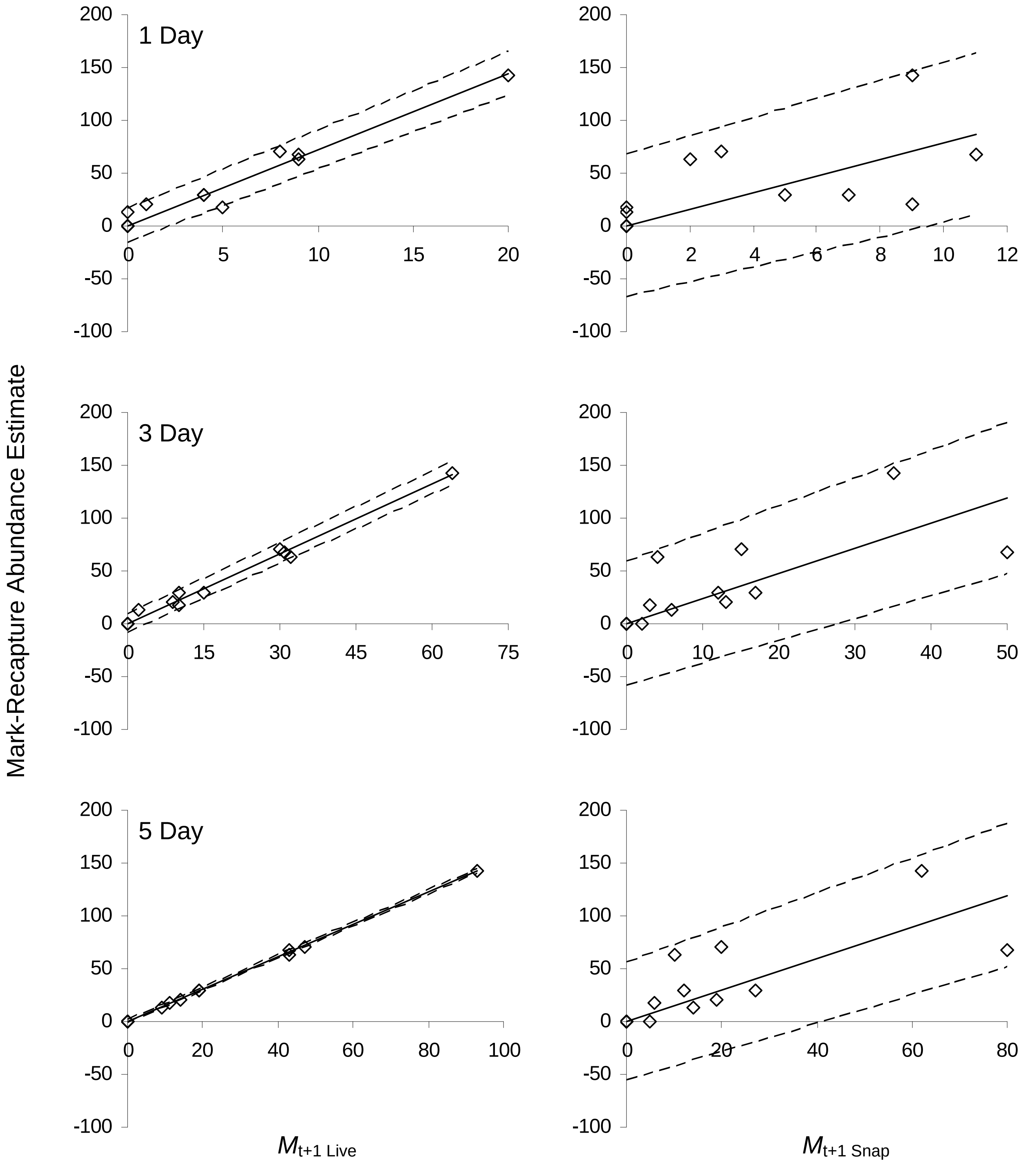

Figure 8. Relationship between *Suncus murinus* mark-recapture abundance estimates generated from livetrapping data and M_{t+1} from 1 day, 3 days, and 5 days of livetrapping ($M_{t+1\ Live}$) and snaptrapping ($M_{t+1\ Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. *S. murinus* was not captured on Rota and the 4 sites from this island are not included. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value. Note the change in M_{t+1} scale as sampling duration increases.

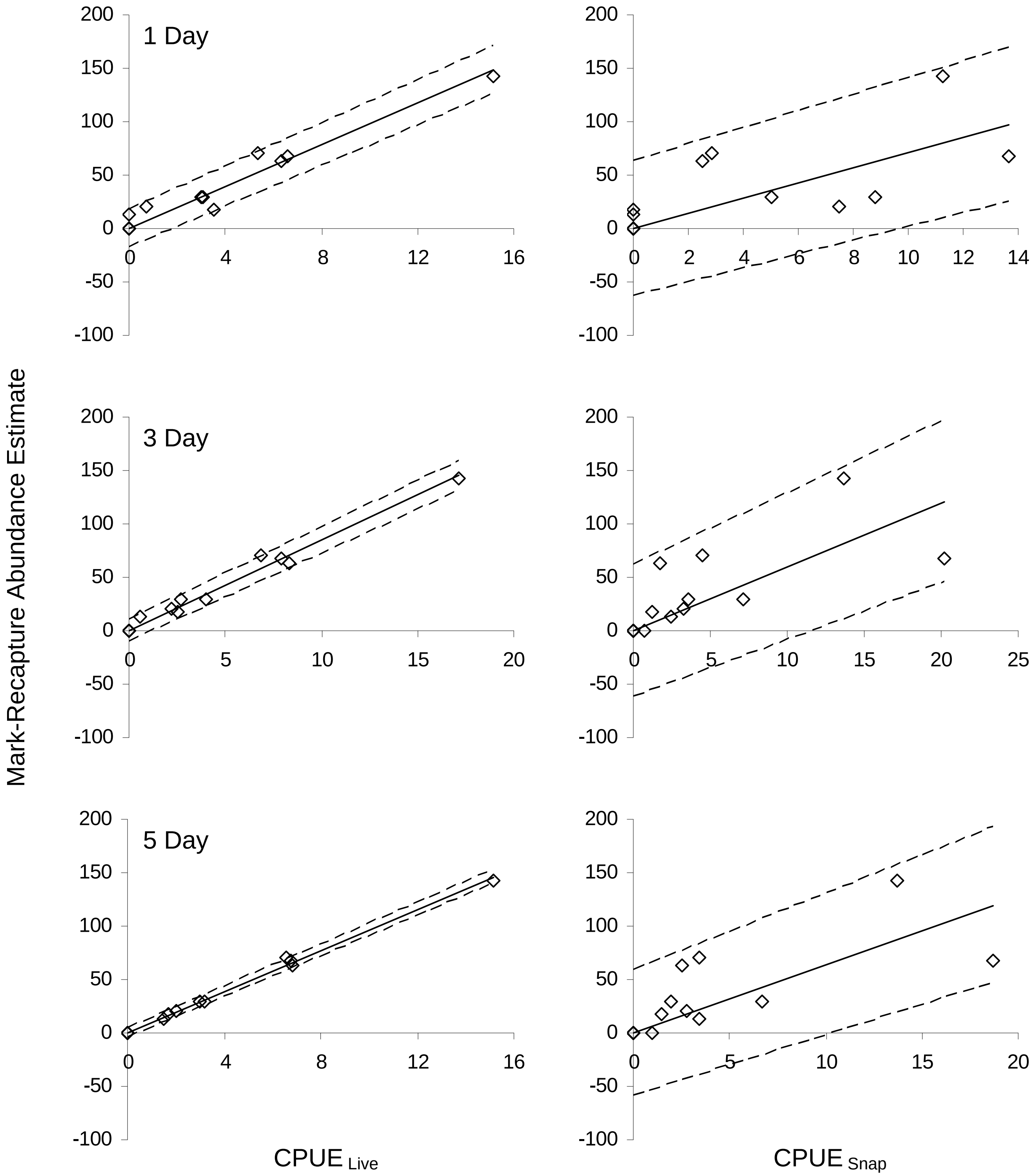

Figure 9. Relationship between *Suncus murinus* mark-recapture abundance estimates generated from livetrapping data and CPUE (captures / 100 corrected trap nights) from 1 day, 3 days, and 5 days of livetrapping (CPUE $_{Live}$) and snaptrapping (CPUE $_{Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. *S. murinus* was not captured on Rota and the 4 sites from this island are not included. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value.

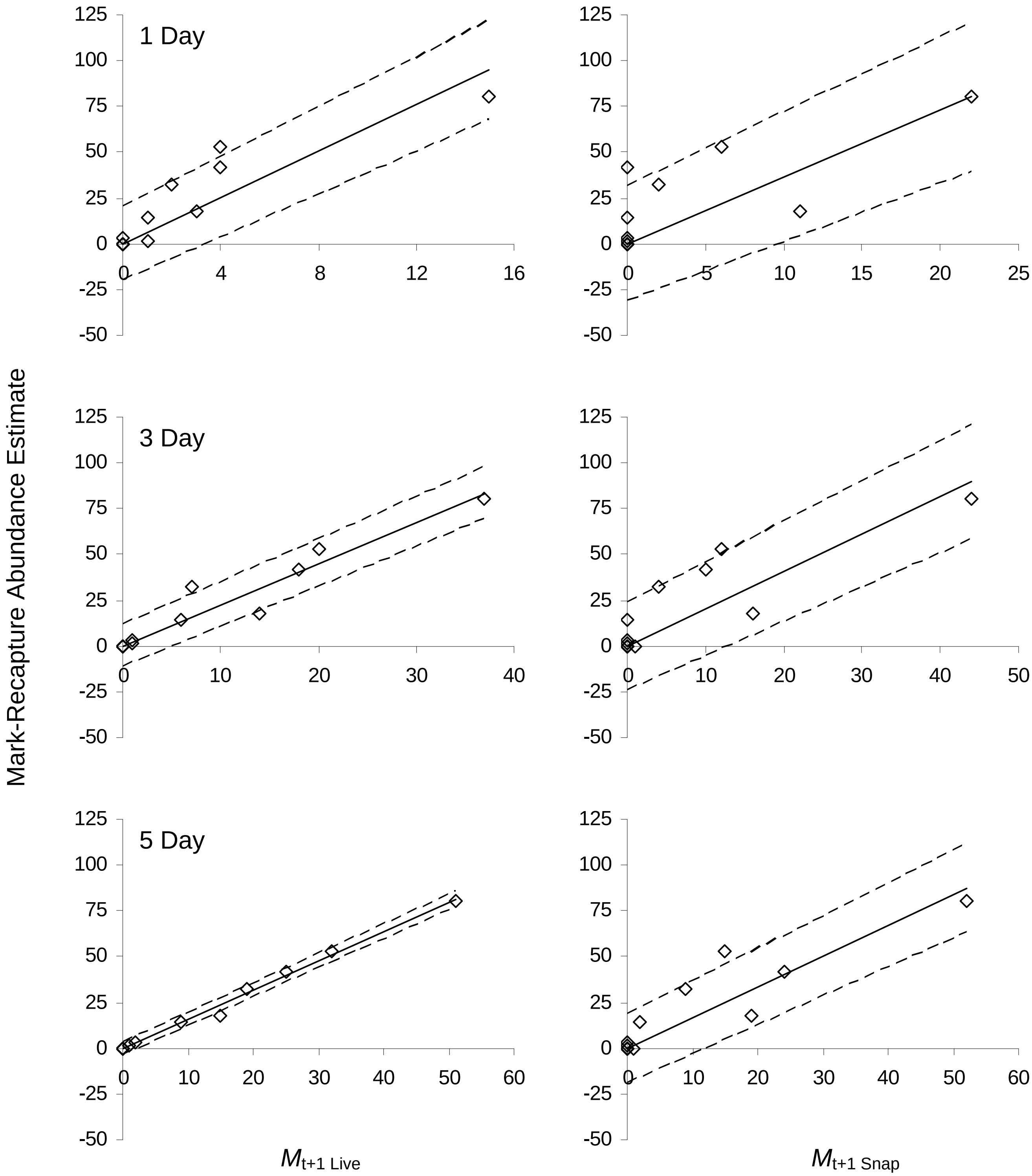

Figure 10. Relationship between *Mus musculus* mark-recapture abundance estimates generated from livetrapping data and M_{t+1} from 1 day, 3 days, and 5 days of livetrapping ($M_{t+1\ Live}$) and snaptrapping ($M_{t+1\ Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value. Note the change in M_{t+1} scale as sampling duration increases.

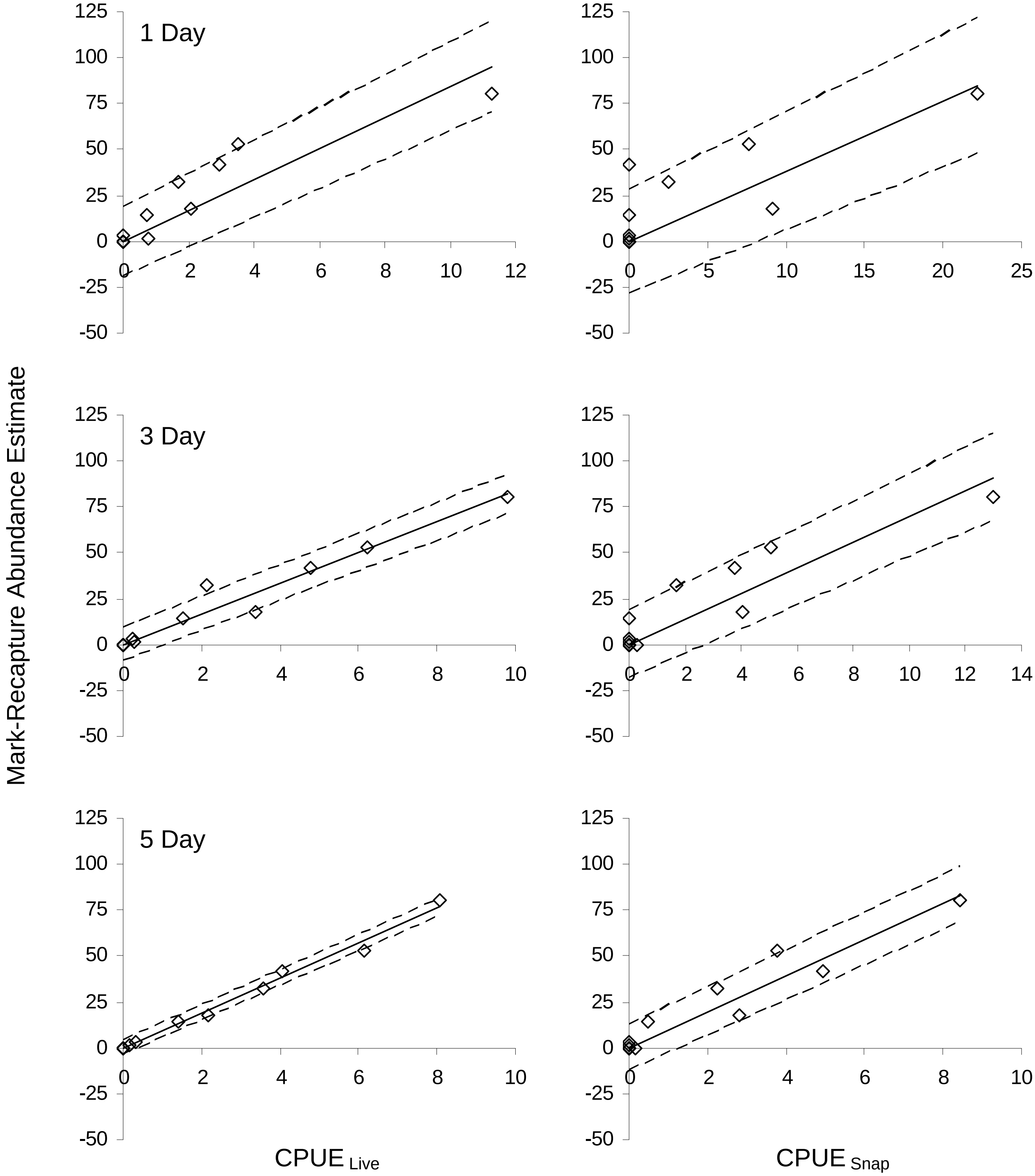

Figure 11. Relationship between *Mus musculus* mark-recapture abundance estimates generated from livetrapping data and CPUE (captures / 100 corrected trap nights) from 1 day, 3 days, and 5 days of livetrapping ($CPUE_{Live}$) and snaptrapping ($CPUE_{Snap}$) conducted at 19 sites on Guam (n = 7), Rota (n = 4), Saipan (n = 5), and Tinian (n = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value.

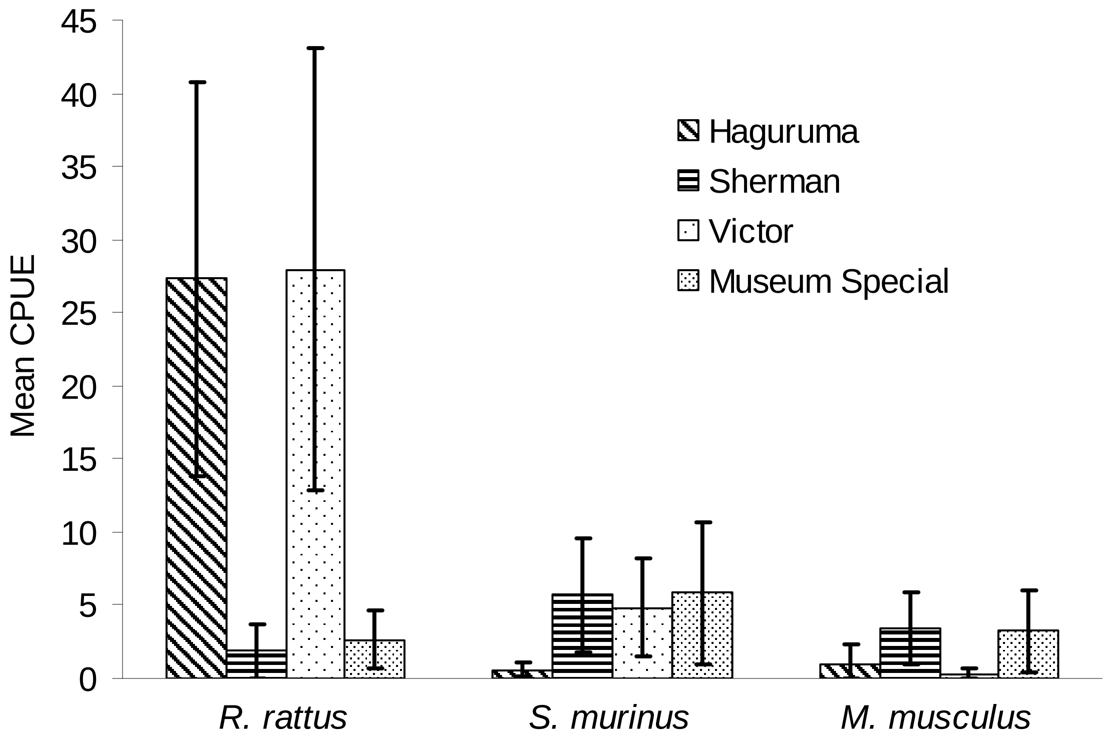

Figure 12. Mean *Rattus rattus*, *Suncus murinus*, and *Mus musculus* CPUE (captures / 100 corrected trap nights) in Haguruma and Sherman live traps (livetrapping) and Victor and Museum Special snap traps (snaptrapping) during small mammal sampling on Guam, Rota, Saipan, and Tinian, 2005–2006. Sampling effort in CPUE calculations includes only sites where a species was captured: *R. rattus* $n = 17$, *S. murinus* $n = 10$, and *M. musculus* $n = 9$. Bars indicate 95% confidence intervals.

APPENDIX 2A. Post-hoc investigation of possible geographic closure violations during small mammal sampling on Guam, Rota, Saipan, and Tinian, 2005–2006

Attempts to generate removal abundance estimates from small mammal livetrapping and snaptrapping data collected on Guam, Rota, Saipan, and Tinian, 2005–2006, were largely unsuccessful, possibly because of a lack of population closure. Failure of population closure (births, deaths, emigration, or immigration) is problematic for all closed population estimation techniques, but especially so for removal abundance estimation methods which also assume that captures decline over successive sampling occasions (Otis et al. 1978, White et al. 1982, Pollock 1991). If we consider only short-duration sampling events, births and deaths are unlikely to impact population closure in a significant fashion. Similarly, it seems unlikely that significant numbers of animals would move away from the sampling area (emigration) during a short-duration sampling event. Further, if emigration did occur during sampling, it would decrease the number of animals in the sampling area and facilitate a decline in new captures. It is therefore unlikely that we would be able to distinguish emigration from the desired effect of declining captures of new individuals over successive sampling occasions. Thus, the most plausible avenue for a failure of population closure, and the only one likely to account for non-declining captures of new individuals, is immigration. While immigration generally refers to the physical movement of new individuals into the sampling area, we might also consider situations where resident animals with very low capture probability (e.g., juvenile or otherwise non-dominant individuals) become more trappable over time as a form of immigration. This might occur as juveniles mature (unlikely to be important during short-duration sampling) or as the social structure of the sampling area is disrupted by the removal of dominant individuals, resulting in increasing social status (and perhaps increasing capture probability) for formerly non-dominant individuals (Summerlin and Wolfe 1973).

If physical immigration were to occur during sampling, we would expect this failure of population closure to be manifested as higher than expected captures in perimeter traps (defined as the 2 outer "rings" of traps; Figure A.1) of the sampling grid, especially during later sampling occasions (unfortunately, changes in social status can not be investigated in this way). Instead, the average deviation in *R. rattus* perimeter captures (observed - expected) during livetrapping was -6% (i.e., fewer perimeter captures than expected), with a maximum daily deviation of only 2% (Figure A.2). Similarly, the averaged deviation in *S. murinus* and *M. musculus* perimeter captures during livetrapping was 6.9% and 0.4%, respectively, with maximum daily deviations of 10% for *S. murinus* and 13% for *M. musculus* (Figure A.2). Immigration seems more likely during snaptrapping, as the physical removal of animals creates territorial vacancies which might attract animals into the sampling area, even over relatively short time spans (Stickel 1946, Fitzgerald et al. 1981, White et al. 1982). It is not surprising, then, that both the average and maximum daily deviation in perimeter captures were greater during snaptrapping for *R. rattus* (1.6% and 9%, respectively), *S. murinus* (7.5% and 17%, respectively), and *M. musculus* (6.1% and 28%, respectively; Figure A.3). It is notable that the maximum daily deviation in perimeter captures for *S. murinus* and *M. musculus* occurred on the first and second day of sampling, rather than during later sampling occasions as might be expected if significant numbers of animals were moving into the sampling area (Figure A.3).

Unfortunately, there is no defined level of increased perimeter captures which might be considered sound evidence either for or against immigration and failure of population closure. Further, one of the inherent issues with grid-based sampling is that more animals are exposed to perimeter traps than interior traps, because perimeter traps are available to animals with territories within the grid as well as animals with territories intersecting the perimeter of the grid, whereas interior traps are only available to animals with territories within the grid (Dice 1938, Stickel 1954, Otis et al. 1978). Thus, a slight positive deviation in perimeter trap captures might be expected as a result of perimeter trap captures of animals with home ranges only partially within the sampling grid (and therefore not likely to be captured in interior traps). Overall, although these results do not seem suggestive of significant immigration, especially during livetrapping, they do not provide sufficient evidence to rule out a failure of population closure due to immigration at any individual study site.

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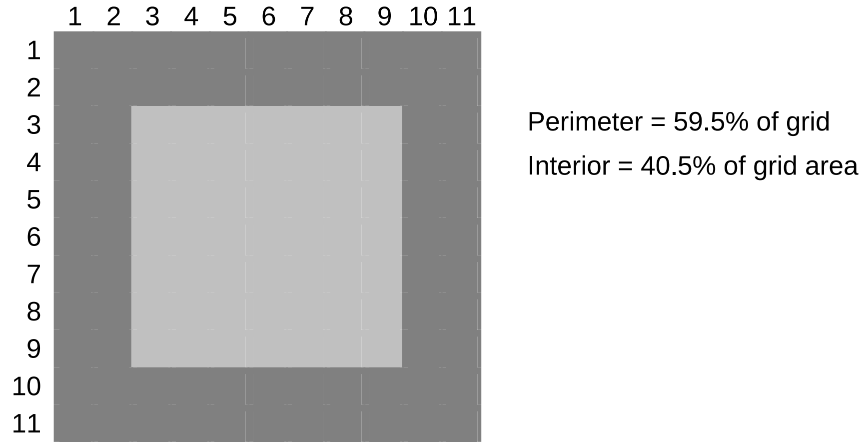

Figure A.1. Schematic representation of perimeter and interior trap assignment for evaluation of geographic closure during livetrapping and snaptrapping.

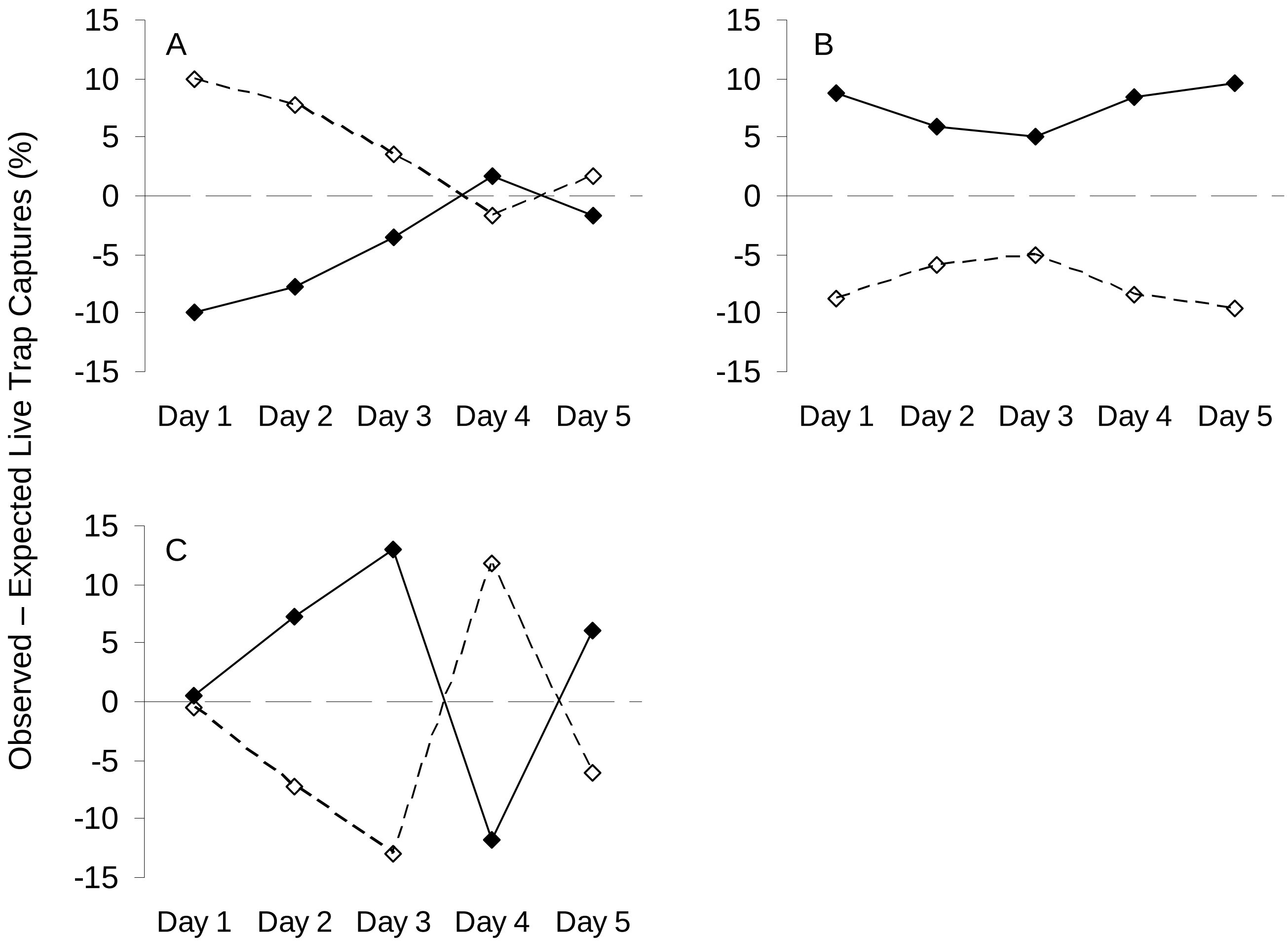

Figure A.2. Percent deviation in observed live trap captures of *Rattus rattus* (A), *Suncus murinus* (B), and *Mus musculus* (C) in interior (◊ and dashed line) and perimeter traps (♦ and solid line), relative to expected live trap captures based on the grid area encompassed by interior and perimeter traps, as specified in Figure A.1.

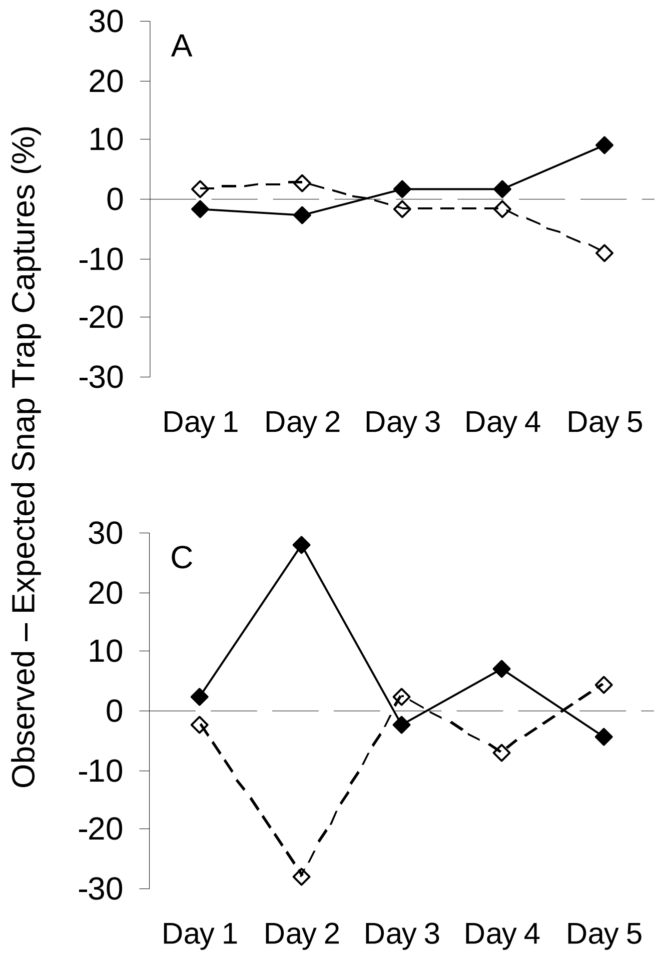

Figure A.3. Percent deviation in observed snap trap captures of *Rattus rattus* (A), *Suncus murinus* (B), and *Mus musculus* (C) in interior (◊ and dashed line) and perimeter traps (♦ and solid line), relative to expected snap trap captures based on the grid area encompassed by interior and perimeter traps, as specified in Figure A.1.

APPENDIX 2B. Post-hoc evaluation of relationship between count-based indices and removal abundance estimates from snaptrapping data

Due to concerns that our evaluation of M_{t+1} and CPUE from livetrapping ($M_{t+1\ Live}$ and $CPUE_{Live}$) and snaptrapping ($M_{t+1\ Snap}$ and $CPUE_{Snap}$) may have been biased by our use of mark-recapture abundance estimates from livetrapping ($\hat{\hat{N}}_{M-R\ Live}$) as a proxy for true abundance, we reevaluated the predictive utility of these indices using removal abundance estimates from snaptrapping ($\hat{\hat{N}}_{REM\ Snap}$). Note that this change was not justified based on our evaluation of these abundance estimates, as $\hat{\hat{N}}_{M-R\ Live}$ were clearly more informative (e.g., smaller CVs and narrower 95% CIs) than $\hat{\hat{N}}_{REM\ Snap}$.

Indices generated from 1, 3, and 5 days of livetrapping and snaptrapping data were strong correlates ($r^2 \geq 0.8$) with $\hat{\hat{N}}_{REM\ Snap}$ in 7 of 12 comparisons (58%) for *R. rattus*, 5 of 12 comparisons (42%) for *S. murinus*, and 11 of 12 comparisons (92%) for *M. musculus* (Table B.1). In all cases, regression coefficients were > 1.0 (Table B.1).

The utility of M_{t+1} and CPUE as predictors of small mammal abundance differed depending on the sampling method (livetrapping vs. snaptrapping) and sampling duration the index was generated from. For *R. rattus*, $M_{t+1\ Snap}$ and $CPUE_{Snap}$ were better predictors of $\hat{\hat{N}}_{REM\ Snap}$ than $M_{t+1\ Live}$ and $CPUE_{Live}$ (Figures B.1, B.2). In all cases, the predictive value of indices improved with increased sampling duration, with the narrowest 95% prediction intervals (95% PIs) observed for indices generated from 5 days of sampling data. For example, a mid-range $M_{t+1\ Snap}$ value from 1 day of sampling (15 individuals) predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 50–275 individuals, whereas a mid-range $M_{t+1\ Snap}$ value from 5 days of sampling (60 individuals) predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 130–220 individuals (Figure B.1). In contrast, there was less improvement in predictive value between a mid-range $M_{t+1\ Live}$ value from 1 day of sampling (10 individuals; 95% PL $\approx$ 0–350 individuals) and a mid-range $M_{t+1\ Live}$ value from 5 days of sampling (50 individuals; 95% PL $\approx$ 25–250 individuals (Figure B.1). Similar patterns were evident in the predictive value of CPUE. For example, a mid-range $CPUE_{Snap}$ value from 1 day of sampling (20 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 90–290 individuals, whereas the same mid-range $CPUE_{Snap}$ value from 5 days of sampling predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 200–290 individuals (Figure B.2). Again, 95% PIs were wider for $CPUE_{Live}$, ranging from approximately 0–350 individuals for a mid-range $CPUE_{Live}$ value from 1 day of sampling (7 individuals/100 corrected trap nights) to approximately 25–300 individuals for a mid-range $CPUE_{Live}$ value from 5 days of sampling (Figure B.2).

For *S. murinus*, the predictive value of $M_{t+1\ Snap}$ and $CPUE_{Snap}$ improved with additional sampling occasions, whereas the predictive value of $M_{t+1\ Live}$ and $CPUE_{Live}$ was relatively independent of sampling duration, and quite poor overall (Figures B.3, B.4). For example, a mid-range $CPUE_{Snap}$ value from 1 day of sampling (7 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 50–300 individuals, whereas a mid-range $CPUE_{Snap}$ value from 5 days of sampling (10 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 200–275 individuals (Figure B.4). In contrast, a mid-range $CPUE_{Live}$ value (8 captures/100 corrected trap nights) predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 0–400 individuals, independent of sampling duration (Figure B.4).

For *M. musculus*, the predictive value of $M_{t+1\ Snap}$ and $CPUE_{Snap}$ improved with additional sampling occasions, although this effect is likely an artifact of an anomalous observation at a single site on the first day of sampling. At this site, where $\hat{\hat{N}}_{REM\ Snap} = 54$ individuals, there were 0 *M. musculus* captures on the first day of sampling which inflated the 1-day 95% PIs for both $M_{t+1\ Snap}$ and $CPUE_{Snap}$ (Figures B.5, B.6). Without this outlier, 95% PIs from the first day of sampling were similar to 95% PIs from 3 and 5 days of sampling, suggesting that the predictive value of $M_{t+1\ Snap}$ and $CPUE_{Snap}$ was relatively constant, with a mid-range $CPUE_{Snap}$ value (5 captures/100 corrected trap nights) from 5 days of sampling predicting $\hat{\hat{N}}_{REM\ Snap}$ of approximately 50–75 individuals (Figure B.6). In contrast, the predictive value of $M_{t+1\ Live}$ and $CPUE_{Live}$ seemed to decrease slightly with additional sampling occasions (Figures B.5, B.6). For example, a $CPUE_{Live}$ value of 5 captures/100 corrected trap nights from 1 day of sampling predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 40–70 individuals, whereas the same $CPUE_{Live}$ value from 5 days of sampling predicts $\hat{\hat{N}}_{REM\ Snap}$ of approximately 30–85 individuals (Figure B.6).

After reevaluating M_{t+1} and CPUE, it is clear that our evaluation is biased towards whichever abundance estimate ($\hat{\hat{N}}_{REM\ Snap}$ or $\hat{\hat{N}}_{M-R\ Live}$) is used as a proxy for true small mammal abundance. This is a troubling result, as it complicates any conclusions we might draw from our evaluation of count-based indices of abundance. We can conclude that the predictive value of count-based indices is related to sampling duration, with indices generated from 1 or 3 days of sampling data often having poor predictive value (i.e., wide 95% PIs). Further, we found little difference in the predictive value of M_{t+1}

$_{\text{Live}}$ vs. CPUE $_{\text{Live}}$ or $M_{\text{t+1 Snap}}$ vs. CPUE $_{\text{Snap}}$, perhaps not surprising as CPUE is an extension of M_{t+1}. We also note that although $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$ were better predictors of $\hat{\hat{N}}_{\text{REM Snap}}$ than were $M_{\text{t+1 Live}}$ and CPUE $_{\text{Live}}$, there was little difference in the width of 95% PIs between $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$ for predicting $\hat{\hat{N}}_{\text{REM Snap}}$ or $\hat{\hat{N}}_{\text{M}-\text{R Live}}$, especially for indices generated from 1 or 3 days of sampling data (e.g., compare 95% PIs between Figure B.1 and Figure 6 in main body of Chapter 2, Figure B.2 and Figure 7 in main body of Chapter 2, etc). In other words, $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$ were no better for predicting $\hat{\hat{N}}_{\text{REM Snap}}$ than they were for predicting $\hat{\hat{N}}_{\text{M}-\text{R Live}}$, except for *S. murinus* 5 day $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$ and *M. musculus* 5 day $M_{\text{t+1 Snap}}$. It is not entirely clear, however, if this result is a product of the high variance of $\hat{\hat{N}}_{\text{REM Snap}}$, or is related to some characteristic of $M_{\text{t+1 Snap}}$ and CPUE $_{\text{Snap}}$.

Table B.1. Linear regression slope coefficients (β), standard errors (SE), and squared correlation coefficients [a] (r^2) relating the number of individuals captured (M_{t+1}) and captures/100 corrected trap nights (CPUE) derived from 1-, 3-, and 5-days of livetrapping ($M_{t+1\ Live}$, $CPUE_{Live}$) and snaptrapping ($M_{t+1\ Snap}$, $CPUE_{Snap}$) to model-averaged removal abundance estimates generated from 5-day snaptrapping data ($\hat{\hat{N}}_{REM\ Snap}$). All regressions were constrained to pass through the origin.

	1 Day			3 Day			5 Day		
	β	SE	r^2	β	SE	r^2	β	SE	r^2
R. rattus (*n* = 19)									
$\hat{\hat{N}}_{REM\ Snap}$ vs. $M_{t+1\ Live}$	16.00	2.63	0.49	4.30	0.44	0.75	2.83	0.24	0.82
$\hat{\hat{N}}_{REM\ Snap}$ vs. $M_{t+1\ Snap}$	10.90	0.89	0.83	4.18	0.20	0.94	2.93	0.09	0.97
$\hat{\hat{N}}_{REM\ Snap}$ vs. $CPUE_{Live}$	19.88	3.60	0.42	15.25	1.77	0.70	16.40	1.65	0.76
$\hat{\hat{N}}_{REM\ Snap}$ vs. $CPUE_{Snap}$	9.02	0.60	0.89	10.36	0.37	0.97	12.37	0.31	0.98
S. murinus (*n* = 15)									
$\hat{\hat{N}}_{REM\ Snap}$ vs. $M_{t+1\ Live}$	19.07	3.36	0.54	5.82	0.99	0.56	4.06	0.67	0.58
$\hat{\hat{N}}_{REM\ Snap}$ vs. $M_{t+1\ Snap}$	27.68	3.77	0.69	8.71	0.31	0.97	5.39	0.07	0.99
$\hat{\hat{N}}_{REM\ Snap}$ vs. $CPUE_{Live}$	25.90	4.51	0.55	22.36	3.82	0.56	25.61	4.21	0.59
$\hat{\hat{N}}_{REM\ Snap}$ vs. $CPUE_{Snap}$	25.26	2.60	0.81	22.44	0.62	0.98	23.80	0.52	0.99
M. musculus (*n* = 19)									
$\hat{\hat{N}}_{REM\ Snap}$ vs. $M_{t+1\ Live}$	8.36	0.38	0.96	2.81	0.14	0.94	1.91	0.14	0.89
$\hat{\hat{N}}_{REM\ Snap}$ vs. $M_{t+1\ Snap}$	5.00	0.55	0.78	2.77	0.14	0.94	2.23	0.03	0.99
$\hat{\hat{N}}_{REM\ Snap}$ vs. $CPUE_{Live}$	10.99	0.53	0.95	10.20	0.66	0.91	11.06	1.04	0.83
$\hat{\hat{N}}_{REM\ Snap}$ vs. $CPUE_{Snap}$	5.06	0.53	0.80	9.17	0.38	0.96	12.53	0.45	0.97

[a] Squared correlation coefficients for constrained regressions were calculated as $r^2 = 1 - \frac{SSE}{SST_c}$, where SSE = the sum of squared residuals and SST_c = the corrected total sum of squared deviations.

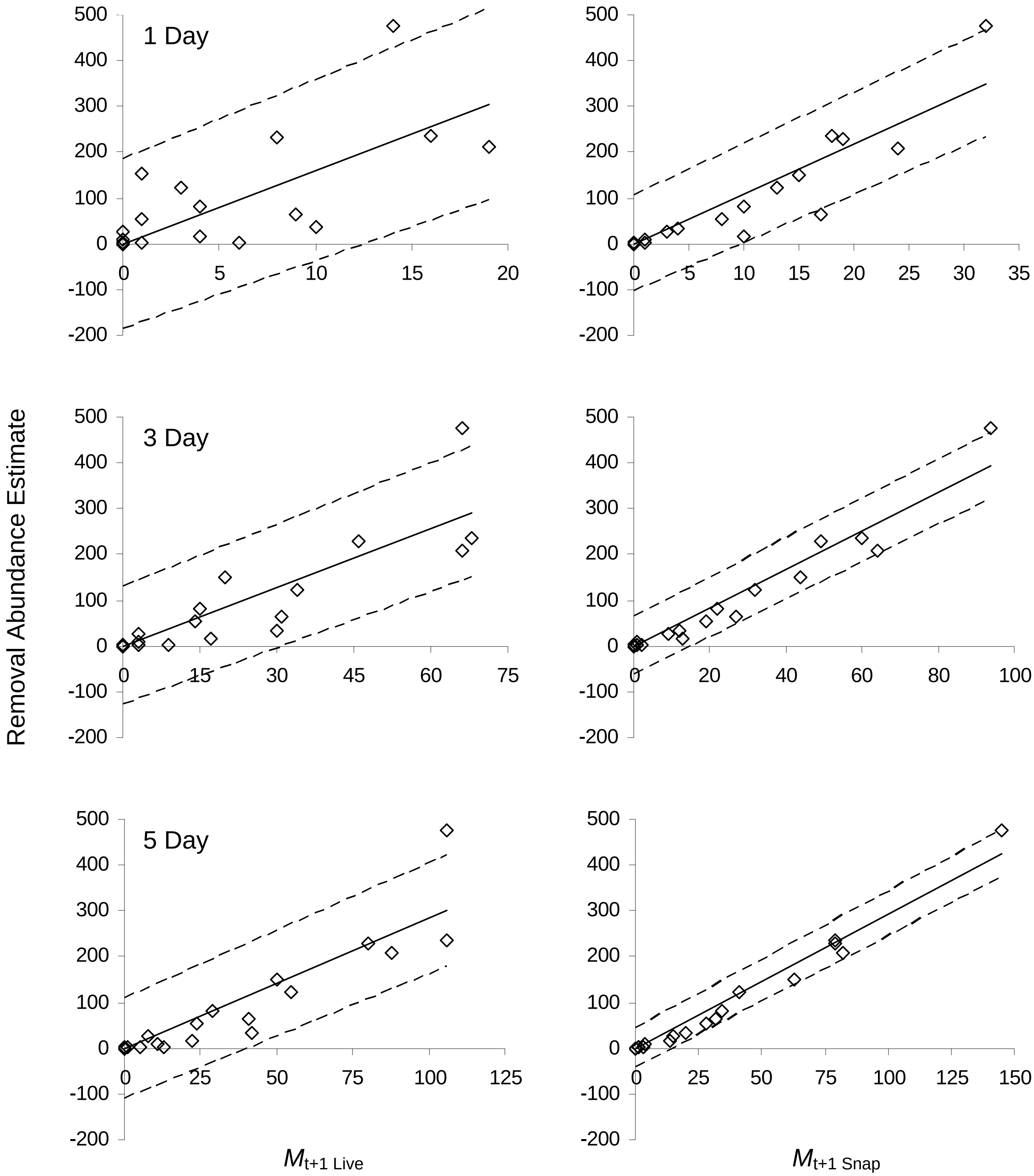

Figure B.1. Relationship between *Rattus rattus* removal abundance estimates generated from snaptrapping data and M_{t+1} from 1 day, 3 days, and 5 days of livetrapping ($M_{t+1\ Live}$) and snaptrapping ($M_{t+1\ Snap}$) conducted at 19 sites on Guam (n = 7), Rota (n = 4), Saipan (n = 5), and Tinian (n = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value. Note the change in M_{t+1} scale as sampling duration increases.

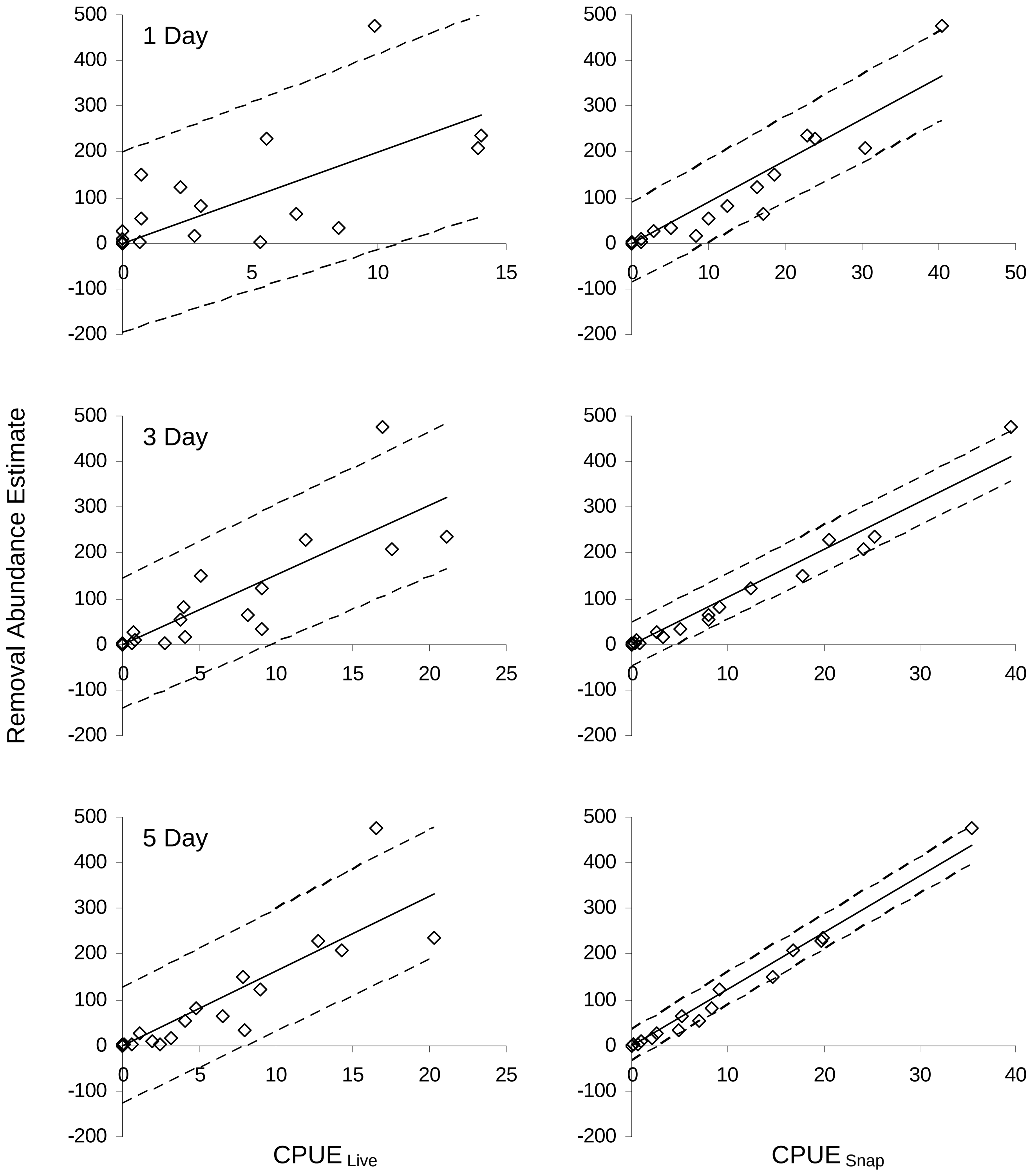

Figure B.2. Relationship between *Rattus rattus* removal abundance estimates generated from snaptrapping data and CPUE (captures / 100 corrected trap nights) from 1 day, 3 days, and 5 days of livetrapping (CPUE $_{Live}$) and snaptrapping (CPUE $_{Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value.

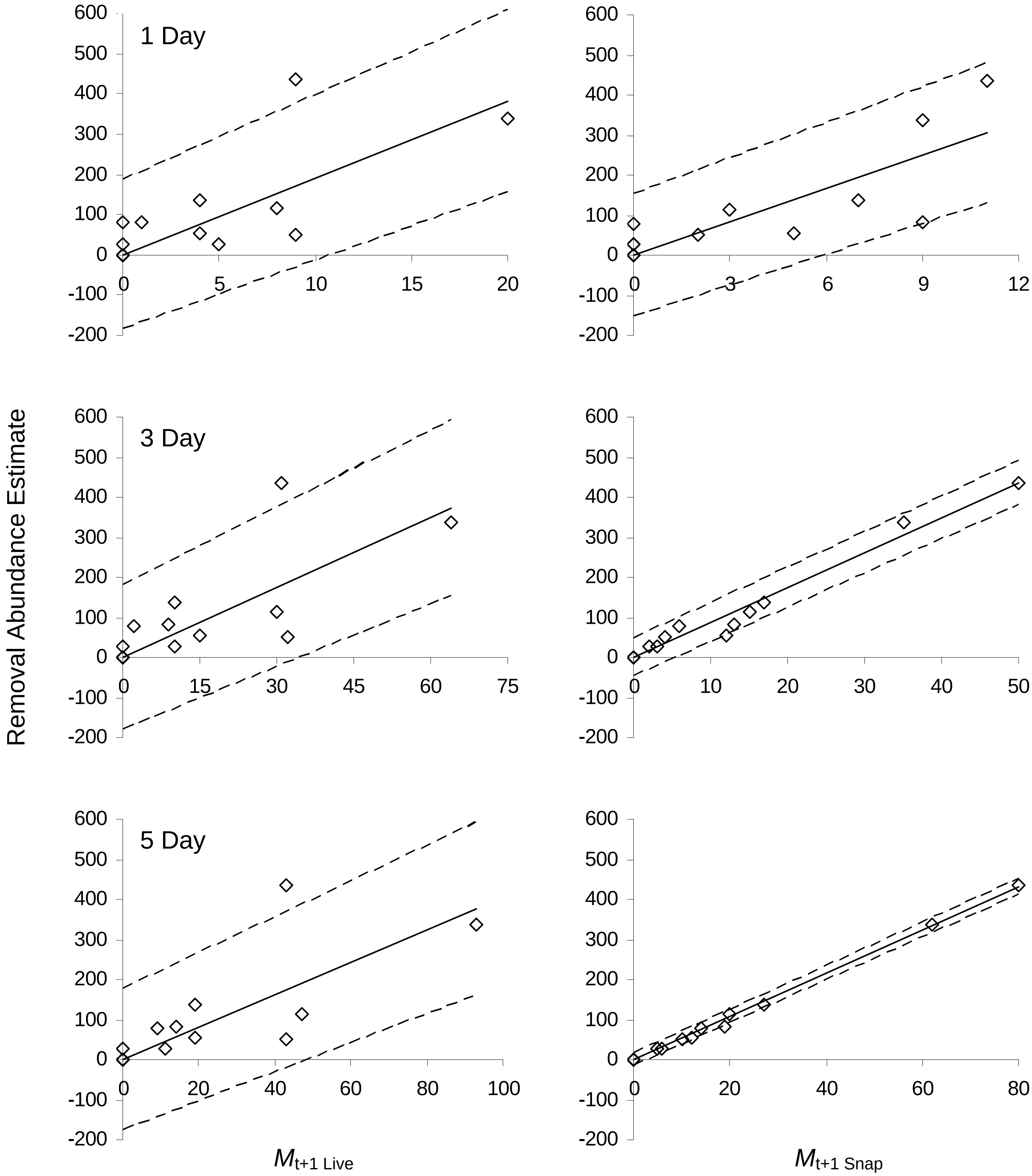

Figure B.3. Relationship between *Suncus murinus* removal abundance estimates generated from snaptrapping data and M_{t+1} from 1 day, 3 days, and 5 days of livetrapping ($M_{t+1\ Live}$) and snaptrapping ($M_{t+1\ Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. *S. murinus* was not captured on Rota and the 4 sites from this island are not included. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value. Note the change in M_{t+1} scale as sampling duration increases.

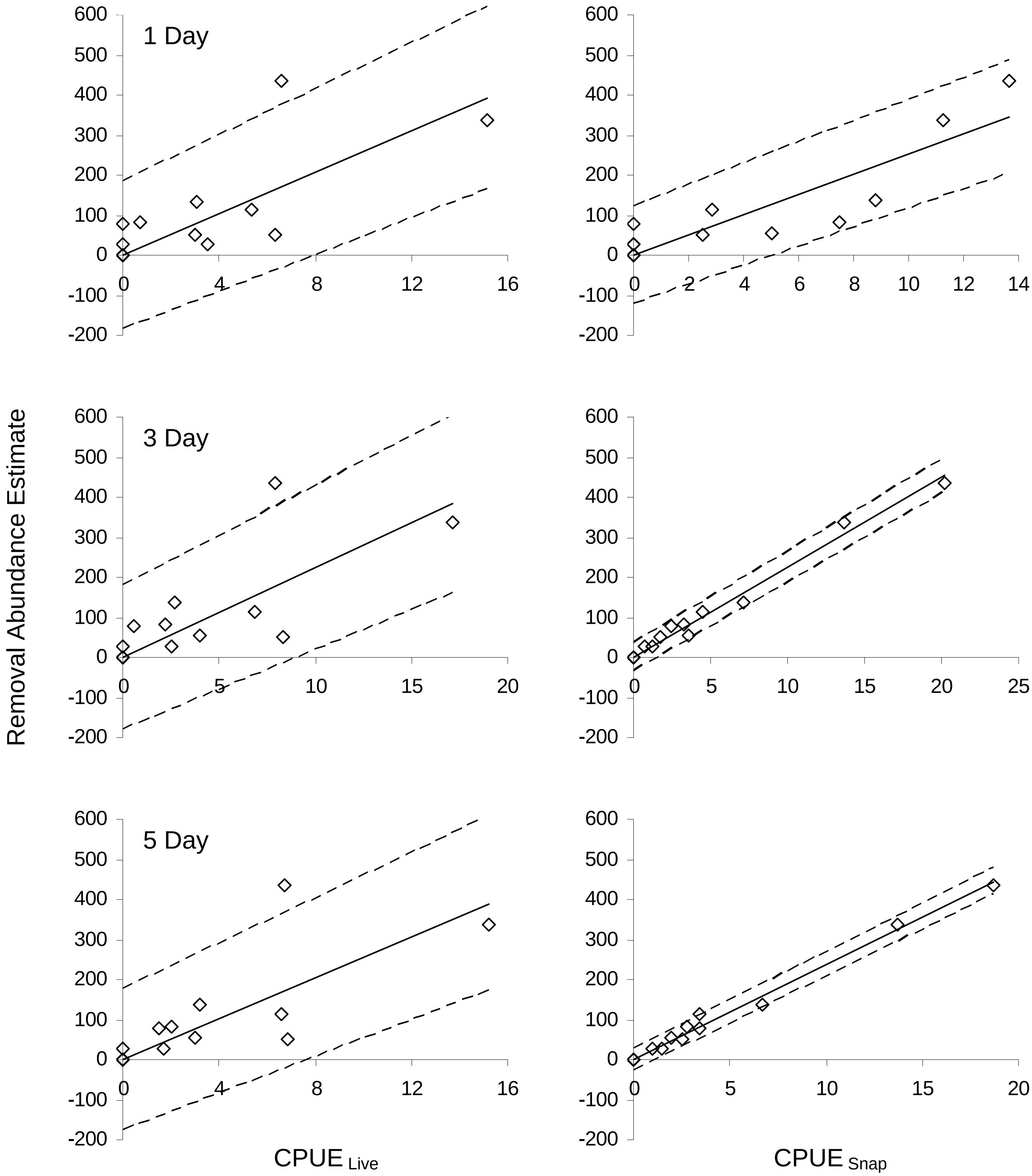

Figure B.4. Relationship between *Suncus murinus* removal abundance estimates generated from snaptrapping data and CPUE (captures / 100 corrected trap nights) from 1 day, 3 days, and 5 days of livetrapping ($CPUE_{Live}$) and snaptrapping ($CPUE_{Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. *S. murinus* was not captured on Rota and the 4 sites from this island are not included. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value.

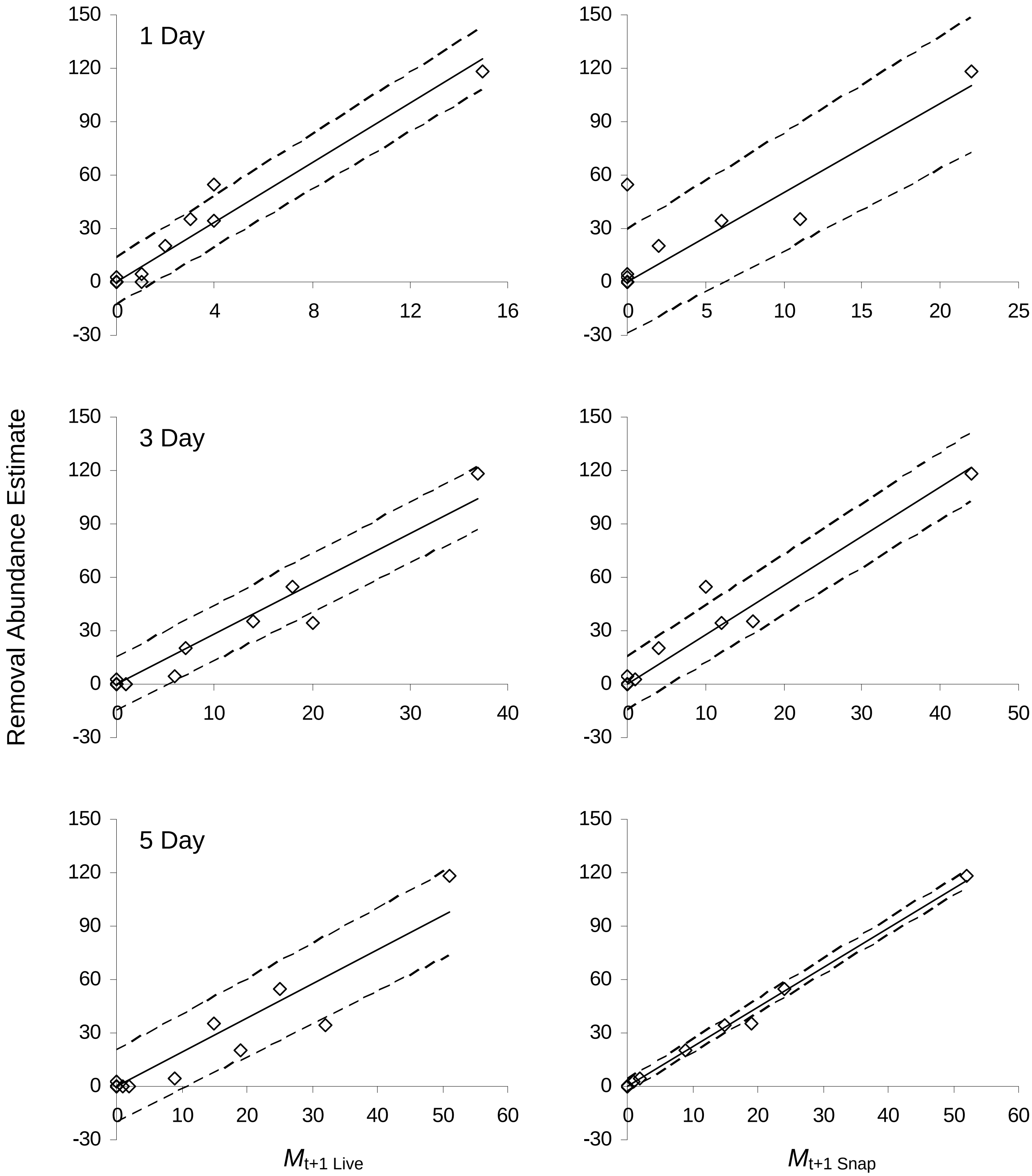

Figure B.5. Relationship between *Mus musculus* removal abundance estimates generated from snaptrapping data and M_{t+1} from 1 day, 3 days, and 5 days of livetrapping ($M_{t+1\ Live}$) and snaptrapping ($M_{t+1\ Snap}$) conducted at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value. Note the change in M_{t+1} scale as sampling duration increases.

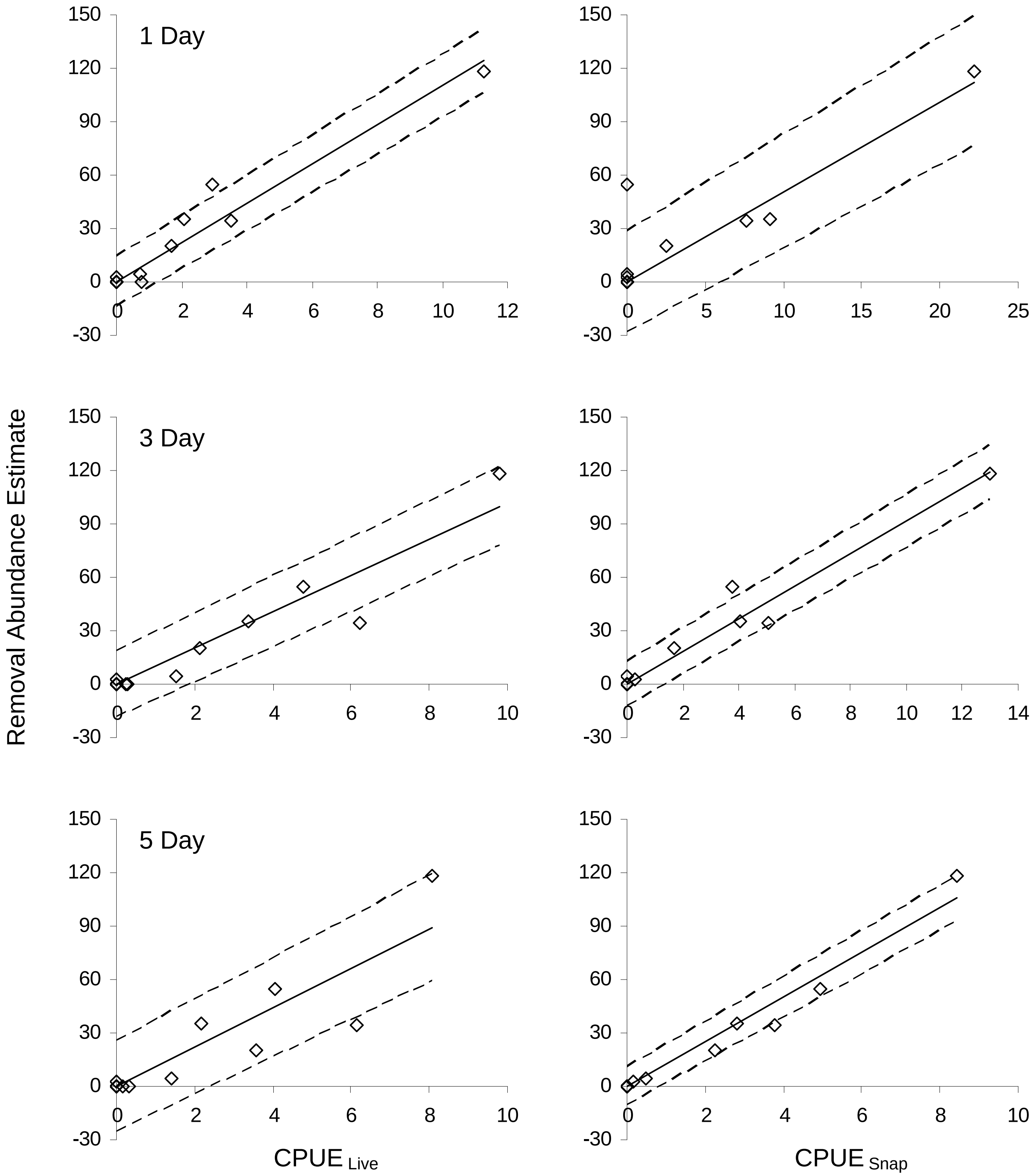

Figure B.6. Relationship between *Mus musculus* removal abundance estimates generated from snaptrapping data and CPUE (captures / 100 corrected trap nights) from 1 day, 3 days, and 5 days of livetrapping (CPUE $_{Live}$) and snaptrapping (CPUE $_{Snap}$) conducted at 19 sites on at 19 sites on Guam (*n* = 7), Rota (*n* = 4), Saipan (*n* = 5), and Tinian (*n* = 3), 2005–2006. Solid lines indicate the best-fit line, constrained to pass through the origin; dashed lines indicate 95% confidence intervals for an individual predicted value.

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Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008
- Final Report -

Top to bottom (left to right): Aguiguan Island by Curt Kessler, Tinian Monarch by Eric VanderWerf, Goat by Scott Vogt, Coconut Crab by Cheryl Phillipson, Red-taled Tropicbird by Scott Vogt, Mourning Gecko by Gordon Rodda, Shrew by Curt Kessler, Lepidoptera larvae by Shellly Kremer, Rufous Fantail by Eric VanderWerf, and Tinian Island by Curt Kessler.

FINAL REPORT

Terrestrial Resource Surveys of Tinian and Aguiguan, Mariana Islands, 2008

COMPILED AND EDITED BY

U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
Honolulu, HI

PREPARED FOR

Marine Force Pacific (MARFORPAC)
and
Naval Facilities (NAVFAC), Pearl Harbor
Honolulu, HI

DECEMBER 2009

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These surveys would not have been possible without the support and participation of many people and organizations. Permits, participation in the surveys, and support were provided by the Commonwealth of the Northern Mariana Islands Department of Land and Natural Resources (DLNR), the DLNR Division of Agriculture, and the Tinian Mayor's Office. We would especially like to thank the Honorable Jose P. San Nicolas, Dr. Ignacio de la Cruz, Sylvan Igisomar, Joe Lizama, Henry Cabrera, Rosemary Camacho, Antonio Castro, David Evangelista, John King, Elvin Masga, Fabrious Muna, Jess Omar, Gayle Martin, Paul Radley, Laura Williams, Ignacio "Cutz" Aldan, Greg Camacho, Rodney Camacho, Vincente Camacho and all of the personnel from the Tinian Mayor's Office, Brown Treesnake Program, the Division of Fish and Wildlife's Fisheries Section, Division of Parks and Recreation, and the Division of Fish and Wildlife Admin Office that assisted with transect cutting, logistics, and administrative support for the surveys. Funding and assistance for the project was provided by the Naval Facilities (NAVFAC), Pearl Harbor and Marine Force Pacific (MARFORPAC) with administrative and field support from Navy biologists Vanessa Pepi and Scott Vogt. Research, analysis, and review for some of the surveys were provided by the U.S. Geological Survey, Biological Research Discipline and the University of Guam. Helicopter support for the surveys was provided by Americopters and pilots Rufus Crowe and Naoto Kogure. Additional field support for establishing the territory mapping plots on Tinian was generously provided by Yogesh Singh. We would also like to thank the following staff from the Pacific Islands Fish and Wildlife Office and Portland Regional Office for participating in the bird surveys and providing logistical support: Patrice Ashfield, Peter Dunlevy, Joshua Fisher, Adonia Henry, Shelly Kremer, James Kwon, Megan Laut, Patrick Leonard, Aaron Nadig, Jay Nelson, Jeff Newman, Cheryl Phillipson, Jeff Zimpfer, Elaine Bok, Mike Roy, John Nuss, and Kit Hershey. This report was compiled by Curt Kessler, Ann Marshall, and Fred Amidon, Pacific Islands Fish and Wildlife Office. Finally, we would like to give special thanks to the private landowners and people of Tinian for allowing access to their lands during the surveys and for their hospitality.

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Terrestrial snail surveys were conducted on Tinian. The individual hired to conduct the surveys has not provided a final report.

1.0 INTRODUCTION

1.1 GOALS AND OBJECTIVES

Pursuant to an Interagency Service Agreement (Agreement) between the U.S. Fish and Wildlife Service (USFWS), Marine Force Pacific (MARFORPAC), and the Department of Defense (DoD), the USFWS was contracted to conduct surveys of marine and terrestrial resources of some of the islands in the Mariana archipelago. The DoD is authorized to contract with appropriate Federal agencies under the provisions of the Sikes Act of 1960, as amended (31 U.S.C. 868) to promote planning, development, maintenance, and coordination of wildlife, fish and game conservation and rehabilitation on military reserves. This Agreement was developed in order to determine what resources may be impacted during the relocation of the U.S. Marine Corps Forces from Okinawa to the Mariana Islands and during training activities planned for various locations in the Mariana Islands.

Under the terms of the Agreement, some of the terrestrial surveys were conducted in 2008. The following report includes the results of the surveys conducted on the islands of Tinian and Aguiguan, Commonwealth of the Northern Mariana Islands. Further survey work will occur archipelago-wide in the following several years.

1.2 BACKGROUND

Tinian (100 square kilometers (km)) is the second largest island in the Commonwealth of the Northern Mariana Islands (Figures 1 and 2). It is 20 km long and 7 km at its widest point and the highest points on the island are Carolinas Ridge (178 meters (m)) and Mount Lasu (160 m) (Mueller-Dombois and Fosberg 1998). Aguiguan is a small island (7 km^2) approximately 9 kilometers south of Tinian (Figure 3). It is approximately 5 km long and 1.5 km wide at its widest point and the highest point on the island is 163 m (Engbring *et al.* 1986).

Both Tinian and Aguiguan constitute the Municipality of Tinian in the Commonwealth of the Northern Mariana Islands. In 2000, the population on Tinian was approximately 3,540 people, with the majority in the village of San Jose (U.S. Census 2008), while

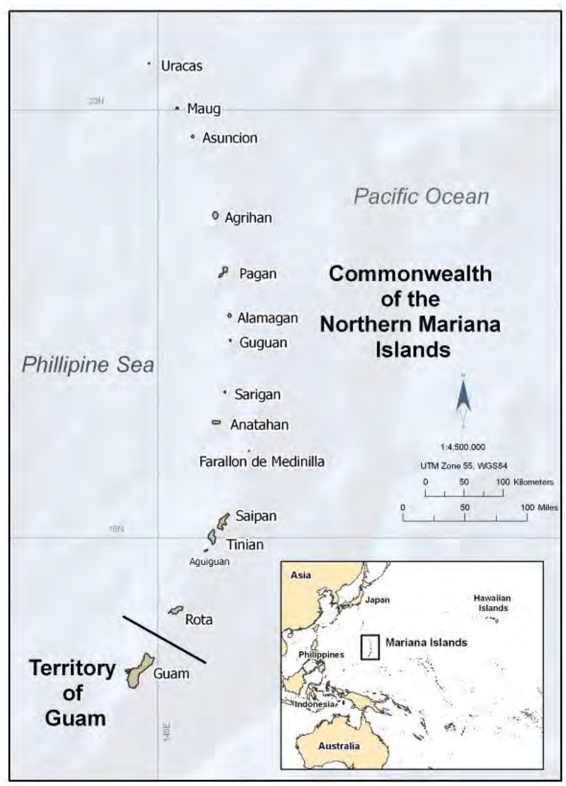

Figure 1. Location of the Commonwealth of the Northern Mariana Islands, Mariana archipelago.

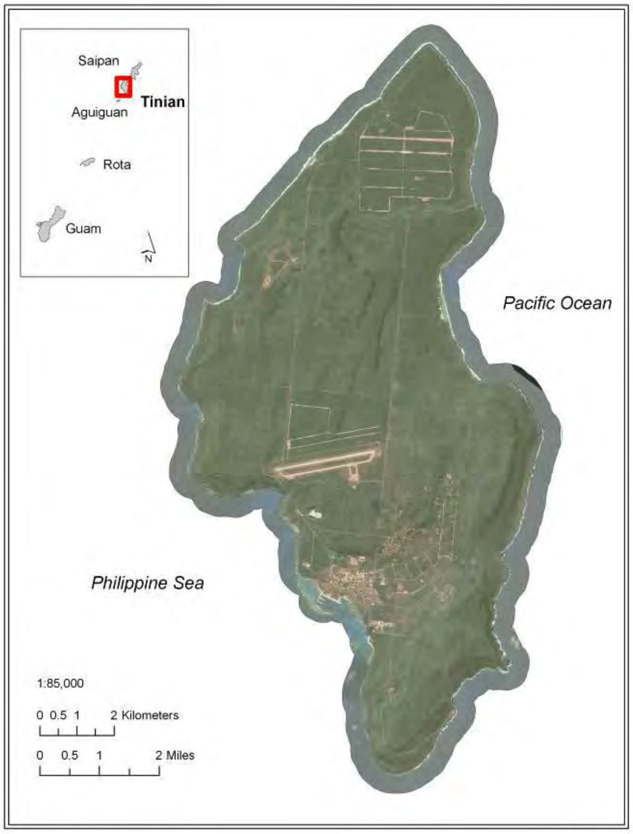

Figure 2. The island of Tinian, Commonwealth of the Northern Mariana Islands.

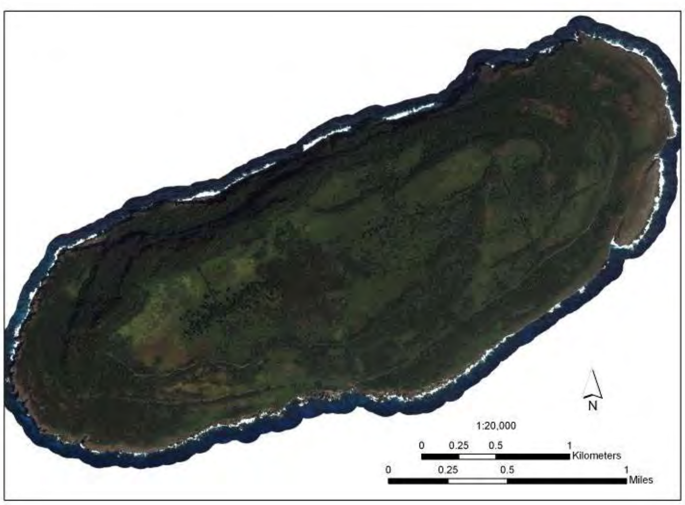

Figure 3. The island of Aguiguan, Commonwealth of the Northern Mariana Islands.

Aguiguan is uninhabited. The climate on both islands is tropical and temperatures remain and relatively consistent during the year, ranging daily from 25 degrees to 30 degrees Celsius. Rainfall varies considerably between years but averages 218 centimeters annually, most of which falls from July to November. A dry season occurs between January and May when rains diminish to 8 to 15 centimeters per month.

Approximately 80 percent of arable land on Tinian was put into sugarcane production during the 1930s (Bowers 1950). Tinian was also the site of a major U.S. beach landing during WWII and much of the island developed into a major airbase to support bombing operations on Japan (Rottman 2004). The airbase was abandoned after the war but the Department of Defense currently leases approximately two-thirds of the northern part of the island for training purposes. Currently, training consists of once a year battalion size exercises that last for about two weeks and occasional helicopter touch and go practice along the airstrip for the rest of the year.

Aguiguan was also partially developed by the Japanese for sugar cane production and for timber harvest during the 1930s (Davis 1954). However, it was spared invasion during WWII and has remained uninhabited since.

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2.0 TERRESTRIAL SURVEYS

2.1 VEGETATION SURVEYS ON TINIAN AND AGUIGUAN

Western Coast of Aguiguan. Photoby Curt Kessler

Pina Region of Tinian. Photoby Curt Kessler

Prepared by: **Fred Amidon, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI**

INTRODUCTION

The first large scale land cover mapping of islands in the Commonwealth of the Northern Mariana Islands was undertaken by the Forest Service in the 1980s (Falanruw *et al.* 1989). This mapping effort included the islands of Tinian, Rota, and Saipan but did not include the other islands in the archipelago. These maps were developed using 1976 aerial photographs and site visits during the 1980s (Falanruw *et al*. 1989) and an earlier version of these estimates were included in Hawaiian Argonomics (1985) and Engbring *et al*. (1986). Engbring *et al*. (1986) also mapped the land cover on Aguiguan as part of their bird surveys of the island sometime during the 1980s using 1968 aerial photographs.

In 2006, new land cover maps for Tinian, Rota, and Saipan were developed by the Forest Service. These updated maps were developed using 2.3-meter IKONOS (GeoEye®, Dulles, VA) multispectral data and 0.6-meter Quickbird (DigitalGlobe®, Longmount, CA) pan-sharpened natural-color imagery collected in 2000 or 2001 and fieldwork conducted in 2005 (Liu and Fischer 2006). Unfortunately, the remaining islands in the Commonwealth of the Northern Mariana Islands were not mapped during this effort.

In 2008, the Department of Defense contracted the U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office to conduct terrestrial and marine surveys on Tinian and Aguiguan. The following report outlines the results of updating the Forest Service's 2006 land cover map of Tinian using recent satellite imagery and the development of a land cover map of the island of Aguiguan.

METHODS

Tinian

We utilized the Forest Service's 2006 land cover map of Tinian as our base map for evaluating habitat changes since this map was completed. A copy of this vegetation map is available online on the Forest Service's national website - http://www.fs.fed.us/r5/spf/fhp/fhm/landcover/islands/index.shtml. This map was created utilizing satellite imagery from 2000 or 2001 and fieldwork conducted in 2005 (see Liu and Fischer 2006 for more detailed information on how this map was created). Because the imagery utilized to develop this map was over five years old, we utilized 2006 DigiGlobe® satellite imagery of the island to note any new clearings or roads. Areas that were recently cleared were delineated directly on the digital image using ArcMap 9.2 (ESRI, Redlands, CA). These areas were then reclassified in the Forest Service vegetation cover layer using ArcTools (ESRI, Redlands, CA) and new acreages for each cover type were calculated using XTools Pro 5.2.0 (Data East, LLC, Novosibirsk, Russia).

Due to the different land cover categories used in the Forest Service's recent assessment of Tinian (13 categories) and their assessment in the 1980s (16 categories), it was not possible to assess overall land cover changes between the two time periods. However, Engbring *et al.* (1986) reported land cover estimates for Tinian in similar categories to those in the 2006 Forest Service assessment. These estimates were based on an early version of the land cover maps presented in Falanruw *et al.* (1989). Unfortunately, the methods utilized to develop both of these land cover estimates were not the same and so direct comparisons of acreages would not be appropriate. Therefore, we compared percent land cover in each of the land cover categories provided by Engbring *et al.* (1986) for the two time periods. As the 2006 Forest Service estimate included more land cover categories then those provided by Engbring *et al.* (10 categories) we combined several categories. Specifically, agroforest-coconut was combined with agroforest, casuarina (*Casuarina equisetifolia*) thicket was combined with mixed introduced forest for the secondary forest category, and urban vegetation was combined with urban.

Aguiguan

The land cover map of Aguiguan was produced using 0.6-meter resolution, 2001 QuickBird imagery as the primary source. Areas under cloud cover were assessed using 2006 imagery of the island in GoogleEarth (Google, Inc., Mountain View, CA). Six land cover types were delineated: native forest, secondary forest, tangantangan (*Leucaena leucocephala*) thicket, open field, coastal scrub, and non-vegetated. These categories were selected because they were identifiable and corresponded with important bird habitats. Native forest consisted of primarily native trees growing on limestone substrate. Important components of the forest included *Pisonia grandis, Cynometra ramiflora*, *Erythrina variegata* and *Guamia mariannae*. Secondary forest consisted primarily of forest dominated by *Delonix regia*, *Acacia confusa*, *Pithecellobium dulce*, and *Casuarina equisetifolia* trees in the canopy. Tangantangan thicket is a type of secondary forest almost exclusively dominated by *Leucaena leucocephala*. Open fields were dominated primarily by introduced *Lantana camara* but patches of *Chromolaena odorata* and *Miscanthus* spp. were also found in these areas. Coastal scrub included low scrubby species like *Pemphis acidula* and non-vegetated areas were primarily bare rock areas along the coast. Land cover types were differentiated based on differences in tone, texture, pattern, and color and were delineated directly on the digital image using ArcMap 9.2. Aerial photographs of Aguiguan from 1948 (black and white, 1:24,000), 1968 (black and white, 1:20,000), and 1994 (color, 1:20,000) were also utilized to assist with delineating secondary forest and limestone forest habitats. All images were registered using a second-order polynomial transformation with at least seven ground control points per photograph. A draft land cover map was ground-truthed in June and August 2008 and any changes were incorporated in the final land cover map.

RESULTS AND DISCUSSION

Tinian

Five sites on the island were identified as having been cleared or modified since the Forest Service's vegetation assessment of the island between 2001 and 2006 (Figures 1 and 2). All of these sites were previously disturbed and consisted of open fields, secondary forest, tangantangan thickets, and mowed or maintained areas (Table 1). Their clearing and modification resulted in their conversion to urban land cover (Table 1).

All modifications were incorporated into the Forest Service's 2006 land cover map and the total acreages for each land cover type were calculated (Table 2). Tangantangan thickets were the dominate cover type (34 percent of the island) followed by mixed secondary forest (27 percent) and other shrub and grass (19 percent). Native limestone forest only made up 5 percent of the land cover while urban areas (urban and urban vegetation) made up approximately 7 percent of the island.

When the recent land cover estimates were compared to those developed in the 1980s several changes were noted. First, overall coverage of open fields decreased while coverage of secondary forest increased (Table 2). This may be a result of succession over the last two decades as open areas are abandoned and claimed by secondary forest. A decrease in tangantangan was also found in addition to an increase in urban land cover (Table 2). The increase in urban cover is likely the result of increased development on the island (including homesteads, casinos, and the airport expansion) and the decline in tangantangan and open fields may also be associated with this development.

Aguiguan

The dominate land cover types on Aguiguan ranked from highest to lowest were native forest, open field, secondary forest, tangantangan thicket, no vegetation/barren, and coastal scrub (Table 3, Figure 3). Aguiguan is currently uninhabited, therefore urban and agricultural field cover types were not recorded. When compared to the land cover estimates by Engbring *et al.* (1986) for the 1982 surveys, the percentage of the island in open field decreased while the percentage in secondary forest and tangantangan increased (Table 3). This shows a transition from open field habitats to secondary forest type habitats over the two survey periods. Interestingly, tangantangan was not included in the landcover for 1982 despite it being a common landcover type on the neighboring islands of Tinian and Saipan (Engbring *et al.* 1986). Engbring *et al*. (1986) report a few small patches that were less than 5 hectares in size. Apparently the larger patches currently found on Aguiguan grew sometime during the last two decades. Based on the present state of extensive browsing of goats (*Capra hircus*) in this habitat type (Figure 4), the growth of tangantangan may have occurred when goat populations were suppressed between 1989 and 1990 (Rice 1991). An assessment of some areas currently containing tangantangan thickets with recently acquired aerial photographs of the island appears to support this theory (Figure 5). The emergence of tangantangan was observed on Sarigan Island after the eradication of goats (C. Kessler, USFWS, pers. comm.) and supports the theory that goats suppress this type of tree.

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Table 1. Approximate land cover changes (in hectares) in six sites on Tinian that were cleared after the U.S. Forest Service's 2006 land cover assessment of Tinian. See Figures 1 and 2 for locations of sites.

Site	Land Cover Classification	Secondary Forest	Tangantangan	Open Field	Urban	Total
Airport	Forest Service	48	20	50	53	171
	Update	0	0	0	171	171
Voice of America	Forest Service	0	8	7	1	16
	Update	0	0	0	16	16
New Casino	Forest Service	4	0	1	0	5
	Update	0	0	0	5	5
Quarry	Forest Service	0	1	0	1	2
	Update	0	0	0	2	2
Sports Track	Forest Service	1	0	2	0	3
	Update	0	0	0	3	3
Old Roads	Forest Service	11	6	1	1	19
	Update	0	0	0	19	19

Table 2. Tinian - Acreage (hectares), percent cover, and change in percent cover of ten land cover types based on a 2006 Forest Service assessment, an update of the Forest Service assessment, and estimates by Engbring *et al.* (1986) for the 1980s. Change in land cover was the difference between the Engbring *et al.* estimates and the update of the Forest Service assessment.

Classification	Engbring *et al.*	Forest Service	Update	Percent Change
Native Forest	490 (4.9%)	549 (5.4%)	549 (5.4%)	+ 0.6%
Secondary Forest	1927 (19.2%)	2980 (29.5%)	2916 (28.8%)	+ 10.3%
Tangantangan	3852 (38.3%)	3453 (34.1%)	3417 (33.8%)	- 4.5%
Agroforest	0 (0.0%)	40 (0.4%)	40 (0.4%)	+ 0.4%
Open Field	3107 (30.9%)	2011 (19.9%)	1950 (19.3%)	- 11.6%
Cultivated	190 (1.9%)	134 (1.3%)	134 (1.3%)	- 0.6%
Strand	356 (3.5%)	223 (2.2%)	223 (2.2%)	- 4.5%
Urban	78 (0.8%)	616 (6.1%)	776 (7.7%)	+ 6.9%
Wetland	26 (0.15%)	26 (0.3%)	26 (0.3%)	+ 0.1%
Bare	33 (0.3%)	81 (0.8%)	81 (0.8%)	+0.5%
Total	10,048 (100%)	10,113 (100%)	10,113 (100%)	0.0%

Table 3. Aguiguan - Acreage (hectares), percent cover, and change in percent cover of six land cover types based on a 2008 assessment and estimates by Engbring *et al.* (1986) for the 1980s. Change in land cover was the difference between the Engbring *et al.* estimates and the recent estimates.

Classification	Engbring *et al.*	2008	Percent Change
Native Forest	281 (47%)	340 (49%)	+ 2%
Secondary Forest	21 (4%)	95 (14%)	+ 10%
Tangantangan	0 (0%)	44 (6%)	+ 6%
Open Field	256 (43%)	158 (23%)	- 20%
Coastal Scrub	15 (3%)	28 (4%)	+ 1%
Bare	23 (4%)	34 (5%)	+ 1%
Total	596 (100%)	699 (100%)	0%

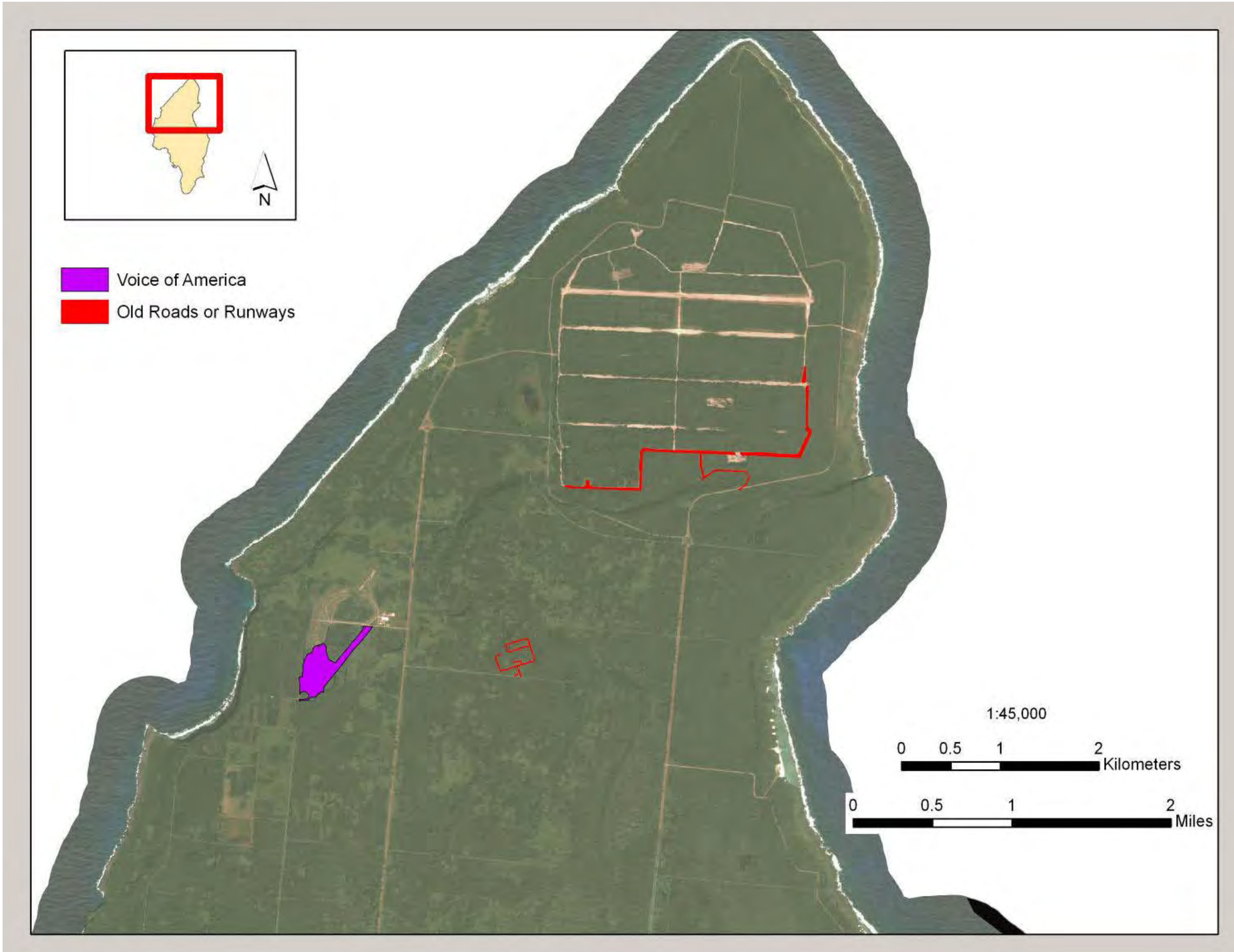


Figure 1. Locations of areas cleared in northern Tinian after the Forest Service's 2006 land cover assessment.

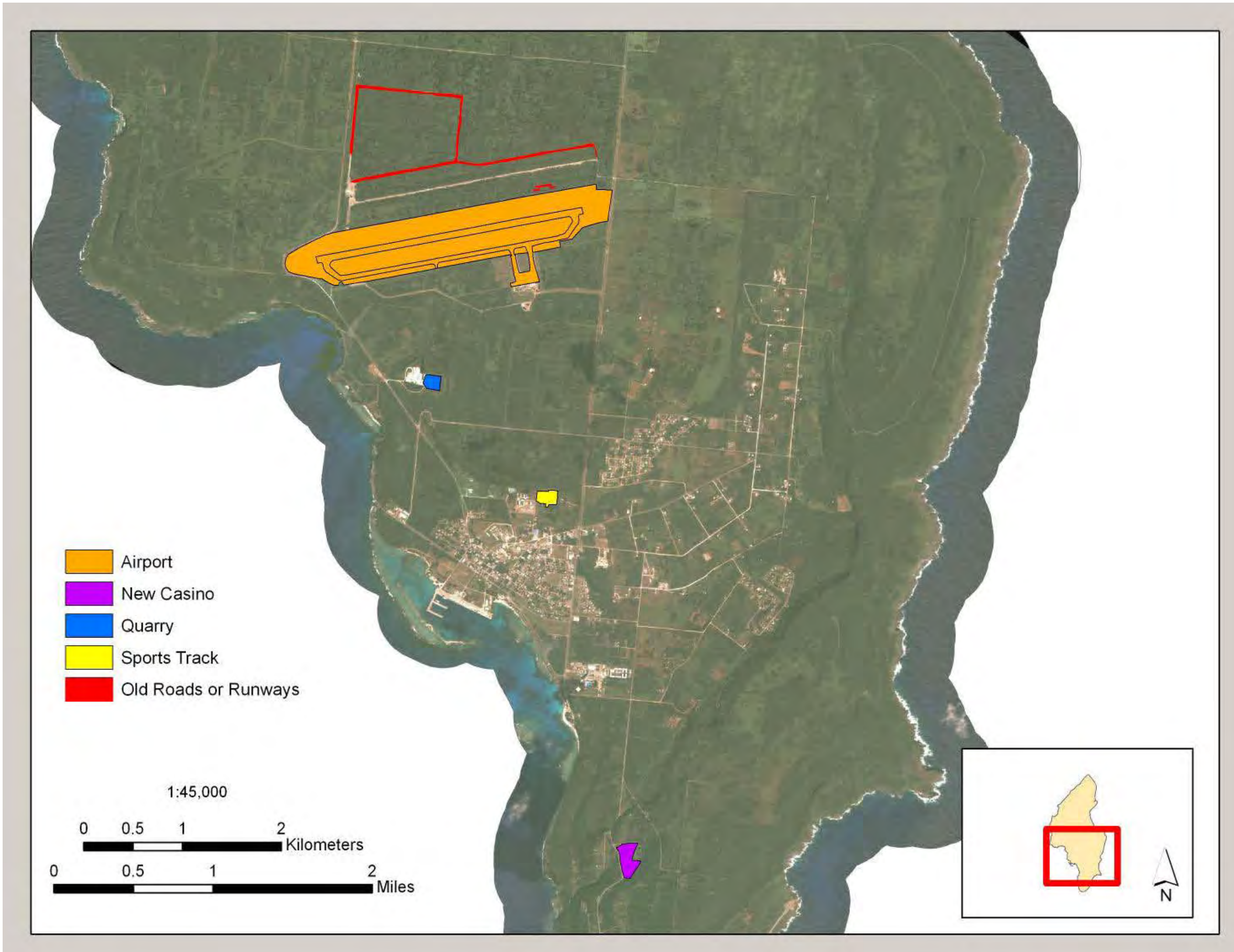


Figure 2. Locations of areas cleared in southern Tinian after the Forest Service's 2006 land cover assessment.

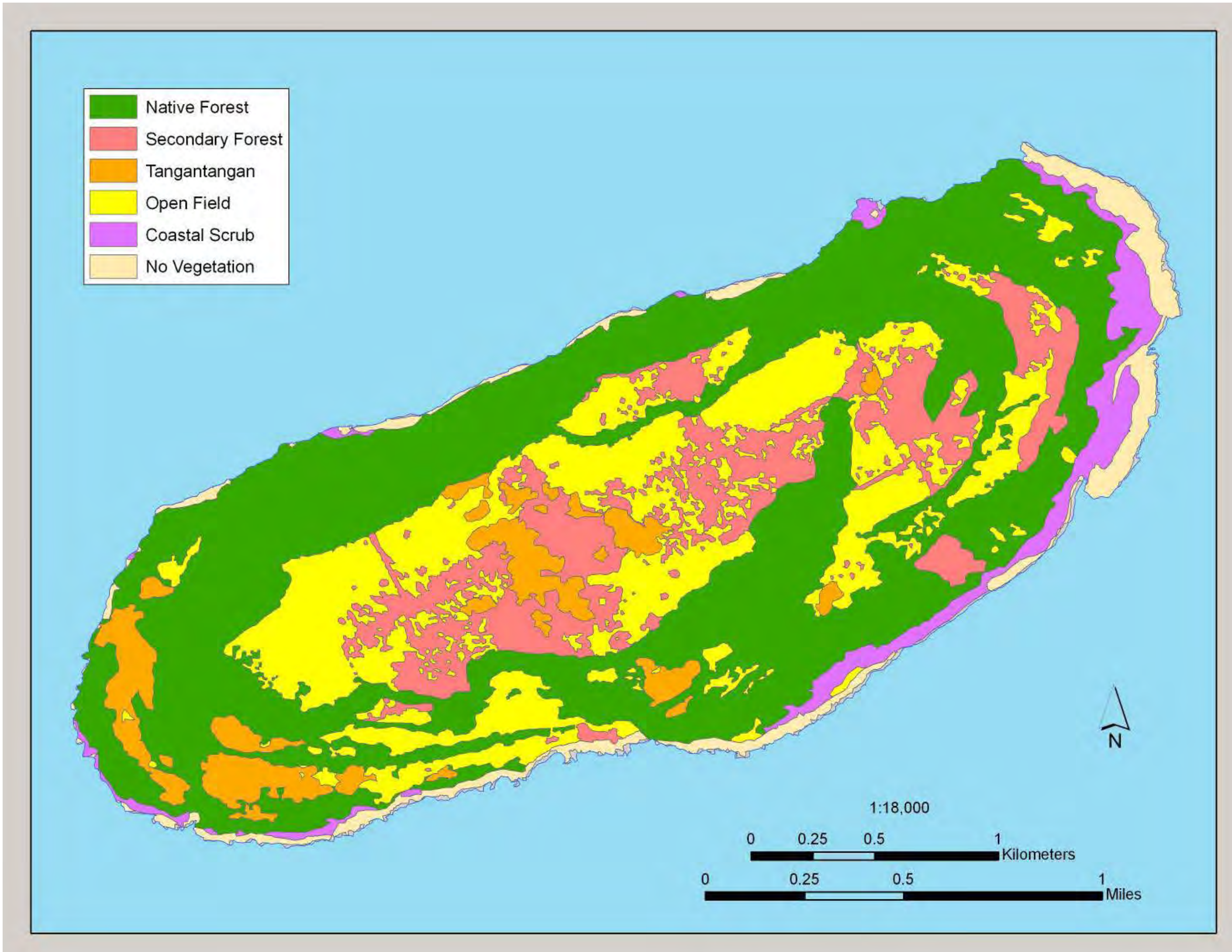


Figure 3. Land cover types on the island of Aguiguan, 2008.

Figure 4. A goat browsing in the understory of a tangantangan thicket. Note the lack of understory. Photo by Aaron Nadig, USFWS, August 2008.

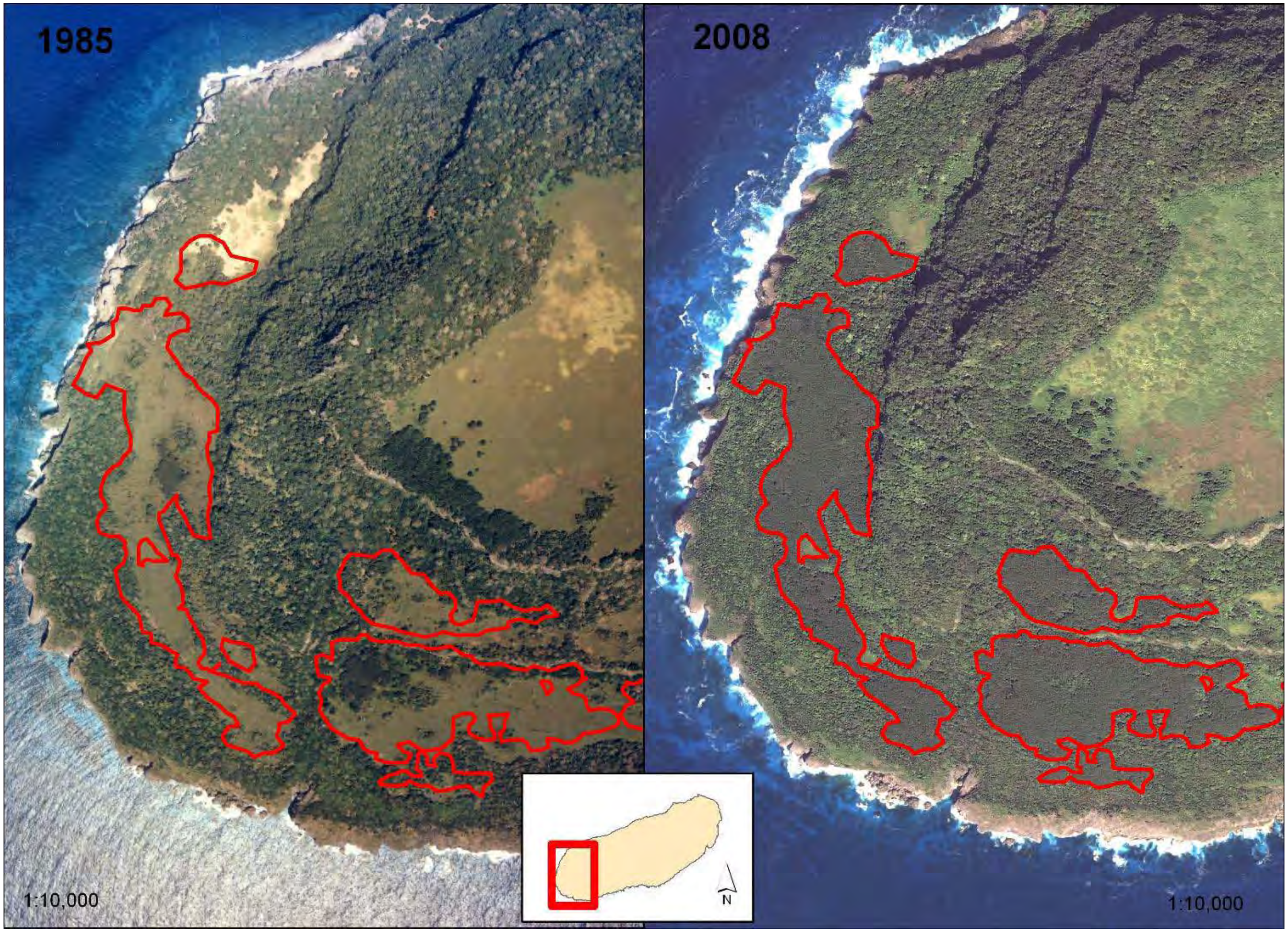
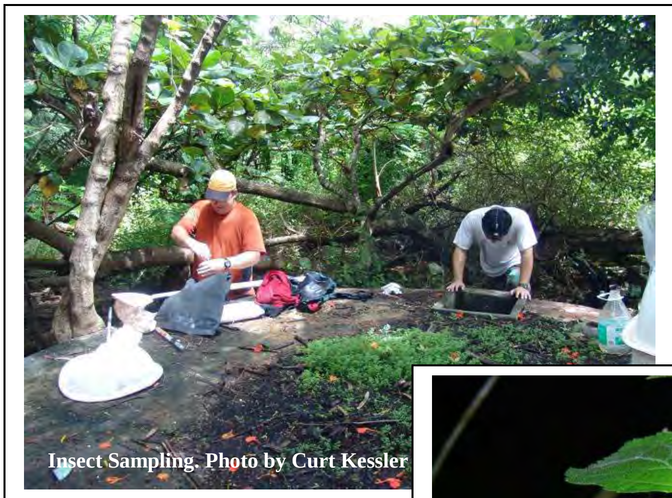


Figure 5. Approximate location of tangantangan thickets in 2008 (outlined in red) that were open fields in 1985 in the southwestern section of Aguiguan.

2.2 INVERTEBRATE SURVEYS

2.2.1 GENERAL INSECT SURVEYS ON TINIAN AND AGUIGUAN


Insect Sampling. Photo by Curt Kessler


Paper Wasps. Photo by Adonia Henry


Hypolimnas anomala. Photo by Adonia Henry.

Prepared by: Michael Richardson, USFWS, Honolulu, Hawaii and Stephan Lee and Cory Campora, US Navy, NAVFAC Pacific, Pearl Harbor, Hawaii.

INTRODUCTION

A general entomological survey was conducted on the island of Tinian, Commonwealth of the Northern Mariana Islands (CNMI) from August 6-15, 2008; this survey included one day of survey work on the island of Aguiguan on August 12, 2008. In addition to generally surveying predominantly native limestone forest areas on Tinian and Aguiguan for native and nonnative arthropod species, surveys to determine the presence or absence of two butterfly species, *Vagrans egistina* and *Hypolimnas octocula mariannensis* (Lepidoptera: Nymphalidae) and their documented host plants were conducted. The primary efforts of the general entomological surveys involved a focus on the insect ecology within the native forest areas including those possibly associated with the two candidate butterflies. In particular, the status of insect species which may threaten the butterflies' host plant species or the butterflies directly through predation or parasitism was assessed. In addition, survey efforts were focused on ascertaining the presence/absence of invasive species of medical and socio-economic importance (i.e., mosquitoes, ants, termite, etc.), and additionally, aquatic species which may potentially be impacted within the project area (i.e., leased military training areas).

Prior Arthropod Surveys

Based on a review of available literature, very few entomological surveys have been conducted on the island of Tinian. The most comprehensive report found was delivered to the United States Navy (Contract N62742-84-C-0141) from Hawaiian Agronomics (International), Inc. in December, 1985. Hawaiian Agronomics spent a total of seventeen days from November 1984 to November 1985 over the course of four separate visits, collecting insects (including Lepidoptera) utilizing various methods of collection and accounting for temporal differences. The purpose of this study was not outlined in the report and one may only deduce that the intent was to produce a general status report for arthropods on the island at the request of the Navy. Hawaiian Agronomics spent a total of 355 field hours during their study, of which 102 hours were spent visiting coastal, mixed, and scrub limestone forest. Approximately 250 field hours were spent surveying a wide variety of sites across the island including San Jose, village, farms, tangantangan forest, wetlands and ponds, pastures, and even 10 hours at the primary dump (landfill site).

In their report, Hawaiian Agronomics provided a general discussion of their efforts and results by general habitat type, (i.e., wetlands, tangantangan forest, etc.), but did not describe survey results within specific localities. The overall conclusion of the report was a high abundance, yet low diversity of insects on Tinian. A single paragraph described results of efforts surveying within the upper elevation, mixed limestone forests. Notably, ants were listed as the most common insect collected, followed by termites. Other insects collected in these areas as described by the report included micro-lepidopterans, leafhoppers, wood-boring and girdling beetles. Within the leaf litter of these mixed limestone forest areas, Hawaiian Agronomics collected mites, centipedes, millipedes, flies, collembolans, and thysanurans.

The 1995 Hawaiian Agronomics report describes encounters with the nonnative wasp species, *Polistes stigma* (Family Vespidae) in some of the disturbed habitat areas surveyed. Specifically, the report describes the nests of this species occurring as close together as 10 feet in proximity within tangantangan and other nonnative secondary forest. However, no account of this species was given for surveys within the limestone forest areas surveyed. Interestingly, the Hawaiian Agronomics report briefly stated that no rare, threatened, or endangered species of insects or arthropods were observed within the areas surveyed; however, the date of the surveys precluded the establishment of Federal candidate arthropod species within the CNMI.

Candidate Butterfly Species
Currently, *Vagrans egistina* and *Hypolimnas octocula mariannensis* (Family Nymphalidae) are listed as candidates for listing under the Endangered Species Act. Both butterfly species are considered rare and have been recorded only on the islands of Saipan, Rota and Guam (Schreiner and Nafus 1996). *Vagrans egistina* was last collected on Guam in the late 1970s and on Rota in the1980s and 1995. *Hypolimnas octocula mariannensis* is historically known from Guam and Saipan and after an intensive survey for this species in 1995, investigators found only 10 populations on the island of Guam and none on the island of Saipan (Schreiner and Nafus 1996). During intensive surveys for these species in November of 2000 within the USFWS Ritidian Point Wildlife Refuge, only adults of *H. octocula mariannensis* were observed (M. Richardson, USFWS, pers. comm. 2008).

During their 1985 survey of Tinian, Hawaiian Agronomics collected 275 lepidopteran specimens comprised of 14 families, 36 species, and 10 unidentified species. Neither *Vagrans egistina* nor *Hypolimnas octocula mariannensis* were among the species collected, although neither species had been previously recorded on Tinian. The report does describe the difficulty encountered in differentiating the several species of adult nymphalid butterflies that were observed flying during their surveys. While neither species have ever been observed on Tinian, it is certainly possible, due to the close proximity of the islands in the Marianas archipelago and with episodic weather events, such as typhoons, that *V. egistina* or *H. octocula mariannensis* may have been distributed to islands outside of their known ranges in the past, including the island of Tinian. This is particularly true for those islands which do currently (including Tinian and Aguiguan) or have in the past, supported their host plants. Although not overtly cryptic, both *V. egistina* and *H. octocula mariannensis* are known to be fast fliers and only a trained biologist is likely to make a positive confirmation of their presence on islands where they have not been previously recorded.

The recorded host plant for *Vagrans egistina* is *Maytenus thompsonii* (Family *Celastraceae*), a small tree/shrub endemic to the Marianas and found primarily in the understory of native limestone forests (Vogt and Williams 2004, Schreiner and Nafus 1996). The recorded host plants for the *Hypolimnas octocula mariannensis* are *Procris pedunculata* and *Elatostema calcareum*, both forest herbs (Family *Urticaceae*) found growing on limestone outcrops in native limestone forest (Schreiner and Nafus 1996).

METHODS AND MATERIALS

Prior to arriving to Tinian for our August 2008 survey efforts, the following primary objectives to be modified as needed or as circumstance required were formulated:

Tinian 1st Priority Goals:

- Survey for the butterflies and host plants within remnant native forest areas on military lands.
- Survey for nonnative insect threats to the butterflies (predators/parasitoids) and to the host plants (true bugs, etc.) on military lands.
- Survey for other possible native insects, including aquatic species such as the odonates on military lands.

Tinian 2nd Priority Goals:

- Survey for the butterflies and host plants within remnant native forest areas on NON-military lands.
- Survey for nonnative insect threats to the butterflies (predators/parasitoids) and to the host plants (true bugs, etc.) on NON-military lands.
- Survey for other possible native insect species on NON-military lands.
- Survey for presence/absence of other important alien arthropod groups including mosquitoes and ants.

Aguiguan (Goat Island) Goals

- Survey for the butterflies and host plants within remnant native forest areas
- Survey for & collect nonnative insect threats to the butterflies (predators/parasitoids) and to the host plants (true bugs, etc.)
- Survey for & collect other possible native insects including aquatic species such as the odonates.
- Survey for presence/absence of & collect other important nonnative arthropod groups including mosquitoes and ants.

The habitat areas selected for surveys were identified using maps and reports prepared by U.S. Fish and Wildlife Service and Department of Defense biologists between June and August 2008. Due to the limited amount of time available for us to conduct the surveys, we decided to spend no more than a portion of each work day surveying along known or recently constructed transects within each of the several identified limestone forest sites. Most sites were visited during the daylight hours, although some sites were visited during the night to check traps or to run a blacklight. Equipment and methods used during surveys of terrestrial areas included sweep netting of vegetation, visual inspections of vegetation, caves, under rocks, and beneath rotting vegetation. Use of baiting and traps were also employed. For aerial insects, the following traps types were utilized: UV light with sheet and water pan, EVS light trap with LED light, BG Sentinel trap with BG-lure and Octenol lure, and a collapsible cone trap with protein bait. Ants were collected in every locality by hand collection, sweeping, aspiration, and with the use of 3”x5” index cards baited with both peanut butter and honey. Aquatic localities were surveyed directly by wading, use of a kayak, sweeping, use of a mosquito dipper, and benthic sampling with a D-frame aquatic net. All collection sites and transects are shown in Figures 1 through 4.

During visual searches for *Vagrans egistina* and *Hypolimnas octocula mariannensis* and their host plants, our own knowledge of the species as well as an information guide produced by USFWS personnel were utilized. The information guide provided photographs of both butterflies and their host plants as well as descriptions of the larval stages of the butterflies. Geographic positioning system (GPS) points were taken of all transects within each locality surveyed. Additionally, to facilitate future monitoring efforts, points were recorded for all host plants located during each survey. A total of 21 host plants sites were located on Tinian and 3 host plant sites were located on Aguiguan during our surveys. Nine host plant sites were located on Department of Defense leased land (see Figure 1 - Japanese Caves Transects North and South and Chiget Cliff) and 15 on CNMI public lands (see Figure 3 - Carolinas Nature Trail and Figure 4 - Aguiguan).

Identification of some specimens was completed by USFWS and Department of the Navy entomology staff; these specimens were submitted to the Bishop Museum, Department of Entomology for cataloguing and permanent storage. The majority of specimens collected were submitted to the Bishop Museum, Department of Entomology for identification, cataloguing, and permanent storage. See Appendix A for a list of all specimens collected during this survey.

RESULTS

A description of the survey efforts within each locality by date is outlined below. Note, within these descriptions, common names are primarily used; please refer to Appendix A for scientific names of all collected specimens.

August 7, 2008 – *Lake Hagoi*

(Inside Military Lease Area)
Coordinates: UTM 55 15.068083 145.625033
Habitat Type: Aquatic/Semi-aquatic and Mixed Introduced/Tangantangan Forest
One entomologist spent approximately 4 hours surveying this site and surrounding vegetation Access to Lake Hagoi was attempted from the road east of the lake. Aerial observation during the flight from Saipan to Tinian indicated the water level was low and that the lake had only two small pockets of open water. Navigation to the open water portions of the lake was extremely difficult due to the dense vegetation that surrounded the area. The water/mud-ooze level within the vegetation gradually deepened toward the center of the lake area, and once the reed portion of the lake area was reached, the water and mud was knee-deep, and passage by foot was no longer possible. A D-frame aquatic net was used to sample the water amidst the reeds and the substrate at the beginning of the reed area of the lake. An adult damselfly, damselfly nymphs, an adult aquatic beetle, aquatic beetle larvae, water boatmen, a spider, and aquatic snail shells were collected. There were many adult damselflies flying amongst the reeds, and they all appeared to be of the same of species. After leaving the lake area and returning to the entry point on the road east of the lake, insects were collected by net along the road. Specimens collected

included an adult dragonfly, two different species of leaf footed bugs, a carpenter bee, and one Nymphalid butterfly species.

Aerial view of Lake Hagoi showing the two small areas of open water.

In the evening a UV light trap was set up by one entomologist at the intersection southeast of the lake. The trap consisted of an ultraviolet bulb set against a white sheet with a pan of soapy water at the bottom. The trap was engaged just prior to sunset and then checked after approximately three hours. The trap was checked again the following morning prior to dismantling. Winged termites (alate form) were immediately attracted to the illuminated sheet and collected by hand. A water strider was attracted to the trap and was collected. The large marine toad, *Bufo marinus*, was also attracted to the trap due to large amount of insects swarming around the light. Upon checking the trap after three hours of operation, the toads had knocked over the pan of water. Specimens were salvaged from spilled water as much as possible. Aquatic species were targeted for collection, therefore water boatmen and other various adult beetles were collected while many of the flies and moths were not. Particularly abundant were what appeared to be koa haole, or tangantangan, moths, *Macaria abydata*.

On the same evening (August 7^{th}), one entomologist set up a separate light trap west of the Lake. An established path that ran north from the road south of Lake Hagoi was used to locate a survey site west of Lake Hagoi. Before sunset (6:45 PM), an EVS light trap with a white LED as a light source and a BG-Sentinel trap with BG-Lure and Octenol lure were set up in the survey area in a shaded area. The BG-Lure mimics chemicals produced by human skin, and the Octenol lure has mosquito pheromone-like properties.

UV Light trap with sheet and water pan.

Koa haole, or tangantangan, moths, *Macaria abydata*, on light trap sheet.

August 7, 2008 – *Mount Laso*
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Mixed Native Limestone Forest
This site was visited by one entomologist for approximately 1 hour. An established trail from the shrine at Mount Laso that runs south was used to locate a survey site. The survey site was near the beginning of the trail in a shaded area. An EVS light trap with a white LED as a light source and a BG-Sentinel trap with BG-Lure and Octenol lure were set up in the survey area before sunset.

August 7, 2008 - *Japanese Villiage Ruins*
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Nonnative Shrub and Grassland
One entomologist set up an EVS light trap with a white LED as a light source was set up in an area off the road that leads to the Japanese Village Ruins away from direct sunlight. The EVS trap was set up before sunset, between Eighth Avenue and the arch that remains as part of the Japanese Village Ruins.

August 8, 2008 – *Near Japanese Village Ruins*
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Nonnative Shrub and Grassland and Mixed Forest and / Mixed Native Limestone Forest
One entomologist attempted to locate a semi-permanent pond that was in the vicinity of the Japanese village ruins. The intent was to collect aquatic insects. Unfortunately, there was no trail to this pond and passage through the grass and vegetation was very slow.

After approximately two hours, the search for the pond was abandoned and insects were collected along the road that leads past the ruins. A variety of butterflies were collected in this area, along with a large species of plant bug. There were also some adult dragonflies in the area, but capture of these fast flying insects was not possible. One of the dragonflies looked very different from the common red colored species – its coloration appeared to be grayish blue with maybe some yellow markings. At the end of this road, a small patch of native forest was found. Within the fringe of this native forest area, subterranean and drywood termites were collected from a living tangantangan tree and a dead coconut palm.

The EVS trap and BG-Sentinel traps at this location were checked. Both traps had failed to capture mosquito specimens, yet they were filled with a large number of fungus gnats. A decision was made to forgo setting subsequent mosquito traps at this location based on trap rate and time constraints.

August 8, 2008 - Lake Hagoi

(Inside Military Lease Area)
Coordinates: UTM 55 15.068083 145.625033
Habitat Type: Mixed Nonnative / Tangantangan Forest
This site was again visited by one entomologist for approximately 2 hours. Trapped specimens were collected from the EVS trap and BG-Sentinel trap that were placed west of the lake. Before sunset (6:44 PM), a blue LED light source was placed in the EVS trap, and the BG-Sentinel trap with BG-Lure and Octenol lure was reset. Before sunset at this location, an entomologist collected mosquitoes off of himself with an aspirator. Mosquito identification is pending authorization to utilize the taxonomic services of Bishop Museum.

Also in the evening the UV light trap was engaged, however on this occasion it was placed just off the road north of the lake area. Nothing new was collected in the trap relative to what was caught the night before. The koa haole, or tangantangan, moth was again present in high numbers.

August 8, 2008 – *Mount Laso*
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Mixed Native Limestone Forest
No mosquito specimens were collected from the EVS trap and BG-Sentinel trap, because no mosquitoes were caught in either trap. A decision was made to forgo setting subsequent mosquito traps at this location based on trap rate and time constraints. A malaise trap was set up in an open grassy area adjacent to tangantangan trees at this site.

August 8, 2008 – *Old Japanese Communications Center*
(Inside Military Lease Area)
Coordinates: (Not Available)

Habitat Type: Building
A collapsible Diptera/Hymenoptera cone trap was set up at the Old Japanese Communications Center to trap wasps. Canned chicken was used as protein bait. Subsequent visits to check the traps would reveal foraging ants to be a constant problem here.

August 8, 2008 – *Japanese Air Administration Building and Air Operations Building*
Coordinates: (Not Available)
Habitat Type: Building
Two collapsible Diptera/Hymenoptera cone traps were set up at the Japanese Air Administration Building and one cone trap was set up at the Japanese Air Operations Building to trap wasps. Canned chicken was used as protein bait. Wasps were very common around the Japanese Air Administration Building, but no wasps appeared to be interested in the protein bait. Subsequent visits to check the traps would reveal foraging ants to be a constant problem here.

August 9, 2008 - *Maga Transect*
(Inside Military Lease Area)
Coordinates: UTM 55 15.059444 145.621667
Habitat Type: Mixed Native Limestone Forest
Three entomologists spent the better portion of this day surveying this site along and off the established transect. Movement was slow as we developed an understanding for progressing carefully within the wet understory of the forest and avoiding the dreadful and unexpected sting of the *Polistes stigma* wasps, whose nests found along even the cut transect trail. Insects were sampled at several points by sweeping vegetation and hand collection from vegetation, under stones, and within substrate. Ants of several species were collected with baited cards. Neither adult candidate butterflies nor host plant species were located.

Native limestone forest collecting site on the Maga transect.

A nest of the paper wasp, *Polistes stigma*, in the forest.

August 9, 2008 - *Lake Hagoi*

(Inside Military Lease Area)
Coordinates: UTM 55 15.068083 145.625033
Habitat Type: Mixed Nonnative/Tangantangan Forest
One entomologist revisited established traps at this site for approximately 2 hours. Trapped specimens were collected from the EVS trap and BG-Sentinel trap before noon. Before sunset (6:44 PM), an EVS light trap with a green LED as a light source and a BG-Sentinel trap with BG-Lure and Octenol lure were set up in the survey area. Before sunset, mosquitoes were self-collected off himself with an aspirator. Mosquito identification is pending authorization to utilize the taxonomic services of Bishop Museum.

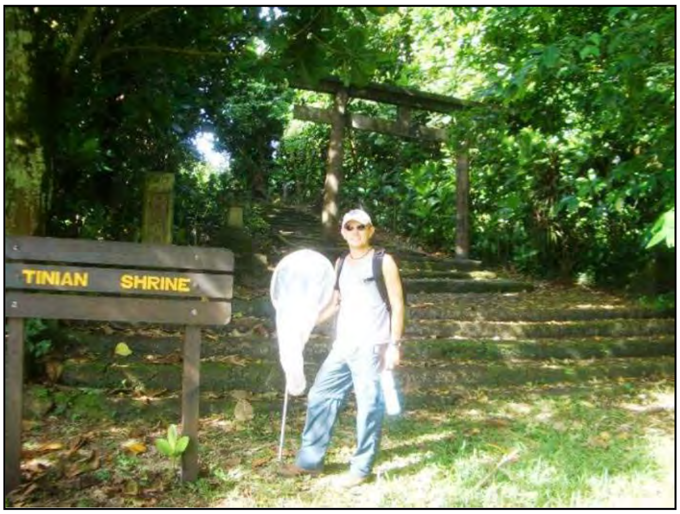
August 10, 2008 - *Carolinas Nature Trail (CNT) Area*

(Outside Military Lease Area)
Coordinates: UTM 55 14.939233 145.633783
Habitat Type: Mixed Native Limestone Forest
Based upon discussions with fellow biologists regarding known densities of both host plant species at this site, we (three entomologists) decided to visit this site to get a better feel for the distribution and appearances of the host plants' various life stages, as well as to sample insects from the host plants. A very large cluster of *Elatostema calcareum* was located in this area, growing along the numerous limestone outcroppings and within large corridor-like crevices in the stone. Very few insects were located on the plants themselves, most notably spittlebugs (Family Aphrophoridae) and ants of several species. Insects were sampled from the host plants and surrounding vegetation by sweep-netting, hand collection, and with the use of baited cards. The *E. calcareum* in various stages including with fruiting bodies, appeared quite healthy with no obvious signs of herbivory by either ungulates or insects. Some leaves were collected and bagged and two days letter yielded 2 small weevils (Family Curculionidae). Neither species of butterfly was located in either the adult or larval stage, despite the inspection of 30+ plants. As it turned out, the cluster of *E. calcareum* in this area was the largest in density and size that we would locate during the week long survey of all sites.

Several individual *Maytenus thompsonii* plants were also located within this site, but we did not have the opportunity to inspect them very closely prior to a very heavy downpour which hastened our retreat.

***Elatostema calcareum* in the Carolinas Nature Trail (CNT) area.**

<u>August 10, 2008 - *Tinian Shinto Shrine (Carolinas Heights)*</u>
(Outside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Mixed Native Limestone Forest
After a heavy rain shower mid-day, this mixed native limestone forest with some nonnative secondary forest components was surveyed by three entomologists for approximately two hours in the afternoon on this date. Neither adult candidate butterflies nor host plant species were located. The vegetation in this area was very dense and movement was slow due to lack of an established transect in this area. Ants of several species were very high in density within this locality as were termites of several species. One adult scorpion (*Liocheles australasiae*) and a colony of drywood termites were located within a rotten log. Several large mosquito larvae (identification pending), were collected in rain-filled portions of the old Shinto Shrine in this area.



Entomologist Mike Richardson at the Tinian Shinto Shrine

Liocheles australasiae

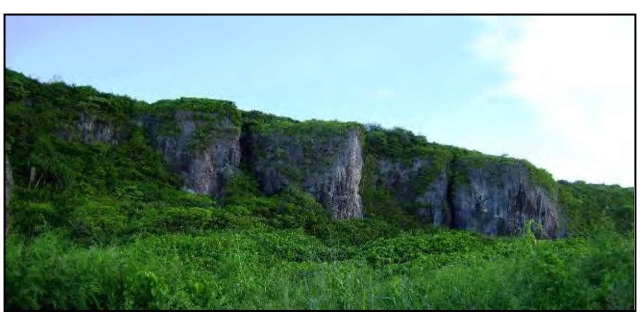
<u>August 10, 2008 - *Lake Hagoi*</u>
(Inside Military Lease Area)
Coordinates: UTM 55 15.068083 145.625033
Habitat Type: Mixed Nonnative/Tangantangan Forest
One entomologist revisited established traps in this area for approximately 1 hour. Trapped specimens were collected from the EVS trap and BG-Sentinel trap before noon. Mosquito identification is pending authorization to utilize the taxonomic services of Bishop Museum.

<u>August 11, 2008 - *Makpo Wells (Tinian Pumphouse Area)*</u>
(Outside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Nonnative marshland
Three entomologists visited the marshy terrain immediately surrounding the Tinian pumphouse on the morning of this date. No standing water could be located despite

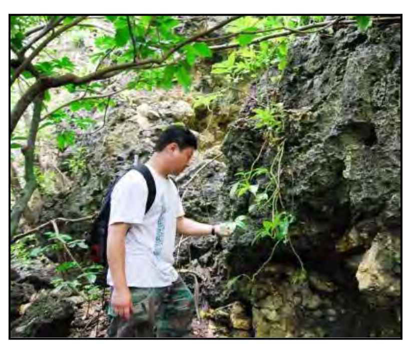
recent heavy rains the day prior. No odonates were located. Several species of ants and one nonnative wasp species, (Family Vespidae, *Delta* sp.) were collected.

A wasp (*Delta* sp.) on its mud nest.

<u>August 11, 2008 - *Laderan Chiget Cliffs Transect (CC)*</u>
(Inside Military Lease Area)
Coordinates: UTM 55 15.060816 145.647866
Habitat Type: Mixed Native Limestone Forest
Three entomologists spent approximately 6 hours was spent walking this entire transect beginning from where the ridge intersects the paved road to the west until it ends at the Chiget beach area. Several individual *Maytenus thompsonii* plants were located and recorded with our GPS equipment. Only a single stand of *Elatostema calcareum* was located near the beach end of the transect. This stand was closely inspected for candidate larvae and other insects, but none were located. All individual plants of both host species appeared healthy and free of any appearance of herbivory. Very few insects were collected within surrounding native vegetation along this transect during this date, due to the amount of time needed to traverse the area and also because of our intention to return and conduct more sampling (which unfortunately did not occur due to time constraints). No adults of either candidate butterfly species were observed during this date. The densities of *Polistes stigma* nests along this transect were very high, in some areas two or more nests occurred within just five feet of each other. The nest height location varied from 1.5 feet from the ground to over 30 feet high from the ground. The single largest nest in terms of number of individuals was observed in this area, with a total of 40+ wasps. One single, large adult female coconut crab was observed within this area. Several mosquitoes were aspirated off the surveying entomologists.



Limestone cliffs that are skirted by the Laderan Chiget transect.



Entomologist Stephan Lee inspects *E. Calcareum* on the Laderan Chiget transect.

August 11, 2008 - *Korean Memorial & Saint Lourdes Shrine Cave (San Jose Village)*
(Outside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Mostly Nonnative Secondary Forest w/some Native Limestone Forest Components
Two entomologists visited the Saint Lourdes Shrine Cave and adjacent forest, located on the western edge of the San Jose village in the evening of this date. Unfortunately, a decent downpour prevented much of the work we had intended in the forest and we spent about one hour collecting insects and blacklighting within the cave itself and at the mouth of the cave. No insects were attracted to the blacklight and no scorpions were located.

Entrance to St Lourdes Shrine Cave

St Lourdes Shrine Cave interior.

August 11, 2008 – *Mount Laso*
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Mixed Native Limestone Forest
One entomologist revisited established traps within this area for approximately 1 hour. Insect specimens were collected from the malaise trap that was set up on August 8, 2008. Mosquitoes were separated from the insects collected.

August 11, 2008 – *Old Japanese Communications Center*
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Building
One entomologist revisited established traps within this area for approximately 1 hour. No wasps were trapped in the collapsible Diptera/Hymenoptera cone traps that were set up on August 8, 2008.

August 11, 2008 – *Japanese Air Administration Building and Air Operations Building*
(Inside the Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Building
No wasps were trapped in the collapsible Diptera/Hymenoptera cone traps that were set up on August 8, 2008. No leftover bait was found at the Japanese Air Administration building.

<u>August 12, 2008 - *Aguiguan Lower West Limestone Forest*</u>
(Outside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Mixed Native Limestone Forest
One entomologist spent approximately two hours surveying the northeastern lower tier of mixed limestone forest. Neither adult candidate butterflies nor host plant species were located in this area. Arthropod samples were taken by net-sweeping surrounding native vegetation, use of baited cards, and hand sampling vegetation, under rocks, and in substrate. Individual and small herds of goats were observed during this time. Vegetation along this entire transect showed very obvious signs of ungulate herbivory, presumably by goats. *Polistes stigma* nest density was noticeably lower in this area than that observed on Tinian.

August 12, 2008 – *Aguiguan Cisterns Near Base Camp*

(Outside Military Lease Area)
Coordinates: UTM 55 14.851366 145.556800
Habitat Type: Aquatic/Semi-aquatic and Mixed Nonnative Forest
Two entomologists surveyed the aquatic environment inside of World War II era cisterns constructed by the Japanese during their occupation of island from approximately 1936 to 1945. There are numerous Japanese-era sites on the island with cisterns that contain water, but due to time constraints, the entomologists where only able to survey cisterns located in the center of the island, near the base camp. This area, which had once been a Japanese plantation village, had approximately 28 cisterns of various sizes and shapes (circular or rectangular with variable dimensions) and in various states of decay. Many of the cisterns were full of water, and some were empty or collapsed. Six of the cisterns containing water were sampled using a D-frame aquatic net and a mosquito dipper. Cistern biota sampled consisted of dragonfly nymphs, veliid bugs or broad shouldered water striders, chironomid or midgefly larvae, mosquito larvae, pleid bugs or pygmy backswimmers, annelid worms, a tetragnathid spider, and an adult beetle of unknown identification.

Some terrestrial insects were also collected in areas immediately adjacent to the cisterns. Both subterranean and drywood termites were collected from woody debris on the ground. A beetle larvae and an adult passalid beetle were also collected from wood debris (separate pieces of wood). Large millipedes were common in this area and were seen crawling within the substrate. Six of these millipedes were collected and were tentatively identified as *Trigoniulus lumbricinus*. Additionally, adult dragonflies (red species) were commonly seen flying through the cistern area. One of these dragonflies was caught in the base camp area, and was later identified by the Bishop Museum as *Trapezostigma transmarina*.

Approximately 1 hour was also spent surveying the mostly nonnative vegetation immediately surrounding the base camp area. Arthropod samples were taken by net-sweeping surrounding vegetation, use of baited cards, and hand sampling vegetation, under rocks, and in substrate. One immature scorpion (*Liocheles australasiae*) was located in the vegetation near the base camp.

Partially open cistern with vegetation.

Entomologist Stephan Lee sorting through a sample from open cisterns.

Collapsing cisterns with no water.

Intact cisterns.

<u>August 12, 2008 - *Aguiguan Upper West Limestone Forest*</u>

(Outside Military Lease Area)
Coordinates: UTM 55 14.854216 145.550683
Habitat Type: Mixed Native Limestone Forest
Three entomologists spent approximately two and a half hours surveying the northeastern upper tier of mixed native limestone forest. No adult candidate butterflies or *Elatostema calcareum* host plants were observed, but several individual *Maytenus thompsonii* plants were located and inspected carefully. These were the only flowering individuals of this species that we located during the week long survey. Most individuals showed signs of herbivory by goats along the base of the plant or on lower stems. Very few insects other than ant species and a couple of beetle species were collected from these host plants. Note, one *M. thompsonii* that was located within this area showed signs of insect feeding (chewing) on a large majority of leaves (see photos), but this feeding was not indicative of lepidopteran chewing, more likely chewing by beetles. Other arthropod samples were taken by net-sweeping surrounding native vegetation, use of baited cards, and hand sampling vegetation, under rocks, and in substrate.

A goat browsed
Maytenus thompsonii on
Aguiguan.

Signs of insect feeding on leaves of *Maytenus thompsonii*.

August 12, 2008 - *Aguiguan Lower Rock Shelf*
(Outside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Exposed Limestone Rock
Two entomologists spent approximately 15 minutes surveying small pools of water in the lower limestone shelf near the boat landing site. Drangonfly nymphs and mosquito larvae were found in the pools. A quick taste test suggested that the water was perhaps partly saline. Unfortunately more time could not be spent at this site due to an impending emergency evacuation of an injured biologist.

Entomologist Cory Campora examines the rock pools near the boat landing site on Aguiguan.

August 13, 2008 - *Japanese Defensive Caves Trail South (Laderan Lasu, Mt. Lasu)*
(Inside Military Lease Area)
Coordinates: UTM 55 15.039333 145.636833
Habitat Type: Mixed Native Limestone Forest
Three entomologist spent approximately six hours surveying the established southbound transect in this area. Several clusters of *Elatostema calcareum* host plants were located and recorded with our GPS unit. No plants contained phytophagous insects and none exhibited signs of any herbivory. A few scatter individual *Maytenus thompsonii* plants were also located and recorded with our GPS. None exhibited signs of any herbivory. Arthropod samples were taken by net-sweeping surrounding native vegetation, use of baited cards, and hand sampling vegetation, under rocks, and in substrate. *Polistes stigma* nests were very high in density along this transect. Several mosquitoes were aspirated off the surveying entomologists.

***Elatostema calcareum* growing off the lower limestone cliff on the South Japanese defensive caves trail.**

August 14, 2008 - *Japanese Defensive Caves Trail North (Laderan Mangpang, Mt. Lasu)*
(Inside Military Lease Area)
Coordinates: UTM 55 15.042333 145.634000
Habitat Type: Mixed Native Limestone Forest
Three entomologist spent approximately six hours surveying the established southbound transect in this area. No *Elatostema calcareum* host plants were located; however, a few scatter individual *Maytenus thompsonii* plants were located and recorded with our GPS. None exhibited signs of any herbivory. Arthropod samples were taken by net-sweeping surrounding native vegetation, use of baited cards, and hand sampling vegetation, under rocks, and in substrate. Several of the deeper WWII Japanese defensive caves were examined closely with both a LED headlamp and separately with a blacklight with no scorpions or other arthropods observed. One cave did contain a mid-sized juvenile coconut crab. *Polistes stigma* nests were very high in density along this transect. Densities of both *Hypolimnas bolina* and *Hypolimnas anomala* (Family *Nymphalidae*) were quite high along the entire length of this transect.

<u>August 15, 2008 - *Maga Transect*</u>
(Inside Military Lease Area)
Coordinates: UTM 55 15.059444 145.621667
Habitat Type: Mixed Native Limestone Forest
On the final day of field work, one entomologist resurveyed this site for approximately three hours for the purpose of confirming absence of host plant species as noted on the August 9, 2008 visit to this site. No host plants were located despite careful searching along both the upper cliff edge, below the cliffs, and within the forest below the transect itself. Visual searches for the adult candidate butterflies were unsuccessful and no arthropods were collected on this date.

<u>August 15, 2008 - *NKK Railroad Shrine Trailhead*</u>
(Inside Military Lease Area)
Coordinates: (Not Available)
Habitat Type: Nonnative Secondary Forest
With a small amount of remaining time on the final day of field work, this nonnative, secondary forest site was surveyed for approximately 2 hours by one entomologist. Interestingly, but perhaps not surprisingly, insect diversity was much higher than that observed within the mixed limestone forest sites surveyed. Several specimens were collected including many insect and spider species not observed within the mixed limestone forest sites. Within the two acre area surveyed at this site, *Polistes stigma* nests were infrequently encountered and appeared to be less dense than that observed within the mixed limestone forest sites.

***NKK Railroad* Shrine Trailhead.**

August 15, 2008 – *Lake Hagoi*

(Inside Military Lease Area)
Coordinates: UTM 55 15.068083 145.625033
Habitat Type: Aquatic/Semi-aquatic Marshland
An entomologist returned to Lake Hagoi for approximately three hours with a kayak for better access to the open water portions of the lake. Passage through the vegetation was

again difficult, but once the reeds were reached, movement over the water and mud was much easier. Unfortunately the height of the reeds prevented a clear view of where the open water portions of the lake were located. Due to this navigational difficulty and time constraints, the large open water portions of the lake were not visited. Small pockets of open water within the reeds where sampled however. These areas were teeming with water boatmen and water striders. Samples were taken with a D-frame aquatic, but no new benthic and aquatic organisms were collected compared to what was caught on August 7th. Many dragonflies were seen flying over the reeds, mostly the large red species, but a smaller species was also common. Damselflies were also common, but again only one species was apparent. This was the same species that was seen on August 7th. A sweep net was used to collect some more of the damselflies and two tetragnathid spiders were also collected.

Kayak being pushed through reeds in Lake Hagoi.

Path through reeds in Lake Hagoi created by Kavak.

DISCUSSION

The primary objectives of this week long survey were to determine the presence or absence of candidate species, *Vagrans egistina* and *Hypolimnas octocula*. *mariannensis*, to survey for and locate the host plant species, to inspect and survey the host plant habitat for potential insect threats to either the candidate butterflies or the host plants, and finally, to gather some information regarding the presence or absence of particular arthropod groups on the islands of Tinian and Augean, including insects of socie-economic importance (i.e., mosquito vector species, ants, and termites) and others including aquatic fauna such as odonates. The major limitation of this survey effort was the short duration of our visit which did not allow us to gather as much detailed information or to cover as many areas as we would have preferred. Heavy downpours affected our ability to survey on some days, but were not a significant factor. Surprisingly, the insidious *Polistes stigma* wasp was a substantial deterrent to moving quickly in most forested areas we surveyed. Coupled with the tricky terrain, humidity and high temperatures, and dense vegetation, the extent of the area surveyed at each site was less than we had hoped and intended to accomplish.

Candidate Butterflies (*Vagrans egistina* and *Hypolimnas octocula mariannensis*)
Neither adults nor larvae of either candidate butterfly species were observed during our survey efforts. All host plants (both *Elatostema calcareum* and *Maytenus thompsonii*) that we located appeared healthy and flush with new vegetation for the most part, and all plants were inspected to the best of our abilities. Neither host plant species at any of the sites we surveyed exhibited evidence of lepidopteran feeding. Conditions on both islands were fairly moist with several rain showers and a couple of downpours occurring during our week long survey effort, so it was likely not too dry for the butterflies to have been present. Many of the life stages including larvae, pupae, and adults of the several nymphalid butterflies known to be present on Tinian were frequently observed during our surveys of the limestone forest areas. The species most commonly and frequently observed were *Hypolimnas anomala* and *H. bolina*.

Both the number and the density of invertebrates collected on the two host plant species located on Tinian (only *Maytenus thompsonii* was located on the one day of surveying on Aguiguan), was surprisingly low. The most commonly collected insect on both host plant species were ants. Very few phytophagous insects were observed. The following groups of insects were collected on *Elatostema calcareum* in very low numbers: weevils (Family Curculionidae); tephritid flies (Family Tephritidae); spittle bugs (Family Aphrophoridae); mealybugs (Family Pseudococcidae); plant hoppers (Family Fulgoroidea); and one katydid (Family Tettigoniidae). No plants except one individual of *M. thompsonii* located on Aguiguan showed signs of insect herbivory (apparently by beetles). Only on the island on Aguiguan did we observe signs of ungulate herbivory, apparently goat browsing on *M. thompsonii*.

***Polistes stigma* and Other Wasps**
Polistes stigma is a eusocial species of wasp belonging to the Vespidae family. They are generalist predators which forage for protein to nourish the larvae that are developing and housed within their paper nests. While this species may forage on nearly any sort of meat including that from human garbage, there is high potential for them to prey upon any invertebrates including butterfly larvae within their foraging area. Unfortunately, captured prey items are masticated (chewed up) when they are brought to the nest prior to being fed to the larvae, so it is difficult to ascertain what is being collected by the wasp. During our surveys of the mixed limestone forest areas, nests of this wasp species were generally observed to be as frequent as 4 nests within a 30 square foot area, occasionally occurring within 5 feet of each other.

Based upon our observations and prior survey work on the other islands within the CNMI, including Guam, we believe that densities of *Polistes stigma* nests on both Tinian and Aguiguan are extremely high and perhaps a significant factor which could preclude the two candidate butterfly species from utilizing the available host plant habitat on both islands. We believe it would be worthwhile to design a study to determine which groups of insects are being preyed upon by this species and to determine an actual measurement of nest density within the mixed limestone forest areas of Tinian and Aguiguan. Certainly, this information would be highly recommended prior to any efforts to augment populations of the two candidate butterflies that are discovered on these islands, or prior to any effort to translocate these species there as part of a larger recovery process. Additionally, it would be useful to understand and compare the density of *P. stigma* nests within habitat occupied by the candidate butterflies on Guam and elsewhere. Based upon our firsthand knowledge, nest density is certainly much lower within occupied areas on Guam.

Several other species of predatory wasps are known from Tinian. Of these, *Delta* spp. solitary wasps are the most likely possible predators of the candidate butterflies. Being solitary wasps, however, the impact of their predation is likely much lower than that of the eusocial *Polistes stigma*. We collected two specimens of this genus within areas outside the mixed native limestone forest sites.

Ants

Numerous species of ants collected during our surveys are pending identification, but it should be noted that certain species occurred in high densities within the mixed limestone forest areas that we surveyed. Most species are common tramp ants found throughout the Pacific region and some of these species are likely capable of inducing predation pressure on the larvae of the candidate butterflies.

Mosquitoes

The mosquitoes collected on Tinian for this survey are awaiting identification. Mosquitoes are vectors of human diseases and animal diseases and nuisance pests of humans. Mosquito transmission of bird disease on Tinian is not a concern of USFWS. However, the Navy and Marine Corps will be concerned about mosquito-borne human diseases on Tinian if Tinian will be utilized for Navy and Marine Corps training and berthing. Vector-borne disease transmission to humans relies on several factors: a competent disease vector, the presence of a pathogen, a host reservoir, and favorable environmental conditions. The 1985 Hawaiian Agronomics report listed two species of mosquitoes found on Tinian during their survey from November 1984 – November 1985: *Aedes albopictus* and *Culex quinquefasciatus*. *A. albopictus* can serve as a vector of dengue fever. Culex quinquefasciatus is a vector of West Nile virus, various viral encephalitides, dog heartworm, and avian malaria. Past surveys have found other *Aedes* and *Culex* species including *Culex tritaeniorhynchus*-vector of Japanese encephalitis, *Aedes aegypti*-a vector of dengue fever and yellow fever, and *Anopheles indefinitus* a possible vector of malaria. If human activity in Tinian increases, the chance of accidental introduction of a mosquito-borne disease infected host and a competent mosquito vector also could increase. Implementation of appropriate quarantine measures would be a logical course of action as well as implementation of mosquito surveillance programs.

Termites

In many parts of the world, termites are ranked among the most significant economic insect pests. The Mariana Islands are no exception. Termite species in the Mariana Islands are primarily recorded from collections on Guam and Saipan. Light (1946) listed the following three species from Guam collected in 1936: 1) *Cryptotermes hermsi* Kirby (a synonym of *Cryptotermes domesticus* (Haviland)) (Kalotermitidae), 2) *Neotermes* *connexus* Snyder (Kalotermitidae), and 3) *Prorhinotermes inopinatus* Silvestri (Rhinotermitidae); and one more species collected from an unknown location in the Mariana Islands, *Calotermes marianus* Holmgrem (species name no longer used - maybe a synonym of *Incisitermes marianus* Holmgren). Later in the 1970's *Coptotermes formosanus* Shiraki (Rhinotermitidae) was documented as established on Guam (Su and Scheffrahn 1998); however, it was subsequently found that this termite was actually *Coptotermes gestroi* (Wasmann) (Rhinotermitidae) (Su and Sheffrahn 1998), formerly known as *Coptotermes vastor* Light (Rhinotermitidae) (Yeap *et al.* 2007). In 1993 Su and Sheffrahn (1998) found three additional termite species on Guam: *Cryptotermes dudleyi* Bank (Kalotermitidae), a *Microceretermes* species (Termitidae), and a *Nasutitermes* species (Termitidae). A more recent paper describing the complex of termites in the Mariana Islands (Yudin 2002) mentions *Schedorhinotermes* (Rhinotermitidae) and *Macrotermes* (Termitidae) as present on Guam and Saipan.

Outside of Guam and Saipan the distribution of termite species in the Mariana Islands does not appear to be well documented. The Hawaiian Agronomics, Inc. (1995) report refers to termites as abundant on Tinian, and mentions both subterranean (Rhinotermitidae) and drywood (Kalotermitidae) termites; however, no further identifications are provided. Table III-2 of their report listed 3 different species as collected, but unidentified. The report from the Chiba expedition to the Northern Mariana Islands (Natural Museum and Institute, Chiba 1994) lists only two species of termites: 1) *Cryptotermes domesticus* Haviland (Agihan, Anatahan, Guguan, and Sarigan) and 2) *Prorhinotermes inopinatus* (Agrihan, Anatahan, and Sarigan).

Identifications are pending, but it appears that at least three different species of termites were collected during the current survey. A large forest drywood (Kalotermitidae – most likely *Neotermes connexus*) and a species of the subterranean genus *Prorhinotermes* (Rhinotermitidae - most likely *Prorhinotermes inopinatus*) were found on both Tinian and Aguiguan. A second subterranean species, *Coptotermes gestroi* was collected on Tinian only.*Coptotermes gestroi* is by far the most damaging economic pest of the three species collected. As a subterranean termite, it primarily lives in large colonies underground, but constructs mud tubes to forage above ground and connect to sources of wood or other cellulosic materials. Colonies of this termite can cause significant structural damage in relatively short periods of time; therefore any construction on Tinian should take into consideration building design and building materials that will minimize the risk of termite infestation.

Odonates

The odonate fauna of the Mariana Islands has been described as meager, with only two endemic species (*Anax piraticus* Kennedy and *Agrionoptera insignis guamensis* Leiftinck) among the14 recorded taxa (Polhemus 2000). However, 8 years ago a new species, *Ischnura luta,* was discovered on the island of Rota and determined to be the first endemic damselfly recorded for the Mariana Islands (Polhemus 2000). Due to the fact that the insect fauna on Tinian and Aguiguan has not been well studied, and considering that both islands have some freshwater bodies, it was determined that this order of insects should receive some additional focus.

Adult Anisoptera, or dragonflies, were commonly seen flying in most open areas on Tinian. Specimens of adult dragonflies were collected at Lake Hagoi, at the Tinian Dynasty Hotel Fountain, and within the town of San Jose. Species of adult Anisoptera collected included *Trapezostigma transmarina* Brauer, *Pantala flavescens* (Fabricius), and *Diplacodes bipunctata* (Brauer). These species are all indigenous to the region, and considered common. Lieftinck (1962) states that due to their strong migratory tendencies, *P. Flavescens* and *D. punctata* are the dominant dragonflies of Micronesia. *Trapezostigma transmarina* is not as widely distributed - the Micronesian range of its distribution only includes Bonin, Southern Mariana, Palau, and Yap (Lieftinck 1962). The only aquatic area sampled on Tinian for immatures, or nymphs, was Lake Hagoi, and although many adults were seen flying above the lake, dragonfly nymphs were not found within the lake. There appeared to be at least one species present on Tinian that we saw, but were unable to catch, and which was different from the three species that were collected. This species was medium sized with bluish gray and maybe some yellow coloration, and was seen near the Japanese Village Ruins and also at the trailhead of the Japanese Defensive Caves Trails.

One adult dragonfly was collected on Aguiguan near Japanese-era cisterns that are partially filled with water. This specimen was identified as *T. transmarina*. Dragonfly nymphs were collected from these cisterns, and from small rock pools near the ocean at the boat landing site. There were a number of these pools in the limestone rock, filled presumably by rainwater or spray from crashing waves. These nymphs were semi-translucent and greenish in color. Mosquito larvae were also present in these pools in high numbers. Identification is pending for all dragonfly nymphs collected on Aguiguan.

Adults and nymphs of Zygoptera, or damselflies, were collected at Lake Hagoi. The adults were identified as *Agriocnemis femina femina* (Brauer), and the identifications of the nymphs are pending. This species appeared common within close proximity to Lake Hagoi, however adult damseflies were not seen anywhere else on the island. *Agriocnemis femina femina* is considered a widely spread, indigenous species (Lieftinck 1962) and is not of any particular conservation concern.

It appears that neither of the two endemic dragonfly species were collected on Tinian or Aguiguan during this survey, but until the nymphs collected on Aguiguan are identified this cannot be stated with certainty. These two species are found only in the southern Mariana Islands, *Anax. piraticus* having been found on Guam and Saipan, and *Agrionoptera insignis guamensis* having been found only on Guam.

<u>Other Aquatic Insects</u>

Aquatic insects collected on Tinian in Lake Hagoi are awaiting further identification; however, the taxa match fairly well with the aquatic organisms recorded in the Hawaiian Agronomics survey (Hawaiian Agronomics, Inc. 1995). The aquatic organisms collected from cisterns on Aguiguan are interesting because there is apparently no record of any previous aquatic sampling within the island's Japanese-era structures. Identifications are pending, but the following is a preliminary list of organisms collected from the cisterns: 1) Heteroptera: Veliidae, 2) Heteroptera: Pleidae, 3) Diptera: Chironomidae, 4) Odonata, 5) Coleoptera, and 6) Aranea: Tetragnathidae.

Of particular interest are the pleids, or pygmy backswimmers, that were collected. There was no record of the family Pleidae in Micronesia until 2007 when a paper was published describing the discovery in 2006 of *Paraplea puella* (Barber) on Guam in a river outflow (Zack *et al.* 2007). *Paraplea puella* is a North American species of pleid and is speculated to have been accidentally transported to Guam recently via the aquaculture or aquarium trade. How pleids would have arrived on Aguiguan is somewhat of a mystery since it is an uninhabited island. The cistern in which the pleids were found is a remant structure of a Japanese-era plantation village that existed from 1936 to 1945 (Butler 1990). It is possible that pleids were introduced to Aguiguan by the Japanese at this time. If the pleid specimens can be identified to the species level, the history of their presence on Aguiguan may become better understood.

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Figure 1. Northern arthropod collection sites and survey transects, Tinian, CNMI, 7-15 August 2008.

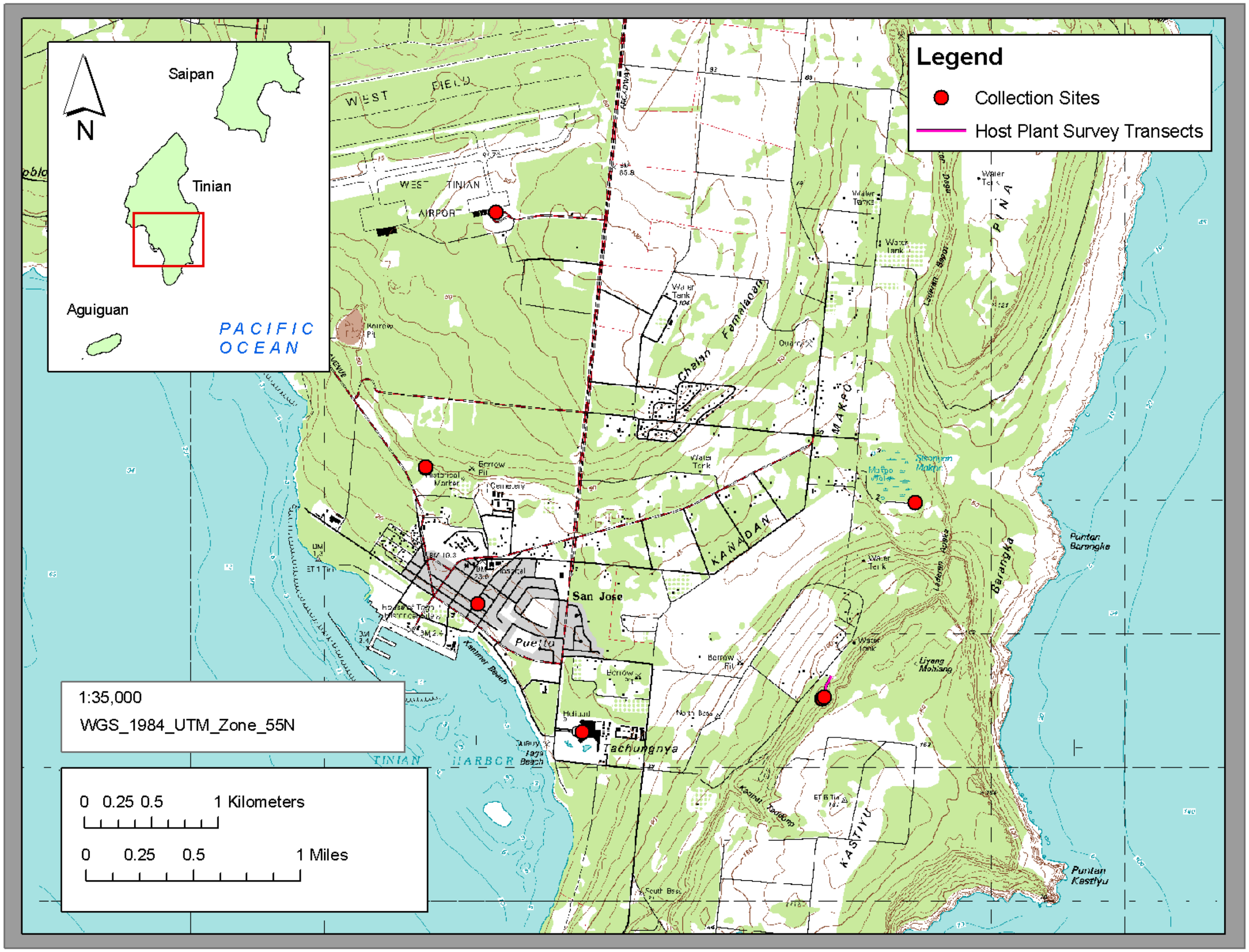

Figure 2. South central arthropod collection sites and survey transects, Tinian, CNMI, 8-11 August 2008.

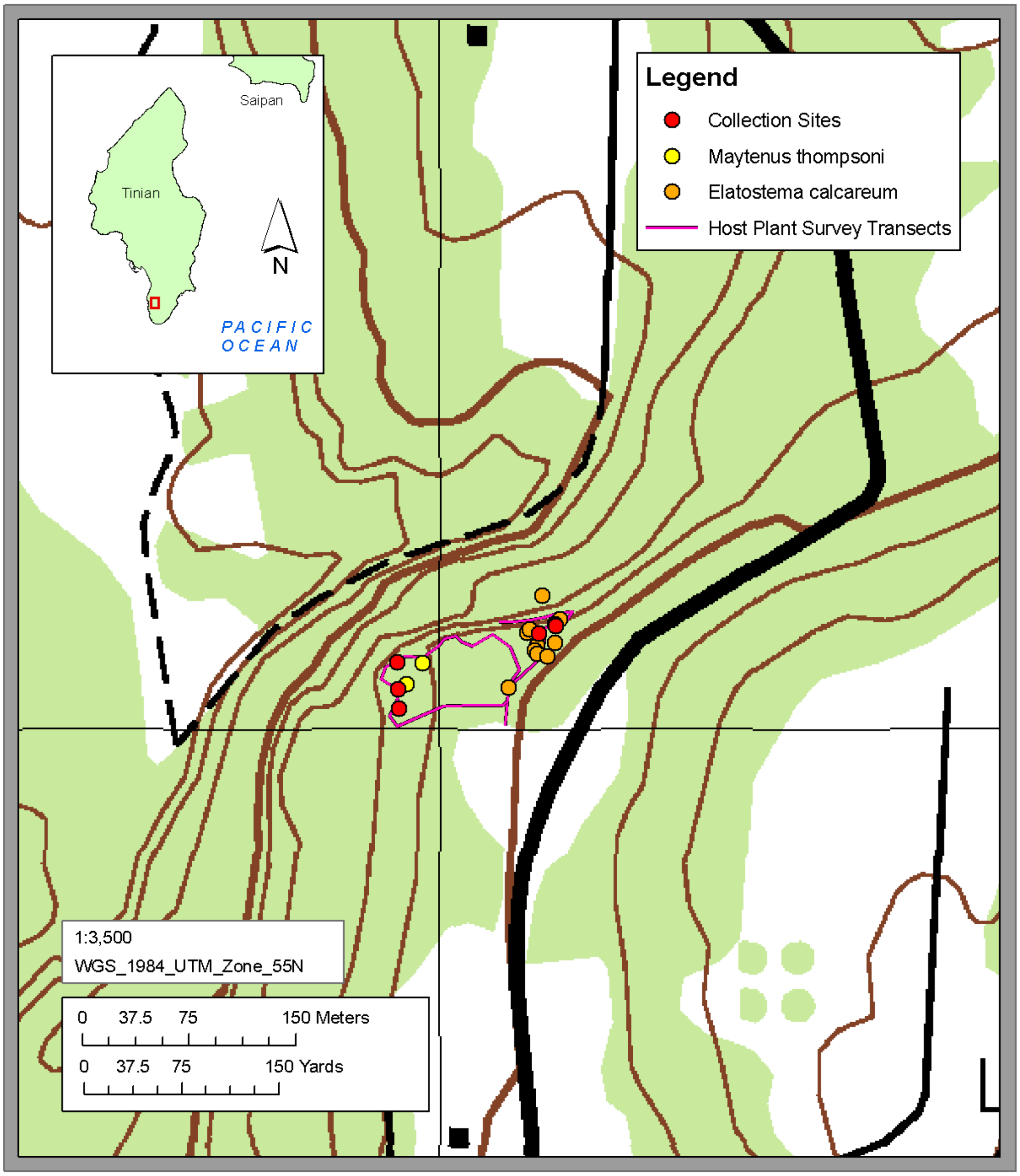

Figure 3. Southern arthropod collection sites and survey transects, Tinian, CNMI, 10 August 2008.

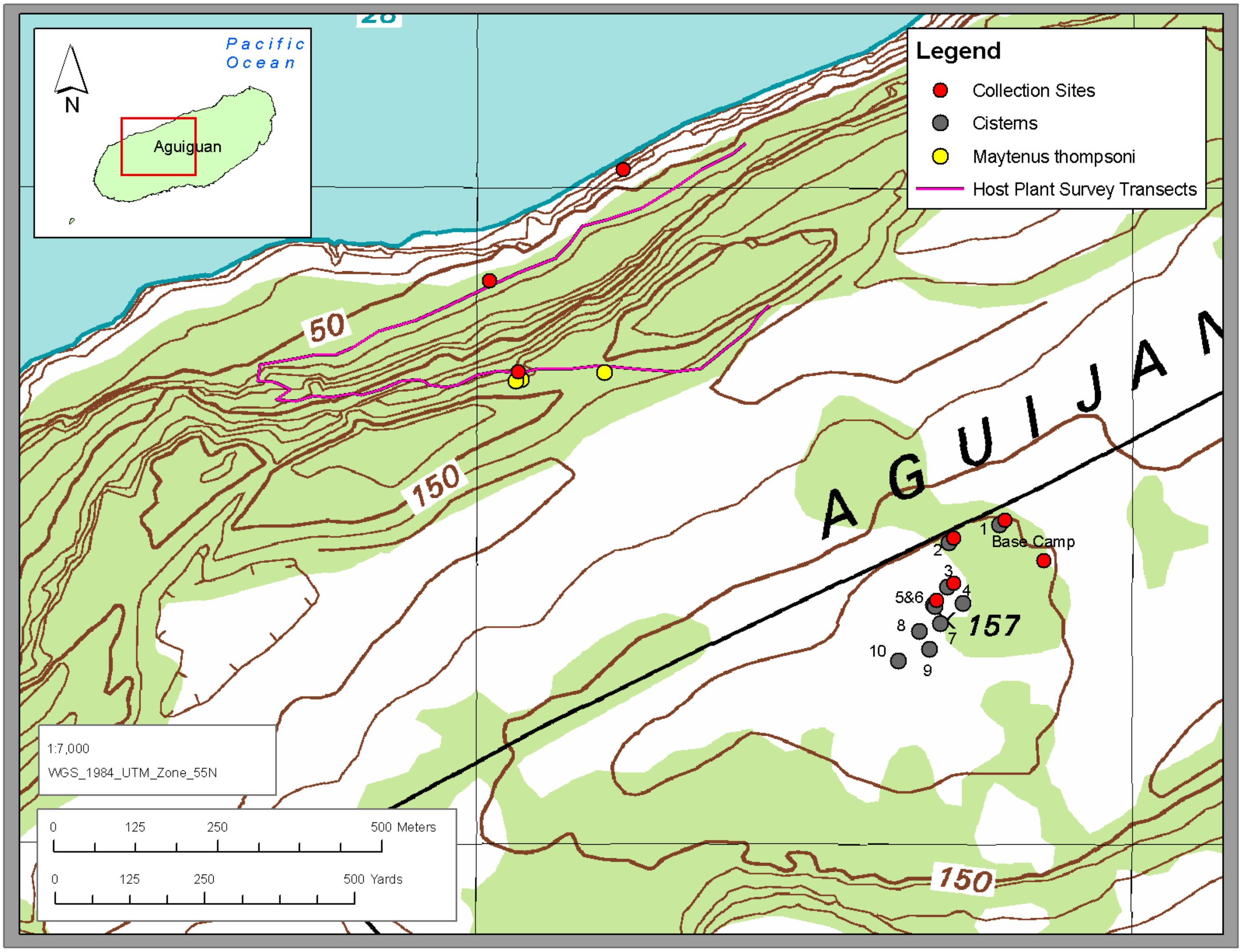

Figure 4. Arthropod collection sites and survey transects, Aguigan, CNMI, 12 August 2008.

2.2.2 CANDIDATE BUTTERFLY SURVEYS ON TINIAN

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INTRODUCTION

A survey was conducted on the island of Tinian, Commonwealth of the Northern Mariana Islands (CNMI) from June to October, 2008 to determine the presence or absence of two butterfly species, Marianas rusty butterfly *Vagrans egistina* and the forest flicker *Hypolimnas octocula mariannensis* (Family *Nymphalidae*). Currently, *V. egistina* and *H. octocula mariannensis* are listed as candidates for listing under the Endangered Species Act. Both butterfly species are considered rare and were only recorded on the islands of Saipan, Rota and Guam (Schreiner and Nafus 1996). *V. egistina* was last collected on Guam in the late 1970s and on Rota in the1980s and 1995. *H. octocula mariannensis* is historically known from Guam and Saipan and after an intensive survey for this species in 1995, investigators found only 10 populations on the island of Guam and none on the island of Saipan (Schreiner and Nafus 1996).

Based on a literature review, very few entomological studies have been conducted on the island of Tinian. The most comprehensive report available was prepared for the United States Navy (Contract N62742-84-C-0141) by Hawaiian Agronomics (International), Inc. in December, 1985. Hawaiian Agronomics staff spent a total of seventeen days between November 1984 to November 1985 collecting insects (including Lepidoptera) utilizing various methods of collection that accounted for temporal differences. They did not collect *Vagrans egistina* or *Hypolimnas octocula mariannensis*. This result was not surprising as both species have not been recorded on the island of Tinian, CNMI, previously. However, *Vagrans egistina* or *Hypolimnas octocula mariannensis* may have historically been found on Tinian or were missed during past survey efforts. A key factor in potentially finding either butterfly species is the presence of host plants on Tinian.

The recorded host plant for *V. egistina* is *Maytenus thompsonii* (Family *Celastraceae*), a small tree/shrub endemic to the Marianas and found primarily in the understory of native limestone forests (Vogt and Williams 2004, Schreiner and Nafus 1996). The recorded host plants for the *H. octocula mariannensis* are *Procris pedunculata* and *Elatostema calcareum*, both forest herbs (Family *Urticaceae*) found growing on limestone outcrops in native limestone forest (Schreiner and Nafus 1996).

METHODS

The primary objective of this survey was to determine the presence or absence of both Candidate species *Vagrans egistina* and *Hypolimnas octocula mariannensis* by locating host plant sites for each species and monitoring sites for life cycle stages. Since a large group of biologists were involved in surveying the flora and fauna on the island of Tinian, CNMI from June to August, 2008 an information guide (Figure 1) was produced and distributed to each biologist. The guide provided photographs of both butterflies and their host plants as well as descriptions of the caterpillars. The goal of the guide was to help identify host plants and *V. egistina* and *H. octocula mariannensis* in the field in order to collect GPS points of their locations for additional monitoring.

Four host plant sites were identified by U.S. Fish and Wildlife Service and Department of Defense biologists from June to August, 2008. Two host plant sites were located on Department of Defense leased land at Japanese Cave (Figure 2), and Chiget Cliff (Figure 3) and two on CNMI Public Lands at Carolinas Nature Trail (Figure 4) and Sisonyan Makpo (Figure 5).

A host plant area is an area with host plants for either *Vagrans egistina* or *Hypolimnas octocula mariannensis* within a 25 meter perimeter. For the purpose of this survey, only visual search hours were recorded while the observer was in a host plant area. Each identified host plant site was visually scanned for life cycle stages (eggs, caterpillar, chrysalis, and imagoes/adults) by one or two observers for up to two weeks at various time of the day. As time permitted a further scan of the area was conducted of up 1500 meters to determine if additional host plant sites had gone undetected.

Due to time constraints, this survey was unable to account for seasonal variation. The bulk of the survey occurred during the months of September and October which are considered part of the rainy season. Therefore, limited sampling was done during the dry season. However, Schreiner and Nafus (pers. comm. 2008) observed both species to be more numerous on islands they are recorded from during the rainy season although adults were observed year round.

Two butterfly bait traps (lip type obtained from BioQuip.com) were set at each host plant site for up to two weeks. The butterfly bait traps were re-baited every three days with locally obtained mashed, rotting bananas, a liberal dose of raw cane sugar, and a dash of water. The bait was prepared on the afternoon prior to the morning of use and typically became well fermented prior to being placed in the field. The traps were positioned within 5 meters of a host plant cluster and at approximately 3-4 meters above the ground.

RESULTS

No individuals of either candidate butterfly species were observed. A total of four host plant areas were identified and monitored from 9/10/08 till 10/21/08. A description of the search effort at each site is outlined below.

Carolinas Nature Trail (CNT) Area
Two sites, greater than 50 meters apart, were monitored at the Carolinas Nature Trail Area (UTM 55 P0353070 1652046). A total of 13 days were spent conducting visual searches (1,574minutes) with 624 hours spent trapping with 2 traps (Table 1). Common melon flies (*Bactrocera* sp.) were observed during thirteen of the fifteen times the traps were checked and were only recorded at one of the other monitoring areas, Chiget Cliff. However, no *Vagrans egistina* or *Hypolimnas octocula mariannensis* were recorded at

this site. This area is not in the Military Lease Area and supported the single largest cluster of *Elatostema calcareum* found during this survey.

Japanese Cave (JC) Mount Lasu Area
The Japanese Cave Mount Lasu area (UTMs 55 P 0353408 1663125 and 55 P 0353357 1663105) is located in the Military Lease Area and consisted of several small clusters of host plants (*Maytenus thompsonii* and *Elatostema calcareum*). The two fruit baited traps were stationed at the two largest clusters (UTM site-1 = 55 P 0353408 1663125 and site-2 = 55 P 0353357 1663105). At Japanese Cave site-2, two caterpillars and four chrysalises of the blue moon butterfly *Hypolimnas bolina* were found feeding/pupating on *E. calcareum*, the chrysalises were reared in the lab for confirmation. Additional smaller clusters were visited several times over the 15 monitoring period with 1765 visual search minutes recorded and the two traps produced 696 total traps hours (Table 1). Over 8 kilometers of cliff line in the Mount Lasu area were surveyed for additional host plant sites during this period. Several small pockets consisting of 1-5 *E. calcareum* individuals were identified and scanned for life cycle stages of the candidate species, but none were found. Three *Melanitis leda* (Family *Satyridae*) and one *H. bolina* (Family *Nymphalidae*) were found feeding in the traps at Japanese Cave site-2. In addition, large congregations of mating *H. bolina* and *Hypolimnas anomala* (guardian butterfly) were observed, which supports Kemp's (2000) finding that the reproductive activity increases in *H. bolina* during months of higher rainfall and humidity levels.

Chiget Cliff (CC) -Laderan Chiget Area
Only one stand of *Elatostema calcareum* was identified and monitored at the Chiget Cliff site (UTM 55 P 0354957 1665402) after an extensive search (4 km) of the area. The site had approximately 175 individual *Elatostema calcareum* stems that were scanned for life cycle stages. Approximately 960 minutes were spent monitoring this site during the 12 day period, with 408 total trap hours (Table 1). No *Vagrans egistina* or *Hypolimnas octocula mariannensis* were recorded at this site. However, three *Gehyra oceanica* (Oceanic Gecko) were observed in the traps feeding themselves on melon flies (Bactrocera sp.). This site is entirely in the Military Lease Area.

Sisonyan Makpo (SM) Area
The Sisonyan Makpo site (UTM 55 P 0355868 1656618) was surveyed for 6 days with 505 visual search minutes and 120 total trap hours (Table 1). No *Vagrans egistina* or *Hypolimnas octocula mariannensis* were recorded at this site. This site is not in the Military Lease Area and was only surveyed as time permitted.

DISCUSSION

The primary objective of this survey was to determine the presence or absence of the two candidate species butterfly species, *Vagrans egistina* and *Hypolimnas octocula*. *mariannensis* After 4806 minutes (approx. 80 hours) of visual searching and 1848 documented trap hours (approx. 77 days) during the months of September and October, 2008 no life cycle stage of either species was collected. This finding was not entirely surprising as neither *V. egistina* or *H. octocula mariannensis* were previously collected or observed on Tinian despite the fairly comprehensive surveys conducted by Hawaiian Agronomics Inc. from 1984-85.

The bulk of the survey was represented by only two months of the rainy season, September and October, 2008. Several biologists however were actively investigating areas for host plant sites and individuals for at least 2 months prior to the survey, July and August, 2008. Even though the survey did not account for seasonal variation, it can be concluded that some life cycle stage of either species (*Vagrans egistina* and *Hypolimnas octocula mariannensis*) should have been collected after this level of effort. However it is recommended that host plants site should be observed monthly for at least one year to be certain.

Tinian is not known to be part of either species' historical range. However, the likelihood of introduced pests arriving to Tinian due to an increase in sea and air transports is a concern for a suite of native butterfly species. Additionally, any reduction of host plant sites for *Vagrans egistina* and *Hypolimnas octocula mariannensis* should be a conservation concern if translocation is considered as part of any future recovery or enhancement plans.

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Personal Communications

Schreiner, I.H., Oct. 3, 2008 note, via email communication.

Table 1. Level of effort: Visual and trap hours at four host plant sites, Tinian, CNMI. Site codes are CNT- Carolinas Nature Trail, JC – Japanese Cave, SM – Sisonyan Makpo, and CC – Chiget Cliff. Weather codes are CC – Cloud Cover, W – Wind, and R – Rain.

Site	Date	Observation Time (minutes)	Staff	# of Traps	Trap Hours	Weather Notes
CNT Site Set Up	9/10/08	45	1	0	0	na
CNT	9/11/08	75	2	2	48	CC:40% W:1-2 R:0
CNT	9/12/08	60	1	2	48	CC:90% W:1 R:0
CNT	9/13/08	150	1	2	48	CC:90% W:1-2 R:0
CNT	9/14/08	150	1	2	48	CC:95% W:2-3 R:Y
CNT	9/16/08	170	1	2	48	CC:90 W:1-2 R:Y
CNT	9/17/08	50	1	2	48	CC:80% W:1-2 R:Y
CNT	9/18/08	75	1	2	48	CC:70% W:2-3 R:Y
CNT	9/20/08	150	1	2	48	CC:70% W:2-3 R:Y
CNT	9/21/08	160	1	2	48	CC:65% W:1-2 R:0
CNT	9/22/08	120	1	2	48	CC:65% W:1-2 R:0
CNT	9/23/08	120	1	2	48	CC:65% W:1-2 R:0
CNT	9/24/08	120	1	2	48	CC:65% W:1 R:0
CNT	9/25/08	130	2	2	48	CC:65% W:1 R:0
CNT Total	**13 days**	**1575**			**624**	
JC Site Set Up	9/25/08	120	2	0	0	Set up traps host plant visual
JC	9/26/08	120	1	2	48	CC:65% W:1 R:Y
JC	9/27/08	135	1	2	48	CC:45% W:1 R:Y
JC	9/28/08	90	1	2	48	CC:70% W:1 R:0
JC	9/29/08	120	1	2	48	CC:75% W:1-2 R:Y
JC	9/30/08	120	1	2	48	CC:80 W:2-3 R:Y

Site	Date	Observation Time (minutes)	Staff	# of Traps	Trap Hours	Weather Notes
JC	9/31/08	120	1	2	48	CC:70% W:1 R:0
JC	10/1/08	120	1	2	48	CC:75% W:1-2 R:0
JC	10/2/08	120	1	2	48	CC:65% W:1 R:0
JC	10/3/08	120	1	2	48	NA
JC	10/4/08	60	1	2	48	NA
JC	10/5/08	60	1	2	48	CC:35% W:2 R:0
JC	10/6/08	100	1	2	48	CC: 50 W:1-2 R:0
JC	10/7/08	60	1	2	48	CC:40 W:1 R:0
JC	10/8/08	120	1	2	48	CC: 65% W:1-2 R:0
JC	10/9/08	180	2	1	24	CC:40% W:1 R:0
JC Total	**15 Days**	**1765**			**696**	
SM Site Set Up	10/9/08	85	1	0	0	NA
SM	10/10/08	120	1	1	24	CC:35% W:1 R:0
SM	10/11/08	90	1	1	24	CC:35% W:1 R:0
SM	10/12/08	90	1	1	24	CC:40% W:0 R:0
SM	10/13/08	60	1	1	24	CC:65% W:1 R:0
SM	10/15/08	60	1	1	24	CC:30% W:1 R:0
SM Total	**6 days**	**505**			**120**	
CC Site Set Up	10/10/08	120	2	0	0	CC:40% W:1 R:0
CC	10/11/08	60	2	1	24	CC:30% W:1 R:0
CC	10/12/08	90	2	1	24	CC:35% W:2 R:0
CC	10/13/08	80	2	1	24	CC:50% W:1 R:0
CC	10/14/08	80	2	1	24	CC:40% W:1 R:0
CC	10/15/08	90	2	1	24	CC:65% W:1-2 R:0
CC	10/16/08	60	1	2	48	CC:95% W:2-3 R:0

Site	Date	Observation Time (minutes)	Staff	# of Traps	Trap Hours	Weather Notes
CC	10/17/08	60	1	2	48	CC:70% W:1-2 R:0
CC	10/18/08	100	1	2	48	CC:40% W:1 R:0
CC	10/19/08	100	1	2	48	CC:40% W:1 R:0
CC	10/20/08	60	1	2	48	CC:30% W:1 R:0
CC	10/21/08	60	1	2	48	CC:40% W:1-2 R:0
CC Total	**12 days**	**960**			**408**	

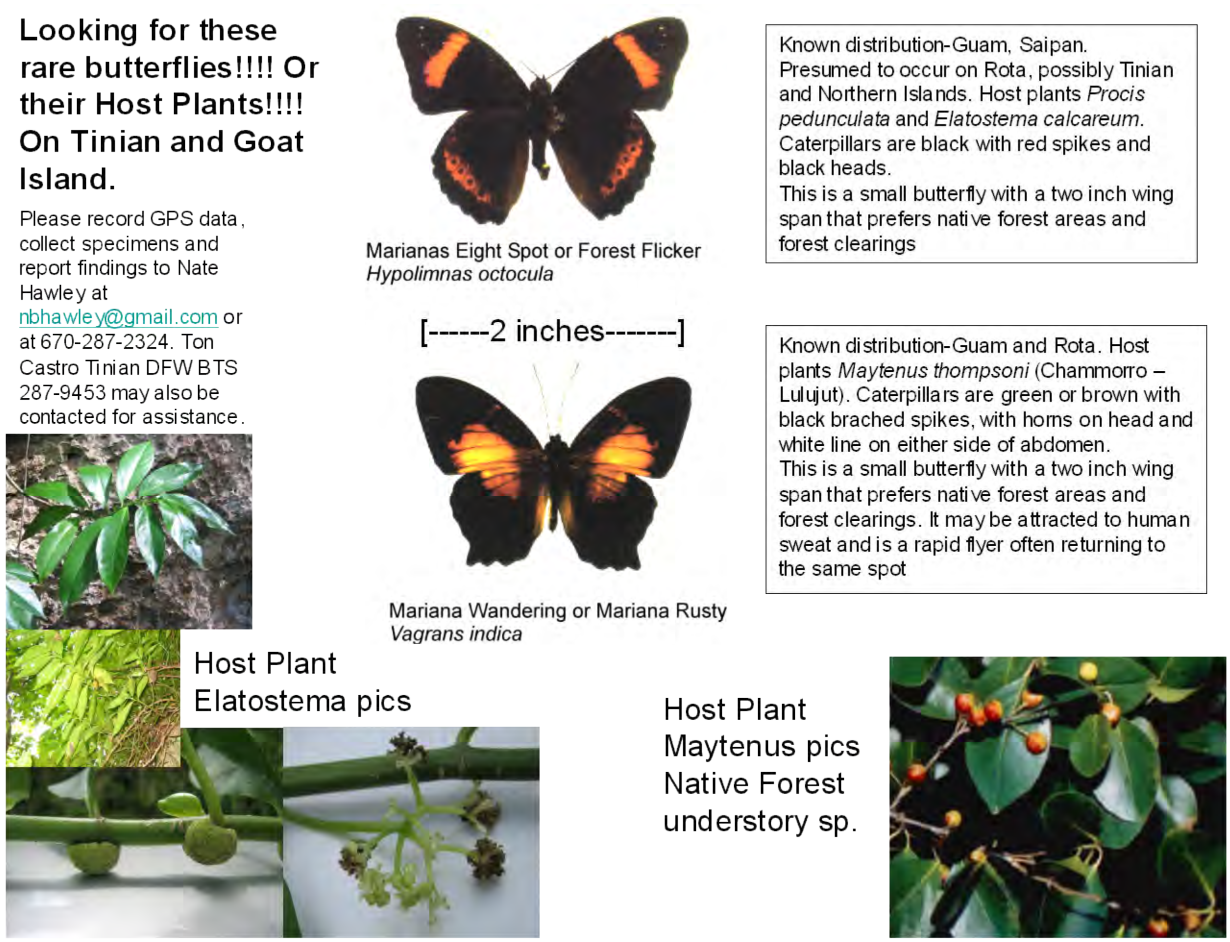


Figure 1. Butterfly Information Guide.

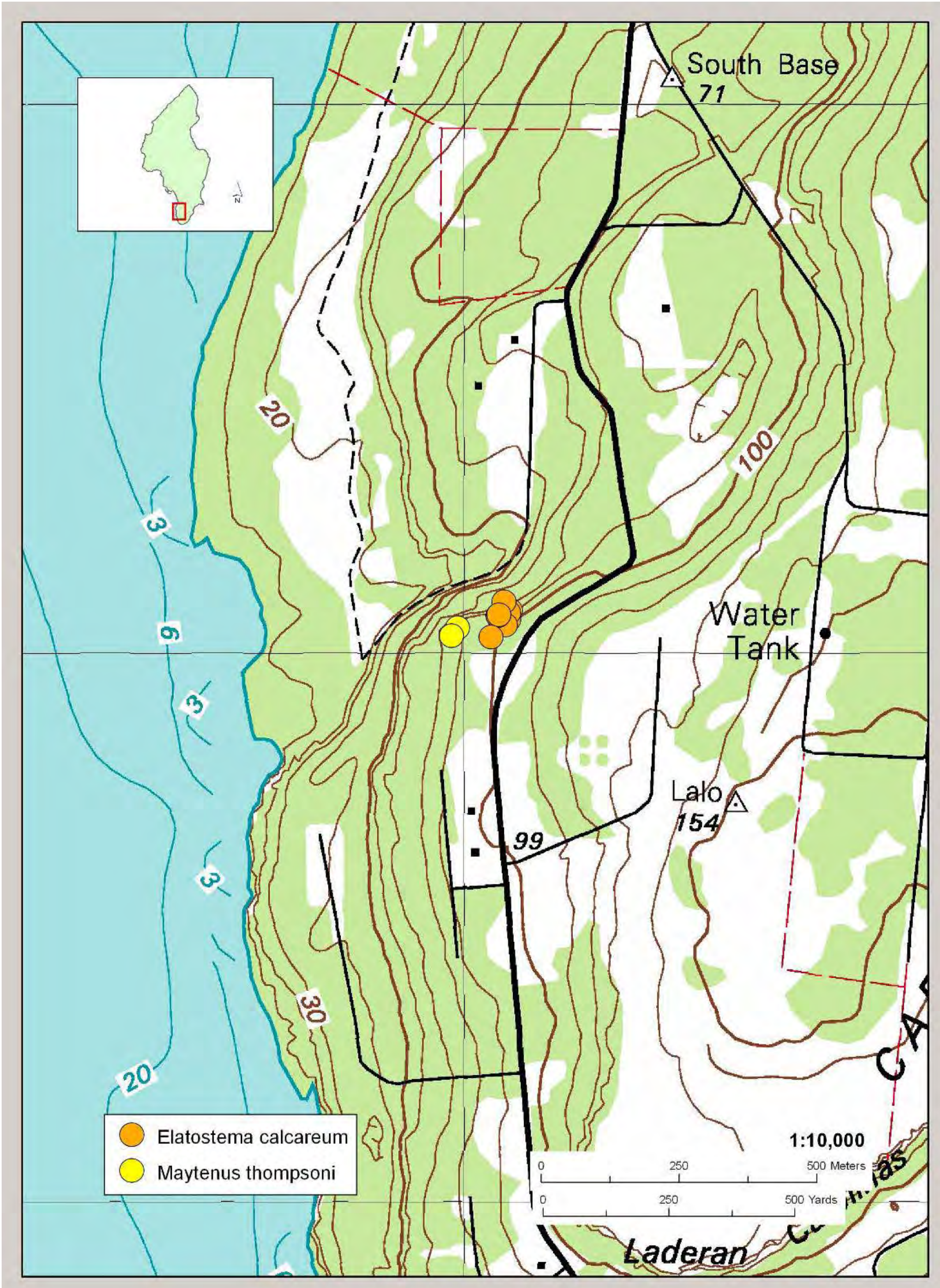


Figure 2. Host Plant Sites for *Vagrans egistina* and *Hypolimnas octocula* near the Carolinas Nature Trail, Tinian, CNMI.

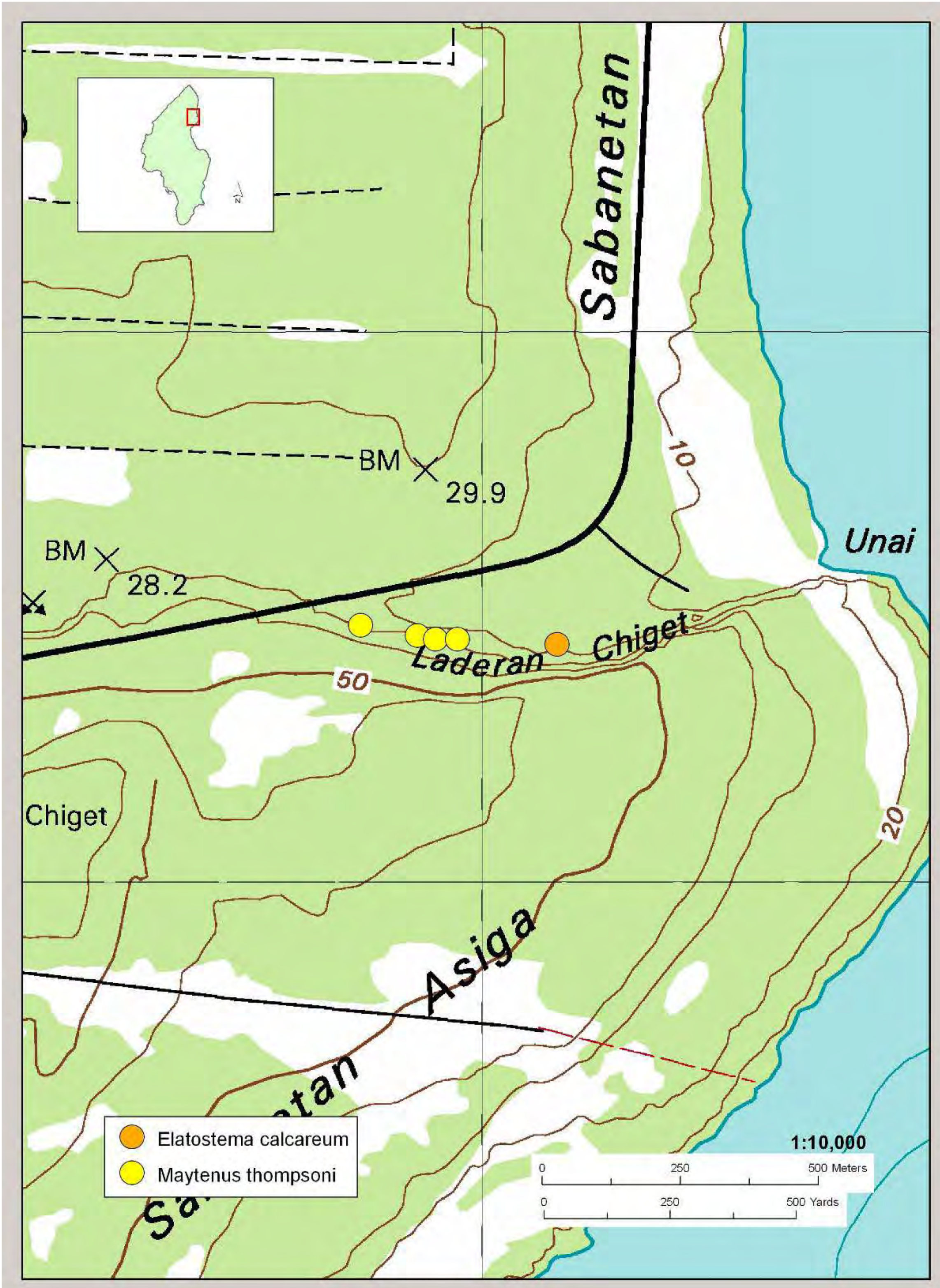


Figure 3. Host Plant Sites for *Vagrans egistina* and *Hypolimnas octocula* near Chiget Cliff, Tinian, CNMI.

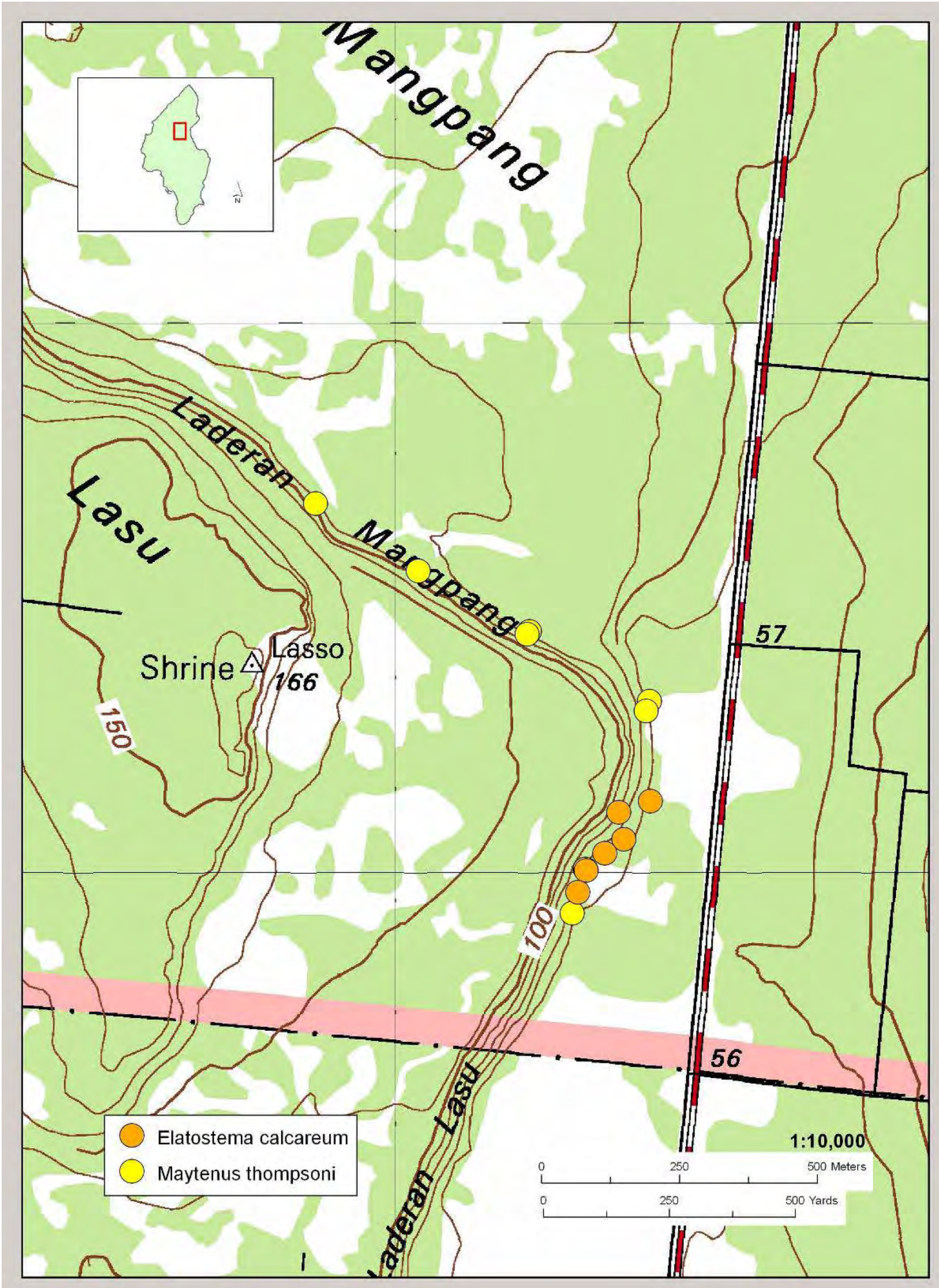


Figure 4. Host Plant Sites for *Vagrans egistina* and *Hypolimnas octocula* near the Japanese Caves, Tinian, CNMI.

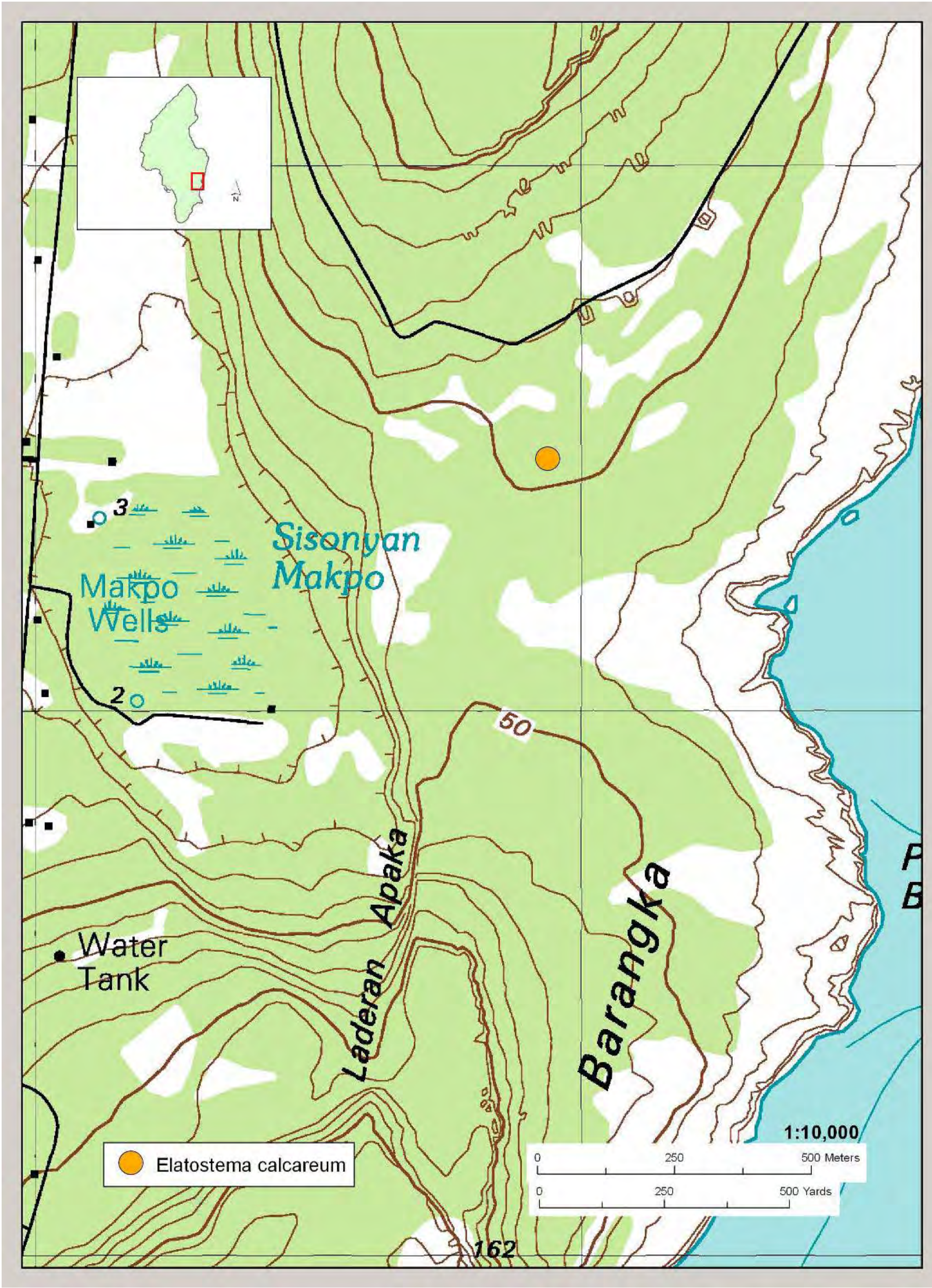


Figure 5. Host Plant Sites for *Vagrans egistina* and *Hypolimnas octocula* near Sisonyan Makpo, Tinian, CNMI – Sisonyan Makpo.

2.2.3 COCONUT CRAB SURVEYS ON MILITARY LEASE LANDS ON TINIAN


Coconut Crab. Photo by Scott Vogt.

Prepared by: **Scott Vogt, Wildlife Biologist, U.S. Navy, NAVFAC Pacific, Honolulu, HI**

EXECUTIVE SUMMARY

Coconut crabs (*Birgus latro*) were sampled on military lease lands on the island of Tinian and also on the uninhabited island of Aguijan just south of Tinian. Crabs were sampled by bait station transect lines and on 2 mark recapture bait station grids. Transect lines sampled 4 different habitat types (tangantangan forest, native forest, coastal forest , and grassland) and the trapping grids sampled 2 habitat types (tangantangan forest and native forest). Crab demographics and population densities were documented. The data show that on Tinian and Aguiguan, coconut crabs are being over-harvested and that present harvest rates cannot be sustained. Compared with unharvested populations, the Tinian and Aguiguan crab sizes are much smaller and densities are much lower.

INTRODUCTION

The Coconut or Robber Crab (*Birgus latro*) has a wide distribution ranging from Eastern Africa, through the Indian Ocean islands to the Pacific Ocean islands. Due to its large size, ease of collection and palatable flesh, the coconut crab is often over-harvested when it occurs in the vicinity of human habitation. The Mariana islands are no exception and surveys on Guam (USFWS, 2001) and Saipan (Kessler, 2006) have documented over-harvested populations.

Tinian is the second largest island in the Commonwealth of the Northern Mariana Islands (CNMI) with an area of 102 sq. km (39 sq. miles), and a human population of 3,500. Most habitat on Tinian is degraded due to a history of the grazing impacts of feral and domestic cattle, extensive sugar cane cultivation and disturbance during WWII. Vegetation is currently dominated by non-native species, principally the tangantangan tree (*Leucaena leucocephala*), Native limestone forest is generally confined to the sides of cliffs or other areas that were not suitable for cultivation. The northern 2/3rds of Tinian is leased by the U.S. Navy for training, although there are presently no military buildings there. A radio relay station for the Voice of America is on Tinian military lands and covers about 20 hectares.

The Commonwealth of the Northern Mariana Islands has a legal crab hunting season from September 15-November 15. Only crabs with a thoracic width larger than 3 inches (76 mm) are allowed to be taken and females carrying eggs (berried) of any size are prohibited. Coconut crabs are a type of hermit crab, however they drop the habit of residing in a shell at a small size and go through life with no shell. They are the largest land dwelling invertebrate in the world and can reach a weight in excess of 5kg. Coconut crabs breed on land but the female releases the eggs in the ocean where they immediately hatch. The oceanic larval stage lasts 2-3 weeks (Fletcher and Amos, 1994). Once on land the growth rate is slow and it probably takes 8-10 years for crabs to reach the CNMI legal size limit (Brown and Fielder, 1991).

The goals of this study were to establish coconut crab population densities and demographics on Tinian, and calibrate the catch per unit of effort index of bait station transect lines. With a calibrated index, crab densities can be calculated from the catch rates on transect lines of bait stations.

STUDY AREA

This study sampled coconut crabs on Navy leased lands on Tinian. The northern 2/3 of the island is leased by the U.S. Navy for training activities.

There are four main habitat types in this area: native limestone forest, introduced tangantangan (*Leuceana leucocephala*) forest, grassland, beach strand and mixed tangantangan grassland.

Crabs were sampled in February, April and May of 2007.

In October, 2006 a sampling trip was made to Aguiguan, an uninhabited island several miles south of Tinian. It was hoped that this island would provide a less harvested control population to compare with Tinian.

METHODS

Bait station transects

Coconut crab abundances were initially measured by transect lines of fermented coconut bait stations. The fermented coconut is a local technique (called "Poni"), coconut meat is grated, and allowed to ferment in a closed container for 5~10 days. One handful of poni bait was set on the ground (1 station) to attract crabs. Transect lines of poni bait stations, spaced every 20 meters, were used to sample native forest, introduced tangantangan, mixed tangantangan forest, grassland and beach strand habitat types. A total of 12 transect lines were monitored (Figure 1.). Four in native forest, 5 in tangantangan and mixed forest, 2 in grassland and 1 in beach strand. Each transect had 20-30 stations and was monitored for 1 or 2 nights. On Aguiguan 55 stations (20 meter spacing) on two lines were set in native forest for 3 nights and one line of 18 stations (20 meter spacing) was set in tangantangan mixed forest for 1 night.

Crab abundance was expressed as the catch per unit of effort (CPUE). CPUE was calculated by the number of crabs captured divided by the number of trapping nights. The number of trapping nights was the number of bait stations multiplied by the number of nights they were monitored. For example, 25 stations monitored for 2 nights was 50 trapping nights. Ten crabs captured on a 25 station transect monitored for 2 nights would be a CPUE of 0.20. Crabs captured between bait stations were also used in the CPUE calculation.

Figure 1. Location of bait station transect lines.

Mark recapture grids

Bait station grids were used to establish coconut crabs densities. Two grids of 100 coconut bait stations were set up in native forest and tangantangan forest (Figure 2.). Bait stations were spaced every 20 meters and the grids were 10 stations by 10 stations (100 stations total, 180 meters by 180 meters) and covered an area of 3.24 hectares. The locations of the grids were selected based on the CPUE of the bait station transects. The native forest grid was set on the cliff line facing North Field and approximately 1500 meters northwest of Mt Lassa. The tangantangan grid was placed in one of the forest blocks immediately off of the southwest end of runway able.

Figure 2. Location of mark-recapture grids.

Each bait station consisted of a whole coconut that had fallen off the tree but still had juice and had not yet sprouted. A small hole (~3 cm diameter) was cut into the coconut exposing the meat and juice. The coconut was wired to a tree or stuck onto a cut sapling tree so that the coconut was 10-30 cm off the ground. Vanilla extract was then poured into the coconut to magnify the scent. The crabs will stay on the coconut feeding and can be easily captured at night. Crabs on the ground at, and between, bait stations were also collected, marked and measured.

The grids were monitored for 5 nights within a one week period. Crabs captured on the grid were measured for thoracic length, weighed, sexed, marked and released. Crabs were marked with, fingernail polish, permanent magic marker or clear epoxy glue over a paper number.

Mark recapture data was analyzed using Program MARK to estimate the size of the population. This population estimate was then used with the effective area sampled (see below) to calculate the crab density for each habitat sampled. MARK also estimates the capture probability and recapture probability.

Telemetry and Thread Bobbins

A difficulty in trying to establish animal densities using trapping grids is determining how many animals come from outside the grid to be captured. So, the grid samples a larger area than its dimensions. It is often difficult to calculate the size of the sampled area and this is vital for accurate density estimates. A way to solve this problem is to fit animals with transmitters so that movements within and outside the grid can be ascertained. In this way a buffer strip can then be added to the grid boundary for density calculations. In other words, from telemetry data an extra 50 meters might be added to the grid boundary so that the true area sampled was 280m x 280m and not 180m x 180m. This problem is often overlooked or taken lightly in grid sampling but, small changes can have very large effects on the final density estimate.

Wildlife Track transmitters were attached to crabs with non-toxic marine putty. The transmitters weighed 10 grams and the putty added an additional 10 grams for 20 grams total. Crabs that were smaller than 150 grams were not fitted with transmitters. The transmitters have a 12 month battery life.

Crabs captured within the grids were weighed, measured for thoracic length and width, sexed and those larger than 150 grams were fitted with transmitters. Crabs were then released at the point of capture.

Barber thread bobbins were also attached (with non-toxic marine putty) to 8 crabs captured on the bait station transect lines. After attaching the bobbin crab was released. The thread feeds out and can be followed.

Comparison with a non-harvested population

Coconut crab fieldwork was conducted on the island of Diego Garcia at the Mini Mini conservation area in July 2003 and March 2004. Because of tight security and access restrictions this area contains a true non-harvested coconut crab population. Population density and demographics were documented for this area and are used here as a control population for comparison.

RESULTS

Transect lines

Transect lines in native forest had the highest CPUE with an average of 0.11 (range, 0.07-0.13). Tangantangan had a mean CPUE of 0.03 (range, 0-0.06). No crabs were captured in the grassland or beach strand habitats. The catch rates in tangantangan and native forest were very consistent.

Two bait station lines on Aguiguan produced a CPUE of 0.20. A bait station transect (20 stations, 20 meters spacing, monitored for 2 nights) on Diego Garcia in a mixed coconut/native forest produced a CPUE of 1.78.

Mark recapture grids

The native forest grid captured 34 crabs and the tangantangan grid captured 12 animals. This was consistent with the line transect data for these habitat types in that the native forest grid captured ~3 times as many crabs as the tangentangen grid.. There were no recaptures on either grid. The majority of the crabs were captured within the first 3 days: 82% on the native forest grid and 75% on the tangantangan grid. Since there were no recaptures, the data were analyzed as removal plots. Due to the short sampling period, the population was assumed to be closed (no deaths, births, immigration or emigration). Because of the behavioral response to being captured the model "Full Closed Captures with Heterogeneity" in program MARK was chosen for the analyses. This model takes into account the behavioral response to being captured and also individual heterogeneity in capture (different individuals have different capture probabilities). See Table 1 for the population estimates and capture probability estimates for the 2 mark recapture grids.

Table 1. Population Estimate and Capture Probability of the Trapping Grids.

	Population estimate	95% confidence interval	Capture probability	95% confidence interval
Native forest plot	38.78	34.93-58.50	0.33	0.18-0.52
Tangantangan plot	14.32	12.21-37.57	0.28	0.08-0.65

Telemetry and Thread Bobbins

Not as much data was collected as desired due to problems with the radio receivers. Both units initially worked for 1-2 days and then stopped picking up the signals. Another receiver was borrowed from COMNAVMAR but several days of data were missed because of this. All crabs left the grid area, or lost/destroyed the transmitter, 1-14 days after having the transmitter attached.

An apparent behavioral response was shown by all crabs with transmitters. All crabs took shelter in rock crevices and stayed there for 1-5 nights before resuming foraging.
Eight crabs on the native forest grid were fitted with transmitters and 6 on the tangantangan grid. Twenty eight out forty six (60%) of the crabs, captured on the grids were too small for transmitters (less than 150 grams).

Two transmitters were found in the field having apparently fallen off the crab. One, in the native forest grid, was within 2 meters the capture point. The other was off of the tangantangan grid and was found 210 meters from the point of capture just outside of the forest on the runway tarmac.

The thread bobbins did not provide as much data as hoped due to the thread breaking within 40 meters of the release point. All crabs released with bobbins climbed trees within 15 meters of capture. The thread broke on 6 of the crabs within 15 meters after climbing down from the tree. One crab after climbing down the tree took refuge in a karst crevice where the thread broke. One crab stayed in a crevice 2 days and nights before moving out and then the thread broke.

Population densities
While not as much telemetry data was collected as hoped, enough was collected to estimate the actual size of the area trapped. The mean of the maximum distance moved (MMDM) by each crab, within the one week grid sampling period, was added as a buffer to the dimensions of the trapping grids. The data from both grids were pooled for this due to the low sample size. This was 50 meters. So the effective trapping area was 280 meters x 280 meters or 7.84 hectares for both grids. See Table 2 for the density estimates for each habitat type.

Table 2. Comparison of Crab Densities in Native Forest and Tangentangen Habitats.

	Population estimate	95% confidence interval
Native forest plot	4.95 crabs/hectare	4.46-7.46 crabs/hectare
Tangantangan plot	1.83 crabs/hectare	1.56-4.79 crabs/hectare

A similar crab mark recapture project with a bait station grid on Guam had an MMDM buffer strip of 44 meters (USFWS 2001). This MMDM was calculated by recaptured crabs on the grid (the distance between recaptures) and not telemetry but the similarity is noteworthy.

The density estimate for the Diego Garcia population, using quadrat sampling, was 233 crab/ha, 107-358. This is roughly 42 times higher than Tinian.

Using the area of each habitat type (Liu and Fisher 2006) we can estimate the total crab population for Navy lands on Tinian. Native forest (150ha) = 742 crabs; secondary growth forest (2021 ha) and tangantangan forest (2302 ha) = 7,911 crabs. Total population estimate for these forest communities is 6,653 crabs. Of this estimate, 421 crabs (6.33%) are legal size. Note, that since the catch rates of the bait station transect lines were similar for tangantangan and secondary forest, the densities are presumed to be similar.

Our study, to a degree, has calibrated the catch rate index (Charts 3, 4, and 5). A higher catch rate on the transect lines did in fact predict a higher density of crabs. Using the Aguiguan catch rate of 0.20 we can reasonably conclude that the density is at least double that of Tinian native forest which had an average catch rate of 0.11. So, we can reasonably conclude that Aguiguan has crab densities of about 10 crabs/ha. The area of Aguiguan is 699 ha and of this, 479 ha (68%) is forested (Chapter 2. this report). For the forested area, we estimate the Aguiguan population to be 4,790 crabs. We did not survey the non-forested areas (mostly dominated by introduced *Lantana camara*). So crab numbers on Aguiguan are undoubtedly higher than this estimate.

Population Demographics
Counting captures from the transect lines, the grids and road captures, a total of 79 crabs on Tinian, were measured and weighed in this study. Out 79 crabs, 5 were legal size (6.33%). Of the 79 crabs, 41 were female and 38 were male.

Comparing the mean sizes and weights with the Diego Garcia (non-harvested) population is interesting (Table 3). The differences are stark (Charts 1. and 2.). The graphs show that the reason the average weights at Diego Garcia are roughly 4 times higher than Tinian is due to an almost total lack of crabs above the legal size limit (~37 mm TL) on Tinian.

Table 3. Coconut Crab lengths and weights: Diego Garcia vs Tinian

	Diego Garcia: Mean with 95% confidence interval	Tinian: Mean with 95% confidence interval
Male thoracic length, mm	48, 45-52	30, 28-32
Female thoracic length, mm	42, 40-45	27, 26-29
Total thoracic length, mm	46, 44-48	29, 28-30
Male weight, grams	988, 722-1254	238, 197-279
Female weight, grams	529, 391-667	183, 158-208
Total weight, grams	844, 649-1038	209, 185-234

Chart 1. Size Classes of Coconut Crabs on Tinian

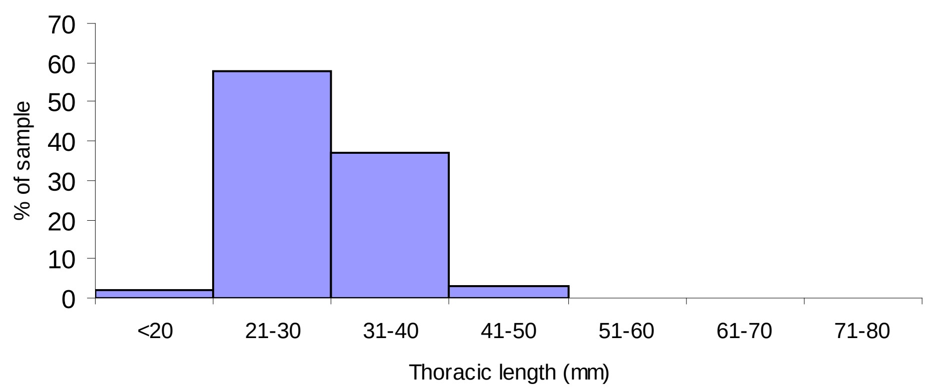
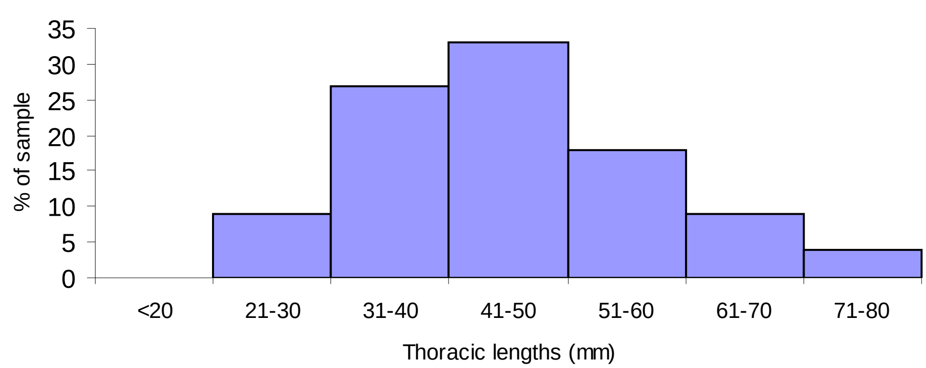


Chart 2. Size Classes of Coconut Crabs on Diego Garcia

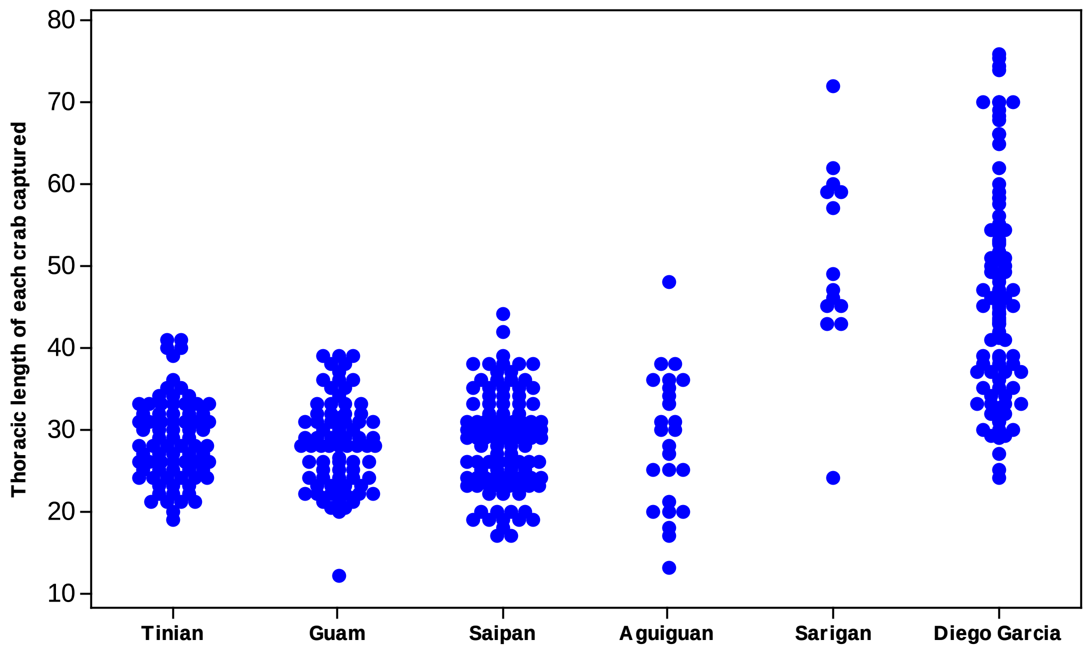


On Diego Garcia the most common size class, 41-50mm, represents about 35% of the population. On Tinian this size class is only 3% of the sample, and there were no crabs found that were larger than this size class. On Diego Garcia crabs larger than the 41-50mm size class represent an additional 31% of the population.

This is further graphically shown in chart 3, comparing Guam, Saipan, Tinian and Aguiguan data with the Diego Garcia non-harvested standard. On these Marianas islands there is nothing above 50 mm TL and very few that are above 40 mm TL, while on Diego Garcia the majority of the population is above 40mm TL.

The data from Aguiguan is hampered by small sample size due to the short time spent on the island. While the catch rate was almost double that of Tinian the demographics were similar to Tinian (Guam and Saipan also) and indicate that Aguiguan is also overharvested (Chart 3, Appendix 2.). The proportion of the Aguiguan sample over the legal size limit, 12% (4 out of 25) was also double what it was on Tinian. This produces an estimate of 574 legal size crabs on the forested areas of Aguiguan.

Chart 3. Comparison of Coconut Crab Sizes from the Marianas and Diego Garcia



We documented only 1 crab smaller than 20mm TL on Tinian. Crabs smaller than 20rnm TL are typically not well documented with surveys like these (Chauvet, C. and T. Kadiri-Jan.1999). The habits of these smaller crabs make them harder to find and they are typically nearer to the ocean (Kadiri-Jan and Chauvet 1998). So we cannot comment on juvenile recruitment with this study even though this is obviously an important factor.

Calibration of the CPUE index

The CPUE index was strongly correlated with the number of crabs captured on the grid and the estimated densities (Charts 4, 5, and 6). The previously mentioned Guam study produced a CPUE of 0.15, captured 45 crabs and produced a density estimate of 14 crab/ha.

The Guam, and Tinian data fit well together with a very strong correlation between the CPUE, the total number of crabs captured (Chart 4.) and the estimated crab densities (Chart 5.).

Chart 4. The correlation between CPUE and the total number of Coconut Crabs captured on bait station grids on Tinian and Guam

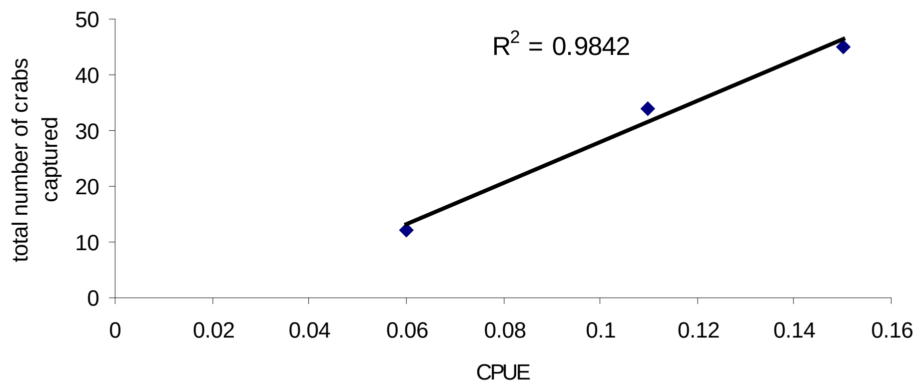
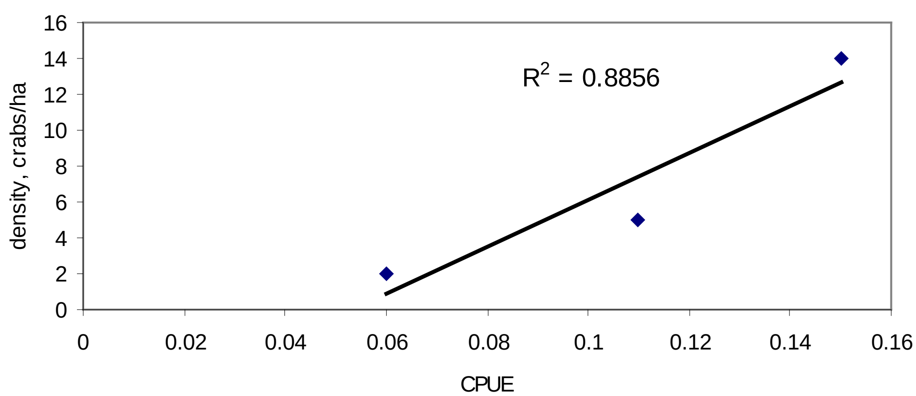
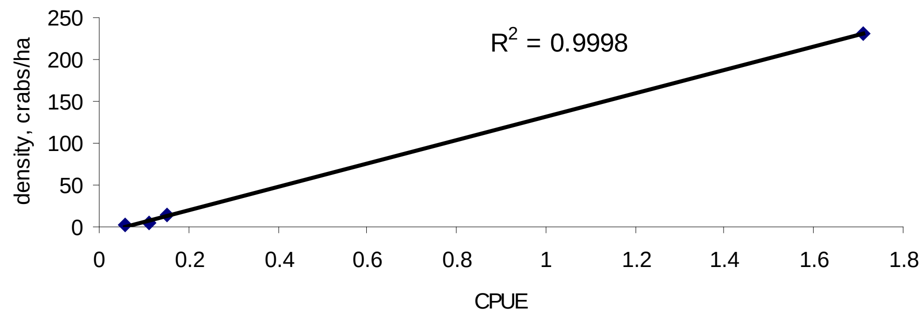


Chart 5. The correlation between CPUE and Coconut Crab densities on Tinian and Guam



When the Diego Garcia data is added, the correlation is very strong (Chart 6.). The relationship on the regression graph appears linear however there is a very large data gap between the Marianas and Diego Garcia. The relationship might not be linear as the CPUE for Diego Garcia was 15 times higher than the CPUE for native forest on Tinian but, the true density was in fact 46 times higher. We suspect that there is a leveling off or saturation point with the bait stations, in that one can only get so many crabs on one station. So, the relationship is probably sigmoid and not linear.

Chart 6. The correlation between CPUE and Coconut Crab densities on Tinian, Guam and Diego Garcia



DISCUSSION

This study has shown that the demographics of coconut crabs on Tinian favor much smaller crabs than a non-harvested population (Diego Garcia) There are few crabs over the legal size limit and population densities are much lower than the non-harvested population. Over-harvest is the suspected reason for this.

Crab surveys on Aguiguan in 2000 (Cruz *et al.* 2000) pointed to an over harvested population. The average width and weight (thoracic length was not measured) was 66 mm and 293 grams. In 2006 the average width and weight was slightly smaller at 61 mm and 245 grams. The catch rate in 2000, however, was much higher with 3.7 crabs/bait station for 1 night of trapping.

When compared with a non-harvested population, the differences are stark. At all sampling sites old bait stations from crab hunters were seen. Anecdotally, out of season poaching is reported to be rampant. There are also reports of crabs being sold (this is illegal) for $50-$100 per crab (depending on the size) (C. Sanchez pers. com.). The CNMI economy is very poor at present and it is possible that crabs are being sold to supplement household income.

The telemetry data shows 2 predominant movement patterns by the crabs. Crabs occupy a small area for a short period of time or constantly move in random directions and distances. The movement patterns increase the likelihood of over-harvest as one does not need to move trap lines after an area has been trapped out. Crabs will quickly move back into the area. Kessler (2006) documented similar movements on Saipan, where a 3.25 hectare grid was trapped out in one week and 2 months later a similar number of crabs were caught on the same grid. This pattern is likely to contribute to the belief that crabs are very abundant on Tinian. Most people when informed we were doing a crab study commented on the abundance of crabs on Tinian. Many people also talked about how 15-20 years ago one could drive the North Field roads and runways at night and collect many crabs on the road.

Both grid trapping sites had similar capture probabilities (0.28 and 0.33). On both habitat types ~ 30% of the population can be captured on a given night. This is a high capture probability that also makes the crabs susceptible to over-harvest.

Given the movement patterns of the crabs and that North Field on Tinian has a fairly extensive road system, slowly cruising the roads at night would be a low effort method to harvest coconut crabs. Three crabs were captured on roads during this study, on the way home after checking bait stations on the grids or the transect lines. Fresh bait stations were also observed placed just off the road, 2-3 meters in the forest, leading to the Mt Lasso over look. This would also provide a quick and easy method for crab harvest.

Size data and telemetry suggest that small crabs are being harvested. The transmitter found on the tarmac of North Field appeared to have been purposefully removed by a poacher, as it was 210 meters from the release site out on the tarmac with no cover or vegetation The other transmitter that fell off did so within 2 meters of the capture site, suggesting that the putty had not dried sufficiently before the crab was released. This crab was far below legal size at 28 mm TL, 58 mm width and 154 grams weight.

Sustainable crab harvest should not exceed the natural, annual, mortality of the legal sized population (Fletcher and Amos, 1994). This was estimated to be 5% of the population. With the Tinian population estimate for Navy lands this calculates to 21 crabs that can be harvested this year and 20 crabs for Aguiguan.

Given the evidence for large scale harvesting, poaching, and the skewed demographics it is obvious that the Tinian (and quite possibly Aguiguan) population is being harvested at an unsustainable rate.

MANAGEMENT RECOMMENDATIONS

The obvious recommendation is to stop out of season poaching with increased law Enforcement, strictly enforce size and bag limits during the crab season and keep records of this sizes of harvested crabs. In light of the current economic situation on Tinian and the dollar value for a single crab, this could prove very difficult.

The best way to help the crab population recover would be a 5 year harvest moratorium, with population monitoring. After the 5 year period is up, allow a well regulated and controlled harvest. The population would be estimated as was done in this study and then a harvest goal would be set. Once this goal is reached, then the season would be closed.

The 5 year time period is somewhat arbitrary but enforcing a longer period of time is probably not feasible.

Because the coconut crab is such a popular game species a total crab moratorium might not be feasible. A more realistic approach might be to close select zones to crabbing for 5 years while allowing crab harvest elsewhere. At the end of 5 years the closed zone is opened and other areas are closed.

More information is needed on small sized crabs (< 20mm TL). A specific study on this size class is recommended to quantify juvenile densities, juvenile recruitment and establish distribution patterns.

We also recommend doing more work on calibrating the CPUE index with the true population density. The data gap between the lower and higher densities needs to be filled. As a management tool, being able to quickly estimate population densities from 2 or 3 night bait station transects would be invaluable.

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Attachment 1.

Coconut Crab Telemetry Data

Crab #	**Sex**	**TL mm**	**Weight grams**	**Distances moved (meters)**	**Native forest or tangan tangan**
45	F	32	263	Crab moved off of grid immediately and could not be found till the following month. It had moved 435 meters from the capture point	native forest
50	F	26	163	20,5,5,5,32	native forest
54	M	28	194	20,20,5	native forest
56	F	32	275	75	native forest
57	M	33	366	59,61, 10	native forest
58	F	28	160	5, crab stayed in the same crevice for 5 days and nights. The following month the crab had left the grid.	native forest
59	F	33	375	Transmitter fell off within 2 meters of capture point	native forest
63	F	33	238	50	native forest
2	M	35	306	Unable to collect data due to the transmitter frequency being the exact same frequency as that of the Voice of America relay station	tangan tangan
3	F	39	371	28	tangan tangan
5	F	31	241	15	tangan tangan
8	M	28	154	Transmitter fell off within 210 meters from capture point	tangan tangan
9	M	27	172	89, 50	tangan tangan
10	F	30	204	120, 140	tangan tangan

Attachment 2.

Weights and Measures of Sampled Crabs
Aguiguan Crabs

Sex	Thoracic Length (millimeters)	Weight (grams)	Width (milimeters)
m	25	140	52
m	36	360	77
m	36	400	80
m	33	270	72
m	28	na	na
m	21	60	40
m	25	105	50
m	35	315	76
m	30	230	65
m	36	370	81
m	38	440	78
m	30	220	64
m	20	72	43
m	34	365	72
m	20	90	43
m	48	990	110
m	17	50	36
m	13	25	28
m	38	460	82
f	27	178	56
f	18	55	39
f	31	260	68
f	31	240	64
f	25	110	50
f	20	65	44

Attachment 2. Continued
Tinian Crabs

Sex	Thoracic Length (millimeters)	Weight (grams)	Width (milimeters)
f	28	205	63
f	22	64	42
f	32	315	69
m	33	345	69
m	34	360	72
m	32	230	65
f	24	102	43
f	29	158	59
m	23	98	47
m	41	535	83
f	33	325	70
f	26	158	59
m	32	255	59
m	40	525	83
m	33	265	67
f	29	206	58
f	33	325	69
m	40	490	80
m	24	115	48
m	31	234	64
m	21	76	43
m	29	250	58
m	31	270	66
f	27	178	58
m	24	114	49
f	26	140	52
m	31	200	63
f	35	274	73
f	23	93	48
m	34	334	69
m	30	181	59
m	26	115	52
f	28	205	62
m	23	90	47
m	41	490	82
m	28	175	56
f	22	93	45
m	36	390	72
f	30	220	62
f	27	173	58
m	31	245	65
f	25	135	47
m	31	245	61
f	26	155	55

Tinian Crabs Continued

Sex	Thoracic Length (millimeters)	Weight (grams)	Width (milimeters)
f	30	250	69
m	27	220	58
f	32	263	67
f	20	72	41
f	25	98	54
m	30	193	64
m	34	313	70
f	26	163	57
f	24	123	52
f	21	80	43
m	22	84	47
m	28	194	60
f	32	328	72
m	27	126	51
m	33	346	74
f	28	160	54
f	33	313	71
f	25	143	55
m	25	102	50
f	26	163	57
f	33	238	62
f	26	130	52
m	35	306	70
f	39	371	79
f	21	94	45
f	31	241	62
m	25	122	52
f	24	116	49
m	28	154	58
m	27	172	54
f	30	204	61
f	19	62	39
f	24	146	52
m	21	92	49
f	31	211	65

2.3 REPTILE AND AMPHIBIAN SURVEYS

2.3.1 REPTILES AND AMPHIBIANS OF TINIAN

Littoral Skink, Photo courtesy of USGS, BRD

Cane Toad, Photo courtesy of USGS, BRD

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INTRODUCTION

This work covers the terrestrial (as opposed to marine) reptiles and amphibians of Tinian. For marine turtles see US Fish and Wildlife Service (1996), Pultz *et al.* (1999), and Kolinski *et al.* (2004). This report describes all herpetofauna within the land environment, including subterranean (= fossorial), terrestrial, and arboreal species.

The data reported herein were generated primarily during field work supported by the U.S. Fish and Wildlife Service using funding from the U.S. Navy. Why might the Navy care about the status of reptiles on Tinian? Presumably the Navy is interested in conserving the diversity of life on lands that they manage by preserving required habitats, or minimizing detrimental habitat change. Accordingly, the 2008 fieldwork was conducted exclusively on Navy-leased lands of Tinian and the geographic scope of this report is Tinian's Military Lease Area. In addition, military operations of all services may impact Tinian's biodiversity and quality of life by accidentally introducing new species to Tinian. Thus a focus of this study is the interaction between native and introduced species. Finally, the health and resilience of ecosystems is often reflected in the composition of the ecological communities found in a place, and the Navy may wish to conserve that health and resilience both for the direct benefits to residents of the Northern Mariana Islands and for the greater latitude it provides for addressing ecological problems created elsewhere. For example, Tinian might become a refuge for bird or lizard species extirpated on Guam, thereby minimizing operational restrictions that might otherwise impact military activities on Guam. Alternately, if the Brown Treesnake or another invasive species were to become established on Tinian, military use of Tinian would be negatively impacted because shipments leaving Tinian for pest-free areas would present a biosecurity risk to destination sites; this would necessitate inspection and interdiction efforts for military cargo, with associated costs in time and money. Thus the Navy can prevent future expenses by maintaining a healthy natural community on Tinian. Toward that end, we provide a snapshot of the terrestrial reptiles of Tinian in 2008, and compile historical records indicating change over time.

In this report we assume that the conservation of native species is warranted, but the protection of introduced species is not. Why do native reptiles deserve precedence over introduced species? The easiest example is the ecological disaster associated with the introduction of the Brown Treesnake on Guam (Savidge 1987; Fritts and Rodda 1998). In that case, the introduction of a single new reptile eliminated many of the native birds, bats, and lizards of Guam (Rodda *et al.* 1999). The net result was a spectacular loss of global biodiversity, but despite this, Guam now has more reptile and amphibian species than it did prior to the arrival of the Brown Treesnake. The additions to Guam were common widespread species, whereas the lost species were unique local ones. From Guam's perspective, local biodiversity increased. The snake's arrival spread a common species over an additional island, but eventually removed unique local bird and bat species from the entire world – global biodiversity decreased. As the bottom line is global biodiversity, species introductions are normally detrimental and should be avoided.

At 10,180 hectares, Tinian is the sixth largest of the ~2500 islands of Micronesia. Despite its relatively large size, Tinian has experienced only two herpetological inventories. The first islandwide compendium was published in 1948 (Downs 1948), though the entomologist Townes (1946) gave earlier useful notes. Downs collected 35 specimens, but missed one common species (Mourning Gecko, *Lepidodactylus lugubris*) and at least five rarer ones. Owen (1974) provided much useful information, but did not attempt a comprehensive inventory. Forty years later Wiles *et al.* (1989) produced the first comprehensive review, including not only original field work but also a review of all earlier literature records. Rodda *et al.* (1991) put the Tinian inventory of Wiles *et al.* (1989) into the context of the entire Mariana archipelago. The methods of Wiles *et al.* (1989) however did not lend themselves to quantification of the population densities of any species; their surveys provided only qualitative descriptions of relative density. Thus Wiles *et al.* (1989) provided a baseline inventory, but did not attempt the task of monitoring populations. This study provides the first quantification of population densities, including field data from 1989 and 2008.

Pregill (1998) made a major contribution to our understanding of the nativeness of various species by sampling subfossil cave remains on several Mariana Islands including Tinian. He found that only the Brahminy Blindsnake, *Ramphotyphlops braminus* was unequivocally native (occurred in prehuman layers), though the prehuman sediment sample was very small. On biogeographic grounds, and species' occurrence in the earliest prehistoric strata, it is likely that several other species arrived in the Marianas unaided by humans, as detailed in the species accounts. An unexpected result of Pregill's study was the discovery that several species previously thought to have been in the Marianas since antiquity arrived on Tinian only following the time of Western contact

(Oceanic Gecko, *Gehyra oceanic;* Mutilating Gecko, *Gehyra mutilata;* Mangrove Monitor, *Varanus indicus*) and were undoubtedly human introductions on Tinian.

MATERIALS AND METHODS

Two methods were used islandwide in 1989: glueboard surveys and visual searches. Three methods were used in 2008, exclusively in the Military Lease Area: glueboard surveys, visual searches at night, and total removal plots. All study sites are mapped in Figure 1. Habitat names follow Mueller-Dombois and Fosberg (1998), with the exception of the "mixed" category, which is intermediate in composition and structure between *Leucaena* forest and limestone forest.

Glueboard sampling. - Glueboard sampling methods are detailed in Rodda *et al.* (1993, 2005b). The glueboards used in the 1989 sampling on Tinian were of several manufacturers, and were subsequently determined to be suboptimal for density studies. Therefore, the 1989 samples (Table 1) are not directly comparable to the 2008 samples (Table 2), which were conducted with paper mouse glueboards (Victor, Lititz PA). These traps were set individually in lines of 12 on the ground in shade. The traps were separated by at least 5 meters and aligned in either a straight line parallel to a road, shoreline, or trail edge, or in a ring surrounding a total removal plot. The traps were checked every 30 min for three morning hours (2008) or periodically throughout the day for 24 h (1989 and 2008). Capture rates are expressed as captures per trap-hour.

Table 1. Glueboard sampling of Tinian, 1989. Throughout this document, latitudes and longitudes are given to the precision implied by the number of significant digits and all are in the WGS84 projection.

Site	Latitude	Longitude	Micro-habitat	Time of day	Trap -Hrs	Date (1989)	Lizard Captures
***Pemphis* coastal zone**							
PTAH	N 15.1011	E 145.6449	Rocky shore	0730-0730	1152	15-17 Aug	24
Limestone forest							
CPNB	N 14.94	E 145.640	Forest floor	0930-1200	318	17-18 Aug	6

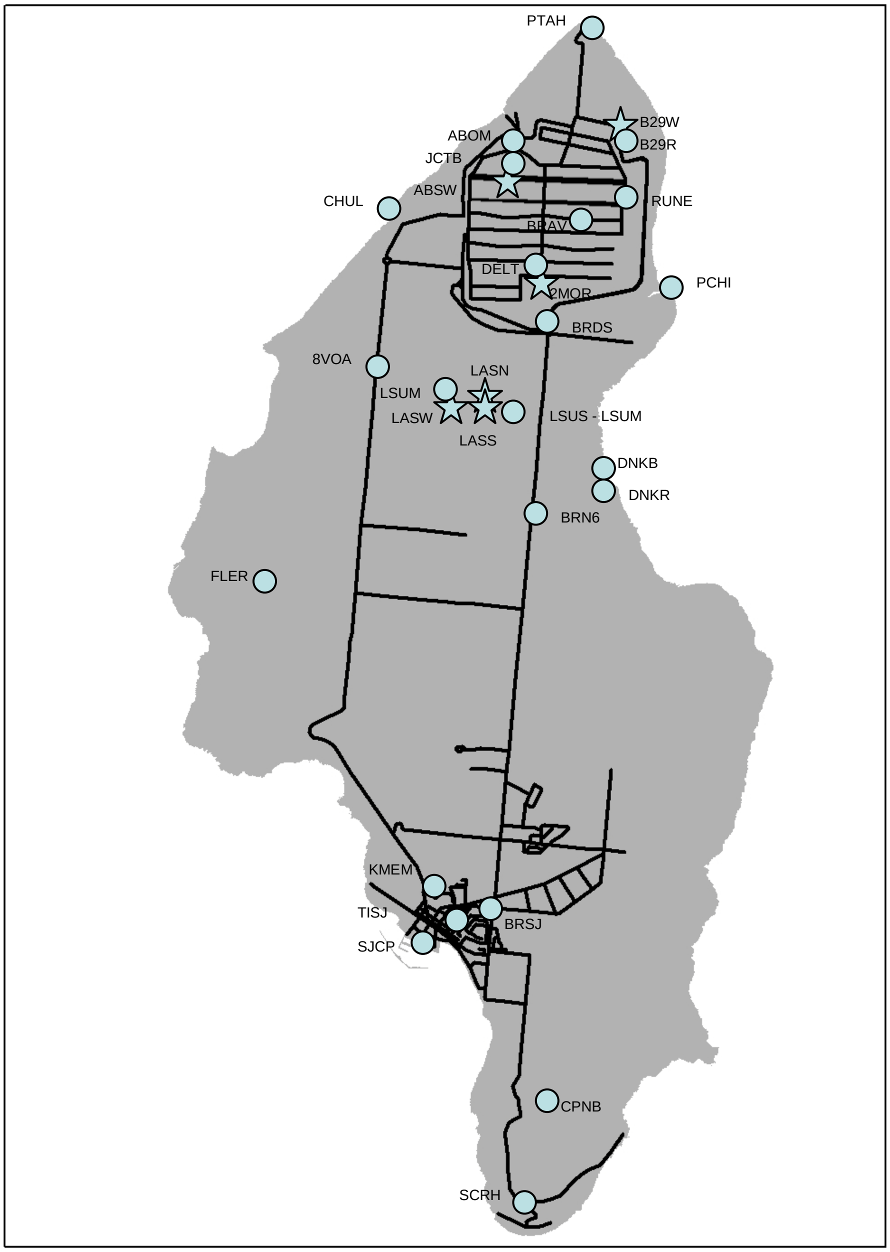

Figure 1. Outline map of Tinian showing sites sampled in 1989 or 2008. Starred sites incorporated total removal sampling. Coordinates for each site are given in the appropriate accompanying tables.

Table 2. Glueboard sampling of military lease lands on Tinian, 2008.

Site	Latitude	Longitude	Micro-habitat	Time of day	Trap -Hrs	Date (2008)	Lizard Captures
***Pemphis* coastal zone**							
PTAH	N 15.1011	E 145.6449	Rocky shore	0800-1100	36	17 July	4
CHUL	N 15.073	E 145.616	Rocky shore	0837-1137	42	17 July	10
Strand coastal zone							
CHUL	N 15.073	E 145.616	Forest floor	0830-1150	39.6	17 July	10
DNKB	N 15.030	E 145.648	Forest floor	0800-1100	36	17 July	11
***Leucaena* forest**							
ABSW	N 15.0776	E 145.6327	Forest floor	0733-1033	36	24 June	22
ABSW	N 15.0776	E 145.6327	Tree trunks	0730-0715	285	24-25 June	0
B29W	N 15.0855	E 145.6495	Forest floor	0758-1058	36	24 June	12
B29W	N 15.0855	E 145.6495	Tree trunks	0800-0730	282	24-25 June	1
FLER	N 15.0198	E 145.5884	Forest floor	0740-1055	72	17 July	44
DNKR	N 15.030	E 145.648	Forest floor	0740- 1040	36	17 July	23
Mixed (*Leucaena* – Limestone) forest							
2MOR	N 15.063	E 145.638	Forest floor	0810-1110	36	24 June	13
2MOR	N 15.063	E 145.638	Tree trunks	0740-0740	288	24-25 June	0
LASW	N 15.042	E 145.626	Forest floor	0819-1134	39	28 June	25
LASW	N 15.042	E 145.626	Tree trunks	0735-0735	288	28-29 June	0
Limestone forest							
LASN	N 15.0422	E 145.6302	Forest floor	0905-1205	36	28 June	16
LASN	N 15.0422	E 145.6302	Tree trunks	0833-0803	282	28-29 June	0
LASS	N 15.0410	E 145.6298	Forest floor	0900-1200	36	28 June	8
LASS	N 15.0410	E 145.6298	Tree trunks	0850-0835	286	28-29 June	0
LSUS	N 15.04	E 145.63	Forest floor	0800-1105	72	6 July	6

Visual search method. - Visual search methods are detailed in Rodda *et al.* (2005a). Briefly, the searchers worked individually, walking at about 0.5 km/h, scanning the vegetation on one side of a trail or road, usually at night with the aid of a headlamp. Each reptile seen was identified to species and characterized by its perch height and perch taxon, though the latter data will not be reported here. Relative densities are expressed as captures per unit effort (detections per searcher-hour); sample sizes are given separately for 1989 (Table 3) and 2008 (Table 4). The headlamps used in 1989 were relatively dim narrow-beam dry cell lights (Justrite, Des Plaines IL). Those used in 2008 were the brighter and broader beam Brunton (Riverton WY) and Mila (Sweden) lamps used by orienteering teams (similar to Mila lamps whose effectiveness is reported in Lardner *et al.* 2007, under review).

Table 3. Visual searches of Tinian, 1989. All but the one at Puntan Chiget (PCHI) were at night.

Site	Latitude	Longitude	Search-Hrs	Date (1989)	Lizard Detections
Urban					
JCTB	N 15.080	E 145.633	0.83	8 Aug	10
SJCP	N 14.966	E 145.621	0.53	17 Aug	35
TISJ	N 14.97	E 145.625	1.74	13-16 Aug	30
Coastal habitats					
CHUL	N 15.073	E 145.616	2.36	12 Aug	47
PCHI	N 15.06	E 145.655	0.18	15 Aug	2
***Leucaena* forest**					
ABOM	N 15.08	E 145.63	11.64	9-10 Aug	80
RUNE	N 15.075	E 145.65	3.83	8-13 Aug	9
SCRH	N 14.924	E 145.632	4.56	14 Aug	30
Mixed (*Leucaena* - Limestone) Forest					
BRDS	N 15.055	E 145.639	0.47	15 Aug	12
BRN6	N 15.03	E 145.637	1.00	15 Aug	12
BRSJ	N 14.97	E 145.632	0.60	12 Aug	16
KMEM	N 14.975	E 145.623	1.14	12 Aug	13
Limestone Forest					
LSUS	N 15.04	E 145.63	1.20	15 Aug	0
CPNB	N 15.94	E 145.640	1.99	16 Aug	21

Table 4. Nighttime visual searches of military lease lands on Tinian, 2008.

Site	Latitude	Longitude	Search-Hrs	Date (2008)	Lizard Detections
***Leucaena* forest**					
8VOA	N 15.0505	E 145.6134	1.30	24 July	20
B29R	N 15.09	E 145.64	4.62	15 July	28
BRAV	N 15.074	E 145.650	5.83	15 July	32
DELT	N 15.07	E 145.64	3.80	15 July	24
DNKR	N 15.030	E 145.648	3.96	16 July	39
FLER	N 15.020	E 145.588	4.14	16 July	10
Mixed (*Leucaena* - Limestone) Forest					
BRN6	N 15.026	E 145.637	4.10	18 July	215
LSUM	N 15.04	E 145.63	4.20	16 July	27
Limestone Forest					
LSUS	N 15.04	E 145.63	5.88	9 July	10

Total removal methods. - Total removal methods are described in detail in Rodda *et al.* (2001). In brief, our objective was to physically isolate a 10 × 10 m patch of forest such that no lizards (other than very large *Varanus indicus*) could leave or enter. Arboreal lizard movement was blocked by canopy separation, and terrestrial movement was prevented by erection of a 0.4 m-tall fence of aluminum flashing which was buried in the ground to block shallow subterranean escape, and sprayed with white lithium automotive grease to discourage climbing. The vegetation was then cut down, carefully inspected, and removed in small quantities to discover all non-fossorial non-volant vertebrates present.

To prevent arboreal lizards from fleeing during canopy separation, canopy separation was conducted during the day, when almost all of Tinian's arboreal species are in refugia. To prevent terrestrial lizards from fleeing during erection of the aluminum flashing, fence emplacement occurred at night when the terrestrial species (almost all are diurnal) were in refugia. Three species of lizard and one toad could potentially escape because their activity periods are anomalous in this regard: Cane Toads (*Rhinella marina*) and Pacific Slender-toed Gecko (*Nactus pelagicus*) lizards were potentially capable of escaping on the ground because they are terrestrially-active at night while the fence was being erected; Green Anoles (*Anolis carolinensis*) and Emerald Skinks (*Lamprolepis smaragdina*) are likewise theoretically capable of escaping because they are active in the trees during the day (for example, they might flee the area during canopy separation). We do not believe that these species avoided detection on a large scale by these measures, but we were not able to rigorously quantify any leakage that might have occurred.

The locations of the total removal plots on Tinian (Table 5) were selected by the Navy representative Scott Vogt, in order to best accommodate the technical challenges of erecting a lizard-proof fence while surrounding an area of characteristic vegetation. Thus the exact plot localities were chosen to maximize vegetation representativeness and soil depth (Table 6). They were not chosen with any knowledge of the constituent reptile densities and therefore should be unbiased reptile density samples.

Table 5. Characteristics of total removal sampling plots used on military lease land on Tinian, 2008. The date range is for vegetation modification stages only. The listed "Person-Hrs" is the effort needed to remove and inspect the vegetation. Roughly an equal amount of time was required for other tasks.

Site	Latitude	Longitude	Area (m^2)	Dates (2008)	Person-Hrs	Lizard Captures
***Leucaena* (Tangantangan) Forest**						
ABSW	N 15.0776	E 145.6327	100	25-26 June	49	17
B29W	N 15.0855	E 145.6495	100	5-7 July	72.5	33
Mixed (Limestone-*Leucaena*) Forest						
2MOR	N 15.0631	E 145.6377	100	2-4 July	64	23
LASW	N 15.0422	E 145.6264	100	8-10 July	79	50
Limestone Forest						

LASN	N 15.0422	E 145.6302	100	11-14 July	122	41
LASS	N 15.0410	E 145.6298	80	29 June – 1 July	100	32

We can more precisely understand the relationship between species density and habitat features using the vegetation measurements of each plot (summarized in Table 6). In general, the basal area of *Leucaena* and the count of all woody stems (> 1 cm dbh) decreased in the sequence *Leucaena*-mixed-limestone forest and the number of large stems (>10 cm dbh) and the total vegetative biomass increased in the same habitat order. The dominant ground cover was about 60% leaf litter in all cases, but the amount of coarse woody debris tended to increase in the *Leucaena*-mixed-limestone forest sequence.

Table 6. Vegetative characteristics of the total removal plots. Reported woody percentages are of basal area for the entire plot (all woody stems > 10 mm diameter breast high (dbh)). Reported groundcover percentages are mean ground coverage. The secondary groundcover "CWD" is coarse woody debris.

	Leucaena forest		Mixed forest		Limestone forest	
Site	ABSW	B29W	2MOR	LASW	LASN	LASS
Dominant tree (%)	*Leucaena* (100%)	*Leucaena* (100%)	*Morinda* (73%)	*Leucaena* (66%)	*Leucaena* (40%)	*Premna* (29%)
Secondary tree (%)	-	-	*Leucaena* (24%)	*Aglaia* (21%)	*Premna* (18%)	*Pisonia* (20%)
Canopy height (m)	6.3	6.5	6.3	6.3	7.5	8.0
Wet veg biomass (K kg)[1]	1.4	2.2	2.3	2.1	3.2	3.5
Stems > 10 mm dbh[1]	191	91	112	136	75	44
Stems > 100 mm dbh[1]	0	6	3	7	16	9
Dominant groundcover (%)	Litter (60%)	Litter (53%)	Litter (58%)	Litter (68%)	Litter (64%)	Litter (59%)
Secondary groundcover (%)	Grass (31%)	Herbs (31%)	Ferns (25%)	CWD (13%)	CWD (20%)	CWD (16%)
Litter depth (mm)	22	25	19	13	17	14

[1]. Values for 80 m^2 LASS adjusted to 100 m^2. All other counts based on 100 m^2 plots.

Detection probability estimation and missed ratios. - We paired glueboard sampling with total removal plots to assess the trap detection probabilities of various species. The glueboards were placed as close to the plot as is possible while assuring a 7 m separation between traps (to minimize intertrap interference). On Tinian we always conducted the paired glueboard trapping prior to disturbance of the plot vegetation.

Similarly, we paired visual surveys with total removal sampling whenever the geography of surrounding vegetation made practical visual surveys in the same habitat sampled by total removal. This too allowed an estimate of detection probability from the absolute densities documented in the total removal plots. Detection probability is of interest primarily because it can be used to estimate the proportion of animals that are overlooked in a survey. For example, if the detection probability is 0.25, one out of four animals were detected, on average. Another way to state this is that four animals were usually present for every one that was seen (in other words, we missed three of four). This is the way we state it in this paper, a value we will call the "missed ratio," the inverse of detection probability. In our example the missed ratio of 4.0 indicates that if we saw 8, 32 were most likely present.

When the "missed ratio" is multiplied by the mean detection rate for a habitat-by-species combination (e.g., the Indo-Pacific House Gecko, *Hemidactylus frenatus,* in mixed forest) we obtain an estimate of absolute density for the habitat sampled. This allows a key check on whether the absolute densities reported from total removal plots were representative of the habitat. For example, using missed ratios we estimated that the Mourning Gecko, *Lepidodactylus lugubris,* was generally more common in *Leucaena* habitat than they were in our *Leucaena* total removal plots, but that our total removal samples of the Mutilating Gecko, *Gehyra mutilata,* were very closely matched to their sampled densities in almost all habitats (species specific evaluations included under species accounts).

While missed ratios are especially useful in this way, the pattern of missed ratios is also helpful in understanding which habitats, islands, and species are particularly favorable for detection (few missed) or particularly difficult (many missed). Tables of missed ratios are given under the relevant species accounts.

Validity of the sampling methods. - Of the various sampling techniques, total removal has the highest face validity (Rodda *et al.* 2001), in that the local population is totally enumerated ("censused") rather than sampled ("surveyed"), but the total removal method is not strictly applicable to all species. For example, it is not intended for use on subterranean species such as the Brahminy Blindsnake, *Ramphotyphlops braminus*. Species that may aestivate underground – here the Cane Toad, *Rhinella marina* - could also be missed. Large climbing lizards such as the Mangrove Monitor, *Varanus indicus* can probably vault the barrier and are at such low density that quantification using total removal plots is unlikely to be informative. For the appropriate species, however, total removal sampling is unequivocal and precise, with no ambiguity about the size of the area sampled (unlike index methods and mark-recapture, for which quantification of the area sampled can be elusive) or the number of individuals found therein. Total removal is also the only method under consideration that provides size distributions, biomasses, sex ratios and other unbiased demographic information.

Glueboard sampling seems to work best for strictly terrestrial species such as the Curious Skink, *Carlia ailanpalai* (Rodda *et al.* 2005b). The technique's primary weakness is that it is imprecise (wide confidence limits) and index values are often not strictly proportional to absolute abundance. Thus, for example, an index value of 6 cannot be interpreted as having twice the absolute population density found in a site where the same species has an index value of 3. Glueboard capture rates cannot be legitimately compared among species, and other restrictions may apply (Rodda *et al.* 2005b). For example, it may not give appropriate relative abundances when making comparisons among habitats or islands.

Visual surveys may be the best choice for estimating relative abundance of arboreal species (Rodda *et al.* 2005a), though the confidence intervals may be even wider than for glueboard samples, indicating low precision. Species-specific modulators of visual detection can be inferred from the visual missed ratio tables given in the species accounts.

RESULTS

Glueboard sampling. - Glueboard yields are given in Table 7 (1989) and Table 8 (2008).

Table 7. 1989 Glueboard capture rates (captures per trap-hr). An empty cell indicates that appropriate trapping did not occur for the indicated species at the indicated site. See species accounts for details of appropriate conditions. See Table 1 for placement and number of trap-hours at each locality. Single additional specimens of *Lepidodactylus lugubris* and *Varanus indicus* were caught at CPNB. Glueboards used in 1989 were of a different adhesive and configuration than in 2008, so capture rates are not directly comparable.

	Terrestrial native			Terrestrial introduced	Arboreal introduced	
	Cryptoblepharus. poecilopleurus	*Emoia atrocostata*	*Emoia caeruleocauda*	*Carlia ailanpalai*	*Gehyra mutilata*	*Hemidactylus frenatus*
Coastal habitats						
PTAH	0	0	0	0.005		
Limestone forest						
CPNB	0		0.006	0.062		

Table 8. Glueboard capture rates 2008 (captures per trap-hr) based on appropriate conditions for each species (arboreal species only in tree traps; nocturnal species only in night sets, etc.). An empty cell indicates that appropriate trapping did not occur for the indicated species at the indicated site. See species accounts for details of these conditions. See Table 2 for placement and number of trap-hours at each locality. Omitted lizards had capture rates of zero.

	Terrestrial native			Terrestrial introduced	Arboreal introduced	
	Cryptoblepharus. poecilopleurus	*Emoia atrocostata*	*Emoia caeruleocauda*	*Carlia ailanpalai*	*Gehyra mutilata*	*Hemidactylus frenatus*
Coastal habitats						
CHUL	0.012	0.095	0	0.748		
PTAH	0		0	0.083		
DNKB	0		0	0.306		
$\bar{X}$	0.004		0	0.379		
***Leucaena* forest**						
ABSW	0		0	0.611	0	0.004
B29W	0		0	0.333	0	0
FLER	0		0	0.611		
DNKR	0		0	0.639		
$\bar{X}$	0		0	0.549	0	0.002
Mixed forest						
2MOR	0		0	0.361	0	0
LASW	0		0	0.641	0	0
$\bar{X}$	0		0	0.501	0	0
Limestone forest						
LASN	0		0.028	0.417	0	0
LASS	0		0	0.139	0.014	0
LSUS	0		0	0.083		
$\bar{X}$	0		0.009	0.213	0.007	0

Visual searching. - Visual detection rates are in Table 9 (1989) and Table 10 (2008).

Table 9. Detection rates (sightings/person-hr) during visual surveys on Tinian, 1989. See Table 3 for person-hrs and sample sizes. Omitted lizards had sighting rates of zero.

	Arboreal Native	Terrestrial introduced	Arboreal introduced (or potentially introduced)				
	Lepidodactylus lugubris	*Carlia ailanpalai*	*C. poecilo-pleurus*	*Gehyra mutilata*	*Gehyra oceanica*	*Hemidactylus frenatus*	*Lamprolepis smaragdina*
Urban							
JCTB	3.077		0	0	0	12.048	0
SJCP	0		0	0	0	66.038	0
TISJ	1.724		0	4.598	0	10.345	0.575
Coastal habitats							
CHUL	0.758		1.695	2.119	0	11.441	0
PCHI		11.111	0				0
***Leucaena* forest**							
ABOM	6.186		0	0.172	0	0.515	0
RUNE	9.512		0	0.261	0	0.522	0
SCRH	1.667		0	2.632	0.658	1.096	0.219
Mixed (*Leucaena* - Limestone) Forest							
BRDS	2.128		0	0	0	23.404	0
BRN6	1.000		0	3.000	0	9.000	0
BRSJ	15.000		0	0	0	10.000	1.667
KMEM	4.386	0.877	0	4.386	0	0.877	0.877
Limestone forest							
LSUS	0		0	0	0	0	0
CPNB	2.010		0	3.015	3.518	2.010	0

Table 10. Detection rates (sightings/person-hr) during nighttime visual surveys on military lease lands, Tinian, 2008. Values for BRN6 are somewhat approximate, as the large number of simultaneous detections made it difficult to scrupulously avoid double counting of moving individuals. See Table 4 for person-hrs and capture sample sizes. Omitted lizards had sighting rates of zero. BRN6 was also unusual in being isolated trees in the median of a road; therefore it was not averaged with LSUM to characterize mixed forest visual detection rates. *Anolis carolinensis* and *Lamprolepis smaragdina* were actively spreading their ranges at the time of our samples; therefore it was not appropriate to characterize their relative abundances in *Leucaena* forest by combining sites where the species was present with those sites not yet reached.

	Arboreal Native	Arboreal introduced (or potentially introduced)				
	Lepidodactylus lugubris	*Anolis carolinensis*	*Gehyra mutilata*	*Gehyra oceanica*	*Hemidactylus frenatus*	*Lamprolepis smaragdina*
***Leucaena* forest**						
8VOA	3.077	4.615	0	0	3.077	4.615
B29R	0.433	0	1.082	0	4.329	0
BRAV	0.172	0	0	0	4.631	0
DELT	1.316	0	2.105	0	2.105	0
DNKR	0.758	0	0	0.253	7.828	0.505
FLER	1.691	0	0.242	0	0.242	0.242
$\overline{X}$	1.241		0.572	0.042	3.702	
Mixed forest						
BRN6	9.512	0	1.463	0	39.3	1.707
LSUM	1.667	1.190	0.952	0.238	0.238	0.476
Limestone forest						
LSUS	0.340	0	0.340	0.170	0.170	0.340

Total removal sampling. - For comparisons within a species it is appropriate to consider the absolute densities revealed by total removal sampling (Table 11), but for comparisons among species it is perhaps more appropriate to consider the biomass distribution, as one individual of a large species may consume many times the energy and space that is occupied by a smaller species (Table 12, Figure 2). The most striking attribute of the biomass distribution by fundamental niche (Table 12) is the paucity of terrestrial species biomass, especially in limestone forest, where it constituted only about 1% of lizard biomass. Native species did not constitute as much as half of the lizard biomass in any sampled habitat.

Table 11. Densities of each herpetofauna species on Tinian, as revealed by total removal plots on military lease lands, 2008. Densities are given in units of individuals per hectare, based on sampling of approximately 0.01 hectare.

	Leucaena forest		Mixed forest		Limestone forest	
	ABSW	B29W	2MOR	LASW	LASN	LASS
Subterranean native species						
Ramphotyphlops braminus	0	0	0	100	0	125
Terrestrial native species						
Cryptoblepharus poecilopleurus	0	100	0	0	0	0
Emoia caeruleocauda	0	0	0	600	0	0
Arboreal native species						
Lepidodactylus lugubris	100	800	1000	2600	2700	1875
Perochirus ateles	0	0	0	0	100	0
Terrestrial introduced species						
Carlia ailanpalai	1100	500	800	300	0	125
Rhinella marina	0	0	100	200	400	125
Arboreal introduced (or potentially so) species						
Anolis carolinensis	0	0	0	300	0	0
Gehyra mutilata	0	400	500	1100	500	1125
Gehyra oceanica	0	0	0	0	500	875
Hemidactylus frenatus	500	1500	0	0	0	0
Lamprolepis smaragdina	0	0	0	100	300	0

Table 12. Biomass densities of each lizard species on Tinian, as revealed by total removal plots on military lease lands, 2008. Biomasses are given in units of kilograms per hectare, based on sampling of approximately 0.02 hectare (two total removal plots in each habitat). Omitted lizards had capture rates of zero.

	Leucaena forest		Mixed forest		Limestone forest	
Terrestrial native						
Cryptoblepharus poecilopleurus	0.09		0		0	
Emoia caeruleocauda	0		0.48		0	
Terrestrial native subtotal (% of total)	0.09	(2)	0.48	(9)	0	(0)
Arboreal native						
Lepidodactylus lugubris	0.35		1.80		1.70	
Perochirus ateles	0		0		0.15	
Arboreal native subtotal (% of total)	0.35	(8)	1.80	(33)	1.85	(16)
Terrestrial introduced						
Carlia ailanpalai	1.90		0.78		0.09	
Terrestrial introduced subtotal (% of total)	1.90	(45)	0.78	(14)	0.09	(1)
Arboreal introduced (or possibly so)						
Anolis carolinensis	0		0.44		0	
Hemidactylus frenatus	1.52		0		0	
Gehyra mutilata	0.36		1.29		1.08	
Gehyra oceanica	0		0		5.78	
Lamprolepis smaragdina	0		0.63		2.42	
Arboreal introduced total (% of total)	1.88	(45)	2.36	(43)	9.28	(83)
Terrestrial combined (native and introduced): % of total	1.99	(47)	1.26	(23)	0.09	(1)
Arboreal combined (native and introduced): % of total	2.23	(53)	4.16	(77)	11.13	(99)
Native combined (arboreal and terrestrial): % of total	0.44	(10)	2.28	(42)	1.85	(16)
Grand total (kg/ha)		4.22		5.42		11.22

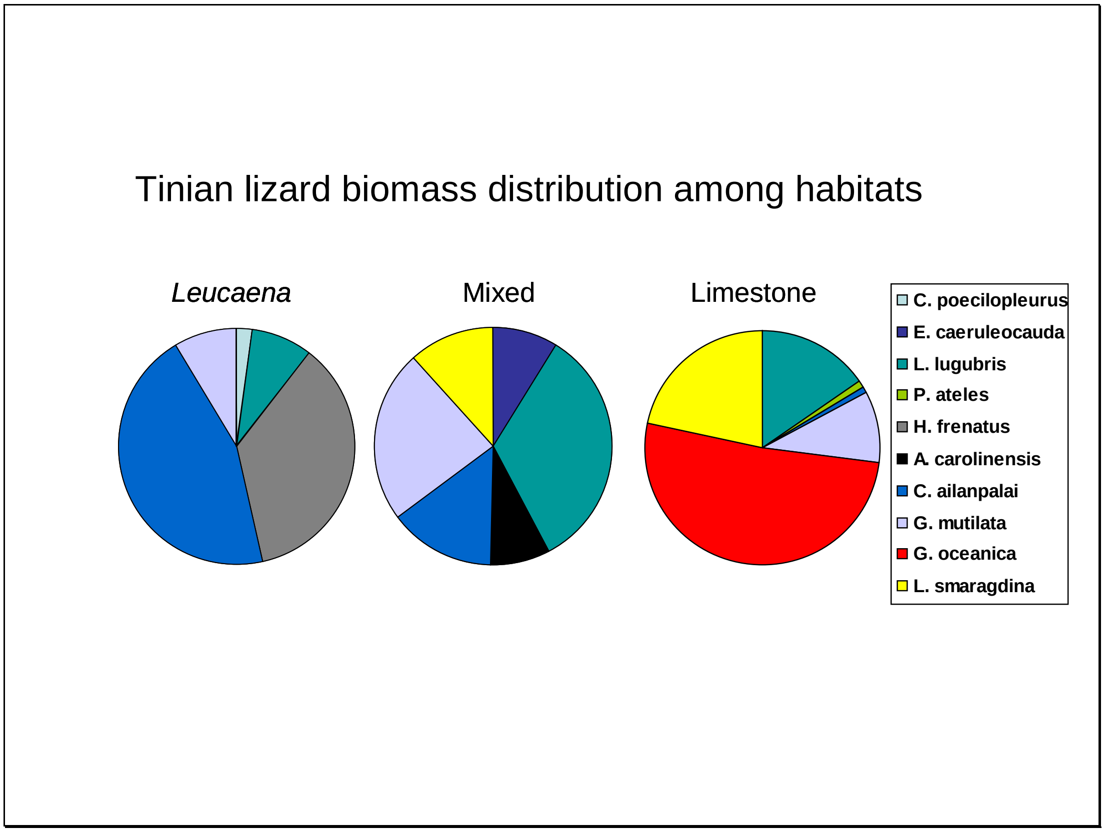

Figure 2. Distribution of lizard biomass among lizards and habitats on military lease lands on Tinian, 2008, as indicated by total removal plots. Amphibians and snakes have been omitted from this table to reflect their uncertain sampling. Species are listed in the same order as the tables (terrestrial native, then arboreal native, and so forth), beginning at twelve o'clock and continuing clockwise.

Species accounts

Native species

Oceanic Snake-eyed Skink, *Cryptoblepharus poecilopleurus*

Body length[1]: 22 - 47 mm   Mass: 0.2 - 1.8 g

Figure 3. The Oceanic Snake-eyed Skink, *Cryptoblepharus poecilopleurus.*

Previous studies – Note that the nominal species is under revision and is likely to contain a number of island endemics in the South Pacific (Horner 2007, G. Zug, 2008 pers. comm.), but the form in the Mariana Islands is relatively widespread in the northwestern Pacific. Because this littoral clade has extensively speciated on islands (reflecting an evolutionarily long residence in the area of speciation), and because this particular species is endemic to the northern Pacific, it is assumed that this species reached many islands on its own (i.e., it was not introduced by man). Because it is very small and its skeleton is fragile, it is not a good candidate for preservation as a subfossil in prehuman remains. Thus we assume it is likely native despite the absence of reported subfossils in prehuman strata (Pregill 1998).

This species is found in a variety of microhabitats, including *Casuarina* (Australian pine) groves, rocky and sandy areas, grass, leaf litter around *Cocos* (coconut) palms, etc. (McCoid *et al.* 1995). The unifying factor in this range of habitat types, however, is that these microhabitats must be closely associated with the littoral zone. For example, *C. peocilopleurus* has been collected on and around *Casuarina*, but only when the trees are immediately adjacent to the shore. Vogt and Williams (2004) report occasional specimens from upland situations (limestone forest implied by not explicitly stated) on Saipan and the Northern Mariana Islands, though these may be associated with cliffs (also found around upland cliffs on Rota (Rodda, pers. obs.). The exception is on Guguan, where this species occurs throughout the island as a sand swimmer in ash fields (McCoid *et al.* 1995). Vogt (2008) comments that its former presence on Sarigan

[1] Sizes given above photographs are ranges for specimens from the Mariana Islands.

(Northern Mariana Islands) may have been attributable to soil disturbance associated with dense populations of goats. It is possible that goat-churned soil could provide a loose soil niche similar to that found in ash fields on Guguan.

The first record of this species on Tinian was three specimens collected by Norm Scott and Herman Muna from *Leucaena* trees at the shrine at Puntan Tahgong (our site PTAH) in 1985 (Wiles *et al.* 1989). These *Leucaena* trees were immediately adjacent to a *Pemphis* belt that occurs in the salt spray zone of the point. We trapped the same place four years later (Table 1), but found only *Carlia* (Table 73). We did find *Cryptoblepharus poecilopleurus* in strand forest at nearby Unai Chulu in 1989 (Tables 3, 9). These were the only published records for Tinian prior to this study.

This study (2008) – We found the Snake-eyed Skink (*Cryptoblepharus poecilopleurus*) at only two sites: adjacent to Unai Chulu (beach) and in the B29W total removal plot just northeast of North Field. The Unai Chulu population was expected, as the species is associated with strand habitat. However, the B29W total removal plot was nearly 1 km inland, in North Field's characteristic monotypic stands of *Leucaena*. To the best of our knowledge, this is the first record for this species anywhere in *Leucaena* habitat or at a great distance from cliff or strand habitat. On the windward side of North Field the *Leucaena* stands were stunted by the prevailing winds and salt spray, and therefore the B29W site was not as far inland in a habitat sense as simple distance from the coast would suggest. Nonetheless, this discovery undermines our confidence in predicting the full distribution of the species on Tinian. Prior to this discovery we would have confidently predicted that the species would occur only immediately adjacent to salt water, especially in the vicinity of *Casuarina* stands, strand vegetation or cliffs. However, the detection in a *Leucaena* stand indicates that it might occur in a variety of sites on the military lease lands of Tinian. It is not, however, present throughout, as we found it in only the two sites mentioned.

Management recommendations - The nominal species has an extensive distribution throughout the northwestern Pacific, though some of these localities may be of closely-related species. It is found along the coast of virtually all of the Mariana Islands, including the far northern islands. As presently understood the species is not considered to be at risk of endangerment or in need of special management. As with all of Tinian's native species, the most important protection is prevention of new introductions. It is notable that Hawley (2008) and Vogt (2008) observed a recent apparent decline of this species on Sarigan; Vogt suggested that the species may benefit from soil disturbance by ungulates. Monitoring soil conditions in conjunction with monitoring populations of this species may shed light on limiting factors.

Littoral Skink, *Emoia atrocostata*

Body length: 28 - 85 mm   Mass: 0.6 – 11.0 g

Figure 4. The Littoral Skink, *Emoia atrocostata.*

Previous studies – This species was not previously known to occur on Tinian, though it was known to occur on small islands both north (e.g., Saipan outlier Maigo Luao) and south (Aguiguan) of Tinian (Rodda *et al.* 1991). Throughout its vast range it occurs in two habitat types: mangrove mud flats and rocky coasts having tide pools. In Palau, it occurs in both of these habitat types. In the Marianas it is known only from tide pool areas (hence the alternate common name: Tide-pool Skink), especially associated with the shrub *Pemphis*, which occurs in the salt-sprayed area immediately inland of the intertidal zone on high-energy rocky shorelines. This is the only suitable habitat for this species on military lease lands of Tinian.

Because this species is strictly limited to the littoral zone, it would not be expected to be found in the upland caves sampled for subfossil material by Pregill (1998), and it was not found there. However, as this taxon is a superlative colonizer of remote islands, and is endemic to the Pacific basin (including Indo-Pacific areas), we treat it as a native species.

This study (2008) – We found the Littoral Skink (*Emoia atrocostata*) to be reasonably common in the *Pemphis* zone north of Unai Chulu. We did not find it in similar habitat at Puntan Tahgong (Ushi Point), or in strand forest 10-20 m inland from the *Pemphis* zone of Unai Chulu. *Carlia ailanpalai* is the dominant terrestrial lizard in the *Pemphis* zone at Puntan Tahgong and several other places where we looked, but it is likely that additional populations of *E. atrocostata* will be discovered in *Pemphis* habitat.

Management recommendations – As this skink is widely distributed (Pacific and Indian Oceans) and common, this is not a species of special concern. However, the absence of the skink from typical habitat such as that found at Puntan Tahgong, and its possible replacement by the introduced Curious Skink (*Carlia ailanpalai*) suggests that monitoring of these two species be continued in the *Pemphis* zone to determine whether the introduced skink displaces the native one.

Pacific Blue-tailed Skink, *Emoia caeruleocauda*

Body length: 21 – 56 mm Mass: 0.1 – 3.7 g

Figure 5. The Pacific Blue-tailed Skink, *Emoia atrocostata.*

Previous studies – The colorful and conspicuous Pacific Blue-tailed Skink (*Emoia caeruleocauda*) is found from Borneo to Vanuatu and throughout the western Pacific on the ground and low in vegetation in forested areas (Brown 1991). Pregill (1998) found it in early prehistoric subfossil material, but did not record it in prehuman strata. However, it is endemic to western Oceania and therefore is presumably native to at least some of the islands therein. For that reason we treat it as native to the Mariana Islands.

In the Marianas it is the only common native skink still found throughout most islands (Rodda *et al.* 1991). However, on Tinian it has been largely replaced (Wiles *et al.* 1989) by the introduced Curious Skink. It is not known if this replacement has been due to direct interaction between the species or an indirect interaction, such as a reciprocal response to a habitat feature (e.g., one species prefers drier areas; the other prefers wetter areas). Previous studies have found the blue-tailed skink to be largely missing from the extensive *Leucaena* stands on military lease lands of Tinian (Wiles *et al.* 1989).

This study (2008) – Our observations corroborated earlier studies showing this species to be rare or possibly absent from most *Leucaena* habitat on military lease lands of Tinian. We found it only in or near native forest on Mt. Lasu (LASW total removal plot; seen near LASS; one trapped at LASN) in low numbers. It was present in the one of our mixed forest total removal sites that was on Mt. Lasu, but was absent from the one on North Field. From this limited information it is impossible to determine whether the difference is geographic or due to proximity to native forest.

The pattern of its abundance in the Marianas (Figure 6) indicates a dramatic difference in abundance between Saipan/Tinian and the islands further south (Guam/Rota). Although this skink appears to be significantly reduced in the presence of the Brown Treesnake (compare upper left bar with the one directly below it in Figure 6), the skink reaches very high abundances on Guam even in the presence of snakes, especially in *Pandanus* habitat, but also in all forested habitats. For example, there are individual localities in *Leucaena* habitat on Guam where the blue-tailed skink attained densities of 6300 per hectare, so we can infer that *Leucaena* forest is appropriate habitat for this species. However, we did not find it in *Leucaena* habitat on either Saipan or Tinian, and even in its preferred habitat of limestone forest it was rare on both islands. The commonality between Saipan and Tinian and the distinction with Rota and Guam may be the Musk Shrew, *Suncus murinus*. This large terrestrial shrew is a notorious consumer of skinks (Barbehenn 1974) and was extremely abundant on Saipan and Tinian, but rare on Guam and absent from Rota (Wiewel *et al.* in press).

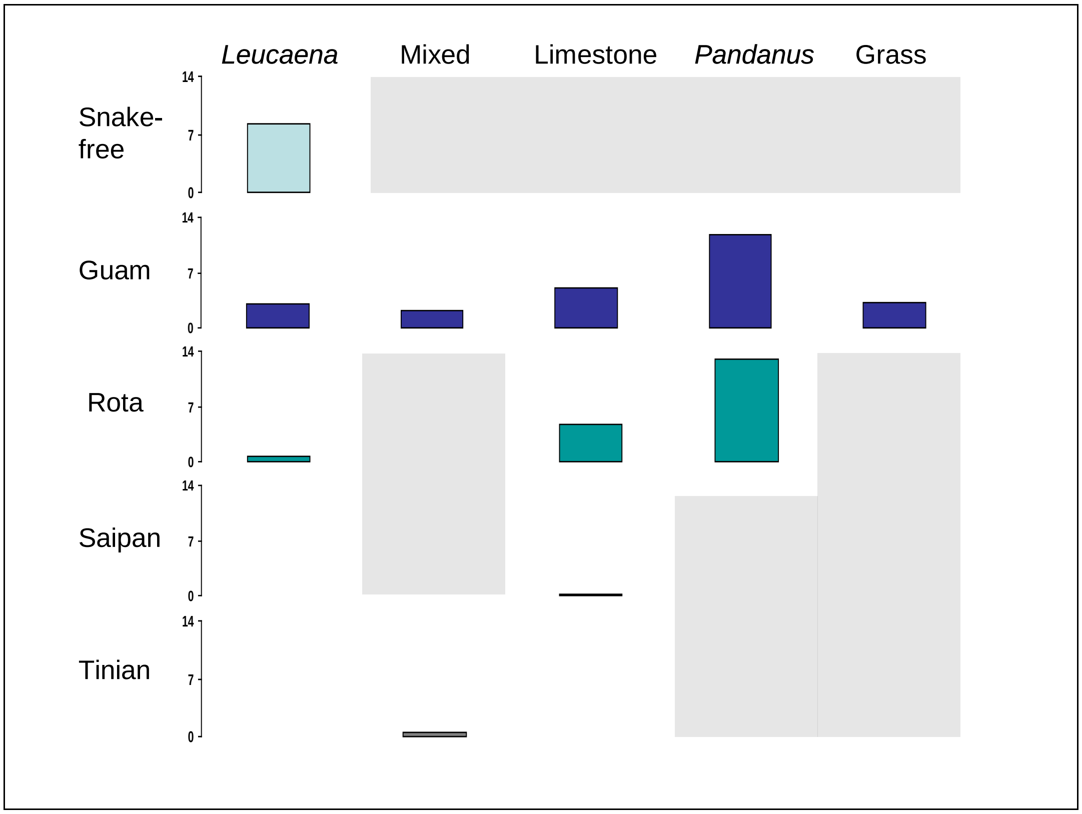

Figure 6. Patterns of abundance of *Emoia caeruleocauda*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Values given are biomass densities (kg/ha). Sample sizes are two plots per island by habitat condition, with the exceptions of Guam (9 Leucaena, 1 Mixed, 1 Pandanus, and 7 Grassland), and 3 *Leucaena* plots on Rota. The grayed-out combinations of habitat and island were not sampled. White-backed areas with no bars indicate zero abundance. The snake-free plots were samples collected in snake exclosures 12 months after snake-removal on Guam, and are provided as a contrast to the abundance indicated immediately below it

(i.e., Guam – *Leucaena*) to indicate the great short-term reduction in lizard abundance associated with snake presence on Guam. Over a longer term we expect and see evidence of contrary, indirect impacts on lizard abundance, probably via the abundance of other lizard-eating animals (shrews, kingfishers, rails, etc.) also reduced by snake predation.

Management recommendations – Although not globally rare (due to its extensive geographic range), this characteristic native species of Mariana forests appears to have been extirpated from most of the military lease lands on Tinian. Retention of the populations that remain probably hinges on retention of limestone forest habitat and prevention of new species introductions. The economic benefits of such retention are unknown, and the ecological benefits have been little studied vis-à-vis this lizard. Townes (1946) and McCoid (1997) found the lizards to be generalized insectivores of non-ant species. Bailey (1976) found a degree of specialization on lepidopteran larvae; thus their presence could benefit agriculture. However, the most important economic contribution of this species may be as a food item for species valued by tourists: Slifka *et al.* (2004) found this to be a highly nutritious prey for kingfishers. Presumably it provides the same benefits to other saurophagous (lizard-eating) birds such as bitterns.

Mariana Skink, *Emoia slevini*

Body length: 20 – 77 mm Mass: 0.4 – 10.4 g

Figure 7. The Mariana Skink, *Emoia slevini*.

Previous studies – The Mariana Skink, *Emoia slevini*, is found only in the Mariana Islands. Pregill (1998) did not detect this species in prehuman strata, but did find it to dominate skink remains in all prehistoric strata. We assume it is therefore native to all of the Mariana Islands. It was first found on Tinian immediately after World War II (Brown and Falanruw 1972, Rodda *et al.* 1991), but has not been detected on Tinian since then (Wiles *et al.* 1989).

This study (2008) – We did not detect this species.

Management recommendations – This species has disappeared from the large southern Mariana Islands in the last 50 years, for no obvious reason (McCoid *et al.* 1995a). Whatever the reason, it may apply to all four large Mariana Islands. Study of this species where it still occurs (far northern Mariana Islands: Alamagan, Asuncion, Guguan, Pagan, Sarigan: Rodda *et al.* 1991) is needed to develop a management strategy to preserve this species, which is endemic to the Mariana Islands and has been extirpated from the bulk of its historic range.

Mourning Gecko, *Lepidodactylus lugubris*

Body length: 19 – 49 mm   Mass: 0.1 – 2.7 g

Figure 8. The Mourning Gecko, *Lepidodactylus lugubris.*

Previous studies – As currently understood, the triploid species *Lepidodactylus lugubris* is a parthenogenetic hybrid derived from diploid *Lepidodactylus moestus* and an undescribed species (Radtkey et al. 1995). Because the present distributions of the parental stocks overlap only in Micronesia, the presumption is that the species arose in Micronesia, or at least somewhere in Oceania. Thus even though no prehuman fossils of this very delicate species have yet been detected in the fossil record (Pregill 1998) we presume this species to be native. This species has been found to be widely distributed in Oceania and reasonably common throughout the Mariana Islands, including Tinian (Wiles *et al.* 1989, Table 9).

This study (2008) – We found evidence of this species in all habitats and all localities considered. It was numerically the most abundant lizard in both mixed and limestone forest habitats (Table 11), but due to its small size it was not responsible for the greatest portion of biomass in any site (Table 12, Figure 2). The Mourning Gecko was one of only two species (the other *Hemidactylus frenatus*) sighted at every locality subjected to visual searches (Table 10). It is known to occur from intertidal habitats to undisturbed upland forest (Sabath 1981), and the evidence from Tinian supports the general conclusion that this species may be found everywhere on the island.

Although widespread, the Mourning Gecko tends to be less conspicuous than its numerical abundance would suggest. In comparison to the Indo-Pacific House Gecko (*Hemidactylus frenatus*) in *Leucaena* habitat on Tinian for example, the Mourning Gecko was about half as abundant as the house gecko in the total removal plots (mean of 450/ha v. 1000/ha: Table 11). Yet in terms of visual sighting rates (Table 10) it averaged only

1.24 detections per hour compared to the house gecko's 3.70 sightings per hour, a *Hemidactylus/Lepidodactylus* ratio of about threefold (compared to an absolute abundance ratio of about twofold).   This suggests that the Mourning Gecko is more difficult to sight than the house gecko.

We can quantify the species' visual detectability with reference to the missed ratios reported in Table 13. The anticipated association between higher missed ratios and visually-obstructed habitats was observed on both Guam and Tinian (compare *Leucaena* and mixed habitats to the other, denser vegetation types). On both islands, limestone forest and *Pandanus* forest habitats had elevated missed ratios (about threefold that of other habitats). However, Mourning Geckos were also about threefold more difficult to detect on Guam than on Tinian (compare matched habitat types). This might be due to the presence of Brown Treesnakes (*Boiga irregularis*), as suggested by the much lower missed ratios for the snake-free samples in *Leucaena* habitat on Guam (mean of 815 vs. 3034). Comparably lower missed ratios of Mourning Geckos are estimated for Tinian, suggesting that Mourning Geckos in snake-infested areas of Guam are less visible, presumably because they are also hiding from foraging snakes on Guam. The mean sighting rate in *Leucaena* forest on Tinian (1.24: Table 10) in combination with the missed ratio in *Leucaena* forest on Tinian (1223: Table 13) implies a mean absolute population density of about 1517/ha in *Leucaena* forest on Tinian. This is about threefold the 450/ha mean density observed in our two total removal plots, suggesting that our total removal plots may have inadvertently sampled areas of relatively low Mourning Gecko density for that habitat type.

Table 13. Patterns of visual missed ratios of *Lepidodactylus lugubris* in the Mariana Islands. The layout and sample sizes of this table follows those of Fig 6. The value expressed is the mean ratio of absolute density assessed in total removal plots to number of detections per hour in visual searches of adjacent vegetation. Higher values therefore indicate lower detectability and a higher proportion of individuals overlooked. "Undefined" indicates a mean value of zero in the numerator (total removals = 0) or denominator (no visual detections). We expect higher missed ratio values in habitats with low visual penetration (limestone forest, *Pandanus*, grass).

Island	*Leucaena*	Mixed	Limestone	*Pandanus*	Grass
Snake-free	815				
Guam	3034	3934	11085	10958	Undefined
Rota	Undefined		Undefined	Undefined	
Saipan	Undefined		Undefined		
Tinian	1223	1158	3155		

Despite this species' high density, we did not detect it with tree-based glueboards (Table 8). Thus care should be taken when judging the density of *Lepidodactylus* from detection or capture rates. Based on the perches occupied by the *Lepidodactylus* seen, the species appears to have a preference for twig-end or foliage perches. Such places are more difficult to search visually, or to trap, than are the trunk/limb locations favored by other geckos. This generalization may not be applicable to all twig-end species: day-active lizards sighted at night in trees (*Anolis*, *Lamprolepis*) are conspicuous because they are bright green and sleep at the very ends of branches, often hanging out into trails, roadways, or other easily-searched venues.

Throughout the Marianas (Figure 9), the Mourning Gecko is ubiquitous and reasonably abundant in all forested habitats. It does better when snakes have been removed (see increase on Guam when “snake-free”: Figure 9), but does not show any dramatic differences in abundance between the Mariana islands, suggesting that none of the other introduced predators (e.g., shrews or rats) greatly affect its numbers. It appears to do slightly better in more mesic habitats, such as limestone forest or *Pandanus*.

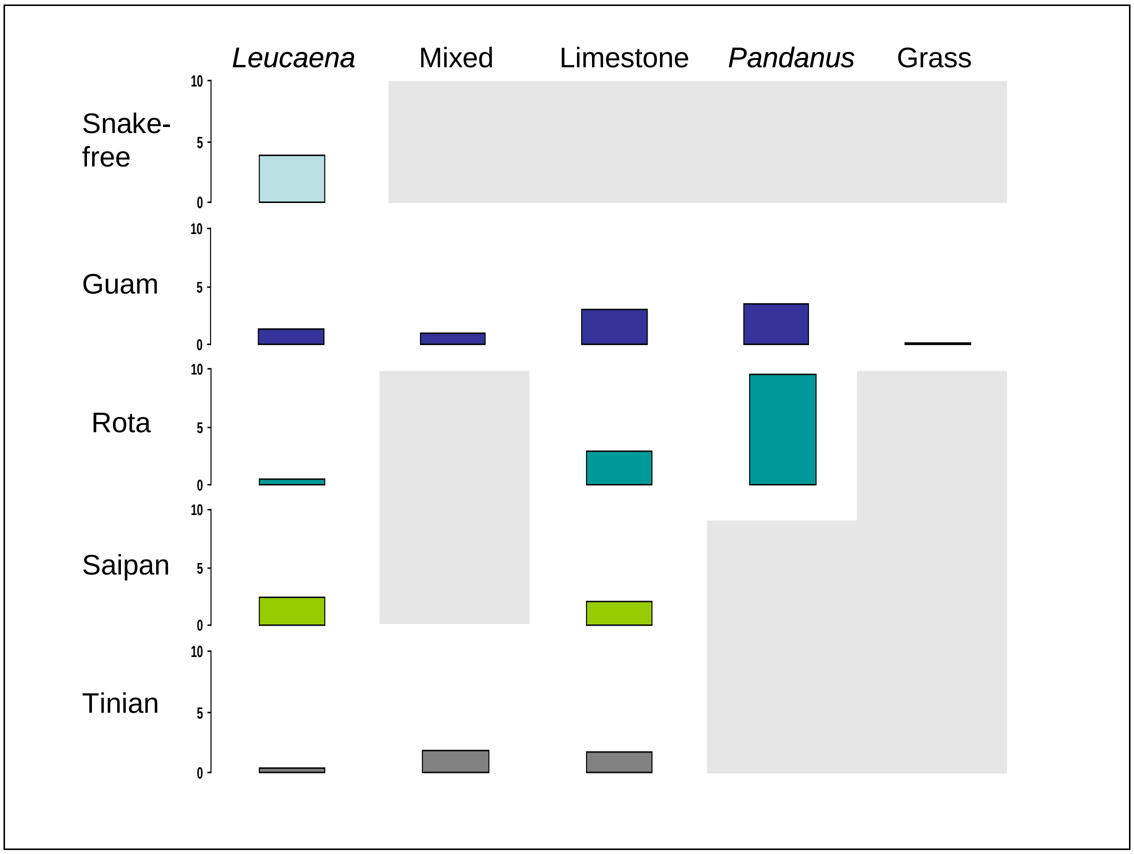

Figure 9. Patterns of abundance of *Lepidodactylus lugubris*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6.

Time trends. - There are two gecko species with sufficient data to begin exploring possible changes in abundance over time on Tinian: *Lepidodactylus lugubris* and *Hemidactylus frenatus*. The best samples are forested habitats, especially *Leucaena* and limestone forests. In 1989 the Mourning Gecko was relatively abundant in *Leucaena* forest, especially in the vicinity of North Field. The mean sighting rate in *Leucaena* forest in 1989 (Table 9) was 5.79/hr, but this includes relatively high sighting rates (mean 7.85/hr) at North Field (ABOM and RUNE) and a relatively low sighting rate (1.67/hr) at the southern tip of Tinian (SCRH). In 2008 our mean sighting rate (Table 10) at North Field (B29R, BRAV, DELT) for this species was only 0.64/hr, a 92% reduction in sighting rate.

Before treating sighting rates as proportional to absolute abundance it is important to consider the possibility that the 1989 searchers were more effective than the 2008 searchers. It is notable that the 1989 searches took place in early August (Table 3), almost exactly the same season as the 2008 searches (July). The gecko species most visually similar to *L. lugubris* is *Hemidactylus frenatus*, which exhibited a sharp increase in the number of sightings 1989 to 2008. Considering only North Field localities (ABOM and RUNE in 1989; B29R, BRAV, and DELT in 2008), the mean sighting rate for *Hemidactylus frenatus* increased from 0.52/hr to 3.69/hr, a 600% increase. Thus it appears unlikely that the decrease in *Lepidodactylus* sightings was due to reduced searcher skill.

Combining the contrary trends in these two gecko species we find that the total number of visual detections in 1989 at North Field for these two species were in the ratio 78:8 or about 93% *Lepidodactylus*, whereas the comparable data for 2008 were 8:55 or only 13% *Lepidodactylus*. From the absolute sighting rates we derive the impression that *Lepidodactylus* has declined in density at North Field and *Hemidactylus* has increased. As these two species are presumably each other's closest competitor, these trends may not be independent; the ascendance of the larger species (*Hemidactylus*) may be partially or wholly spurring the decline of *Lepidodactylus*.

We know of no clear hypothesis to account for this change, as the species have coexisted on Tinian for at least a thousand years (Pregill 1998). However, it is notable that a similar decline in *Lepidodactylus* and concurrent increase in *Hemidactylus* has been noted in total removal plots for similar habitat (*Leucaena* forest north of Northwest Field) on Guam in the period 1995-1999: at the beginning of the period *Lepidodactylus* was numerically slightly dominant 1750/ha v. 1550/ha and constituted about 53% of the two species' counts, but in four years time had declined to only 23% of the combined counts (800/ha v. 2650/ha). These absolute densities are consistent with the Tinian experience in indicating both a decline in *Lepidodactylus* and an increase in *Hemidactylus*. Though the scale of the change is smaller on Guam, the time interval is also shorter; the annual rate of change is roughly comparable. We have no explanation for the change.

<u>Management recommendations</u> – As the species concept is presently applied, the Mourning Gecko is broadly distributed throughout the world (having been introduced in both Africa and the New World), ubiquitous in all habitats on Tinian, and common in all habitats. If what we perceive to be a single Mourning Gecko species turns out to include several cryptic species, some of them rare or highly localized, we would need to reevaluate the assumption that the conservation of this species is assured. The latter scenario is possible, as the species concept is difficult to apply to this parthenogenetic (clonally reproducing) form, and there are many identified strains or clones of this nominal species (Ineich 1988). The clonal representation on Tinian has not been investigated or quantified as it has for nearby areas (Yamashiro *et al.* 2000). Even if the

current conception of the species concept is correct, an introduced insectivorous lizard occupying the same nocturnal twig-end niche could potentially displace it in the Mariana Islands. The most likely competitive displacement of the Mourning Gecko would be by other clones of the same superspecies, as has been suggested by Yamashiro *et al.* (2000). Clarification of clonal composition on Tinian would be of value in understanding the species' apparent population decline.

Micronesian Gecko, *Perochirus ateles*

Body length: 19 – 65 mm   Mass: 0.2 – 6.7 g

Figure 10. The Micronesian Gecko, *Perochirus ateles*.

Previous studies – This species is endemic to Micronesia, and it was the only gecko found in prehistoric subfossil remains on Tinian (Pregill 1998). Thus although it has not yet been detected in prehuman strata, it is highly likely that it is native to the Mariana Islands. Only two specimens of this species were reported prior to this (2008) work; one was collected on Mt. Lasu in 1946 by H. K. Townes (Wiles *et al.* 1989; see also Townes 1946), and the second by Haldre Rogers on southern Tinian (Carolinas Plateau) 12 Aug 2003 (USNM 561148). Scott R. Vogt (US Navy) reported a recent (February 2007) sighting in the vicinity of Mt. Lasu. McCoid and Hensley (1993, 1994a, b) provided useful natural history data from elsewhere in the Marianas.

This study (2008) – A single specimen was taken from a limestone forest total removal plot on Mt. Lasu. No others were seen or trapped.

Management recommendations – Based on the few specimens recently detected in the Mariana Islands (Cocos Island, Rota Island, Saipan Island), and the suggestion by Pregill (1998) that the prehistorically common *Perochirus* tends to be displaced by introduced *Gehyra oceanica*, it seems prudent to consider the endemic Micronesian Gecko to be at risk from the introduced *Gehyra*. Due to the large number of islands on which *Perochirus ateles* occurs naturally in Micronesia, it would appear to be less threatened with global extinction than is the more narrowly endemic *Emoia slevini*, and the prospect for retaining this species on Tinian is much greater in that it still occurs there, albeit in extreme rarity. Surviving populations in the southern Marianas appear to be largely limited to limestone forest, or at least habitats with large diameter perches (McCoid and Hensley 1994a). Where it is common (Buden 2007), the Micronesian Gecko is found in a diversity of habitats, including edificarian habitats as well as native forest, suggesting that the negative pressures against it in the Marianas are currently more forceful in secondary habitats. In the absence of information on what those forces might be it is difficult to ascertain whether reduction in those forces is practical, or whether preservation of the Mariana populations will hinge on maintaining the native forest habitats where the causes of endangerment apply with less force. One conundrum associated with this species' endangerment in the Marianas is that if it is endangered due to predation or competition by *G. oceanica*, why is it most common in the habitats (esp. limestone forest) where the Oceanic Gecko is most common (see species account for Oceanic Gecko)? This suggests that other hypotheses for its rarity should be evaluated. Sabath (1981) reported that Micronesian Geckos were present only in limestone forest in Guam in 1969, but events since this observation underscore the vulnerability of this species, as it is now extirpated from Guam (Rodda and Fritts 1992). In addition to protecting this species by preventing new species introductions and retaining or restoring native limestone forest, research into the ecology of this species would be useful in understanding its habitat requirements. The Micronesian Gecko is yet common in a variety of habitats in the Caroline Islands (Buden 2007), providing practical opportunities for its study.

Brahminy Blindsnake, *Ramphotyphlops braminus*

Body length: 59 – 151 mm   Mass: 0.1 – 1.2 g

Previous studies – Pregill (1998) found the blind snake to be present in the Mariana Islands since at least early prehuman times; thus is unquestionably native. A variety of reports document its presence on Tinian (Cagle 1946c, Downs 1948, Wiles *et al.* 1989), but none has endeavored to establish its distribution or abundance on Tinian.

This study (2008) – We found *Ramphotyphlops braminus* in both mixed and limestone forest total removal plots, but we did not actively search for it in any sites and the total removal method is poorly suited to detection of this species. Elsewhere in the Marianas we have found this species in *Leucaena* forest among many other habitats. We have no reason to believe that it is not common throughout military lease lands on Tinian.

Management recommendations – This parthenogenetic snake presently has a pan-tropical distribution, probably due to the ability of single individuals (they are all females) to found a new population, and the propensity of this species to stow-away in plants, soil, and other protective materials. No biodiversity concerns have been suggested regarding this species.

Potentially native species

Indo-Pacific House Gecko, *Hemidactylus frenatus*

Body length: 20 – 59 mm Mass: 0.1 – 3.9 g

Figure 12. The Indo-Pacific House Gecko, *Hemidactylus frenatus*.

Previous studies – The Indo-Pacific House Gecko (*Hemidactylus frenatus*) may be a complex of several species (N. Arnold, 2007 pers. comm.; A. Bauer 2007 pers. comm.), but as presently recognized it is one of the world's most widespread geckos, introduced throughout the New and Old World tropics and sub-tropics. For this reason, many authors assume that this species was carried to Oceania only through human agency, but Pregill (1998) found it in prehistoric strata that predate the arrival of all other introduced vertebrates, including rats. Thus it may be native to the western part of Micronesia, though evidence from eastern Micronesia suggests it was a human introduction there and in Polynesian sites further east (Pregill 1998). It was the first gecko studied on Tinian (during World War II: Cagle 1946a, b). Although more abundant and conspicuous in the *Leucaena* forests that make up much of the military lease lands on Tinian, it has been recorded in virtually all forest and edificarian environments (Wiles *et al.* 1989).

This study (2008) – We found this species to be the most abundant and conspicuous gecko in *Leucaena* forests (Tables 8, 10-12), but it was not found in our total removal plots in other habitats on Tinian (Tables 11, 12). Based on samples of the other habitats on nearby islands (Figure 13), however, it can survive in relatively low numbers in such habitats. It is possible that the other habitats have some as yet unrecognized limitation that prevents the house gecko from occurring in them on Tinian, but it is as least as plausible that we would have detected it in such sites on Tinian if our sampling had been more extensive. The pattern of densities in the Mariana Islands suggests that the Indo-Pacific House Gecko prefers drier, more disturbed habitats, such as *Leucaena* forest, but the gecko's absence from this habitat on Saipan (the island most similar in ecology to Tinian) has not been explained.

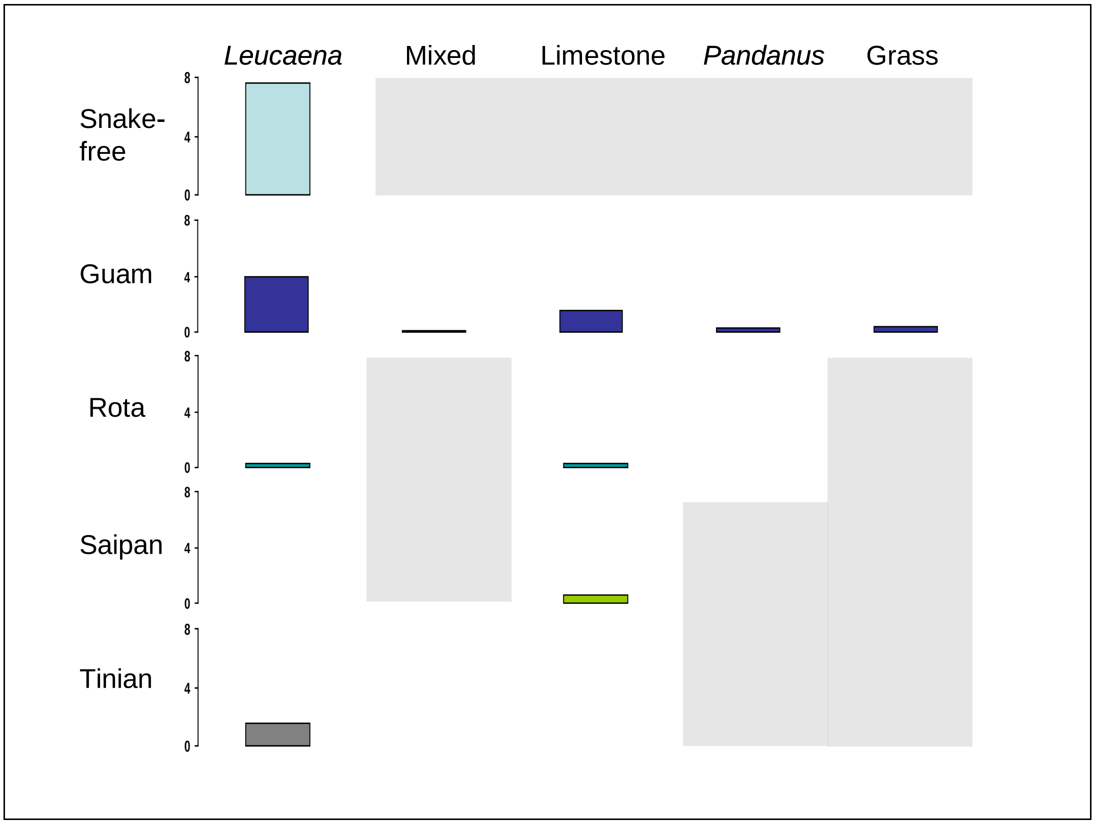

Figure 13. Patterns of abundance of *Hemidactylus frenatus*, as deduced from 40 total removal plots (each 10 x 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6.

The record of missed ratios of the Indo-Pacific House Gecko (Table 14) is sparse, but suggests that the species, like the Mourning Gecko (Table 13), reacts strongly to the presence of Brown Treesnakes, becoming much harder to detect where the snakes are present. Compare the low missed ratio in Brown Treesnake-free *Leucaena* habitat of Guam (174) and Tinian (259) to the much higher values obtained in snake-occupied parts of Guam (2383 and 1151). The mean missed ratio for house geckos in *Leucaena* habitat on Tinian (259) combined with the mean detection rate of 3.70 indicates a probable mean absolute density of around 958/ha for this species in that habitat on Tinian. This comports very well with the mean of 1000/ha indicated by the total removal plots (Table 11), suggesting that the *Leucaena* total removal plots were well representative of that habitat on Tinian.

Table 14. Patterns of visual missed ratios of *Hemidactylus frenatus* in the Mariana Islands. The layout and sample sizes of this table follows those of Figs 6, 9. The value expressed is the mean ratio of absolute density assessed in total removal plots to number

of detections per hour in visual searches of adjacent vegetation. Higher values therefore indicate lower detectability and a higher number of animals overlooked. "Undefined" indicates a mean value of zero in the numerator (total removals = 0) or denominator (no visual detections). We expect higher values in habitats with low visual penetration (limestone forest, *Pandanus*, grass).

Island	*Leucaena*	Mixed	Limestone	*Pandanus*	Grass
Snake-free	174				
Guam	2383	Undefined	1151	Undefined	Undefined
Rota	Undefined		Undefined	Undefined	
Saipan	Undefined		Undefined		
Tinian	259	Undefined	Undefined		

See the discussion of density changes of *Lepidodactylus* and *Hemidactylus* from 1989 to 2008 on Tinian in the *Lepidodactylus* species account.

Management recommendations – This increasing pan-tropical species presents no obvious biodiversity concerns, unless the nominal species turns out to be composed of a variety of species, some of which are rare. The form in the Marianas appears to be of a widespread genotype however (Moritz *et al.* 1993).

Pacific Slender-toed Gecko, *Nactus pelagicus*

Body length: 23 – 68 mm Mass: 0.1 – 7.0 g

Figure 14. The Pacific Slender-toed Gecko, *Nactus pelagicus*.

Previous studies – *Nactus pelagicus* is widespread in the northwestern Pacific, apparently derived from a species complex in Melanesia (Zug and Moon 1995). As an all-female species (parthenogenetic), it would be an excellent candidate for natural dispersal. However, the uniformity of this species in Micronesia suggests an evolutionarily recent and human-aided dispersal. Pregill (1998) found some prehistoric but no prehuman remains; thus there remains some question as to whether this species was introduced by prehistoric settlers. There is only one recorded specimen of this species from Tinian: collected at a "forested" site in 1924 (Wiles *et al.* 1989).

This study (2008) – We did not record this species. Given the dearth of terrestrial lizard biomass on Tinian (see Table 12 and Figs 2, 6, 17), and the apparent vulnerability of this semi-terrestrial species to introduced shrews (Rodda 1992, Rodda and Fritts 1992, Fritts and Rodda 1998), it seems probable that it was eliminated from Tinian by the introduction of the Musk Shrew (*Suncus murinus*).

Management recommendations – Should the shrew be eradicated from Tinian, it would be prudent to take advantage of this event to recover this species on Tinian. However, the nominal species is globally widespread (Zug and Moon 1995) and the species is not at risk of endangerment.

Introduced species

Green Anole, *Anolis carolinensis*

Body length: 24 – 73 mm   Mass: 0.2 – 9.2 g

Figure 15. The Green Anole, *Anolis carolinensis*.

Previous studies – The current *Anolis carolinensis* population on Tinian is believed to date from the late 1990s, when it was found only very near the port (G. Perry 1998 pers. comm.). It was not found during extensive surveys around San Jose 1984-1985 by Wiles *et al.* (1989) or in 1989 by us (Tables 1, 3, 7, 9). However Mayer and Lazell (1992) reported that it had colonized San Jose in 1978. If that colonization persisted into the present, it must have been exceedingly rare during the studies of the late 1980s and early and mid 1990s.

This study (2008) – We did not systematically study the abundance of this lizard around San Jose, but it was conspicuously common there during our stay. John Gourley (2008 pers. comm.) reported it to be very abundant in *Sanseveria* thickets south of the airport in 2008. We found it to be very numerous along 8th Avenue opposite the Voice of America facility and along the adjacent road to the summit of Mt. Lasu (Table 10). We detected it in the total removal plot part way up that road, but did not detect it in the total removal plots at the summit of Mt. Lasu. This leads us to suspect that the population is yet patchy and is still expanding. Further monitoring of this population expansion is warranted. This species is the only diurnal arboreal insectivorous lizard on Tinian other than the introduced *Lamprolepis smaragdina*. It is not generally known to be a threat to native lizards, though Suzuki and Nagoshi (1999) reported that *Cryptoblepharus poecilopleurus nigropunctatus* was apparently disappearing from Hahajima (Ogasawara (= Bonin) Islands) in association with expansion there of the Green Anole colonization.

Management recommendations – Unless new information emerges to suggest an adverse interaction with native lizards, management action need not extend beyond monitoring the spread of this new invader.

Curious Skink, *Carlia ailanpalai*

Body Length: 21 – 67 mm   Mass: 0.1 – 7.2 g

Figure 16. The Curious Skink, *Carlia ailanpalai*.

Previous studies – This species was introduced to Saipan prior to 1964 (Wiles *et al.* 1989), but the date of introduction to Tinian is unknown. Owen (1974) observed a similar species on Tinian, but did not collect any, so the identity of Owen's sighting cannot be determined. *Carlia ailanpalai* was widespread and abundant on Tinian by the 1984-1985 sampling of Wiles *et al.* (1989), especially in *Leucaena* forests. Note that many earlier documents refer to this species in the Mariana Islands as *Carlia fusca*, a nearly identical species found in New Guinea. Zug (2004) clarified that the form found in the Mariana Islands is that found on the island of Manus, Papua New Guinea, *Carlia ailanpalai*, and introduced in the Marianas.

This study (2008) – In our total removal plots (Table 11) we found this species to be the most abundant terrestrial species in *Leucaena* forest (mean = 800/ha) and mixed forest (mean = 550/ha), but relatively rare in limestone forest (mean = 63/ha), although all terrestrial species were rare in limestone forest, constituting only 0.09 kg/ha (about 1% of lizard biomass: Table 12). Despite its absolute rarity in limestone forest (Table 11), *Carlia ailanpalai* was the commonest terrestrial lizard in that habitat, as no other terrestrial lizard species was detected in limestone forests. Thus it was relatively the most successful species among terrestrial lizard species in all habitats, but it was not absolutely very successful compared to how well this species does on other islands (Figure 17). The value given in Figure 17 for Rota is potentially misleading for this comparison, as the colonization by *Carlia ailanpalai* of Rota at the time of sampling included only one of three total removal plots in *Leucaena* (and none in other habitats). For occupied sites, the mean absolute density in *Leucaena* forests for the Curious Skink is lower on Tinian than all other sampled sites, and an order of magnitude lower (800/ha) than on snake-free sites in *Leucaena* habitat on Guam (mean 7950/ha). As noted above for the blue-tailed skink, the conspicuously low density of Curious Skinks on Tinian is most likely attributable to the very high density of shrews on Tinian (Wiewel *et al.* in press). The density of shrews is unlikely to fully explain the scarcity of Curious Skinks in all habitats on Tinian in that the shrew itself is less common (by a factor of about 2) in limestone forest than in *Leucaena* forest (means of 24.2/ha and 52.8/ha in limestone and *Leucaena* forest respectively on Tinian: Wiewel *et al.* in press). On Guam, where shrew densities were uniformly and immeasurably low in *Leucaena*, mixed, and limestone forest (Wiewel *et al.* in press), *Carlia ailanpalai* was appreciably more dense in *Leucaena* (5456/ha: Figure 17) than in mixed (1100/ha: Fig 17) or limestone forest (350/ha: Figure 17). Thus habitat differences appear to play a modulating role in addition to the depressing influence of predatory shrews and snakes.

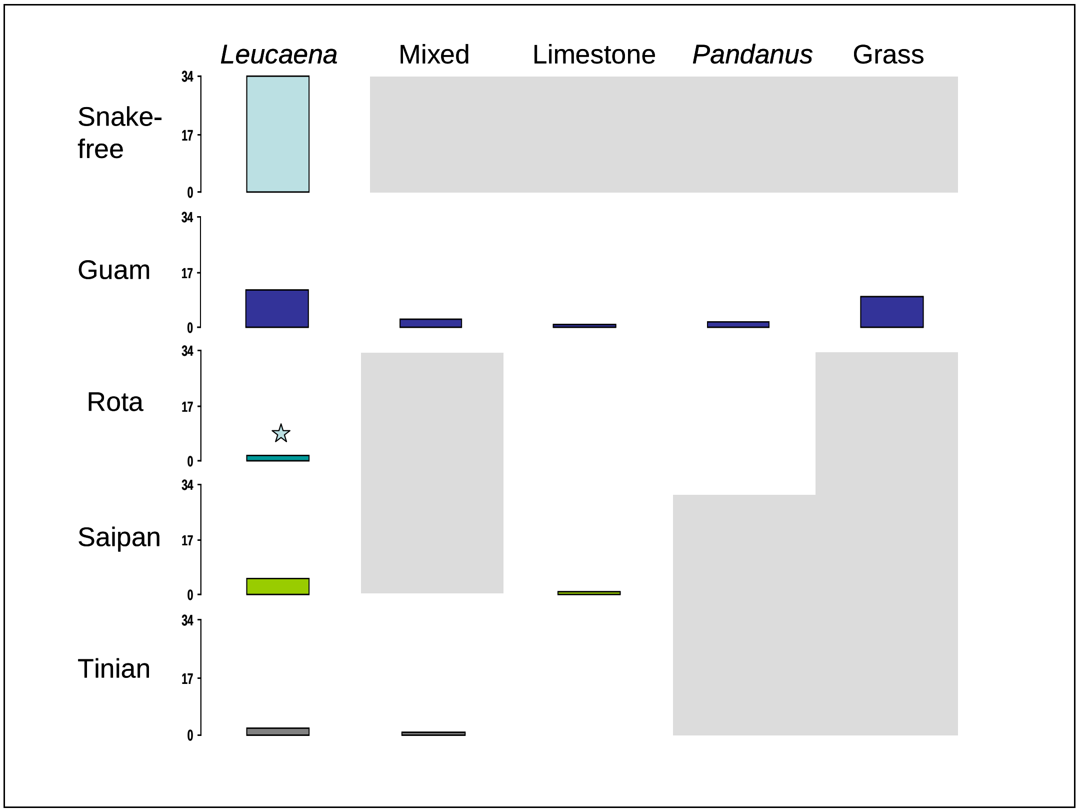

Figure 17. Patterns of abundance of *Carlia ailanpalai*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6. Although *Carlia ailanpalai* was known to be present on Rota at the time the Rota plots were sampled, the extent of colonization covered only one of the three *Leucaena* plots (star indicates bar of concern) and none of the others. In the one occupied *Leucaena* plot the biomass density was therefore three times (5.4 kg/ha) the mean shown, though this higher value may reflect densities prior to achievement of a population density equilibrium.

Missed ratios of *Carlia ailanpalai* (on traps) did not show an obvious pattern (Table 15), though the lower values on Tinian suggest trap capture may be relatively better there. To better understand the influences on detectability of Curious Skinks we built a general linear model on single plot values (not the means shown in Table 15) considering snake presence, island, density, and habitat. Density and detectability were natural log transformed to obtain normal distributions. Unfortunately, several of these variables were partially confounded, but none was found to be associated with ln(detectability) except ln(density), which had a highly significant relationship ($P < 0.0001$), with a slope of 0.454. The positive slope between the missed ratios given in Table 15 and the density shown in Figure 17 implies an inverse relationship between detectability and density. At higher densities, Curious Skinks are less trappable (see Rodda *et al.* 2005b for a comparable result). One plausible explanation is that at high densities subordinate animals are cowed into reduced activity. Another possibility is that at higher densities a skink that might otherwise run onto a glueboard is more likely to be warned of the glueboard's hazards by the struggling or presence of a previously-caught individual. Whatever the cause, the inverse relationship between density and detectability complicates the interpretation of glueboard capture rates, as there would not be a proportional correspondence between the density of the lizard and the trap capture rate. This lack of correspondence limits the utility of an index in novel situations, but does not greatly impact our use of Tinian missed ratio estimates, which are venue-specific.

Taking the observed Tinian mean missed ratios by habitat in Table 15 and the observed mean capture rates in Table 8 we compute estimated mean densities for the three habitat types of 906/ha (*Leucaena*), 672/ha (mixed), and 192/ha (limestone forest). These are reasonably congruent with the total removal plot means of 800/ha, 550/ha, and 63/ha, respectively. This suggests that our total removal plots were reasonably representative of the habitats sampled.

Table 15. Patterns of trap missed ratios of *Carlia ailanpalai* in the Mariana Islands. The layout and sample sizes of this table follows those of Figs 6, 9. The value expressed is the mean ratio of absolute density assessed in total removal plots to number of detections per trap-hour in 3 morning-h glueboard samples of adjacent vegetation. Higher values therefore indicate lower detectability and a higher number of untrapped individuals. "Undefined" indicates a mean value of zero in the numerator (total removals = 0) or denominator (no trap detections).

Island	*Leucaena*	Mixed	Limestone	*Pandanus*	Grass
Snake-free	4336				
Guam	6766	3960	1883	1008	5595
Rota	1231		Undefined	Undefined	
Saipan	2719		6300		
Tinian	1650	1342	900		

Management recommendations – Where Curious Skinks reach high densities they have been suspected of displacing native lizards through predation or competition (Vogt and Williams 2004). It is imaginable that they provide a dietary subsidy for predators such as shrews, leading to greater pressure on alternate prey, an example of "apparent competition." However, Curious Skinks have such low densities on Tinian at present that such negative impacts are unlikely to be a major problem. Periodic monitoring should suffice to assess whether Curious Skinks remain at low density. At a landscape level it may be difficult to manipulate the density of this species, but retention or restoration of limestone forest would appear to be an effective measure (Figure 17).

Mutilating Gecko, *Gehyra mutilata*

Body length: 19 – 56 mm   Mass: 0.1 – 4.3 g

Figure 18. The Mutilating Gecko, *Gehyra mutilata*.

Previous studies – Pregill (1998) established that this species was introduced to Tinian about 500 years ago. Wiles *et al.* (1989) found it to be reasonably common in the Military Lease Area and to have a patchy distribution ("widely dispersed locations") on Tinian.

This study (2008) – We found this species present in moderate numbers in all habitats studied, but the distribution was patchy in *Leucaena* habitat. For example, we found it in one of two *Leucaena*-habitat total removal plots (Table 11), and three of six *Leucaena*-habitat visual surveys (Table 10). It was found in all total removal plots and visual surveys in the other habitats. In all sites it was less numerous and represented less biomass than the Mourning Gecko, *Lepidodactylus lugubris*, but it was nowhere rare. As a proportion of the total lizard biomass (Table 12), it represented 8.5%, 24%, and 9.6% in *Leucaena*, mixed, and limestone forests respectively. This suggests that it does relatively best in mixed forest (Figure 19), which is also the habitat type in which it had the highest mean sighting rate (Table 10).

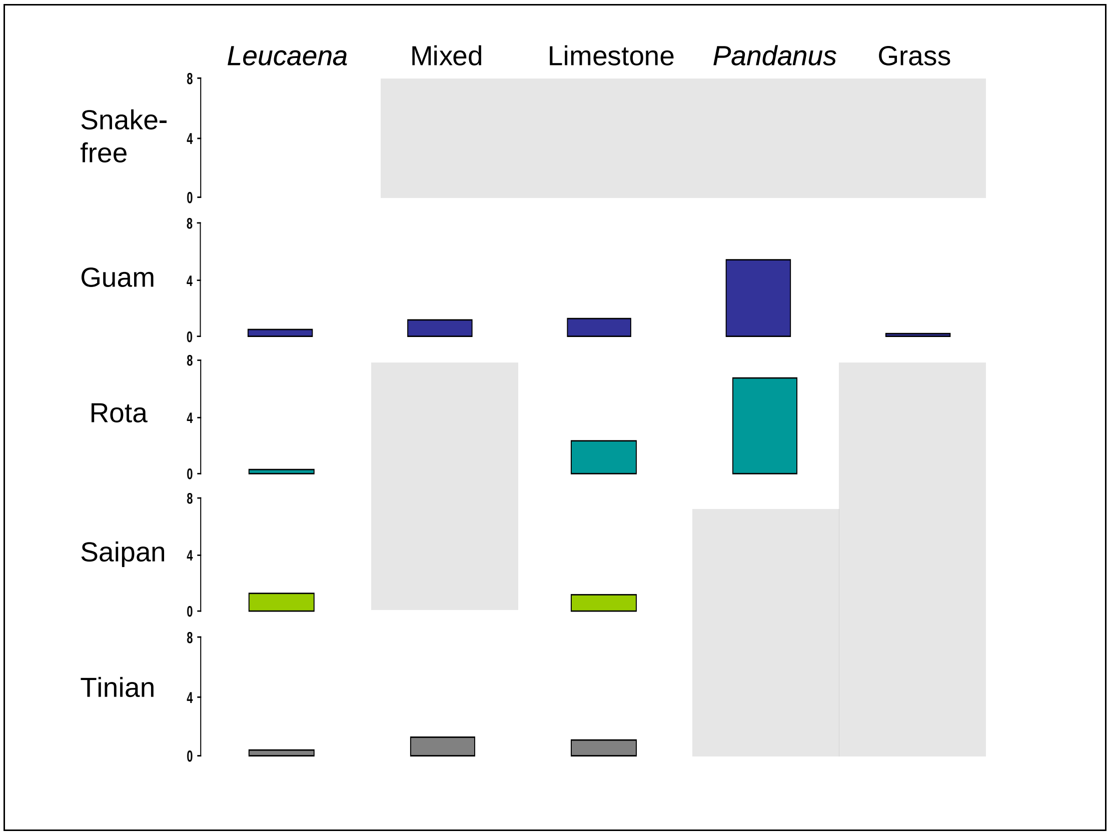

Figure 19. Patterns of abundance of *Gehyra mutilata*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6.

Gehyra mutilata is relatively difficult to see in limestone forest and *Pandanus* habitat (high values: Table 16). Although those habitats are visually obstructed, and therefore expected to have higher values than those for *Leucaena* or mixed habitats, the absolute magnitude of the missed ratios for this species (Table 16) are noticeably higher than those for *Hemidactylus frenatus*, a similar-size gecko species that relies to a similar degree on larger diameter perches (Table 14: visual missed ratio 1511 in limestone forest, compared to 14516 for *G. mutilata*).

Taking our Tinian habitat-specific missed ratios (Table 16) and mean visual detection rates for this species (Table 10), we estimate mean densities of 211/ha, 852/ha, and 813/ha for *Leucaena*, mixed, and limestone forest respectively. These estimates comport well with the corresponding total removal estimates of 200/ha, 800/ha, and 813/ha, and suggest that our total removal plots were representative of their habitats for this species.

Table 16. Patterns of visual missed ratios of *Gehyra mutilata* in the Mariana Islands. The layout and sample sizes of this table follows those of Figs 6, 9. The value expressed is the mean ratio of absolute density assessed in total removal plots to number of detections per hour in visual searches of adjacent vegetation. Higher values therefore indicate lower detectability and more overlooked individuals. “Undefined” indicates a

mean value of zero in the numerator (total removals = 0) or denominator (no visual detections). We expect higher missed ratio values in habitats with low visual penetration (limestone forest, *Pandanus*, grass).

Island	*Leucaena*	Mixed	Limestone	*Pandanus*	Grass
Snake-free	Undefined				
Guam	Undefined	1686	14516	10303	Undefined
Rota	Undefined		Undefined	Undefined	
Saipan	Undefined		Undefined		
Tinian	370	896	2390		

Management recommendations – Although this introduced gecko has the potential to eat smaller native geckos (i.e., *Lepidodactylus lugubris* or juveniles of other species), and to compete with similar-sized lizards, we see no evidence that it is having an adverse impact on Tinian. This conclusion should be re-evaluated in light of new findings when they become available.

Oceanic Gecko, *Gehyra oceanica*

Body length: 29 – 86 mm   Mass: 0.7 – 14.2 g

Figure 20. The Oceanic Gecko, *Gehyra oceanica*.

Previous studies – Pregill (1998) determined that this species was introduced to Tinian about 500 years ago, and suggested that it may have negatively influenced the survival of the native gecko *Perochirus ateles.* Downs (1948) and Wiles *et al.* (1989) collected this species, with the latter declaring it to be common and widespread, with records in all forested habitats. This conclusion was consistent with our 1989 surveys of Tinian (Tables 7, 9).

This study (2008) – Although we obtained visual sightings of this species in all habitat types (Table 10), *Gehyra oceanica* was rarely found on small diameter perches, and we did not record it in either *Leucaena* or mixed forest total removal plots (Table 11). In our limestone forest plots it constituted about half (52%) of lizard biomass, a fraction over twice that of *Lamprolepis smaragdina*, the species with the next highest biomass. The preference for limestone or *Pandanus* forest is evident on all snake-free islands of the Marianas (Figure 21). This species' absence from Guam (it persists only locally in one suburban area of Guam) is presumably related to vulnerability to Brown Treesnakes (Rodda and Fritts 1992). Given this species' predilection for large diameter trees, we were surprised at the absence of individuals on large diameter trees in the middle of north Broadway (BRN6: Table 10). However, it was missing from the several searches of trees on Broadway in 1989 also (Table 9). Perhaps the isolated trees of Broadway are too dry an environment for this moisture-favoring species (Figure 21).

We have too few data comparing visual sighting rates to total removal yields for a meaningful analysis of missed ratios.

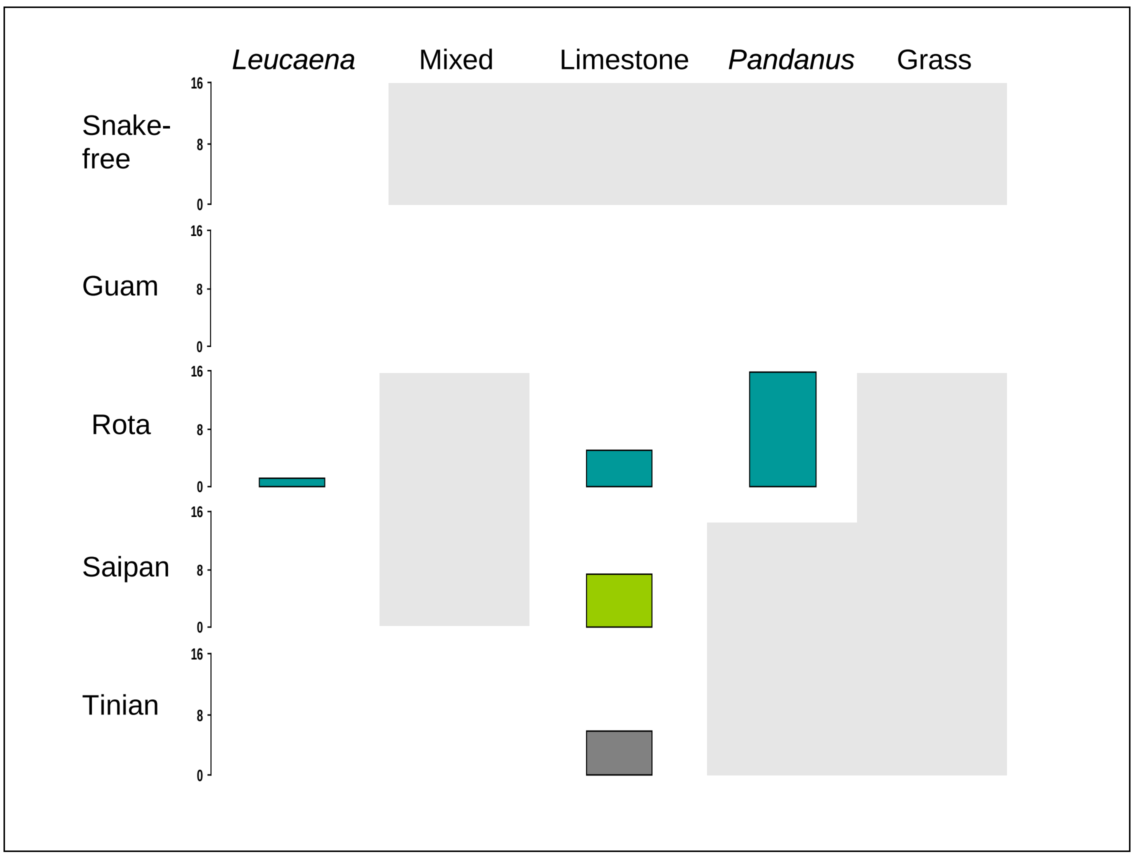

Figure 21. Patterns of abundance of *Gehyra oceanica*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6. Although *Gehyra oceanica* was known to be present on Guam throughout the

period when these Guam total removal plots were sampled, it was not known to be present in the vicinity of the sampled plots.

Management recommendations – Because this species is non-native and potentially hazardous to native geckos such as the Micronesian Gecko, *Perochirus ateles*, conservation of this species is neither necessary nor desirable. However, its high sensitivity to Brown Treesnake presence may allow it to be an early indicator of the presence of Brown Treesnake populations, and any dramatic declines in this species ought to be investigated as potential evidence of Brown Treesnake colonization.

Emerald Skink, *Lamprolepis smaragdina*

Body length: 60 – 110 mm   Mass: 5.0 – 26.8 g

Figure 22. The Emerald Skink, *Lamprolepis smaragdina*.

Previous studies – The first definite record of this highly conspicuous species in the Mariana Islands is from the island of Saipan in 1978 (Wiles and Guerrero 1996). Owen (1974) did not see it on Tinian in 1974, and it is presumed to have reached Tinian from Saipan. Wiles *et al.* (1989) observed it only in south-central Tinian in 1984-1985. With one exception all of their records were near San Jose village, and they commented that it "does not appear to have spread islandwide." Wiles *et al.* (1989) found it primarily in *Leucaena* or secondary habitat, but within that habitat type they found it almost exclusively on flame trees (*Delonix regia*). We found it on Tinian in 1989 (Table 9) in areas that Wiles *et al.* (1989) had observed it, as well as at the southern end of the Carolinas Plateau (site SCRH). We did not find it in native forest in 1989, but we did observe it in a diversity of habitats, including the cliffside vegetation at the Korean Memorial (Table 9). Thus it may have spread somewhat in the 4-5 y between the Wiles *et al.* (1989) study and ours. However, the difference might also be attributable to differential sampling. Perry and Buden (1999) observed this species in a variety of sites in southern Tinian, but did not endeavor to map its distribution.

This study (2008) –We found this species at all sampled locations except North Field (Tables 10-12, Fig 23). Notably, observations included all habitat types including limestone forest (Tables 10-12). The absence from North Field (2MOR, B29W, B29R, ABSW, ABLE, BRAV, DELT) is striking because that region is almost exclusively *Leucaena* habitat (only 2MOR is mixed), which Wiles *et al.* (1989) identified as the primary habitat of this species. Therefore, it seems probable that its absence from North Field is a temporary condition attributable to lack of dispersal to that locality. Note that the Emerald Skink was found in the *Leucaena* total removal plots we conducted on Saipan (Figure 23), but not on Tinian, as our *Leucaena* plots on Tinian were all north of apparently-occupied habitat. We predict that future surveys will eventually find it around North Field as well as suitable habitat to the north of the runway complex.

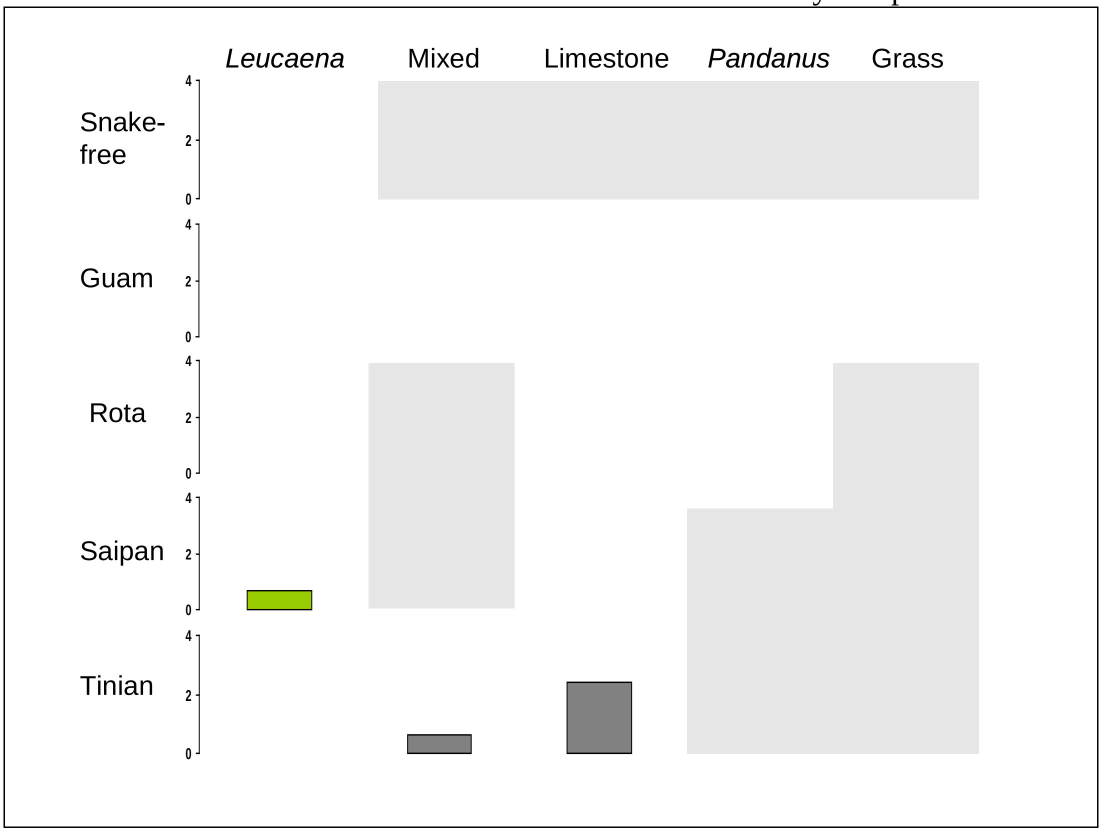

Figure 23. Patterns of abundance of *Lamprolepis smaragdina*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6. *Lamprolepis smaragdina* was not known to occupy either Guam or Rota at the time of sampling.

Management recommendations – This species is capable of consuming smaller lizards (Perry and Buden 1999). The smaller day-active native species of concern include *Emoia caeruleocauda*, *Emoia slevini*, and *Cryptoblepharus poecilopleurus*. Of those species, none is primarily arboreal (although *Cryptoblepharus* is locally arboreal), and the Emerald Skink is almost exclusively so (Brown and Alcala 1980, Buden 1995, Buden 1996a, 1996b, Perry and Buden 1999). Therefore it seems unlikely that the predatory impact of this large skink, if any, will be significantly detrimental to the continued survival of any native species. Nonetheless, the recorded presence of *Cryptoblepharus poecilopleurus* at B29W, a non-littoral *Leucaena* site north of the known distribution of the Emerald Skink is notable in that the Snake-eyed Skink's absence further south may reflect predation by the Emerald Skink. Perry and Buden (1999) found that Emerald Skinks on Tinian usually (67%) perched head down with an abnormally low mean perch height (0.89 m); thus they would be in a physical position to capture the much smaller semi-arboreal Snake-eyed Skink. Future monitoring should take note of the geographic, habitat, and microhabitat occupancies of these two species.

Mangrove Monitor, *Varanus indicus*

Body length: 99 - 540 mm   Mass: 10 – 3650 g

Figure 24. The Mangrove Monitor, *Varanus indicus*.

Previous studies – Pregill (1998) established that monitor lizards on Tinian were likely introduced during the western period (less than 500 years ago); the earliest written observation was by De la Corte (mid 1800s: Wiles *et al.* 1989). Although apparently rare prior to the 1950s (Wiles *et al.* 1989), monitor lizards were documented but not quantified by all observers since Owen (1974). Wiles *et al.* (1989) commented that they were "seen most often in tangantangan [=*Leucaena*] forest and weedy fields and openings."

This study (2008) – Removal plots and glueboards are of low utility for this species. Instead, Scott Vogt (Navy) monitored this species. We saw monitor lizards opportunistically, including in limestone forest.

Management recommendations – Given the non-native status of this species, we see no need to be concerned for its conservation. Although potentially detrimental to smaller native species, we are aware of little evidence suggesting a significant impact.

Cane Toad, *Rhinella marina*

Body length: 23 – 130 mm   Mass: 1.0 – 224.0 g

Figure 25. The Cane Toad, *Rhinella marina*.

Previous studies – Prior to Chaparro *et al.* (2007) the species now known as *Rhinella marina* was termed *Chaunus marinus* and before Frost *et al.* (2006) it was known as *Bufo marinus*. Frost now accepts *Rhinella* and it is under that name that it appears in Amphibian Species of the World 5.2 (http://research.amnh.org/herpetology/amphibia/references.php?id=4034). Under any scientific name it is most commonly called the Marine or Cane Toad. The Cane Toad was introduced to Guam in 1937 (Anon. 1940, Easteal 1981) and introduced from there to Tinian prior to 1944, presumably during World War II (Stohler and Cooling 1945, Townes 1946, Downs 1948). Subsequently it was observed islandwide (e.g., Owen 1974), especially in proximity to standing water. Wiles *et al.* (1989) found it in all habitats of the Military Lease Area.

This study (2008) – We casually observed it crossing roads throughout the island, but did not quantify its abundance except in total removal plots (Figure 26), where it was found in mixed and limestone forested plots. Its absence from the *Leucaena* forest plots is probably coincidental, as the toads congregate in moist areas, and moist areas may have been missing by chance from our two *Leucaena*-forest plots. Figure 26 shows this species' widespread but irregular distribution in the Mariana Islands. The lack of regularity in the total removal results no doubt at least partially reflects proximity to water, which was neither controlled for nor quantified in the selection of plots.

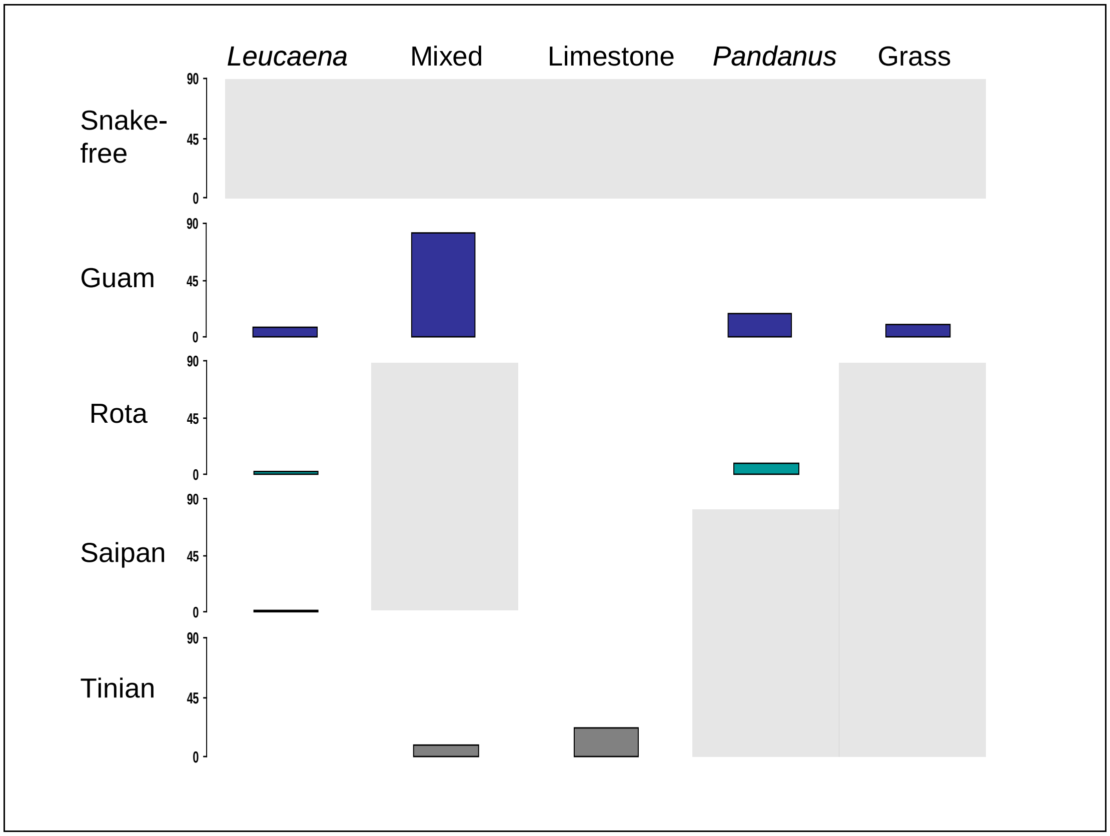

Figure 26. Patterns of abundance of *Rhinella marina*, as deduced from 40 total removal plots (each 10 × 10 m) on the four large Mariana Islands. Symbols and sample sizes as in Figure 6. *Rhinella marina* had been intentionally extirpated from the snake-free plots at the time of sampling, and is therefore grayed-out, though it was present in substantial numbers in the immediate vicinity.

Management recommendations – This recently introduced species is generally viewed as detrimental to native amphibians and predators that attempt to eat the poisonous toads, of which there are none on Tinian. No special management is necessary or desirable for this species' conservation, but reduction in its numbers would be desirable. At this time there are no methods for control of this toad that would be easily applicable to Tinian, but consideration should be given to invoking new control measures should they become available.

Overarching management recommendations

Avoid introducing new species of any type – The greatest threat to the extant herpetofauna of Tinian is likely to come from newly introduced mammalian, avian, or reptilian predators. Biosecurity measures to prevent new colonizations by either inadvertent (i.e., stowaway) or intentional pathways (e.g., release of pets by service personnel) should be the highest priority for conservation of reptiles and amphibians on Tinian.

Conserve and promote native forest habitats – Although the Marianas' rare native lizards (esp. *Perochirus ateles* and *Emoia slevini*) can thrive in all types of habitat under natural conditions, present conditions appear to favor their survival in native forest, especially limestone forest. Tinian's current depauperate native herpetofauna may reflect a long history of agricultural development, and restoration of these hard-pressed or extirpated natives may be compatible with the forest environments appropriate for military activities.

Monitor prey species of Brown Treesnake-control interest – Species that are key prey for Brown Treesnakes (shrews, rats, mice, anoles, and geckos) influence the efficacies of control tools for the snake (Rodda *et al.* 2001, Gragg *et al.* 2007). Periodic monitoring of those species would facilitate effective selection of control tools should the snake arrive on Tinian.

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2.3.2 REPTILES AND AMPHIBIANS OF AGUIGUAN

The Mutilating Gecko (*Gehyra mutilate*)
Photo courtesy of USGS, BRD

Pacific Blue-tailed Skink (*Emoia caeruleocauda*)
Photo courtesy of USGS, BRD

Prepared by: Gordon H. Rodda, Robert N. Reed, and James W. Stanford; U.S. Geological Survey, Biological Resources Disicpline, Fort Collins Science Center, Fort Collins, CO.

INTRODUCTION

Note: Refer to Section 2.3.1, the Reptiles and Amphibians of Tinian, for a general introduction to the rationale for this work, and a more detailed description of the methods used.

Aguiguan Island (or Aguijan Island as it is spelled on USGS maps; the island is also popularly referred to as Goat Island, in reflection of the high density of these introduced ungulates) is a relatively small (720 ha) island lying off the south coast of Tinian. It is a “high” island, with raised limestone terraces and cliffs on all sides. Because it has no beaches or protected anchorages, it can be impossible to land or leave in windy conditions and thus is uninhabited. Nonetheless, it has been the subject of several biological inventory expeditions in the last two decades, and for its size is better known herpetologically than many larger islands such as Tinian. Particularly noteworthy are the visits of Davis (1954), Campbell (1995), Cruz *et al.* (2000), and Esselstyn *et al.* (2003). An enduring element of herpetological interest has been the high densities of monitor lizards found on Aguiguan, which we did not survey in our work; Scott Vogt (U.S. Navy) conducted concurrent surveys of monitor lizards. The other two conspicuous elements of the fauna are the apparent high densities of introduced rats (*Rattus exulans*) and goats (*Capra hircus*). Population densities of rats are covered in the accompanying report (Yackel Adams *et al.* 2009), though the visual surveys for nocturnal reptiles reported in this paper also tracked rat sightings and relevant sighting data are included herein. We recorded no data on goat distribution or abundance, but note here that a high goat density on “Goat” Island is responsible for very open understory vegetation, which greatly enhances sight lines. Thus lizard sighting rates on “Goat” are elevated in comparison to sighting rates on Tinian or the other major islands of the Mariana archipelago.

Our objective in this study was to conduct a modest number of spot searches, to see if any major components of the non-varanid herpetofauna had been overlooked. Although Aguiguan is herpetologically well known for its size, there were a number of species expected to be present that had not been documented; we targeted these species rather than attempting to verify the distribution or status of known resident species. We also added a small body of data on search per unit effort, but we did not stratify sampling by habitat type nor attempt absolute population density estimation as was performed on Tinian.

MATERIALS AND METHODS

See Rodda *et al.* (2009) for detailed methods; of the methods in that report we utilized glueboard sampling (Table 1, a total of 1420.05 trap-hours) and visual searches (Table 2, total of 12.74 search-hours). Most of the surveys were conducted along the indicated bird transects (see Esselstyn *et al.* 2003 for GPS coordinates), with no attempt to delineate geographic or habitat distribution of species within the island. We assume that the island is small enough that any suitable habitat will be occupied throughout the island. Our sampling was concentrated on the west end of the island; if there are any species limited to the eastern end, we would not have encountered them.

Table 1. Glueboard sampling of Aguiguan Island, 2008.

End Date	Transect	Time of day	Elapsed (h)	Target	Traps	Trap-h	Lizard captures
20-Jul-08	A4	0800-1110	3.15	Skinks	12	37.8	2
20-Jul-08	A4	2000-0715	11.25	Geckos	11	123.75	3
22-Jul-08	A2	0845-1145	3	Skinks	13	39	0
22-Jul-08	A2	0850-1150	3	Skinks	12	36	6
23-Jul-08	A4	1930-0816	12.5	*Nactus*	12	150	0
24-Jul-08	A2	2000-0730	11.5	Geckos	12	138	0
24-Jul-08	A4	2000-0630	10.5	*Nactus*	12	126	0
24-Jul-08	A5	1740-0640	13	Geckos	12	156	5
26-Jul-08	Second camp	1111-1011	23	*Crypto-blepharus*	12	276	6
27-Jul-08	Second camp	1125-1425	3	*Crypto-blepharus*	12	36	6
30-Jul-08	W end of plateau	1300-1000	21	Geckos	12	252	3
31-Jul-08	Orig. helispot	1430-0700	16.5	Green lizards	3	49.5	2

Table 2. Nighttime visual surveys of Aguiguan Island, 2008.

Date	Transect	Time of day	Search-hours	Lizard detections
19-Jul-08	Camp Trail and A4	1955-2110	1.25	13
21-Jul-08	A4	1952-2107	1.25	3
21-Jul-08	A4	1854-2000	1.06	33
22-Jul-08	A2	2023-2218	1.92	11
22-Jul-08	A2	2024-2219	1.92	15
23-Jul-08	A4	2021-2123	1.03	5
23-Jul-08	A4	2021-2123	1.03	3
23-Jul-08	A5	1932-2032	1	2
25-Jul-08	A2	1900-2003	1.03	3
30-Jul-08	A4 and Camp Trail	1915-2030	1.25	5

RESULTS

Glueboard sampling. – Mean glueboard rates (captures per trap-h) were computed on the basis of nighttime trap-h only for nocturnal species and daytime trap-h only for diurnal species. Geckos: *Hemidactylus frenatus*: 0.0066; *Gehyra mutilata*: 0.0197; and *Gehyra oceanica*: 0.0033. Skinks: *Emoia caeruleocauda*: 0.0134; and *Cryptoblepharus poecilopleurus*: 0.0081.

Visual sightings. – Ten sightings were sufficiently fleeting that the species of gecko was not determined. Of the 88 sightings for which the species could be unequivocally determined, the gehyras were the most often seen: *Gehyra mutilata*: 2.98/search-h and *Gehyra oceanica*: 3.45/search-h. The two smaller geckos were infrequently seen: *Lepidodactylus lugubris*: 0.157/search-h and *Hemidactylus frenatus*: 0.314/search-h.

SPECIES ACCOUNTS – see Tinian report (Rodda *et al.* 2009) for photographs and body sizes of each species.

NATIVE SPECIES

Oceanic Snake-eyed Skink, *Cryptoblepharus poecilopleurus*

Previous studies – This species was collected by Campbell (1995), Cruz *et al.* (2000) and Esselstyn *et al.* (2003), primarily along the coast (all three studies) and in the mouth of a cave (Campbell 1995).

This study – We collected a substantial number (9) on glueboards in the same general area where they had been previously documented. It is noteworthy that no observers have found this species any appreciable distance from the coastline, although it is not evident what habitat feature is directly responsible for this limitation, as they occur along the coastline in vegetation that appears similar in structure and species composition to sites not occupied further inland.

Littoral Skink, *Emoia atrocostata*

Previous studies – This species is strictly limited to the intertidal zone, and has been found on Aguiguan Island in that habitat by Campbell (1995) and Esselstyn *et al.* (2003).

This study – We did not sample the intertidal zone to confirm that this species remains present in that habitat on Aguiguan.

Pacific Blue-tailed Skink, *Emoia caeruleocauda*

Previous studies – Campbell (1995), Cruz *et al.* (2000), and Esselstyn (2003) found this species to be common throughout the island in a variety of habitats.

This study – Our mean glueboard capture rate for this species (0.0134) was the highest of any diurnal lizard and was similar to that recorded on Tinian, where it was found only in limestone forest, with a mean capture rate of 0.009 (see Rodda *et al.* 2009).

Mourning Gecko, *Lepidodactylus lugubris*

Previous studies – An unspecified number of this species was detected in native and introduced forest by Campbell (1995). Cruz *et al.* (2000) recorded one individual on a glueboard in introduced forest, and Esselstyn *et al.* (2003) did not document this species.

This study – We detected this species by visual searches only (mean sighting rate was 0.156, the lowest of the species seen). It is possible that additional individuals were seen too poorly for species identification (i.e., scored as unknown gecko), but we doubt that many such events transpired, as this species is relatively unwary and easy to identify. For comparison, the sighting rate on Tinian averaged 1.241 sightings/h in *Leucaena* forest and 0.340 sightings/h in limestone forest. Our searches on Aguiguan focused on limestone forest, so while the mean sighting rate was low, our sample size was modest and the detection rate was not beyond the range of values expected for this limestone forest habitat.

POTENTIALLY NATIVE SPECIES

Indo-Pacific House Gecko, *Hemidactylus frenatus*

Previous studies – Campbell (1995) reported the first detection of this species on Aguiguan. He found it only in introduced forest, as did Cruz *et al.* (2000), whereas Esselsyn *et al.* (2003) found it only in limestone forest.

This study – We found it in moderate numbers, by both visual surveys (0.314 detections/h) and glueboard surveys (0.0066 captures/trap-h). These detection rates are in line with those recorded on Tinian.

Pacific Slender-toed Gecko, *Nactus pelagicus*

Previous studies – This species has not been detected in historic times on Aguiguan, despite an abundance of apparently suitable habitat (On Guam it is restricted to relatively undisturbed limestone or ravine forest (Rodda and Fritts 1996), a habitat now reasonably abundant on Aguiguan). Pregill (1998) reported it present in prehistoric strata.

This study – We targeted this species in our searches (see Table 1) but failed to detect it. It may have gone undetected, it may have been extirpated prehistorically and not have recolonized Aguiguan in historic times (though it remained on or recolonized the islands to the north (Tinian, Alamagan, Anatahan, Sarigan) and to the south (Rota, Guam)), or it may be vulnerable to predation from the numerous introduced *Rattus exulans*.

INTRODUCED SPECIES

Curious Skink, *Carlia ailanpalai*

Previous studies – This species is ubiquitous on Tinian and Saipan, but has not previously been detected on Aguiguan.

This study – Although we did not specifically target this species, we sampled extensively in the places were it would be expected to be detected if it were present. We think that it is unlikely to have yet colonized Aguiguan.

Mutilating Gecko, *Gehyra mutilata*

Previous studies – Campbell (1995) first recorded this species on Aguiguan. Cruz *et al.* (2000) and Esselstyn *et al.* (2003) found it in moderate numbers.

This study – This species was the second-most commonly seen gecko (2.98 sightings/h) and the most frequently trapped gecko (0.0197 captures/trap-h). The reported sighting rate is undoubtedly an underestimate, as many of the unknown geckos were probably of this species, which is wary and hard to distinguish from juvenile Oceanic Geckos. The sighting rate for Aguiguan was higher than that reported for this species in any habitat on Tinian, though Tinian has relatively little good habitat for this species and Aguiguan has ample prime habitat.

Oceanic Gecko, *Gehyra oceanica*

Previous studies – Campbell (1995) noted this species presence in both limestone and introduced forest. Cruz *et al.* (2000) trapped it commonly, but Esselstyn (2003) did not trap it at all.

This study – We captured only one of this species on glueboards, but it was the commonest species detected in visual surveys (3.45 sightings/h) and it was extremely dense (subjectively up to $1/m^2$) on the walls in two of the caves we visited. As with its congener, this species probably accounts for some of the unknown geckos, as juveniles of this species are hard to distinguish from *G. mutilata*. However, the species is not particularly wary, and its habitat preferences greatly overlap those of *Nactus pelagicus*, which we targeted. This species elsewhere in the Mariana Islands is found to favor limestone forest as a habitat (Rodda *et al.* 2009). Thus our sighting rate on Aguiguan may overestimate its abundance throughout Aguiguan. Sighting rates on Tinian were substantially lower, and it was not detected by glueboards on Tinian. The failure of Esselstyn *et al.* (2003) to detect it on Aguiguan is likely related to that study's reliance on glueboard captures.

ANCILLARY OBSERVATIONS

Mangrove Monitor, *Varanus indicus*

Previous studies – Peterson (1954, cited in Davis 1954), Davis (1954), Campbell (1995), Cruz *et al.* (2000), and Esselstyn *et al.* (2003) have all provided useful data or observations on the conspicuous abundance of the monitor on Aguiguan Island.

This study – We saw many monitors during our sampling, but did not attempt to quantify their abundance. Refer to Section 2.3.3 Population Densities and Diet of Monitor Lizards on Aguiguan.

Brahminy Blindsnake, *Ramphotyphlops braminus*

Previous studies – This species has not been reported in modern times or historic subfossil strata from Aguiguan Island, but Pregill (1998) found it in prehistoric subfossil strata.

This study – We did not search for this subterranean species, because it cannot generally be obtained by digging (perhaps these burrowing animals can retreat in burrows faster than a human can expose them), and it is more easily and often found simply through opportunistic encounters under rocks or on the surface at night. On 13 July 2008 Ernie Valdez found one near Fault Line Cave 1 (344804 E 1643215 N) in exactly this manner during our visit. We preserved (BSFS 9363) and deposited it in the Bishop Museum.

Green Anole, *Anolis carolinensis*

Previous studies – This species has not previously been reported from Aguiguan Island, but it is common on the adjacent islands of Saipan and Tinian (Rodda *et al.* 2009).

This study – We did not trap or observe this species. The camp cook saw a small green lizard (which could have been this species or *Lamprolepis smaragdina*) near the helipad, and we looked and trapped there to target this species, but turned up no further evidence. It is likely to reach Aguiguan Island in cargo brought from either Tinian or Saipan.

Emerald Skink, *Lamprolepis smaragdina*

Previous studies – This species has not been previously been reported from Aguiguan Island, though it is common on the adjacent islands of Saipan and Tinian (Rodda *et al.* 2009).

This study – We did not trap or observe this species. The camp cook saw a small green lizard (which could have been this species or *Anolis carolinensis*) near the helipad, and we trapped there to target this species, but turned up no further evidence. It is likely to reach Aguiguan Island in cargo brought from either Tinian or Saipan.

Cane Toad, *Rhinella marina*

Previous studies – This species has not previously been reported from Aguiguan Island.

This study – We did not see this species while on Aguiguan. Although common on Tinian and Saipan, it requires standing water which is absent or exceedingly rare on Aguiguan.

DISCUSSION

With the exception of the Brahminy Blindsnake, this study did not detect any new modern populations or species for the island of Aguiguan, but provided some detection rates. We accumulated additional evidence that the Pelagic Gecko does not now occur there, though it did prehistorically. Aguiguan Island is relatively free of introduced reptiles except for the *Gehyra* species. For general conclusions regarding invasive species see the accompanying report on Tinian (Rodda *et al.* 2009).

ACKNOWLEDGMENTS

The rather difficult challenge of getting staff safely to Aguiguan Island was a bureaucratic and logistic burden of the first magnitude, ably carried out on our behalf by Earl Campbell, Karl Buermeyer, Curt Kessler, Nate Hawley, Elvin Masga, Ton Castro, Peter Dunlevy, and especially Jess Omar. We are extremely grateful to all. Nate Hawley assisted with permitting. Funding was provided by the U.S. Navy (Scott Vogt) through the U.S. Fish and Wildlife Service (Earl Campbell). Lea' Bonewell assisted with stateside logistics. Ernie Valdez provided the specimen of *Ramphotyphlops braminus.* Shane Siers and Björn Lardner suggested improvements to the manuscript. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. government.

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2.3.3 POPULATION DENSITIES AND DIET OF MONITOR LIZARDS (*VARANUS INDICUS*) ON AGUIGUAN

Monitor Lizard (*Varanus indicus*). Photo by Gayle Martin

Prepared by: **Scott Vogt, Wildlife Biologist, U.S. Navy, NAVFAC Pacific, Honolulu, HI**

INTRODUCTION

The mangrove monitor lizard (*Varanus indicus*) is present on almost every island in the Marianas chain. While questions exist about if it is truly a native species or not, it has apparently inhabited the Marianas for hundreds if not thousands of years (Cota 2008).

On many of these islands the monitor lizard is the only medium or large sized predator. Feral cats are another, but are not present on some of the uninhabited islands. While some work has been done on breeding behavior, home ranges and diet on Marianas varanids population densities on any island have yet to be documented.

Aguiguan, also known as Goat Island, is 700 hectare island approximately 9km south of Tinian. It was inhabited in historic times by Japanese sugar cane growers but has been uninhabited for roughly 60 years.

Abundance index surveys for this species have been conducted on Aguiguan (Cruz *et al.* 2000, Esselstyn *et al.* 2002), but absolute population densities have not been estimated nor has there been a dietary analyses. Monitor lizard population density, demographic and dietary surveys were performed on Aguiguan during the periods of June 27-29 and July 19-August 5, 2008.

METHODS

Population Density

Population densities were measured by 2 methods, a trapping grid and distance transects.

Trapping Grid

The trapping grid consisted of 25 noose traps (Reed *et al.* 2000) in a 5 x 5 pattern with 40 meter spacing. This covered 2.56 hectares (160 meters x 160 meters). Traps were baited with squid. The grid was set up and baited on July 21, 2008 and monitored twice a day at 11:00-12:00 am and 4:00-5:00 pm, until July 26, 2008. Traps were re-baited as needed. The month before (June 2008) the trapping grid was established, a line of 4 noose traps was monitored for 3 days to test the efficacy of the squid bait. The trap line was approximately 500 meters south of the trapping grid area.

The population estimate from the trapping grid data was analyzed with the mark-recapture analyses software, program MARK.

A difficulty in trying to establish animal densities using trapping grids is determining how many animals come from outside the grid to be captured. The grid samples a larger area than its dimensions. It is often difficult to calculate the size of the sampled area and this is vital for accurate density estimates. One method for helping to mitigate for this problem is to fit animals with transmitters so that movements within and outside the grid can be ascertained. In this way, a buffer strip can then be added to the grid boundary for density calculations. For example, based on telemetry data, an extra 50 meters might be added to the grid boundary so that the true area sampled was 260m x 260m and not 160m x 160m.

Wildlife Track brand transmitters were fitted lizards as a “backpack” with brass bead chain. The transmitter was secured with bead chain around the body anterior to the hind legs and around the base of the tail posterior to the hind legs (Figure 1). All captured lizards were marked with colored duct tape wrapped around the body just anterior to hind legs (Figure 1) to ease identification. All lizards captured were measured for snout to vent length (svl) and tail length.

Because the lizards were tracked for a short period of time there were a low number of location data points. Due to the small number of data points, home ranges were calculated by multiplying the distances between the two furthest points on the east:west axis by the two furthest points on the north:south axis. Half of the largest home range size was added as a buffer strip to the trapping grid. This was calculated by taking the square root of the largest home range size (in square meters) divided by 2. The effective trapping area was used to calculate the lizard density (population estimate divided by the effective trapping area).

Figure 1. Example of transmitter attachment and marking of monitor lizards.

Distance Transects

Distance transects followed existing bird transects and covered all areas of the island. Distance sampling was performed between July 20 and August 4, 2008. Transects were slowly walked in the morning between 08:00 am and 11:00 am. When sighted the perpendicular distance from the observer to the mid-body of the monitor lizard was measured to the nearest cm with a tape measure. Since the lizard would run away, this location had to be estimated. After walking the transect in one direction, the observer waited 5 minutes and then returned along the same transect and collected data. This was added to the total transect length. Transects 1, 2, and 4 were sampled twice and transect 3 was sampled once.

Distance transect data was analyzed with the analytical software, DISTANCE.

Diet and Demographics

Monitor lizards were opportunistically shot with a .22 caliber air rifle. All lizards collected were weighed, measured (snout to vent length and tail length), sexed, and the body condition assessed Stomachs were removed and the contents identified. The snout vent lengths for the lizards collected on the trapping grid were pooled with the others for demographic analyses. For describing differences between males and females only data from those lizards that were sexed by dissection were used.

To assess local differences in diet and demographics, data from Aguiguan surveys are compared with data from the island of Sarigan. In 1998, 1999 and 2006, a total of 40 monitor lizards were opportunistically shot on Sarigan. Diet and demographic data were collected.

RESULTS

Population Density

Trapping Grid

Twelve lizards were captured on the trapping grid. There were no recaptures. Three lizards were fitted with transmitters. In addition to these, 2 lizards that were caught on the trap-line in June (4 lizards captured on 4 traps in 3 days) were fitted with transmitters.

The number of telemetry data points for each lizard was 8, 6, 7, and 6. One lizard apparently dropped the transmitter the next day. The signal was received from high up on a cliff line (transmitter not recovered) and the lizard was identified from the duct tape in a different area (within ~10 meters of capture point).

The model used to analyze the grid data in MARK was “full closed captures with heterogeneity.” This model takes into account behavioral responses to being captured and individual heterogeneity (differing capture rates amongst individuals). Since there were no recaptures out of 12 animals, one assumes some type of behavioral response to being captured.

The capture rates on the inner ring of traps (0.56 lizards/trap) did not differ considerably from the outer ring (0.44 lizards/trap). If a high proportion of the captured lizards were coming off of the grid the outer ring captures would be inflated.

Program MARK produced a population estimate of 14 lizards with a 95% confidence interval of 12-37 lizards.

The telemetry data produced home range estimates of 0.18, 0.88, 0.36, and 0.62 hectares respectively. Home range size was positively correlated with body size (snout to vent length) (Chart 1). Based on size, the two smaller lizards are presumed to be female and the 2 larger ones male. Home ranges of the three lizards with transmitters on the trapping grid did not overlap for the monitored period with one exception (Chart 2). On August 3, 2008, two lizards (#s 3 and 4) were in the same tree but could not be sighted. Due to the size differences, it is probable that one was male and the other female and courtship was occurring. The male entered into the female home range.

The width of the buffer strip was estimated to be 46.5 meters (the square root of 8800 sq. meters, divided by 2). This gave an effective trapping area of 6.40 hectares (253 meters x 253 meters).

The density estimate is 2.19 lizards/ha with a 95% confidence interval of 1.88-5.78 lizards/ha. The mean body weight was 470 grams, so this gives a biomass estimate of 1029.30 grams/ha.

Chart 1. Aguiguan Monitor Lizards: Home Range Size vs Body Size

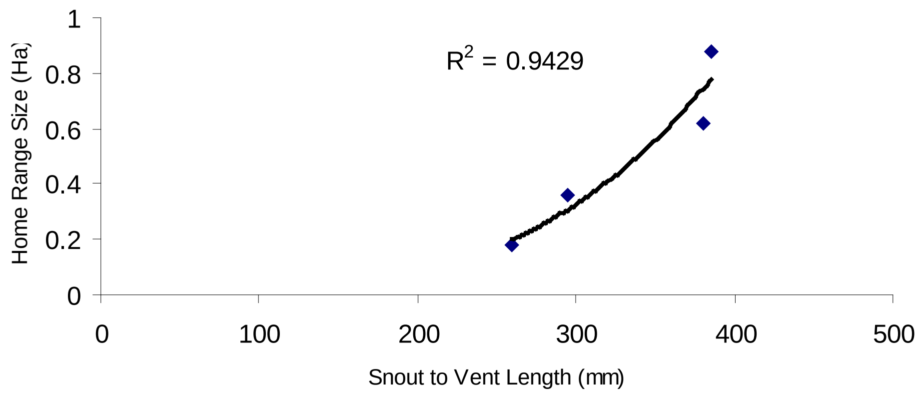
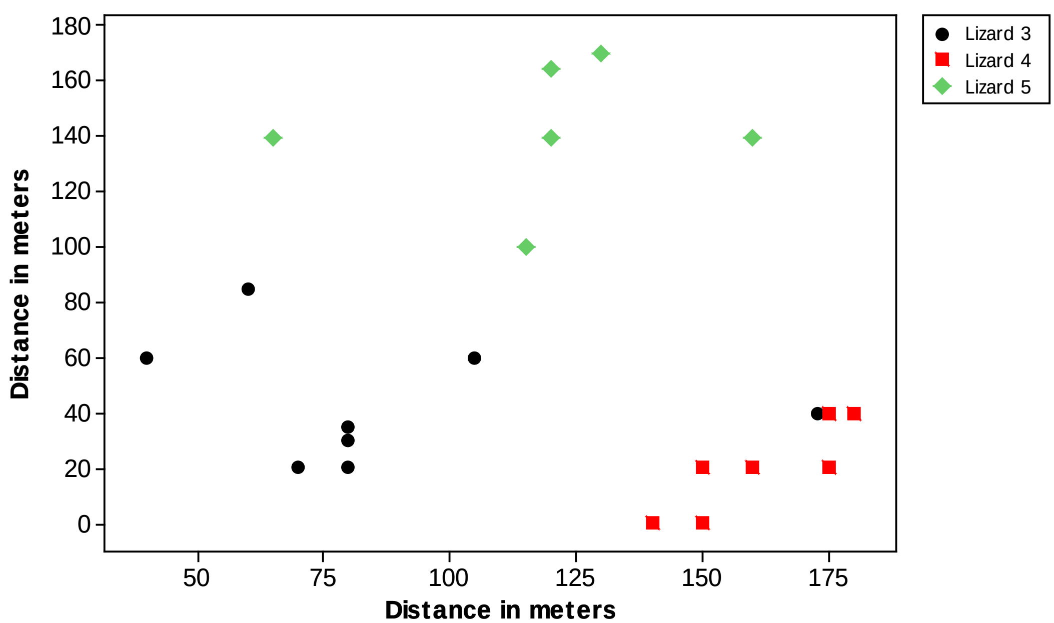


Chart 2. Home Ranges of Monitor Lizards on Aguiguan



Distance Transects

Sixty six monitor lizards were detected on 19,346 meters of transects. During the data collection it was difficult to judge the exact spot on the ground where the center of the body of the individual lizard was. For this reason, the distances were grouped in 50 cm intervals. Grouping data is recommended to improve robustness in the density estimator where the subject animal moves off before detection or heaping of distances (Buckland et al 1993). The data was analyzed using the half-normal-cosine model and right truncated at 400 cm.

The density estimate was 3.67 lizards per hectare with a 95% confidence interval of 2.55-5.29 lizards per hectare. The biomass estimate is 1,724.90 grams/ha.

There are 479 hectares of forested habitat (native, secondary and introduced) on Aguiguan. This extrapolates to a population estimate of 1,758 lizards with a 95% confidence interval of 1,221-2,534. There are an additional 158 hectares of open fields dominated by the introduced plant lantana (*Lantana camara*). Varanids were documented in this habitat, but densities were not established. Distance data was collected but was not used for analyses because of detection differences. Lizards were much harder to detect in this habitat due to the lantana occurring in very dense stands. Goats have greatly reduced the understory in the forests making monitor lizard detections much easier. The sighting rate was 1 lizard/587 meters in open fields while in the forested habitat it was 1 lizard/293 meters. If the densities are similar to the forested habitat then the island wide population estimate is 2,338 lizards with a 95% confidence interval of 1,624-3,370.

Diet

Twenty one lizards were sampled for stomach contents. Three stomachs were empty. The remaining stomachs contained roaches, rats, centipedes, grasshoppers, hermit crab parts, snails, small eggs (gecko or bird), and one stomach had food from the biologists camp (Appendix 1).

The most common prey item was a roach species, *Pycnoscelus indicus*, which was present in 14 stomachs (67%) and was 88% of the prey items documented (Chart 3). The mean number of roaches per stomach was 6 with a range of 2-14. On Sarigan, rats and lizards (skinks and geckos) constituted a significantly higher proportion of prey items (Chart 4).

Chart 3. Stomach Contents of Aguiguan Varanids

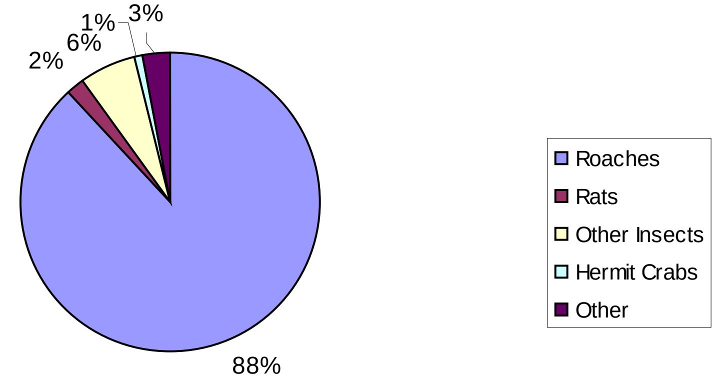
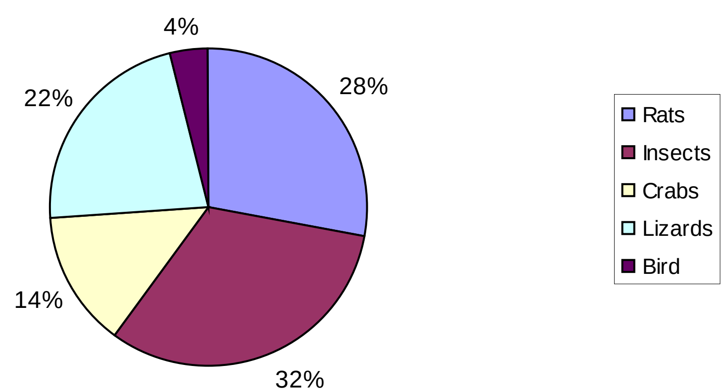


Chart 4. Stomach Contents of Sarigan Varanids



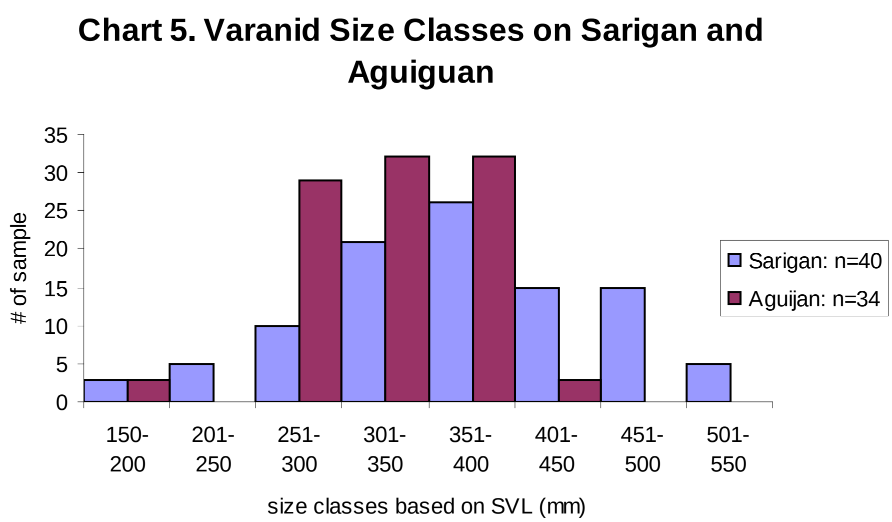
All lizards were in good body condition with large fat deposits. One female had 3 shelled eggs.

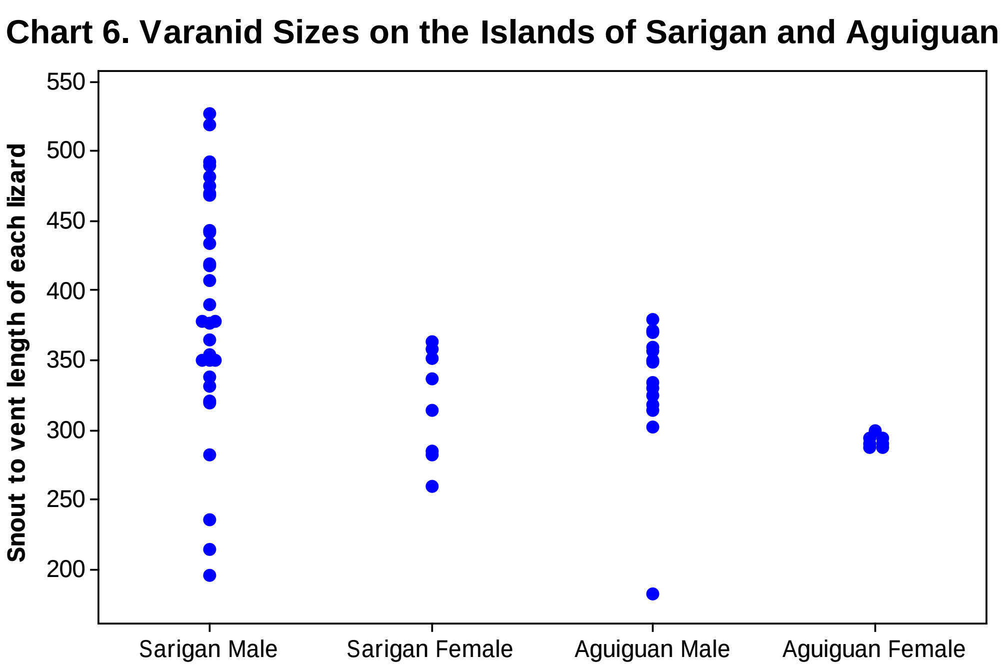
Demographics

Of the dissected lizards, 14 were male and 7 were female.

The sizes of lizards from Aguiguan were smaller than those of Sarigan (Charts 5 and 6) (T test, p= 0.01). The histogram differs from a normal bell curve and shows an abrupt drop off after 400mm snout vent length.

There is a pronounced sexual dimorphism with females being smaller than males (Chart 6). This is consistent on both islands even though the overall lizard size is smaller on Aguiguan. The males on Aguiguan are similar in size to the females on Sarigan and the females on Aguiguan are smaller still. The mean size of females on Sarigan is 18% smaller than the males. The mean size of the females on Aguiguan is 12% smaller than the males.





DISCUSSION

The varanid densities documented on Aguiguan are high for this family, with home ranges being accordingly small. These estimates are most likely conservative as only the adult lizards were sampled. What percentage of the population is juvenile or hatchling is unknown.

The density estimate on the distance transects was higher than the trapping grid but the confidence intervals were almost identical. It is possible that the density in the trapping grid area was lower than the island average.

This is a small sample size, but male biased sex ratios are not uncommon in varanid studies (De Lisle 1996). This is usually caused by males having larger ranges and being more active, causing a higher probability of being sampled (De Lisle 1996). The Aguiguan home range data support this.

In 2000, the Tinian Mayors office, through the Tinian Division of Fish and Wildlife (DFW) implemented a “monitor lizard control program” on Aguiguan. Monitor lizards were opportunistically shot by DFW personnel. In one week an estimated 150 lizards were shot (T. Castro, DFW, pers. comm.) It is not clear if this continued, but, if so, this is a possible cause for the apparent smaller size classes compared with those on Sarigan in that larger animals are more apt to be shot. However, the sexual dimorphism documented on Aguiguan argues against this. If only large lizards were shot then the females should have been closer in size to the males but this was not the case. The female to male size ratio was similar for both islands. If the population was similar in 2000 to the 2008, estimate then 150 lizards represented only about 7% of the population. Also, eight years should have been enough time for the growth of the larger size class.

The CNMI Division of Fish and Wildlife performed varanid trapping and visual transects in 2000 (Cruz *et al*. 2000) and 2002 (Esselstyn *et al*. 2002). In 1995 visual surveys were conducted for varanids but without any trapping (Esselstyn *et al*. 2002). Between 2000 and 2002, trapping rates fell from a mean of 34 lizards/100 trap days to a mean of 14 lizards/100 traps days. There was a corresponding drop in sighting rates from a mean of 10 lizards/hr of search time to a mean of 6 lizards/hr of search time. This drop was attributed to the monitor lizard control program. For the present study, the trapping rate on the grid was 10 lizards/100 trap days and the sighting rate on the transects was 5 lizards/hr of search time. Both of these rates are consistent with the 2002 rates and, if the trapping and sighting rates are a valid index of the population abundance, show a stable population for this time period. One would expect an increase in the population between 2002 and 2008 if the monitor control program in 2000 was in fact a onetime sharp drop in the population.

On Sarigan vertebrates were 54% of the prey items while they were only 2% on Aguiguan. Skink densities appear to be low on Aguiguan and this is probably the reason none were found in varanid stomachs. On Aguiguan, roaches are an important prey item which is surprising given the abundance of rats on the island. Given the large fat deposits and high population density, roaches appear to have a high nutritional value.

This roach species does well in loose soil (C. Campora, pers. comm.). Feral goats, by over grazing, could be enhancing the habitat for this roach species and indirectly fueling the high varanid densities.

The emphasis on vertebrate prey on Sarigan could explain the size differences with Aguiguan, with rats and skinks supporting larger varanids. The invertebrate prey on Aguiguan could support higher numbers of smaller lizards while the higher skink densities on Sarigan negatively affect invertebrate densities and in turn reduce the importance of invertebrates as a varanid prey item.

Monitor lizards are the only large predator on Aguiguan and occur there in high densities. Top level predators can substantially affect ecosystems, both directly and indirectly. What effects the species exerts on the ecology of Aguiguan is difficult to say. If the native Marianas birds did not in fact evolve with varanid predators, then removing the lizards should be ecologically beneficial for those birds. The importance of insects in the Aguiguan varanid diet puts them in direct competition with the endangered Micronesian megapode (*Megapodius laperouse laperouse*). Losos and Greene (1988) speculated that in terms of ecological effects, varanids (excepting the largest species) most closely mimic small foxes or some civet cat species.

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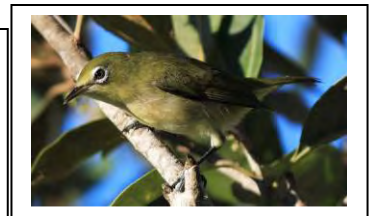
APPENDIX

Stomach Contents of Aguiguan Varanids

	Prey item and # in stomach					
Specimen #	Roaches	Centipedes	Rats	Grasshopper	Hermit Crab	Other
1	7					
2					1	
3	empty					
4	13					
5	empty					
6	7					
7	3					Unknown animal tissue ~5mm x5 mm
8	3					1 snail
9		1				
10						Chicken and fish from camp
11	3					2 small eggs, ~1cm long (gecko or bird)
12	8					
13	14					
14	10	1				
15	empty					
16	3		1			
17	6	1		1		
18	2	2				
19	4					
20			1			
21	3					

2.4 AVIAN SURVEYS

2.4.1 GENERAL LAND BIRD SURVEYS ON TINIAN AND AGUIGUAN



Clockwise: Golden White-eye, Bridled White-eye, and Mariana Fruit-dove. All photos by Scott Vogt.

Prepared by: **Richard Camp (U.S. Geological Survey), Thane Pratt (U.S. Geological Survey), Fred Amidon (U.S. Fish and Wildlife Service), Ann Marshall (U.S. Fish and Wildlife Service), Shelly Kremer (U.S. Fish and Wildlife Service), and Megan Laut (U.S. Fish and Wildlife Service).** (Summarized from from Camp *et al.* (2009; Appendix 3.1) by Fred Amidon, U.S. Fish and Wildlife Service)

INTRODUCTION

The first island-wide surveys of terrestrial bird species on Tinian and Aguiguan were conducted in 1982 by Engbring *et al.* (1986). In 1995 and 1996, the surveys developed by Engbring *et al.* (1986) were repeated on Tinian, however, only the Tinian monarch data were analyzed (USFWS 1996, Lusk *et al.* 2000). On Aguiguan, the Engbring *et al.* (1986) surveys were repeated in 1992, 1995, 2000, and 2002 (Craig *et al.* 1992, Cruz *et al.* 2000, Esselstyn *et al.* 2003, USFWS Unpubl. data). Unfortunately, the data collected in these surveys on Aguiguan were not collected or analyzed using the same methods or were not analyzed.

In 2008, the Department of Defense contracted the U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office to conduct terrestrial and marine surveys on Tinian and Aguiguan. The following report is a summary of Camp *et al.* (2009; Appendix 1) which outlines the survey results from June 2008 forest bird point-transect surveys on Tinian and Aguiguan and assesses population trends on Tinian and Aguiguan using point-transect data collected in 1982 on Tinian and Aguiguan by Engbring *et al.* (1986) and 1996 on Tinian by the U.S. Fish and Wildlife Service (unpublished data).

METHODS

Between 27 April and 8 May 1982 Engbring *et al.* (1986) sampled a total of 216 stations on 10 transects during a survey of Tinian (Figure 1, Attachment 1). All transects were at least 300 meters apart and all stations along each transect were 150 meters apart. These transects were resurveyed during both the 1996 (28 August – 1 September) and 2008 (14 – 19 June) surveys. An additional 4 transects were sampled during the 2008 survey for a total of 254 stations (Figure 1, Attachment 1). The 4 additional transects were included to increase the number of stations in native limestone forest to improve density estimates for Tinian monarchs (see Tinian Monarchs for additional information). These transects were also at least 300 m from the nearest transect and all stations were 150 meters apart.

On Aguiguan an island-wide survey consisting of 66 stations on 4 transects was conducted on 2 and 3 June 1982, and a partial survey (transects 1 and 2 only) was conducted on 10 and 11 March (Engbring *et al*. 1986; Figure 2, Attachment 2). Data from only the June survey were used in this study. All 4 transects were resurveyed during the 2008 (25 – 27 June) survey. An additional transect of 14 stations was sampled during the 2008 survey for a total of 80 stations (Figure 2, Attachment 2). This additional transect was added to sample secondary forest and open field habitats and increase the survey coverage of the island. The additional transect was at least 300 meters away from the nearest transect and all stations along all transects were 150 meters apart.

All surveys followed standard point-transect methods, consisting of 8-minute counts where horizontal distances to all birds heard and/or seen were measured and recorded (see Engbring *et al*. 1986 for details). Sampling conditions recorded included cloud cover, rain, wind, noise level, and habitat type, and these were later used as covariates in density calculations (see below). Counts commenced at sunrise and continued up to 1100 hours and were conducted only under favorable conditions. Two observers surveyed each station in 1982, and one observer surveyed the stations in 1996 and 2008. On Tinian, only data from one counter was used for each station from the 1982 surveys, and the primary counters were identified based on their experience and survey proficiency. Engbring *et al*. (1986) analyzed bird detections from all observers to estimate bird densities. For our analysis, we used detections from only one observer to recalculate densities for the 1982 Tinian survey, thus matching the 1996 and 2008 survey effort. Calculating densities from only one of the counters is a conservative approach and ensures sampling independence. This approach approximately halved the number of birds detected; however, our density estimates were generally greater than, but otherwise similar to, those of Engbring *et al*. (see Table 8; 1986). On Tinian the 95% confidence intervals bracketed Engbring *et al*.'s estimates for all but five birds—Mariana Fruit-Dove, Micronesian Honeyeater, Tinian Monarch, Rufous Fantail, and Bridled White-eye. Differences may have resulted from analytical procedures such as selecting different truncation distances, selecting different models to estimate densities, and analytical advances in distance sampling (see Johnson *et al*. 2006), in addition to estimating densities using detections from only one of the counts (Tinian only). Data from both counters were used to estimate 1982 densities on Aguiguan and the sampling effort was adjusted appropriately.

Population status was calculated as densities (birds/km^2) and number of birds (density by habitat type multiplied by habitat type area). Densities were calculated using the program DISTANCE (Thomas *et al*. 2006) from species-specific global detection functions where data were post-stratified by survey in the stratum layer. Data were right-truncated to facilitate model fitting (Buckland *et al*. 2001), and the model with the lowest Akaike Information Criterion (AIC) was used to select the detection function that best approximated the data. Candidate models included half-normal and hazard-rate detection functions with expansion series of order two (Buckland *et al*. 2001). Sampling covariates were modeled in the multiple-covariate distance engine of DISTANCE (Thomas *et al*. 2006, Marques *et al*. 2007). Covariates (sampling conditions, habitat types, and survey year.) were used to generate the global detection function when the best approximating model was improved by four or more AIC units. Variances and confidence intervals were derived by log-normal based methods. Survey-specific, density-by-station values were generated for the population trends analyses (see below) from the global detection function using the post-stratification-by-sample option in the stratum layers annual estimates and regional estimates. Area of habitat types came from Engbring *et al*. (1986) and recent vegetation cover estimates (see 2.1 Vegetation Surveys). The area of habitat types was not available for the 1996 Tinian survey; therefore, we used the area by habitat types from Engbring *et al*. to calculate the 1996 numbers of birds. This may slightly underestimate the population size if there was more secondary forest in 1996 than 1982. Agriculture habitat type (combined agroforestry and cultivated habitat type classifications) was not used to calculate numbers of birds because the area of this habitat is very small relative to the island (< 2%), the area of the agriculture habitat type has declined (190 ha in 1982 to 174 ha in 2008; see 2.1 Vegetation Surveys), and only two stations were located in the agriculture habitat type, thus it was under-sampled. On Aguiguan, the 1982 estimates of the area of habitat types were not reliable; therefore, numbers of birds were calculated only for the 2008 survey.

Change in bird densities among the three annual estimates on Tinian was assessed with repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, NC). Repeated measures ANOVA was also used to asses change in bird density within regions among the three annual estimates. To stabilize the error variance, densities by station were log transformed after a constant of 1 was added (to avoid ln(0)). Stations were treated as the random factor, and because the number of repeated measures was too small to fit a covariance model, we assumed the variance-covariance structure was a compound symmetry, homogeneous variance model (Littell *et al*. 1996). Degrees of freedom were adjusted using the Kenward-Roger adjustment statement and a Tukey's adjustment was used to control alpha = 0.05 for multiple-comparison procedures.

End-point comparisons of the Aguiguan bird densities were compared using a two-sample *z*-test. Comparing density estimates using *z*-tests is the recommended method (L. Thomas, pers. comm. 2008) and is an extension of the method listed in Buckland *et al*. (2001).

RESULTS AND DISCUSSION

Tinian

On Tinian, a total of 18 species were detected during one or more of the three surveys (Table 1). Sufficient numbers of individuals were detected to calculate density and abundance estimates for the collared kingfisher, island-collared dove (previously known as Philippine turtle-dove), white-throated ground-dove, Mariana fruit-dove, white tern, rufous fantail, Tinian monarch, Micronesian honeyeater, Micronesian starling, bridled white-eye, yellow bittern, and Eurasian tree sparrow. Bridled white-eyes and rufous fantails were the most abundant birds, whereas the white-throated ground-dove and yellow bittern were the least abundant bird (Table 2). Collared kingfisher, white-throated ground-dove, rufous fantail, Micronesian starling, and yellow bittern abundance increased since 1982 while Mariana fruit-dove, Tinian monarch, and Micronesian honeyeater abundance decreased since 1982 (Table 3). Although these declines were not linear, the overall changes between 1982 and 2008 were significant (Table 3). Trends for the white tern and bridled white-eye were considered relatively stable. The introduced island collared-dove and Eurasian tree sparrow both increased since 1982 (Tables 2 and 3).

Only five birds; the white-throated ground-dove, Mariana fruit-dove, rufous fantail, Tinian monarch, and Eurasian tree sparrow, showed significant differences among regions by year (Table 4). Between 1982 and 2008 white-throated ground-dove densities increased in the Diablo and Hagoi regions, and rufous fantail densities increased in the Carolinas and Masalog regions (Figure 3). Over the 27-year period Mariana fruit-dove and Tinian monarch densities declined in the Carolinas and Diablo regions, respectively.

The increase in rufous fantail and Micronesian starling abundance may be related to the decline in open field and increase in secondary forest habitats on the island between the 1980s and 2008 (see 2.1 Vegetation Surveys). Both these species primarily utilize forest habitats, including secondary forest, for foraging and breeding. However, Tinian monarch and Micronesian honeyeater abundance should have increased as well since these species also utilize secondary forest. Therefore, other factors, like a decline in foraging resources, may also be influencing bird populations. For example, the increase in white-throated ground-doves may be related to an outbreak of the introduced vine *Coccina grandis* (scarlet gourd) which is believed to be a factor in the abundance of this species on Saipan (Camp *et al.*, in review).

Aguiguan

A total of 19 species were detected on one or both of the Aguiguan surveys (Table 5). Sufficient numbers of individuals were detected for nine native and one introduced species to calculate density and abundance estimates. Bridled white-eyes were the most abundant bird at over 44,000 birds and collared kingfisher and island collared-dove were the least abundant birds (Table 6). Densities for seven of the nine native birds; collared kingfisher, white-throated ground-dove, Mariana fruit-dove, rufous fantail, Micronesian starling, bridled white-eye, and golden white-eye, were significantly greater in 2008 than 1982 (Table 6, Figure 4). No differences in densities were detected between the two surveys for white tern and Micronesian honeyeater. Densities of the introduced island collared-dove increased significantly between 1982 and 2008.

The increased densities of collared kingfishers, white-throated ground-doves, Mariana fruit-doves, rufous fantails, Micronesian starlings, bridled white-eyes, and golden white-eyes may be related to an increase in forest cover on Aguiguan since the 1982 survey. Recent land cover surveys indicate that the amount of secondary forest and tangantangan has increased since the 1982 survey (see 2.1 Vegetation Surveys). Both of these habitat types could be utilized by these avian species. Interestingly, the densities of Micronesian honeyeater did not increase. However, as noted above for Tinian, this may be related to other factors beside habitat availability.

The magnitude of the increases in rufous fantail, bridled white-eye and golden white-eye densities was surprising. However, when the detections for these species from 1982 were compared to detections along the same four transects in 1992, 1995, 2000, 2002, and 2008 the detections were much lower in 1982 than the other years (Table 7). This could, in part, be related to survey conditions and the quality of the habitat. Goat populations on the island were reduced to very low numbers from 1989 to 1990 (Rice 1991) which may have affected the available habitat for these species and their primary prey, insects. For example the amount of understory vegetation may have increased and as well as the amount of secondary forest and tangantangan habitats (see 2.1 Vegetation Surveys). However, goat populations have since increased and intense browsing is evident throughout the forest. Therefore, a decline in these species would be expected. This was not observed, however, so other factors are also likely at play.

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Table 1. List of birds detected from three different point-transect surveys on Tinian. In 1982 and 1996 216 stations were sampled on 10 transects, and 254 stations were sampled on 14 transects in 2008. The number of stations occupied (# Stns Ocpd) and bird detected (# Dect), and indices of percent occurrence (% Occ) and birds per station (BPS) were calculated. Nomenclature follows Wiles (2005). Density estimates were produced for birds in bold.

		1982				1996				2008			
Species	Scientific Name	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS
Red Junglefowl	*Gallus gallus*	45	105	20.8	0.49	0	0	0.0	0.00	45	77	17.7	0.30
White-tailed Tropicbird	*Phaethon lepturus*	0	0	0.0	0.00	0	0	0.0	0.00	3	5	1.2	0.02
Yellow Bittern	*Ixobrychus sinensis*	10	10	4.6	0.05	16	18	7.4	0.08	34	38	13.3	0.15
Pacific Reef-Egret	*Egretta sacra*	1	1	0.5	<0.01	1	1	0.5	<0.01	0	0	0.0	0.00
Pacific Golden-Plover	*Pluvialis fulva*	1	1	0.5	0.00	0	0	0.0	0.00	3	11	1.2	0.04
Ruddy Turnstone	*Arenaria interpres*	0	0	0.0	0.00	0	0	0.0	0.00	1	1	0.4	<0.01
Brown Noddy	*Anous stolidus*	0	0	0.0	0.00	0	0	0.0	0.00	1	1	0.4	<0.01
White Tern	*Gygis alba*	128	344	59.3	1.59	22	52	10.2	0.24	122	322	48.0	1.27
Island Collared-Dove	*Streptopelia bitorquata*	51	66	23.6	0.31	136	256	63.0	1.19	79	116	31.1	0.46
White-throated Ground-Dove	*Gallicolumba xanthonura*	13	16	6.0	0.07	23	23	10.6	0.11	64	82	25.2	0.32
Mariana Fruit-Dove	*Ptilinopus roseicapilla*	189	623	87.5	2.88	150	240	69.4	1.11	212	462	83.4	1.82
Collared Kingfisher	*Todiramphus chloris*	150	294	69.4	1.36	124	285	57.4	1.32	190	374	74.8	1.47
Micronesian Honeyeater	*Myzomela rubratra*	131	236	60.6	1.09	60	96	27.8	0.44	87	125	34.3	0.49
Tinian Monarch	*Monarcha takatsukasae*	187	539	86.6	2.50	173	500	80.1	2.31	178	361	70.1	1.42
Rufous Fantail	*Rhipidura rufifrons*	202	786	93.5	3.64	188	502	87.0	2.32	235	686	92.5	2.70
Bridled White-eye	*Zosterops conspicillatus*	216	2,222	100.0	10.29	216	1,770	100.0	8.19	253	2,024	99.6	7.97

Micronesian Starling	*Aplonis opaca*	177	513	81.9	2.38	106	226	49.1	1.05	215	614	84.7	2.42
Eurasian Tree Sparrow	*Passer montanus*	1	1	0.5	<0.01	3	13	1.4	0.06	13	62	5.1	0.24

Table 2. Population density and abundance estimates for land birds on Tinian from three point-transect surveys. Data from 10 Engbring *et al.* (1986) transects only. First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: bird abundance (sum of density by habitat type times the area of habitat types) with 95% CI. Agriculture habitat type was dropped for calculating bird abundance due to small sample size; only 2 survey stations were sampled.

Species	1982	1996	2008
Yellow Bittern	1.5 ± 0.89 (0.5–4.4)	7.4 ± 2.49 (3.9–14.1)	18.2 ± 4.56 (11.2–29.6)
	127 (30–550)	764 (270–2,302)	1,695 (835–3,575)
White Tern	144.1 ± 17.24 (113.9–182.2)	25.3 ± 7.01 (14.8–43.2)	169.9 ± 19.66 (135.4–213.2)
	13,980 (9,349–21,512)	2,846 (1,121–7,300)	15,147 (10,067–23,041)
Island Collared-Dove	12.4 ± 2.04 (9.0–17.1)	34.3 ± 3.67 (27.8–42.3)	23.9 ± 3.24 (18.4–31.2)
	1,093 (642–2,024)	3,291 (2,296–4,777)	2,198 (1,374–3,648)
White-throated Ground-Dove	4.1 ± 1.45 (2.0–8.0)	4.6 ± 1.30 (2.7–8.0)	20.2 ± 3.91 (13.8–29.5)
	434 (136–1,421)	440 (174–1,147)	1,827 (1,045–3,226)
Mariana Fruit-Dove	42.6 ± 2.64 (37.7–48.1)	15.8 ± 1.23 (13.6–18.4)	33.1 ± 1.96 (29.4–37.1)
	3,909 (3,185–4,826)	1,539 (1,155–2,065)	3,029 (2,506–3,677)
Collared Kingfisher	7.0 ± 1.46 (4.7–10.5)	22.9 ± 3.28 (17.3–30.3)	61.3 ± 4.33 (53.3–70.4)
	570 (305–1,130)	2,268 (1,329–3,883)	5,439 (4,212–7,090)
Micronesian Honeyeater	77.2 ± 6.79 (64.9–91.7)	31.2 ± 4.26 (23.9–40.8)	41.3 ± 4.86 (32.8–52.0)
	7,859 (5,877–10,700)	2,847 (1,684–4,838)	3,716 (2,458–5,667)
Tinian Monarch	634.5 ± 37.88 (564.3–713.4)	705.7 ± 43.96 (624.3–797.6)	431.3 ± 30.75 (374.9–496.2)
	60,898 (49,484–75,398)	62,863 (50,476–78,758)	38,449 (29,992–49,849)
Rufous Fantail	641.2 ± 39.30 (568.4–723.3)	766.3 ± 40.85 (690.1–851.0)	975.0 ± 48.26 (884.6–1,074.6)
	58,336 (48,119–71,134)	67,191 (55,510–82,000)	86,112 (72,786–102,594)
Bridled White-eye	3,190.9 ± 101.79 (2,996.8–3,397.6)	2,731.9 ± 81.96 (2,575.5–2,897.8)	2,997.2 ± 105.80 (2,795.8–3,213.0)
	302,477 (270,218–338,821)	253,407 (225,258–286,044)	270,785 (239,579–306,772)
Micronesian Starling	133.9 ± 13.53 (109.8–163.3)	125.1 ± 13.34 (101.5–154.2)	349.5 ± 22.47 (308.0–396.6)
	11,543 (7,994–17,041)	10,841 (7,270–16,296)	30,088 (23,633–38,565)

Eurasian Tree Sparrow	2.1 ± 2.07 (0.4–10.7)	26.7 ± 16.42 (8.7–81.5)	110.2 ± 40.54 (54.7–222.2)
	155 (29–817)	1,244 (232–6,662)	2,111 (429–10,666)

Table 3. Repeated measures analysis of variance results for trends in Tinian bird densities among years. Trends are denoted as increasing (▲), decreasing (▼), or stable (▬). Significant changes are marked in **bold**. Degrees of freedom for the differences of least squares means (Diff LSM) are 431.

				Diff LSM								
		Fixed Effects		82-96			82-08			96-08		
Species	Trend	$F_{2,398}$	*p*	Est (SE)	*t*	Adj-*p*	Est (SE)	*t*	Adj-*p*	Est (SE)	*t*	Adj-*p*
Yellow Bittern	▲	13.57	<0.001	-0.04 (0.02)	-1.86	0.153	-0.10 (0.02)	-5.14	<0.001	-0.07 (0.02)	-3.29	0.003
White Tern	▬	43.18	<0.001	0.47 (0.06)	7.55	<0.001	-0.06 (0.06)	-0.91	0.634	-0.53 (0.06)	-8.46	<0.001
Island Collared-Dove	▲	16.22	<0.001	-0.14 (0.03)	-5.66	<0.001	-0.09 (0.03)	-3.38	0.002	0.06 (0.03)	2.28	0.060
White-throated Ground-Dove	▲	27.87	<0.001	<0.01 (0.02)	-0.42	0.906	-0.12 (0.02)	-6.67	<0.001	-0.11 (0.02)	-6.24	<0.001
Mariana Fruit-Dove	▼	64.54	<0.001	0.19 (0.02)	10.92	<0.001	0.05 (0.02)	2.73	0.018	-0.14 (0.02)	-8.19	<0.001
Collared Kingfisher	▲	87.05	<0.001	-0.11 (0.03)	-3.79	<0.001	-0.36 (0.03)	-12.84	<0.001	-0.26 (0.03)	-9.05	<0.001
Micronesian Honeyeater	▼	31.76	<0.001	0.27 (0.04)	7.59	<0.001	0.20 (0.04)	5.90	<0.001	-0.06 (0.04)	-1.69	0.209
Tinian Monarch	▼	10.65	<0.001	-0.09 (0.09)	-0.97	0.597	0.31 (0.09)	3.42	0.002	0.40 (0.09)	4.39	<0.001
Rufous Fantail	▲	19.55	<0.001	-0.24 (0.09)	-2.75	0.017	-0.54 (0.09)	-6.24	<0.001	-0.30 (0.09)	-3.49	0.002
Bridled White-eye	▬	5.26	0.006	0.16 (0.05)	3.24	0.004	0.07 (0.05)	1.42	0.330	-0.09 (0.05)	-1.81	0.166
Micronesian Starling	▲	67.87	<0.001	0.04 (0.07)	0.57	0.836	-0.64 (0.07)	-9.79	<0.001	-0.68 (0.07)	-10.36	<0.001
Eurasian Tree Sparrow	▬	0.96	0.384	-0.02 (0.02)	-0.78	0.713	-0.03 (0.02)	-1.38	0.352	-0.01 (0.02)	-0.60	0.822

Table 4. Repeated measures analysis of variance results for year, region and year-region interaction fixed effects in Tinian bird densities. Data from 10 Engbring *et al.* (1986) transects only. Dash indicates interaction test not conducted because one or both main effects results were non-significant. Differences of least squares means for the significant fixed effects (bold for interaction, italics for region) are summarized in Figure 3.

	Fixed Effects					
	Year		Region		Interaction	
Species	$F_{2,392}$	P	$F_{3,196}$	P	$F_{6,392}$	P
Yellow Bittern	10.17	<0.001	0.20	0.899	—	—
White Tern	40.78	<0.001	4.15	0.007	1.71	0.116
Island Collared-Dove	19.67	<0.001	1.47	0.224	—	—
White-throated Ground-Dove	16.98	<0.001	5.19	0.002	6.60	<0.001
Mariana Fruit-Dove	66.10	<0.001	5.99	<0.001	3.76	0.001
Collared Kingfisher	81.67	<0.001	2.17	0.093	—	—
Micronesian Honeyeater	25.99	<0.001	10.89	<0.001	1.73	0.113
Tinian Monarch	8.94	<0.001	7.61	<0.001	3.10	0.006
Rufous Fantail	28.31	<0.001	5.23	0.002	6.63	<0.001
Bridled White-eye	9.29	<0.001	6.04	<0.001	11.58	<0.001
Micronesian Starling	62.05	<0.001	3.60	0.014	1.43	0.200
Eurasian Tree Sparrow	1.29	0.276	1.36	0.256	—	—

Table 5. List of birds detected from the 1982 and 2008 point-transect surveys on Aguiguan. In 1982 66 stations were sampled on 4 transects (88 counts; several stations were counted more than once), and 80 stations were sampled in 5 transects in 2008. The number of stations occupied (Stns Ocpd), birds detected (# Dect), indices of percent occurrence (% Occ) and birds per station (BPS) were calculated. Nomenclature follows Wiles (2005). Density estimates were produced for birds in bold. Scientific names are provided in superscript.

	1982				2008			
Species	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS
Micronesian Megapode	8	14	9.1	0.16	11	15	13.8	0.19
White-tailed Tropicbird	1	1	1.1	0.01	—	—	—	—
Red-tailed Tropicbird[1]	8	13	9.1	0.15	—	—	—	—
Great Frigatebird[2]	1	2	1.1	0.02	—	—	—	—
Yellow Bittern	1	1	1.1	0.01	—	—	—	—
Brown Noddy	14	20	15.9	0.23	—	—	—	—
Black Noddy[3]	31	75	35.2	0.85	1	1	1.2	0.01
White Tern	54	218	61.4	2.48	34	84	42.5	1.05
Sooty Tern[4]	1	1	1.1	0.01	—	—	—	—
Island Collared-Dove	9	16	10.2	0.18	28	50	35	0.63
White-throated Ground-Dove	10	18	11.4	0.20	25	37	31.2	0.46
Mariana Fruit-Dove	87	757	98.9	8.60	75	240	93.8	3.00
Guam Swiftlet	26	157	29.6	1.78	9	27	11.2	0.34
Collared Kingfisher	56	154	63.6	1.75	53	101	66.2	1.26
Micronesian Honeyeater	87	745	98.9	8.47	74	174	92.5	2.18
Rufous Fantail	84	453	95.5	5.15	77	219	96.2	2.74
Golden White-eye	83	444	94.3	5.05	74	268	92.5	3.35
Bridled White-eye	88	823	100.0	9.35	77	758	96.2	9.48
Micronesian Starling	71	207	80.7	2.35	69	167	86.2	2.09

[1] = *Megapodius laperouse* [2] = *Aerodramus bartschi* [3] = *Sterna fuscata*
[4] = *Anous minutus* [5] = *Phaethon rubricauda* [6] = *Fregata minor*
[7] = *Cleptornis marchei*

Table 6. Population density and abundance estimates for native and alien Aguiguan land birds from two point-transect surveys. First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: 2008 bird abundance (density by habitat times the habitat area) with 95% CI. Significance was assessed at the alpha 0.05 level using two-sample *z*-test (highlighted in bold). Change was defined as increasing (▲), decreasing (▼), or not significantly different (▬).

Species	1982	2008	*z* Value	*P*	Change
White Tern	169.6 ± 27.0 (124.2–231.6)	218.8 ± 44.2 (147.3–325.1)	-0.95	0.341	▬
		1,214 (604–3,651)			
Island Collared-Dove	4.4 ± 1.8 (2.0–9.7)	66.9 ± 16.7 (41.1–108.8)	-3.72	<0.001	▲
		307 (151–658)			
White-throated Ground-Dove	13.1 ± 4.8 (6.6–26.3)	100.2 ± 26.5 (59.9–167.6)	-3.23	0.001	▲
		484 (260–953)			
Mariana Fruit-Dove	107.5 ± 6.5 (95.4–121.1)	141.0 ± 10.8 (121.3–164.0)	-2.67	0.008	▲
		818 (604–1,170)			
Collared Kingfisher	13.1 ± 2.0 (9.7–17.8)	50.3 ± 6.6 (38.9–65.0)	-5.39	<0.001	▲
		347 (184–1,186)			
Micronesian Honeyeater	368.3 ± 19.6 (331.8–408.7)	336.2 ± 27.1 (286.7–394.1)	-0.96	0.337	▬
		2,128 (1,564–3,046)			
Rufous Fantail	568.8 ± 39.6 (496.0–652.2)	1.157.9 ± 89.3 (995.0–1,347.5)	-6.41	<0.001	▲
		6,429 (4,765–13,666)			
Golden White-eye	529.1 ± 40.6 (455.1–615.2)	1,292.6 ± 111.9 (1,089.7–1,533.4)	-6.41	<0.001	▲
		7,496 (4,983–17,387)			
Bridled White-eye	1,685.6 ± 102.3 (1,495.7–1,899.6)	6,771.2 ± 490.2 (5,867.6–7,814.1)	-10.15	<0.001	▲
		44,293 (32,246–63,031)			
Micronesian Starling	86.5 ± 10.9 (67.6–110.7)	505.2 ± 52.7 (411.5–620.3)	-7.78	<0.001	▲
		3,531 (1,902–12,374)			

Table 7. Number of birds detected (# Det) and birds per station (BPS) for 11 species recorded on 4 transects (66 stations) in 1982 (Engbring *et al.* 1986), 1992 (Craig *et al.* 1992), 1995 (USFWS, unpubl. data), 2000 (Cruz *et al.* 2000), 2002 (Esselstyn *et al.* 2003), and 2008. Eight minute counts were utilized in 1982, 1992, 1995, and 2008 while 5-minute counts were utilized in 2000 and 2002. Data from an additional transect sampled in 2008 were not included in the table.

	June 1982		May 1992		June1995		April 2000		March 2002		June 2008	
Species	# Det	BPS	# Det	BPS	# Det	BPS	# Det	BPS	# Det	BPS	# Det	BPS
Micronesian Megapode	14	0.16	11	0.17	18	0.27	12	0.20	16	0.30	13	0.20
Collared Kingfisher	56	1.75	83	1.26	89	1.35	57	0.60	40	0.90	92	1.39
Island Collared-Dove	9	0.18	11	0.17	3	0.05	3	0.02	1	0.05	17	0.26
White-throated Ground-Dove	10	0.20	8	0.12	22	0.33	16	0.20	12	0.30	22	0.33
Mariana Fruit-Dove	87	8.60	138	2.09	140	2.12	76	1.60	102	1.20	185	2.80
White Tern	64	2.48	113	1.71	86	1.30	42	0.83	52	0.67	44	0.67
Rufous Fantail	84	5.15	273	4.14	163	2.47	150	2.70	171	2.40	188	2.85
Micronesian Honeyeater	87	8.47	202	3.06	188	2.85	124	2.10	131	2.00	129	1.95
Micronesian Starling	71	2.35	127	1.92	75	1.14	74	0.90	57	1.20	139	2.11
Bridled White-eye	88	9.35	514	7.79	311	4.71	218	7.50	472	3.50	603	9.14
Golden White-eye	83	5.05	425	3.71	157	2.38	147	2.40	153	2.30	208	3.15

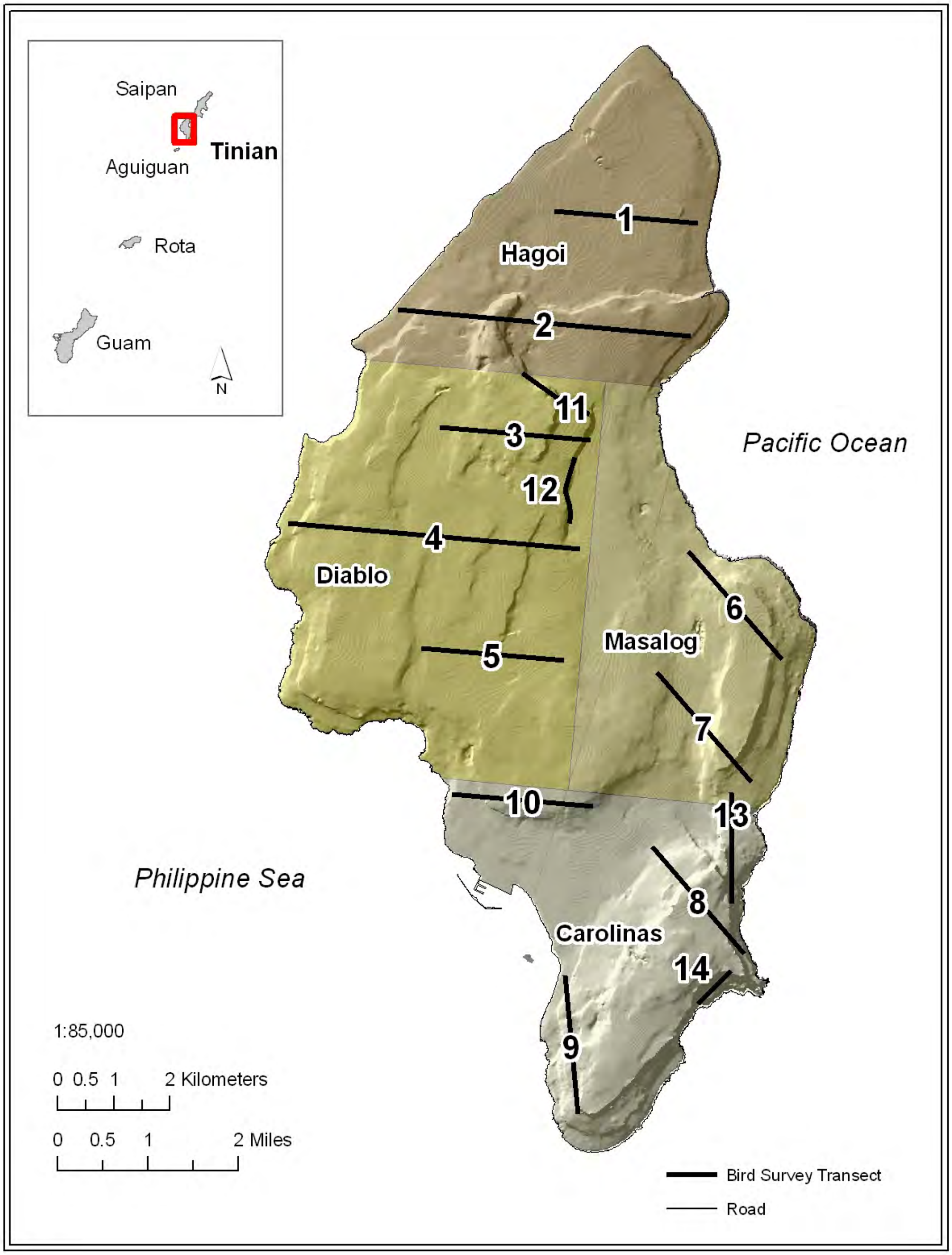


Figure 1. Island of Tinian showing the survey transects and regions (as defined by Engbring *et al.* 1986). Transects 1-10 were counted during all three surveys, and transects 11-14 were established and counted during the 2008 survey.

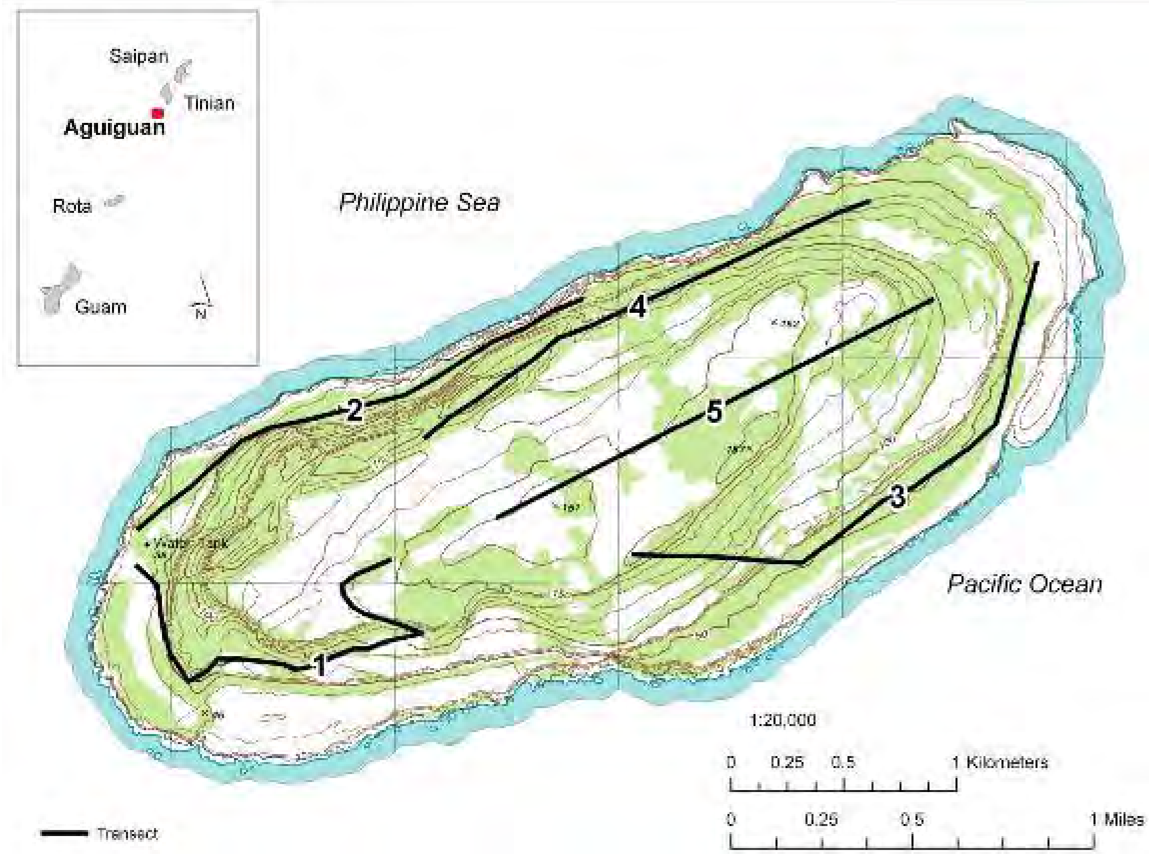
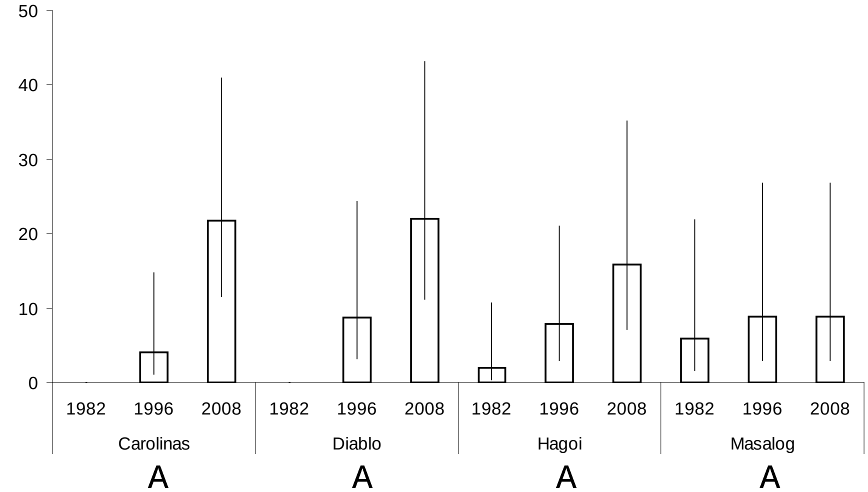
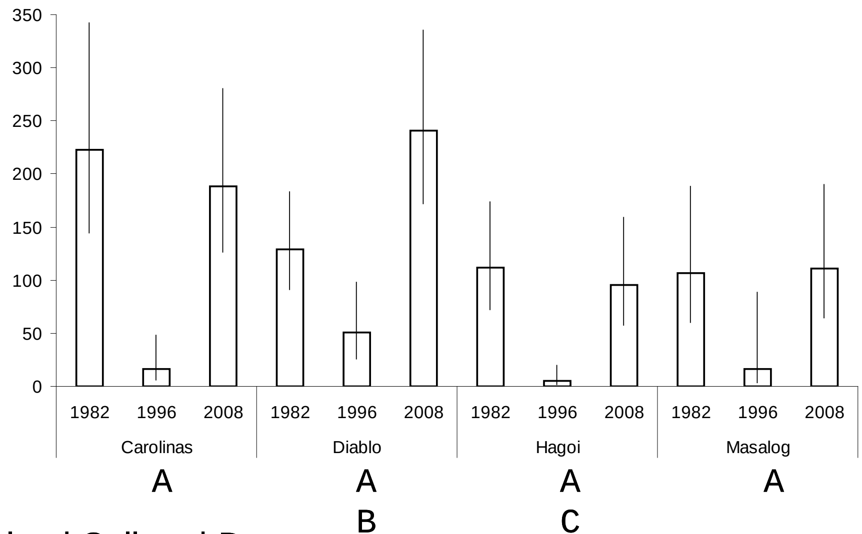


Figure 2. Island of Aguiguan showing the survey transects. Transects 1-4 were counted during both the 1982 and 2008 surveys, whereas transect 5 was established and counted during the 2008 survey.

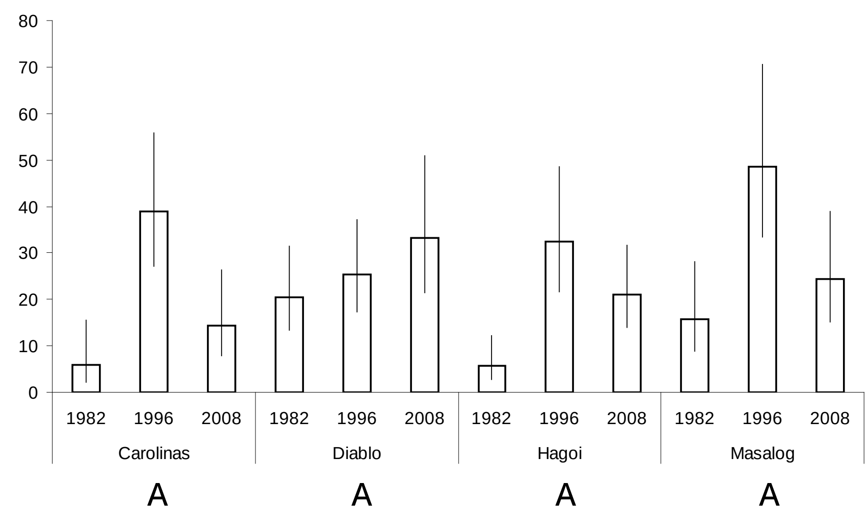
Yellow Bittern

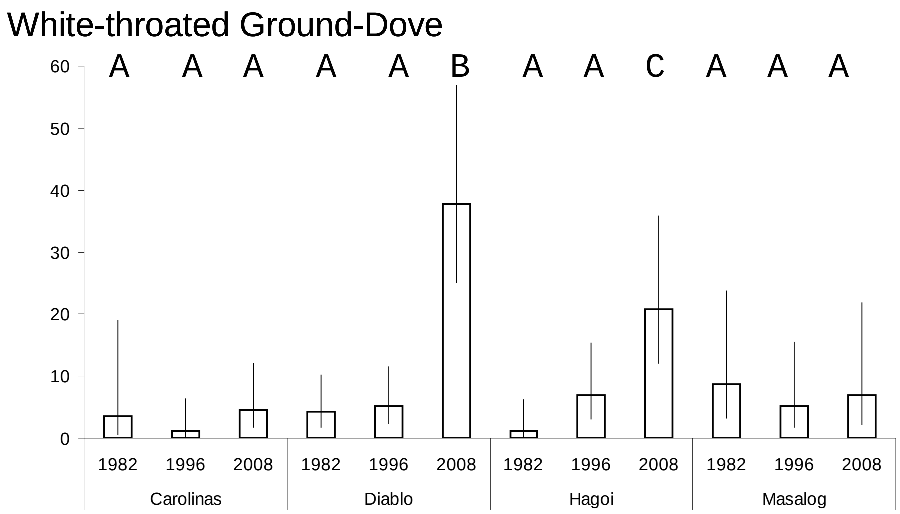


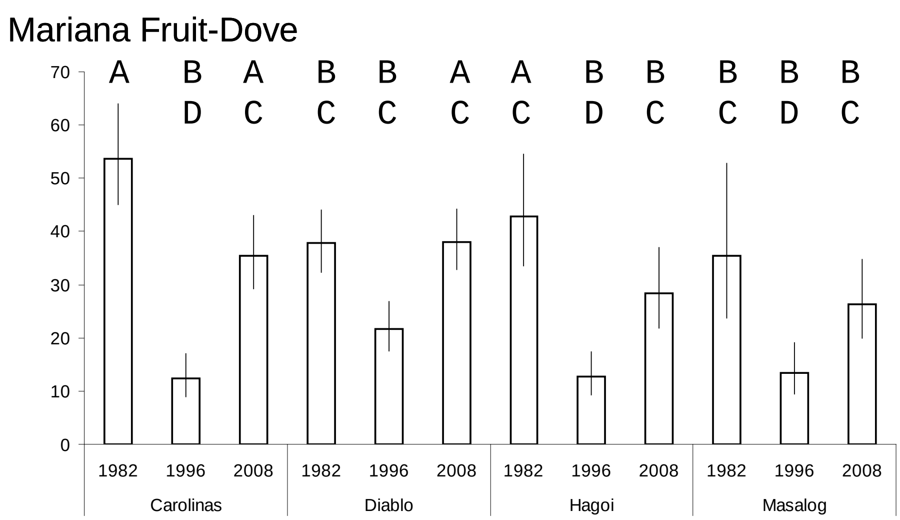
White Tern

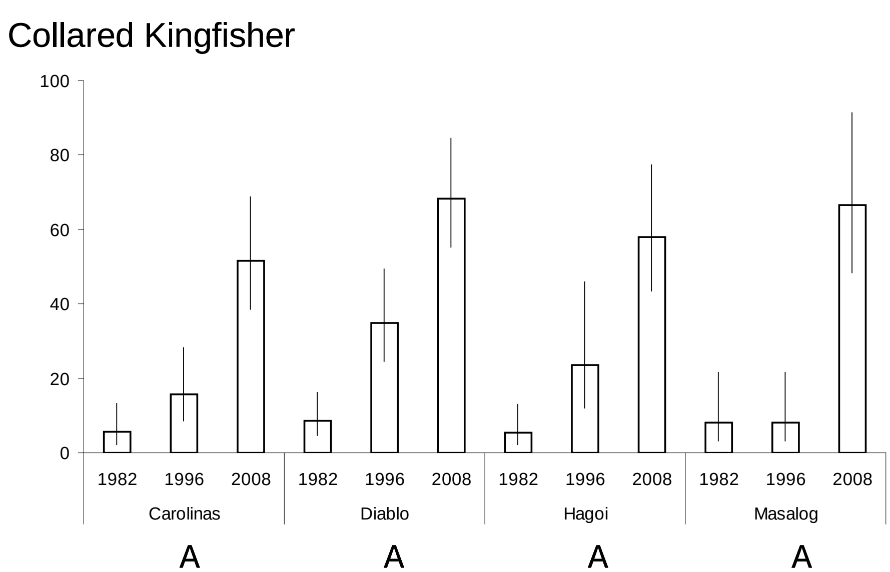


Island Collared-Dove

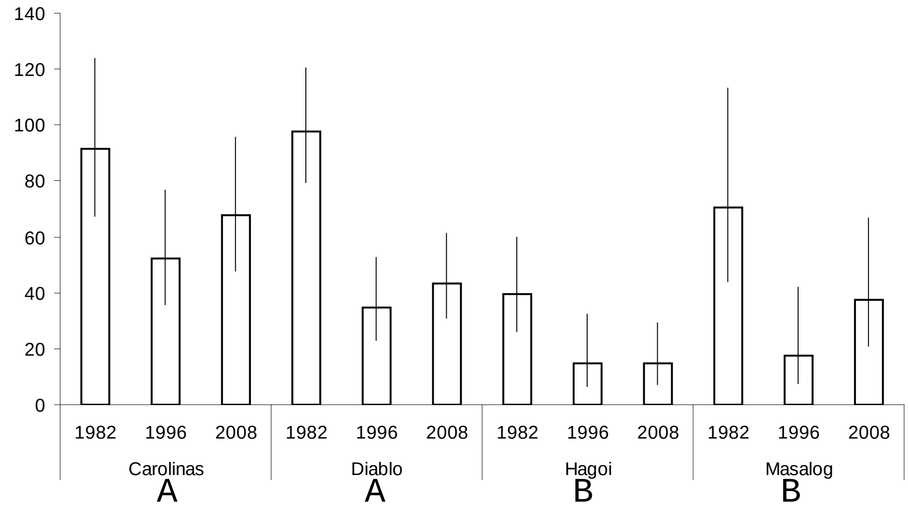



White-throated Ground-Dove
A A A A A B A A C A A A
60
50
40
30
20
10
0
1982 1996 2008 1982 1996 2008 1982 1996 2008 1982 1996 2008
Carolinas
Diablo
Hagoi
Masalog

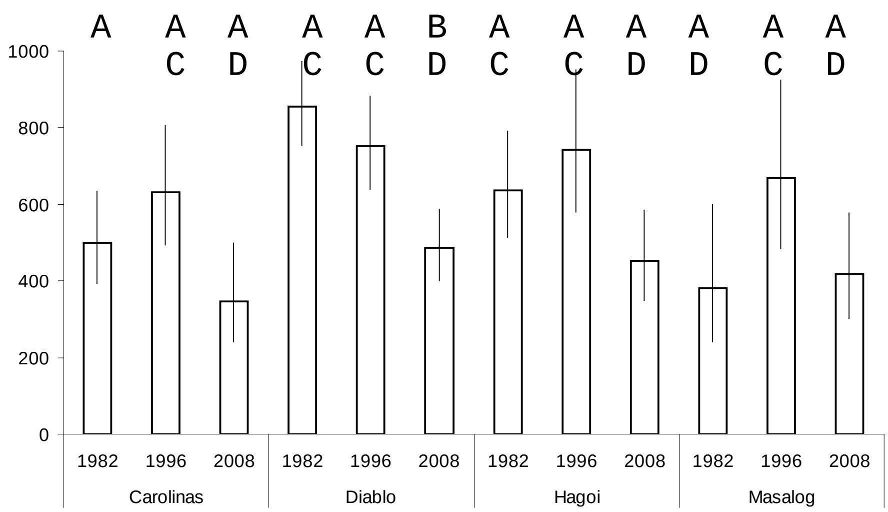

Mariana Fruit-Dove
A B A B B A A B B B B B
D C C C C C D C C D C
70
60
50
40
30
20
10
0
1982 1996 2008 1982 1996 2008 1982 1996 2008 1982 1996 2008
Carolinas
Diablo
Hagoi
Masalog


Collared Kingfisher
100
80
60
40
20
0
1982 1996 2008 1982 1996 2008 1982 1996 2008 1982 1996 2008
Carolinas
Diablo
Hagoi
Masalog
A A A A

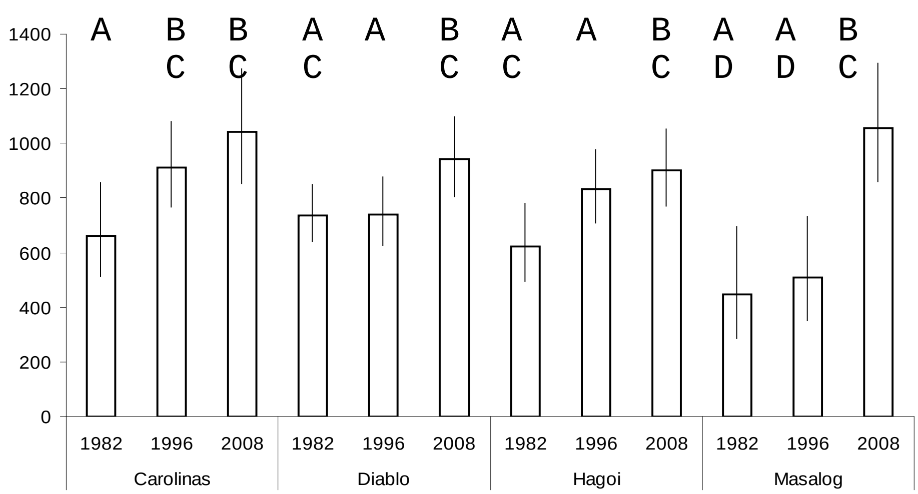
Micronesian Honeyeater



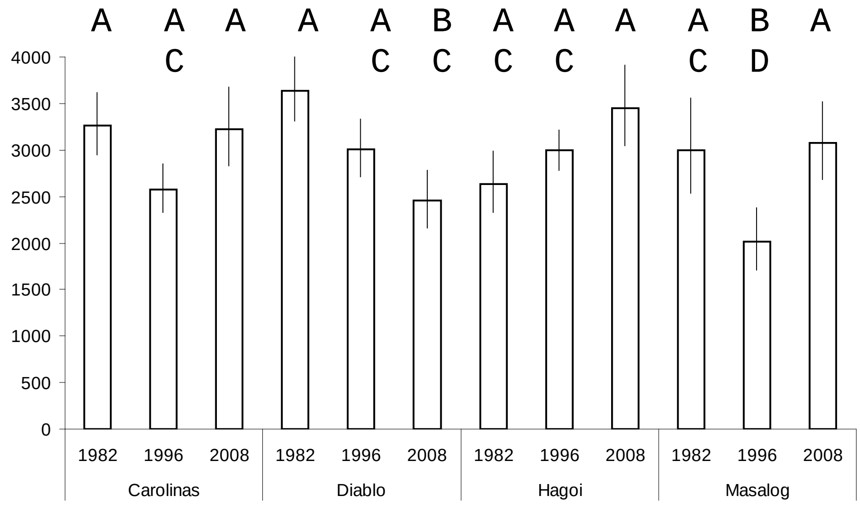
Tinian Monarch



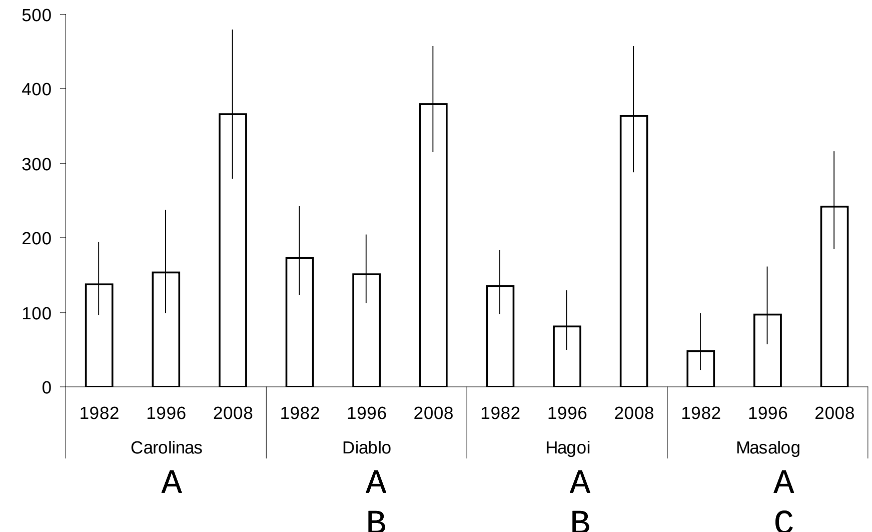
Rufous Fantail



Bridled White-eye



Micronesian Starling



Eurasian Tree Sparrow

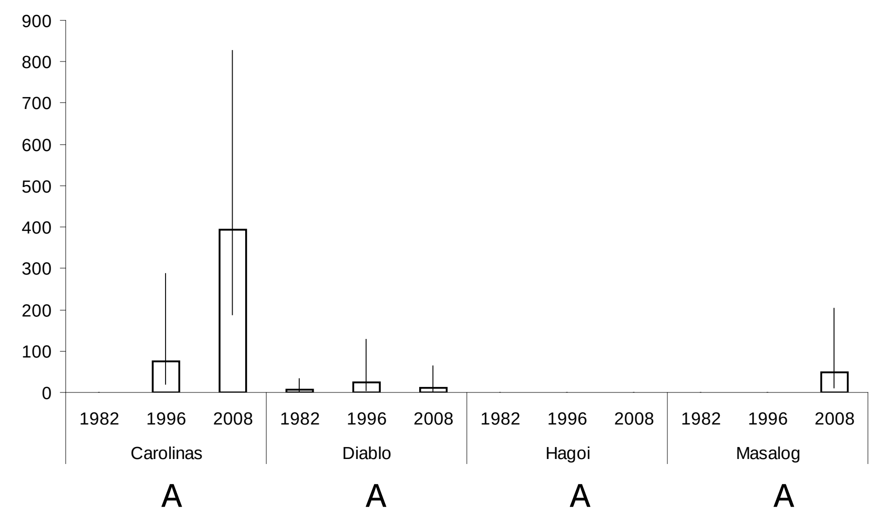


Figure 3. Density estimates (birds/km^2 and 95% CI) for Tinian land birds by region and year from three point-transect surveys. Differences of least squares means were assessed with repeated measures ANOVA. Comparisons that share the same letter are not significantly different at the 0.05 level, adjusted for multiple comparisons. Comparisons below species name are year within region results (i.e., significant year, region and interaction effects), whereas comparisons below x-axis indicate fixed effects results (*i.e.*, region or interaction effects were not significant).

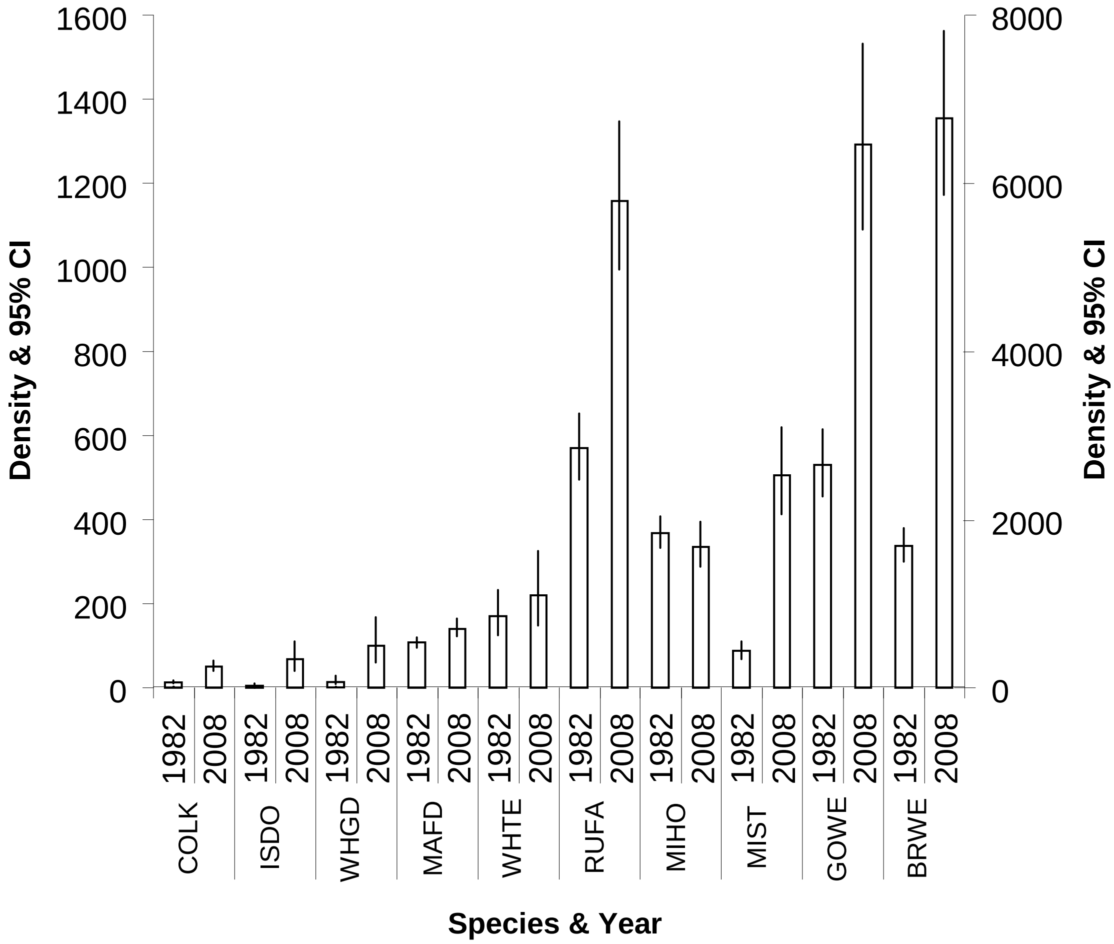


Figure 4. Density estimates (birds/km^2 and 95% CI) for native and alien Aguiguan land birds from two point-transect surveys. The primary y-axis is for the first nine species, and the secondary y-axis is for Bridled White-eye. Species codes are COLK – Collared Kingfisher; ISDO – Island Collared-Dove; WHGD – White-throated Ground-Dove; MAFD – Mariana Fruit-Dove; WHTE – White Tern; RUFA – Rufous Fantail; MIHO – Micronesian Honeyeater; MIST – Micronesian Starling; GOWE – Golden White-eye; and BRWE – Bridled White-eye.

Attachment 1. UTM coordinates for the point-transect or variable circular plot survey transects on the island of Tinian. All coordinates are in WGS84 UTM Zone 5 North. Transects 1 through 10 were established by Engbring *et al.* (1986) in 1982 and transects 11 through 14 was established in 2008.

Transect	Station	Latitude	Longitude
1	1	352759.43	1667002.60
1	2	352908.86	1666989.54
1	3	353058.29	1666976.47
1	4	353207.72	1666963.40
1	5	353357.15	1666950.34
1	6	353506.58	1666937.27
1	7	353656.01	1666924.20
1	8	353805.44	1666911.14
1	9	353954.87	1666898.07
1	10	354104.30	1666885.00
1	11	354253.73	1666871.94
1	12	354403.16	1666858.87
1	13	354552.59	1666845.80
1	14	354702.02	1666832.74
1	15	354851.45	1666819.67
1	16	355000.88	1666806.60
1	17	355150.31	1666793.54
1	18	355299.74	1666780.47
2	1	349965.19	1665235.33
2	2	350114.64	1665222.50
2	3	350264.09	1665209.68
2	4	350413.54	1665196.85
2	5	350562.99	1665184.02
2	6	350712.44	1665171.19
2	7	350861.89	1665158.36
2	8	351011.34	1665145.53
2	9	351160.77	1665132.46
2	10	351310.20	1665119.40
2	11	351459.63	1665106.33
2	12	351609.06	1665093.26
2	13	351758.49	1665080.20
2	14	351907.92	1665067.13
2	15	352057.35	1665054.06
2	16	352206.78	1665041.00
2	17	352356.21	1665027.93
2	18	352505.64	1665014.86
2	19	352655.07	1665001.80
2	20	352804.50	1664988.73
2	21	352953.93	1664975.66
2	22	353103.36	1664962.60
2	23	353252.79	1664949.53
2	24	353402.22	1664936.46
2	25	353551.65	1664923.40
2	26	353701.08	1664910.33
2	27	353850.51	1664897.26
2	28	353999.94	1664884.20

Transect	Station	Latitude	Longitude
2	29	354149.37	1664871.13
2	30	354298.80	1664858.06
2	31	354448.23	1664845.00
2	32	354597.66	1664831.93
2	33	354747.09	1664818.86
2	34	354896.52	1664805.80
2	35	355045.95	1664792.73
2	36	355195.38	1664779.66
3	1	350720.82	1663173.65
3	2	350870.25	1663160.58
3	3	351019.68	1663147.52
3	4	351169.11	1663134.45
3	5	351318.54	1663121.38
3	6	351467.97	1663108.32
3	7	351617.40	1663095.25
3	8	351766.83	1663082.18
3	9	351916.26	1663069.12
3	10	352065.69	1663056.05
3	11	352215.12	1663042.98
3	12	352364.55	1663029.92
3	13	352513.98	1663016.85
3	14	352663.41	1663003.78
3	15	352812.84	1662990.72
3	16	352962.27	1662977.65
3	17	353111.70	1662964.58
3	18	353261.13	1662951.52
3	19	353410.56	1662938.45
4	1	347996.48	1661425.61
4	2	348145.93	1661412.79
4	3	348295.38	1661399.96
4	4	348444.83	1661387.13
4	5	348594.28	1661374.30
4	6	348743.73	1661361.47
4	7	348893.18	1661348.64
4	8	349042.63	1661335.81
4	9	349192.08	1661322.98
4	10	349341.53	1661310.16
4	11	349490.98	1661297.33
4	12	349640.43	1661284.50
4	13	349789.88	1661271.67
4	14	349939.33	1661258.84
4	15	350088.78	1661246.01
4	16	350238.23	1661233.18
4	17	350387.69	1661220.35
4	18	350537.14	1661207.53
4	19	350686.59	1661194.70
4	20	350836.02	1661181.63
4	21	350985.45	1661168.56
4	22	351134.88	1661155.50
4	23	351284.31	1661142.43
4	24	351433.73	1661129.36

Transect	Station	Latitude	Longitude
4	25	351583.16	1661116.30
4	26	351732.59	1661103.23
4	27	351882.02	1661090.16
4	28	352031.45	1661077.10
4	29	352180.88	1661064.03
4	30	352330.31	1661050.96
4	31	352479.74	1661037.90
4	32	352629.17	1661024.83
4	33	352778.60	1661011.76
4	34	352928.03	1660998.70
4	35	353077.46	1660985.63
4	36	353226.89	1660972.56
5	1	350389.08	1659209.01
5	2	350538.53	1659196.18
5	3	350687.96	1659183.11
5	4	350837.39	1659170.04
5	5	350986.82	1659156.98
5	6	351136.25	1659143.91
5	7	351285.68	1659130.84
5	8	351435.11	1659117.78
5	9	351584.54	1659104.71
5	10	351733.97	1659091.64
5	11	351883.40	1659078.58
5	12	352032.83	1659065.51
5	13	352182.26	1659052.44
5	14	352331.69	1659039.38
5	15	352481.12	1659026.31
5	16	352630.55	1659013.24
5	17	352779.98	1659000.18
5	18	352929.41	1658987.11
6	1	356813.25	1658982.58
6	2	356716.59	1659097.29
6	3	356619.94	1659212.00
6	4	356523.29	1659326.71
6	5	356426.64	1659441.42
6	6	356329.99	1659556.13
6	7	356233.33	1659670.84
6	8	356136.68	1659785.55
6	9	356040.03	1659900.26
6	10	355943.38	1660014.97
6	11	355846.73	1660129.68
6	12	355750.08	1660244.39
6	13	355653.42	1660359.10
6	14	355556.77	1660473.81
6	15	355460.12	1660588.52
6	16	355363.47	1660703.23
6	17	355266.82	1660817.94
6	18	355170.16	1660932.65
7	1	354606.71	1658786.90
7	2	354703.36	1658672.19
7	3	354800.02	1658557.48

Transect	Station	Latitude	Longitude
7	4	354896.67	1658442.77
7	5	354993.32	1658328.06
7	6	355089.97	1658213.35
7	7	355186.62	1658098.64
7	8	355283.28	1657983.93
7	9	355379.93	1657869.22
7	10	355476.58	1657754.51
7	11	355573.23	1657639.80
7	12	355669.88	1657525.09
7	13	355766.53	1657410.38
7	14	355863.19	1657295.67
7	15	355959.84	1657180.96
7	16	356056.49	1657066.25
7	17	356153.14	1656951.54
7	18	356249.79	1656836.82
8	1	354504.87	1655695.61
8	2	354601.34	1655580.75
8	3	354697.81	1655465.89
8	4	354794.28	1655351.02
8	5	354890.75	1655236.16
8	6	354987.22	1655121.29
8	7	355083.69	1655006.43
8	8	355180.16	1654891.57
8	9	355276.62	1654776.70
8	10	355373.09	1654661.84
8	11	355469.56	1654546.97
8	12	355566.03	1654432.11
8	13	355662.50	1654317.25
8	14	355758.97	1654202.38
8	15	355855.44	1654087.52
8	16	355951.91	1653972.65
8	17	356048.38	1653857.79
8	18	356144.85	1653742.93
9	1	353177.60	1650850.99
9	2	353164.17	1651000.39
9	3	353150.75	1651149.79
9	4	353137.33	1651299.19
9	5	353123.90	1651448.58
9	6	353110.48	1651597.98
9	7	353097.06	1651747.38
9	8	353083.63	1651896.78
9	9	353070.21	1652046.18
9	10	353056.78	1652195.57
9	11	353043.36	1652344.97
9	12	353029.94	1652494.37
9	13	353016.51	1652643.77
9	14	353003.09	1652793.17
9	15	352989.67	1652942.57
9	16	352976.24	1653091.96
9	17	352962.82	1653241.36
9	18	352949.39	1653390.76

Transect	Station	Latitude	Longitude
10	1	350928.74	1656597.01
10	2	351078.19	1656584.18
10	3	351227.64	1656571.35
10	4	351377.09	1656558.52
10	5	351526.52	1656545.45
10	6	351675.95	1656532.39
10	7	351825.38	1656519.32
10	8	351974.81	1656506.25
10	9	352124.24	1656493.19
10	10	352273.67	1656480.12
10	11	352423.10	1656467.05
10	12	352572.53	1656453.98
10	13	352721.96	1656440.92
10	14	352871.38	1656427.85
10	15	353020.81	1656414.78
10	16	353170.24	1656401.72
10	17	353319.67	1656388.65
10	18	353469.10	1656375.58
11	1	353452.77	1663336.82
11	2	353320.05	1663398.28
11	3	353210.41	1663431.53
11	4	353150.44	1663475.13
11	5	353082.78	1663531.79
11	6	352954.55	1663600.14
11	7	352863.57	1663671.57
11	8	352750.76	1663742.48
11	9	352674.14	1663846.96
12	1	353122.99	1662596.49
12	2	353078.71	1662466.68
12	3	353007.30	1662332.00
12	4	353006.92	1662176.79
12	5	352938.08	1662044.09
12	6	352949.16	1661885.87
12	7	353025.32	1661739.87
12	8	353026.24	1661586.31
12	9	352988.91	1661442.87
13	1	355905.97	1656624.23
13	2	355905.97	1656461.84
13	3	355909.15	1656312.18
13	4	355905.97	1656162.53
13	5	355905.97	1656012.87
13	6	355905.97	1655866.40
13	7	355909.15	1655708.78
13	8	355909.15	1655559.12
13	9	355909.15	1655409.47
13	10	355909.15	1655262.99
13	11	355909.15	1655110.15
13	12	355912.34	1654960.50
13	13	355909.15	1654804.79
13	14	355915.52	1654664.69
14	1	355909.15	1653461.06

Transect	Station	Latitude	Longitude
14	2	355756.31	1653314.59
14	3	355606.66	1653158.57
14	4	355457.00	1653012.09
14	5	355310.53	1652862.44

Attachment 2. UTM coordinates for the point-transect or variable circular plot survey transects on the island of Aguiguan. All coordinates are in WGS84 UTM Zone 5 North. Transects 1 through 4 were established by Engbring *et al.* (1986) in 1982 and transect 5 was established in 2008.

Transect	Station	Latitude	Longitude
1	1	342821.64	1642070.78
1	2	342908.96	1641962.30
1	3	342940.71	1641827.36
1	4	342969.81	1641668.61
1	5	343067.71	1641549.55
1	6	343205.29	1641626.28
1	7	343369.33	1641631.57
1	8	343512.21	1641599.82
1	9	343655.08	1641631.57
1	10	343790.02	1641684.49
1	11	343922.31	1641716.24
1	12	344078.42	1641750.63
1	13	343914.38	1641811.49
1	14	343779.44	1641890.86
1	15	343803.25	1642009.93
1	16	343951.42	1642070.78
2	1	342832.23	1642210.31
2	2	342948.64	1642305.56
2	3	343062.42	1642408.74
2	4	343173.54	1642511.93
2	5	343292.60	1642609.83
2	6	343416.96	1642675.97
2	7	343570.42	1642707.72
2	8	343721.23	1642747.41
2	9	343872.04	1642779.16
2	10	344022.86	1642824.14
2	11	344152.50	1642898.22
2	12	344287.70	1642974.95
2	13	344409.41	1643049.04
2	14	344552.29	1643115.18
2	15	344684.58	1643194.56
2	16	344819.78	1643249.86
3	1	345028.80	1642109.50
3	2	345187.55	1642104.21
3	3	345338.37	1642093.62
3	4	345481.24	1642090.98
3	5	345639.99	1642072.46
3	6	345782.87	1642075.10
3	7	345909.87	1642154.48
3	8	346031.58	1642244.44
3	9	346155.93	1642326.46
3	10	346282.93	1642405.83
3	11	346401.46	1642490.79
3	12	346531.11	1642578.10
3	13	346644.88	1642697.16

Transect	Station	Latitude	Longitude
3	14	346684.57	1642834.75
3	15	346711.03	1642980.27
3	16	346748.07	1643128.43
3	17	346800.99	1643276.60
3	18	346822.15	1643414.18
4	1	344099.58	1642623.12
4	2	344216.00	1642710.43
4	3	344343.00	1642803.03
4	4	344472.65	1642898.28
4	5	344594.36	1642980.30
4	6	344713.42	1643067.62
4	7	344853.65	1643125.82
4	8	344996.52	1643197.26
4	9	345126.17	1643255.47
4	10	345271.69	1643318.97
4	11	345403.98	1643371.89
4	12	345544.21	1643440.68
4	13	345681.80	1643501.53
4	14	345816.20	1643567.70
4	15	345953.79	1643628.56
4	16	346094.02	1643689.41
5	1	344422.01	1642262.89
5	2	344562.43	1642335.11
5	3	344718.89	1642411.33
5	4	344855.29	1642487.55
5	5	344983.66	1642551.74
5	6	345148.15	1642623.95
5	7	345288.56	1642704.19
5	8	345449.03	1642780.41
5	9	345609.50	1642856.64
5	10	345765.96	1642936.87
5	11	345910.39	1643001.06
5	12	346074.87	1643081.30
5	13	346235.34	1643165.54
5	14	346375.75	1643241.77

2.4.2 SEABIRD SURVEYS

Sooty Terns. Photo by Curt Kessler.

Prepared by: **Curt Kessler, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI**

INTRODUCTION

Fifteen seabird species have been recorded nesting in the Mariana archipelago with at least one, and more commonly a suite of species, nesting on each island (Reichel 1991). This guild of species is an important segment of the sea-land-sea nutrient cycle. Disruption of "safe haven" nesting sites could have significant impacts on this group of important birds.

Seabird surveys are systematically conducted on Farallon de Medinilla (FDM) by the U.S. Navy, and on the island of Rota at the Sagua' gaga (I Chenchon) Seabird Sanctuary by the Commonwealth of the Northern Mariana Islands (CNMI) – Division of Fish & Wildlife (DFW). Based on a review of 10 years of monthly surveys on FDM (Vogt 2005), the month of October has the lowest numbers of nesting seabirds on average. Therefore, seabirds found nesting at this time of year are expected to be the minimum number nesting

In 2008, the United States Marine Corp (USMC) contracted the U.S. Fish and Wildlife Service - Pacific Islands Fish and Wildlife Office (USFWS-PIFWO), to conduct terrestrial and marine surveys on Tinian and Aguiguan. The following report outlines seabird surveys that were conducted on the islands of Tinian, Aguiguan, and Naftan

Rock, CNMI during the 2008 survey. These surveys should be considered as a way to delineate those areas that have high concentrations of seabirds and where common colony nesting species occur. Species surveyed for include; brown booby (*Sula leucogaster*), red-footed bobby (*Sula sula*), masked booby (*Sula dactylatra*), brown noddy (*Anous stolidus*), black noddy (*Anous minutus*), sooty tern (*Onychoprion fuscatus,* previously *Sterna fuscata*), white tern (*Gygis alba*), and wedge tailed shearwater (*Puffinus pacificus*). Additionally, tattlers (*Heteroscelus sp*), white-tailed tropicbirds (*Phaethon lepturus*), red-tailed tropicbirds (*P. rubricauda*), and reef heron (*Egretta sacra*) were noted. The white tern was also recorded in the June 2008 island-wide point-transect or variable circular plot surveys on Tinian and Aguiguan. The seabird related results from those surveys are reported here and in Section 2.4.1 of this report. Refer to that section and Appendix 3.1 (Camp *et al*. 2009) for a detailed explanation of the survey methods.

METHODS

Shoreline, helicopter, and ground surveys were conducted in October 2008. A point-transect or variable circular plot survey was conducted to survey all bird species in June 2008 and results from previous point-transect surveys were reanalyzed to assess population trends. A description of each survey method and where they were utilized is outline below.

Shoreline and Helicopter Surveys
A shoreline survey was conducted along Navy leased lands on Tinian from approximately Barcinas Bay (14 59’26.38”N 145 36’10.29”E) to the eastside point at Puntan Masalok (15 1’10.66”N 45 39’53.02E) (Figure 1). Surveys were also conducted around the island of Aguiguan and Naftan Rock (Figure 2). The Tinian survey spanned two days (Oct. 10, 2008, 1700-1800 hrs; Oct 11 0800-1000 hrs, 1330-1430 hrs, Observers; C. Kessler –USFWS, and J. Omar – CNMI-DFW). The Naftan Rock survey took place on October 14, 2008 from 1500 hrs to 2130 hrs and was conducted by C. Kessler and E. Masga (Tinian DFW). Shoreline surveys took place opportunistically on Aguiguan between June and August 2008 and were conducted by C. Kessler, J. Omar, and E. Masga. All observations were conducted from a 17’boat (RIB-Apex brand) with the aide of 8 or 10 power binoculars. The boat cruised at a constant rate of approximately 8 miles per hour and stayed between 20 and 75 meters offshore as conditions permitted. Locations of all species sighted were either recorded using a Garmin 76CSx Global Positioning System unit (GPS) or marked on a map. Double counting was kept at a minimum by noting the direction of individual birds as they flew. At the right distance most birds flushed in the opposite direction of observer course. Limestone cliffs on the west side of Tinian were especially searched for black noddy nesting areas and roosts.

A helicopter survey of southwest coast of Aguiguan was conducted to map brown booby nesting areas. Nests were observed with the naked eye at 50-100 m distance. Nests were easily identified by observing ‘sitting’ birds in combination with bare dirt/cleared areas created by the nesting birds. This survey was conducted on October 13, 2008 at 1200 hrs and consisted of Observer C. Kessler and Pilot N. Kogure of Americopters, Inc.

Ground Surveys
A ground survey was conducted to determine density of nesting sooty tern pairs on Naftan Rock. Naftan Rock, for survey purposes, was delineated into three sections; north rock, south rock, and a small valley between (Figure 3). The area of the north and south rock (894 m^2 and 304 m^2, respectively) occupied by sooty terns was calculated by outlining the colony and determining the area with the aide of aerial photographs and Google Earth. The small valley between the north and south rock did not appear to have any nests at this time of the year and was not included in the acreage calculations. Both north and south areas were walked and the average distance between sooty tern eggs recorded in a field notebook and on digital film. These measurements were then used as the radius of a circle to calculate square meters occupied by one nest. This result was then divided into the total area to determine the number of eggs/nests for each area. It should be noted that the measurements used between nests was an average and actual spacing decreased toward the center of the nesting area and increased as one moved away from the center and approached the edges.

In addition, night vision goggles (NVG) (3rd generation ATN corp. model NVM14-3A) were utilized to record observations of wedge-tailed shearwaters using the grasslands on the north half of Naftan Rock. These observations recorded by C. Kessler on October 14, 2008 between 1900 - 2100 hrs on Naftan Rock.

Point Transect Surveys
Point-transect surveys were conducted on Tinian in 1982 (27 April – 8 May), 1996 (28 August – 1 September), and 2008 (14 – 19 June) on a total of 216 stations along 10 transects (Figure 1). All transects were at least 300 meters apart and all stations along each transect were 150 meters apart. An additional 4 transects were sampled during the 2008 survey for a total of 254 stations. On Aguiguan, 66 stations along 4 transects were sampled on June 2 and 3, 1982, and June 25-27, 2008 (Figure 2). An additional transect of 14 stations was also sampled during the 2008 survey for a total of 80 stations. This additional transect was at least 300 meters away from the nearest transect and all stations along all transects were 150 meters apart. All surveys followed standard point-transect methods, consisting of 8-minute counts where horizontal distances to all birds heard and/or seen were measured and recorded (see Engbring *et al*. 1986 for details). Population status was calculated as densities (birds/km^2) and number of birds (density by habitat type multiplied by habitat type area). Densities were calculated using the program DISTANCE (Thomas *et al*. 2006). Please refer to Section 2.4.1 of this report for a detailed explanation of the methods for the point-transect surveys.

RESULTS

Shoreline and Helicopter Surveys
A total of 36 tattlers, 11 reef herons, 28 black noddies, and 15 white terns were recorded during shoreline surveys of Navy lands on Tinian. In addition, a large colony of white terns numbering 30 plus was observed at 15 2’ 23.50”N 145 35’ 42.91”E roosting in old growth *Barringtonia asiatica* trees just below the cliff line.

No black noddy nesting areas were observed on Tinian during the survey although small groups were noted to be roosting at the north end of Barcina's Bay on the limestone cliffs that overhang the water. The coastline along the west side of the Tinian consists of flat coralline shelves along the water with large boulders in the bays along the shore. This side is protected from the prevailing winds and hosted most of the birds observed. The east side of Tinian has jagged limestone karst and rough seas due to the prevailing winds, and had significantly fewer birds. It is possible that at different seasons this trend could be reversed.

A south side helicopter survey of the cliff edge on Aguiguan recorded 44 brown booby nests (Figure 4). Nests were situated along the edges of cliffs on level ground. Five nests were also observed on large limestone boulders that had broken away from the cliff and now rested along the shore. The helicopter survey also recorded approximately 10 red-footed boobies nesting in the trees at 14 50' 41.48"N 145 33' 33.19"E (Figure 4).

Red footed bobby (Sula sula). Photo S. Vogt

A family group of 4-6 red-tailed tropicbirds were observed in the area of the boat landing on the north side of Aguiguan (Figure 4). In addition, tropicbirds were observed using the caves on the inland cliff face on the south side. Brown boobys were observed on the cliff face on the north east side (Figure 4; 14 51 50.41"N 145 34' 0.34"E). It is estimated that 10 pairs were nesting in this area; however this area was not visited by helicopter.

Black noddies were numerous and inhabited all large sea caves on the north and south west sides of Aguiguan (Figure 4). One of the caves on the north side, called black noddy cave, is known to be used by black noddies for nesting. A rough estimate of black noddies on the island for the month of October would be 400-500 individuals.

In addition to the shoreline and helicopter surveys, large mixed flocks of hundreds of seabirds consisting primarily of shearwaters, noddies, and white terns were observed offshore from Tinian and Aguiguan feeding with schools of tuna. Observations were from a boat in transit between the islands during the June to August survey period. Certain areas consistently had these concentrations of fish and seabirds and are mapped in Figure 5. These feeding areas should be viewed as a significant resource to seabirds and important to local fisherman.

Ground Surveys
Sooty terns were the most numerous nesting birds on Naftan Rock on October 14, 2008. They occupied the entire flat area of the South Rock and about one half of the flat area on the North Rock. Their nesting areas can be clearly seen on aerial photos due to the altered state of the vegetation in the areas where they nest (Figure 3). Sooty tern eggs were on average 0.3 meters apart on the North Rock and 0.46 meters apart on the South Rock. The total estimated number of eggs on Naftan Rock was therefore 3,647 eggs; 454 and 3,193 eggs on the south and north rock, respectively. This means there were approximately 7,294 individual adult sooty terns nesting on this small islet.

Brown boobies were not found to be nesting on Naftan Rock, but 15-25 individuals were observed roosting. Masked boobies were not observed during this survey, however four individuals were recorded on the islet in August 2008, and two individuals were observed in May 2007.

Brown noddies were nesting (feathered nestlings were observed) on the island and are considered to be year round nesters in the CNMI. This species was not as plentiful as observed in May 2007, probably due to seasonal fluctuations. Brown noddies are ground nesters, and were observed nesting around the periphery of the sooty terns along the cliff face and steeper parts of Naftan Rock. For this survey it was estimated 200-300 pairs were nesting on the island. Due to the steep nature of their nesting sites, this species was not rigorously surveyed for and the pair estimate given is only a rough estimate.

Wedge tailed Shearwaters use the grassy area on the North Rock and middle valley for nesting. During this survey, approximately 5-10 shearwaters were observed at night coming in off the ocean and landing in the grass, however no nests were found. However, in May 2007, more than five nests with eggs were observed in burrows in the grassy area and one shearwater was observed under a boulder in the middle valley.


Wedge-tailed shearwater (*Puffinus pacificus*). Photo C. Kessler

Ruddy Turnstone (*Arenaria interpres*) were present and approximately twenty individuals of this migratory species were found to be roosting and feeding on Naftan Rock.

Point Transect Surveys

Three seabird species were detected during the point-transect survey on Tinian (Table 1). However, only sufficient numbers of white terns were detected to calculate density and abundance estimates. The white tern population was estimated to be approximately 15,000 individuals (Table 2) and no significant difference in density was found between the 1982 and 2008 estimates (Repeated Measures ANOVA, $F_{2,398} = 43.18$, $p < 0.001$; Least Square Means, $t = -0.91$, $p = 0.634$). However, there was a significant difference between the 1996 and both the 1982 (Repeated Measures ANOVA, $F_{2,398} = 43.18$, $p < 0.001$; Least Square Means, $t = 7.55$, $p < 0.001$) and 2008 (Repeated Measures ANOVA, $F_{2,398} = 43.18$, $p < 0.001$; Least Square Means, $t = -8.46$, $p < 0.001$) estimates. No significant difference in white tern densities among regions by year was detected (Repeated Measures ANOVA, $F_{6,392} = 1.71$, $p = 0.116$). However, a significant difference in regions was detected (Repeated Measures ANOVA, $F_{3,196} = 4.15$, $p = 0.007$) and the Hagoi region had fewer white terns than the Carolinas, Diablo, and Masalog regions (Least Square Means, $p \leq 0.05$). Please refer to Section 2.4.1 of this report for a detailed explanation of the results for the VCP survey.

Three seabird species were detected during the point-transect survey on Aguiguan (Table 1). However, only sufficient numbers of white terns were detected to calculate density and abundance estimates (Table 2). The white tern population was estimated to be approximately 1,200 individuals and was not significantly different from the 1982 estimate (z value = -0.95, $p = 0.341$). Please refer to Section 2.4.1 of this report for a detailed explanation of the results for the VCP survey.

DISCUSSION

The 44 brown booby nests observed on Aguiguan in October represent a minimum number of nesting pairs on the island. In Nov 2006 between 50 and 100 nests were observed but not fully surveyed (C. Kessler, pers. obs.). In 1984, 250-300 brown boobies were recorded to be nesting along the south cliff line during the summer (DFW 1985). More observations are required to fully understand the extent of nesting in this area.


Brown Bobbies (*Sula leucogaster*) nesting on the southside of Aguiguan Island, CNMI. Nov. 2006. Photo C. Kessler

The estimated density of sooty terns on Naftan Rock (2.7 nests/m^2) falls within the range of densities reported for five other sites across the Pacific (1.3 - 4.5 nests/m^2; Schreiber *et. al.* 2002). The estimate of almost 7,300 adult birds is slightly higher than 6,000 reported in 1984 (Table 3). However in 1984 there are reports of large numbers of eggs being taken by local hunters from Naftan Rock (DFW 1985; E. Masga, pers. comm.). This practice is believed to have slowed down or stopped in recent years and could be one factor in the population increase. Another potential factor is that sooty tern nesting densities appear to be dependent on ground cover and substrate (Schreiber *et. al.* 2002). This was observed on Naftan Rock and is reflected in the densities recorded for the separate halves of the island. The terrain on the north rock was more even than on the south rock and the ground cover was also less.

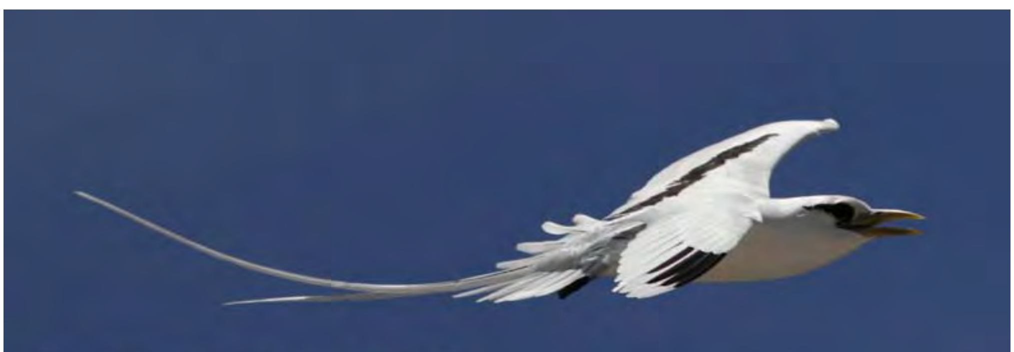
Sooty Terns (*Onychoprion fuscatus*) nesting on Naftan Rock, Mariana Islands. Oct 2008. Photo by C. Kessler.

Sooty tern nests were primarily at the egg stage although a few downy chicks were recorded and one egg was observed to hatch. The observation of sooty terns breeding in October appears unusual although breeding records are not complete. Previous breeding records from the CNMI indicate this species breeds from January to September (Table 3). However monthly surveys of FDM show concentrations of sooty terns on FDM for all month except August. The FDM surveys also reveal that they are not present on the island every year and vary widely between years (Figure 3; S. Vogt, pers. com. 2008). Sooty terns are known to alter their nesting dates by region and weather patterns (Scheiber *et. al*. 2002). For the period June – August 2008 it appears that some environmental factor had changed as evidenced by noticeable die off's of brown and red-footed boobies on Aguiguan (Attachment 1), wedge-tailed shearwaters on Managaha (S. Kremer, pers. comm.) and anecdotal accounts of unusual mackerel species being caught. More research is needed to explore the relationship between weather/ocean patterns, fisheries, and the nesting of sooty terns.

Wedge tailed shearwaters were documented to nest on Naftan Rock in June (2 nests) and August (4 nests) 1984 (DFW 1985) and were observed nesting under large boulders in the central valley area that is primarily covered with the ground hugging seaside succulent *Sesuvium portulacastrum*. In May 2007, one shearwater was observed roosting under a boulder in the central area but nests with eggs were located upon the north rock in the level area adjacent to the sooty terns. This area is covered by thick grass and burrows were formed under the matted grass using the grass as tunnels. No occupied burrows were recorded, but adults were observed landing in the grassy area after dark. October is outside the reported nesting time of May-July. In January 1985 no active burrows were reported, but chewed bones lead the biologists to suspect that *Rattus exulans* might be on the island. No mammals were observed on the October 2008 survey, but a medium size coconut crab (*Birgus latro*; thoracic length = 31 mm) was recorded in the grassy area used by the shearwaters. This large land crab should be considered a predator on seabirds.

Brown noddies are ground nesters and are thought to nest year round (Chardine and Morris 1996). Nesting has been recorded for the Kastiyo area of Tinian and 340 nesting pairs were recorded on Aguiguan (DFW 1988). Naftan rock was reported to have 500 in June 1984 and 2000 in July 1983 (DFW 1988). The low estimate of 200 - 300 nesting pairs recorded during the 2008 survey reflects that these surveys were conducted outside the peak of the breeding season. Brown noddies occupied the steeper parts of the island in October but were distributed throughout the sooty tern core areas in May 2007.

The Tinian shoreline survey was intended to document black noddy cliff line nesting sites. None were recorded which mimics with similar survey in July and August of 1984 (CNMI 1985). However, black noddies are known to nest in Black noddy cave (hence the name) on Aguiguan with 120-130 individuals in July 1983 and 20-30 active nests in February 1984 (CNMI 1988). During this survey it can only be reported that black noddys occupied that cave and others along the coast. This species was also reported nesting in the Masalok area of Tinian in 1986 (DFW 1988).


White-tailed tropicbird (Phaethon lepturus). Photo S. Vogt.

Both white tailed and red tailed tropic birds are known to nest in small numbers on Aguiguan and Tinian. These species use inaccessible cliff ledges and are consistently present in small numbers about Aguiguan throughout the year. Nesting activity was observed along the north cliff face in the vicinity of the boat landing and along the southeast inland cliff face (Figure 4).

Consistently high densities of white terns were recorded during the 1982 and 2008 surveys on Aguiguan and Tinian indicating that populations appear stable. The 1996 white tern estimate on Tinian was lower than the estimates from 1982 and 2008. It is


White tern (Gygis alba). Photo S. Vogt

likely that the low tern estimate was an artifact of when the survey was conducted and not an actual change in the tern population. The original survey in 1982 and the most recent 2008 survey occurred early in the year and early in the breeding season (although terns can breed in all months of the year; Niethammer and Patrick-Castilaw 1998), whereas the 1996 survey was conducted in late August and after the peak breeding season. When not nesting, most individuals spend extended periods at sea (Niethammer and Patrick-Castilaw 1998); therefore portions of the population in 1996 were outside the sampling frame.

The results of this survey and previously reported observations that October typically has the lowest seabird breeding activity in the Mariana Islands (Vogt 2005) indicates that breeding by seabirds occurs throughout the year and that some species are always nesting regardless of month. To fully understand and manage for seabirds a standardized monthly census needs to be conducted, archipelago-wide, over a number of years. Congruently, a banding study should also be conducted to better understand seabird patterns and interactions with local and Pacific-wide fisheries. The association between seabird and fish populations in the region needs study.

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Table 1. List of seabirds detected from three different point-transect surveys on Tinian and Aguiguan. In 1982 and 1996, 216 stations were sampled on 10 transects in Tinian, and in 2008 254 stations were sampled on 14 transects in Tinian. In 1982, 66 stations were sampled on 4 transects (88 counts; several stations were counted more than once), and in 2008, 80 stations were sampled in 5 transects on Aguiguan. The number of birds detected (# Dect), and indices of percent occurrence (% Occ) and birds per station (BPS), were calculated.

				1982			1996			2008	
Species	Island	Year	# Dect	% Occ	BPS	# Dect	% Occ	BPS	# Dect	% Occ	BPS
White-tailed Tropicbird	Tinian	1982	0	0	0	0	0	0	5	1.2	0.02
(*Phaethon lepturus*)	Aguiguan	1982	1	1.1	0.01	-	-	-	0	0	0
Red-tailed Tropicbird	Tinian	1982	0	0	0	0	0	0	0	0	0
(*Phaethon rubricauda*)	Aguiguan	1982	13	9.1	0.15	-	-	-	0	0	0
Great Frigatebird	Tinian	1982	0	0	0	0	0	0	0	0	0
(*Fregata minor*)	Aguiguan	1982	2	1.1	0.02	-	-	-	0	0	0
Brown Noddy	Tinian	1982	0	0	0	0	0	0	1	0.4	<0.01
(*Anous stolidus*)	Aguiguan	1982	20	15.9	0.23	-	-	-	0	0	0
Black Noddy	Tinian	1982	0	0	0	0	0	0	0	0	0
(*Anous minutus*)	Aguiguan	1982	75	35.2	0.85	-	-	-	1	1.2	0.01
White Tern	Tinian	1982	344	59.3	1.59	52	10.2	0.24	322	48.0	1.27
(*Gygis alba*)	Aguiguan	1982	218	61.4	2.48	-	-	-	84	42.5	1.05
Sooty Tern	Tinian	1982	0	0	0	0	0	0	0	0	0
(*Sterna fuscata*)	Aguiguan	1982	1	1.1	0.01	-	-	-	0	0	0

Table 2. Population density and abundance estimates for white terns on Tinian and Aguiguan from point-transect surveys. First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: 2008 bird abundance (density by habitat times the habitat area) with 95% CI. Agriculture habitat type was dropped on Tinian for calculating bird abundance due to small sample size; only 2 survey stations were sampled on Tinian.

Island	1982	1996	2008
Tinian	144.1 ± 17.24 (113.9–182.2)	25.3 ± 7.01 (14.8–43.2)	169.9 ± 19.66 (135.4–213.2)
	13,980 (9.349–21,512)	2,846 (1,121–7,300)	15,147 (10,067–23,041)
Aguiguan	169.6 ± 27.0 (124.2–231.6)	-	218.8 ± 44.2 (147.3–325.1)
	-	-	1,214 (604–3,651)

Table 3. Sooty tern (*Onychoprion fuscatus*) numbers recorded in the Mariana Islands by month and year. Sooty tern population estimates for Farallon de Medinilla are not available.

Location	Month	Year	Population	Citation
Naftan Rock	April	1982	4,500	Engbring et al 1986
Naftan Rock	June	1984	6,000	Pratt 1984
Naftan Rock	August	1984	6,000	Pratt 1984
Naftan Rock	January	1985	1,500	Lemke and Pratt 1985
Naftan Rock	February	1987	Several thousand	Reichel 1987
Naftan Rock	January	1987	0	Reichel 1987
Naftan Rock	November	2008	7,300	This survey
Guguan	July-August	1979	20,000	Clapp pers comm./ CNMI 1988
Guguan	May-June	1983	28,000	Lemke 1983a
Guguan	September	1986	25,900	Glass and Villagomez 1986
Guguan	May-June	1987	35,000	Reichel 1988
Guguan	May	1992	25,000-30,000	Rice and Stinson 1992
Asuncion	June	1992	> 2,500	Rice and Stinson 1992
Uracas	August	1979	10,000-20,000	Clapp pers comm./ CNMI 1993
Uracas	August	1983	4,000-6,000	Lemke 1983
Uracas	February	1984	7,000	Pratt and Lemke 1984b
Uracas	June	1987	250,000	Reichel 1987/CNMI 1993
Uracas	June	1992	206,128	CNMI 1993

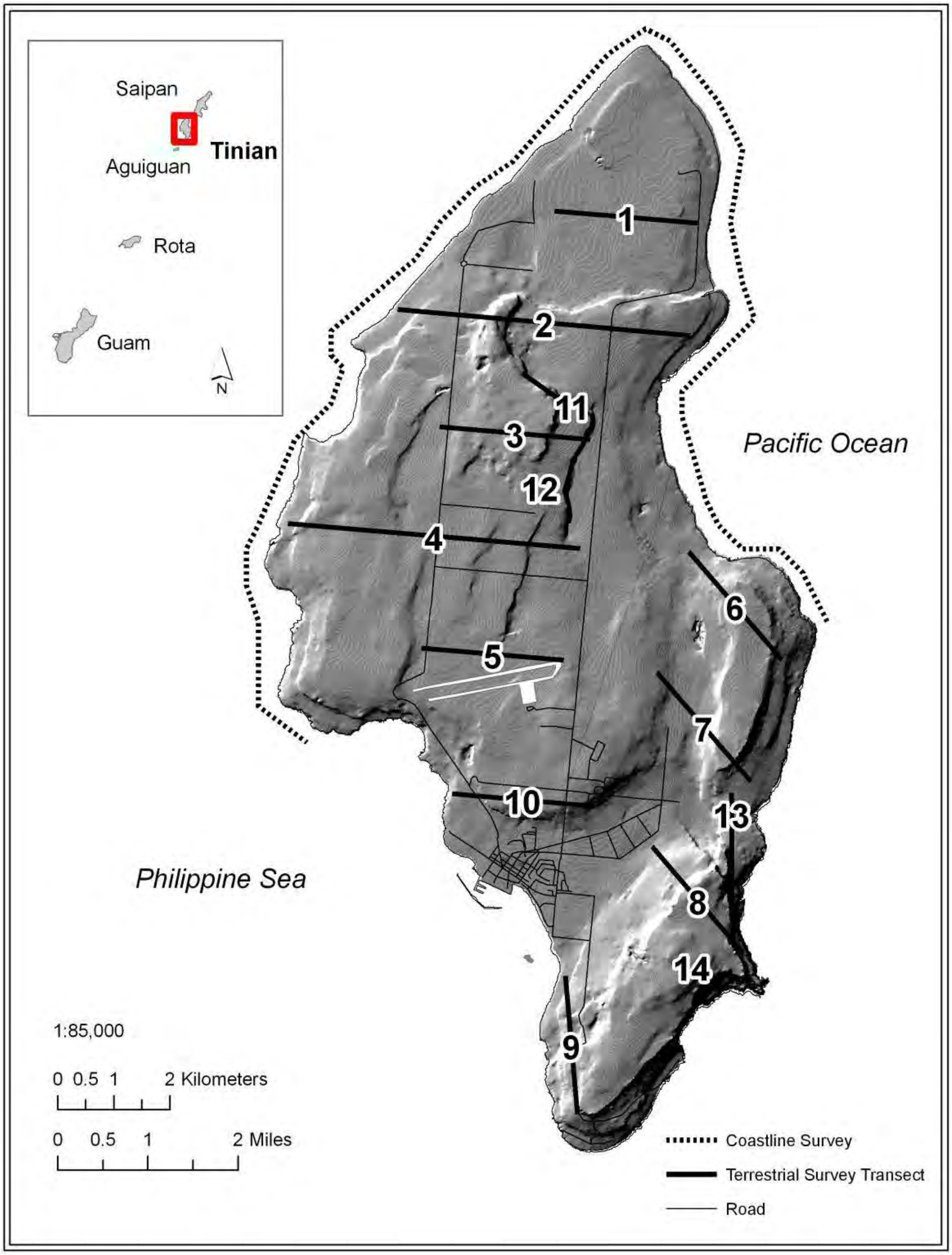


Figure 1. Island of Tinian showing the coastline survey route and terrestrial survey transects. Transects 1-10 were counted during all three surveys, and transects 11-14 were established and counted during the 2008 survey.

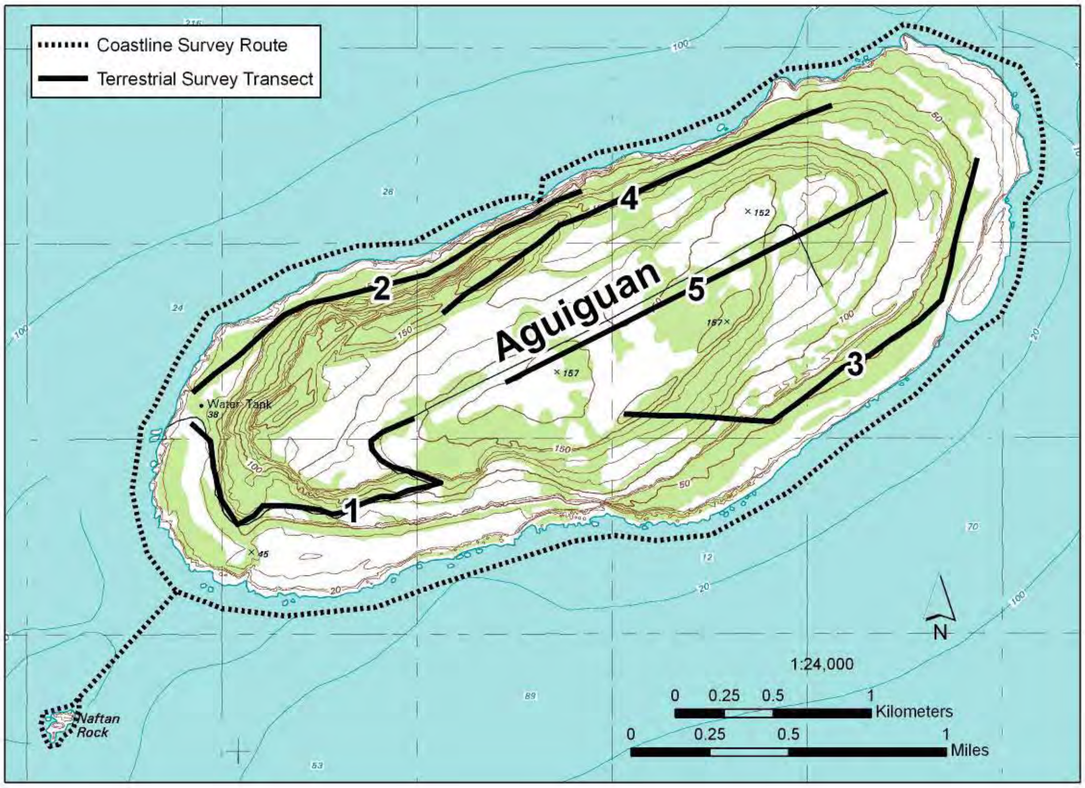
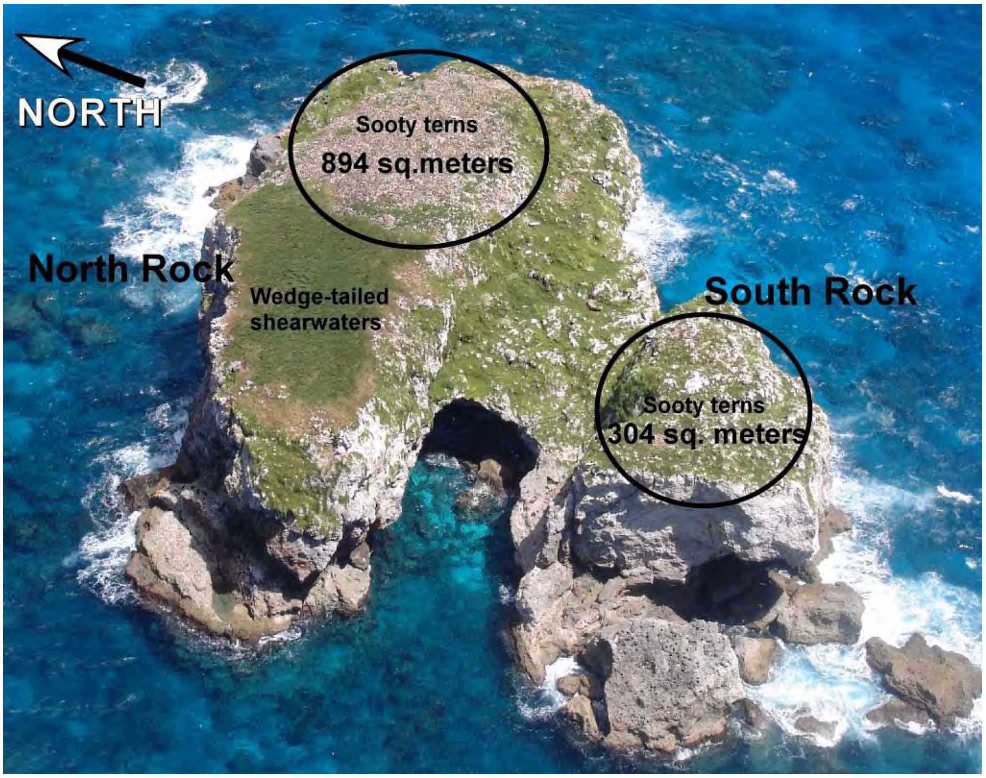


Figure 2. Island of Aguiguan and Naftan Rock showing the coastline survey route and terrestrial survey transects. Transects 1-4 were counted during both the 1982 and 2008 surveys, whereas transect 5 was established and counted during the 2008 survey.



Naftan Rock, Mariana Islands. Sept. 2004. Aerial view outlining areas calculated for Sooty Tern (*Onychoprion fuscatus*) density estimates.

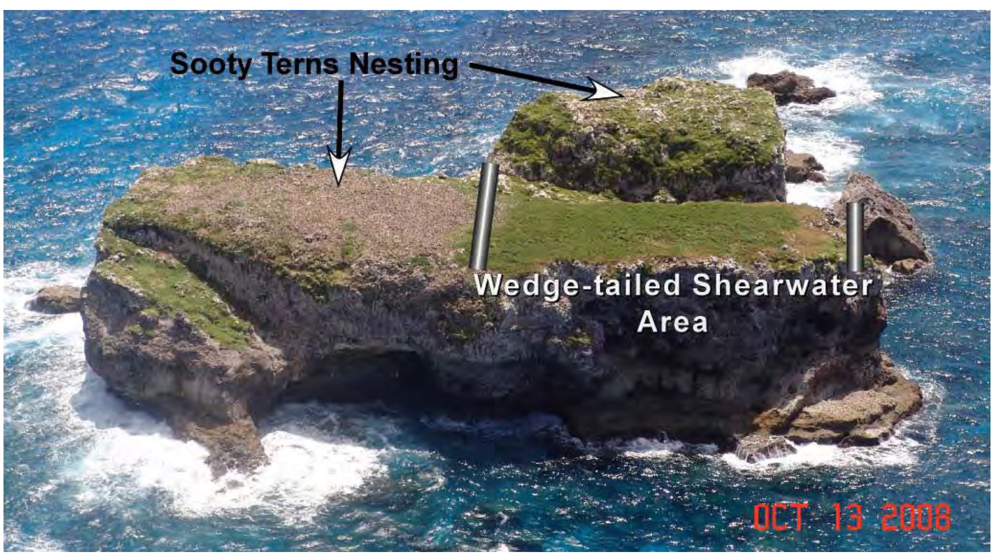


Figure 3. Naftan Rock, Mariana Islands. Oct. 2008. Areas of different species use are clearly discernable due to changes in vegetation

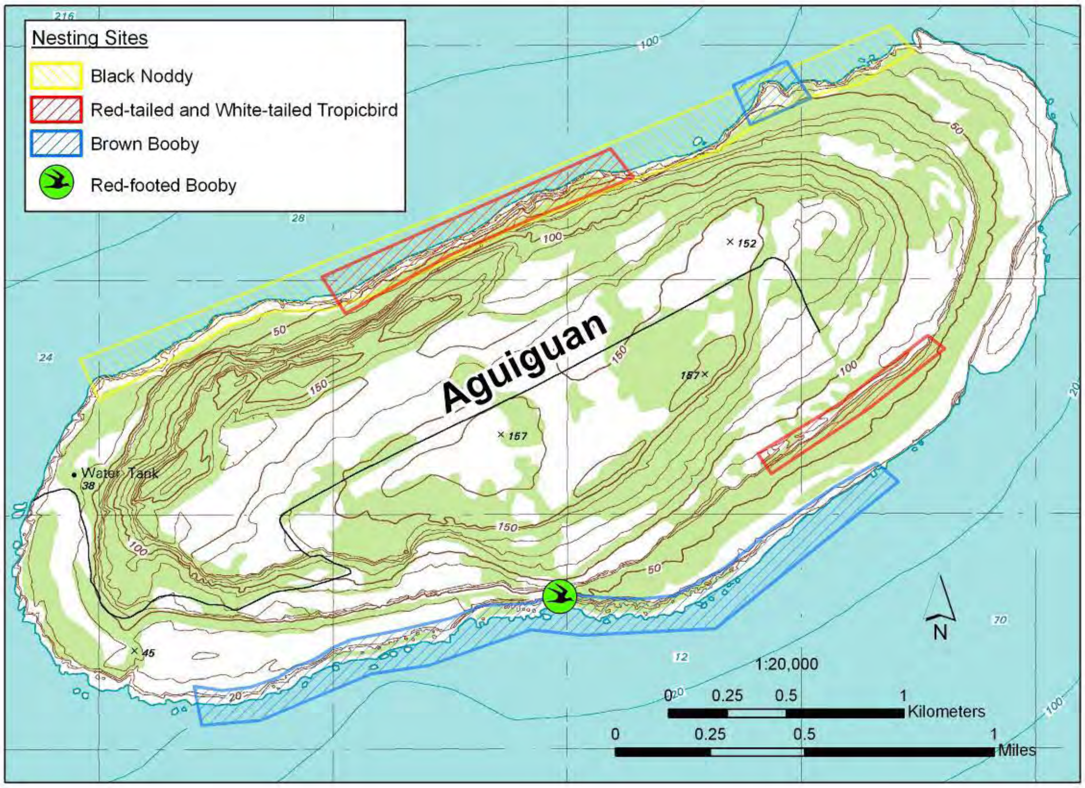


Figure 4. Location of seabird nesting sites observed on the island of Aguiguan during shoreline and helicopter surveys in 2008.

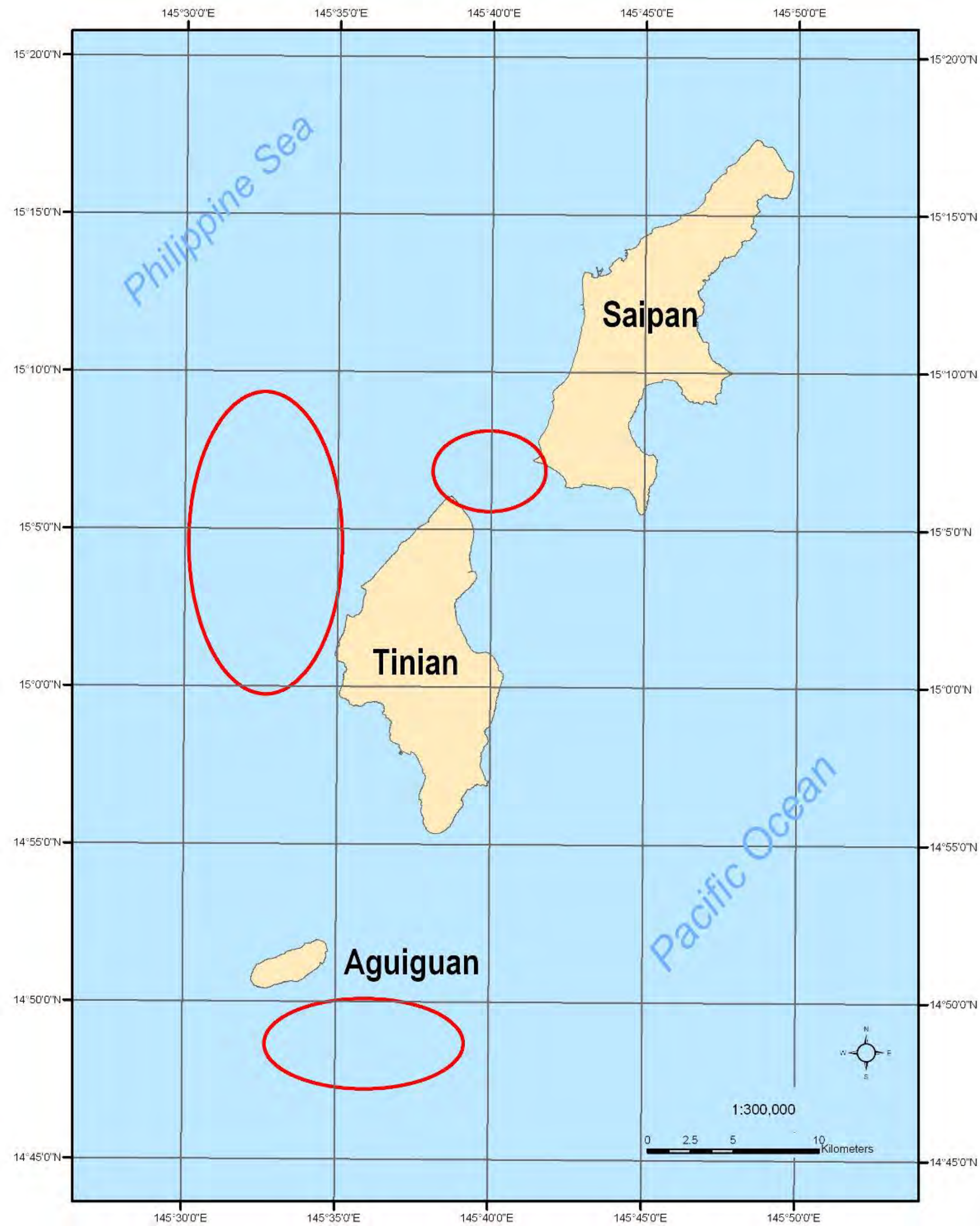


Figure 5. Areas of high seabird and tuna interaction near the islands of Aguiguan, Tinian, and Saipan in 2008.

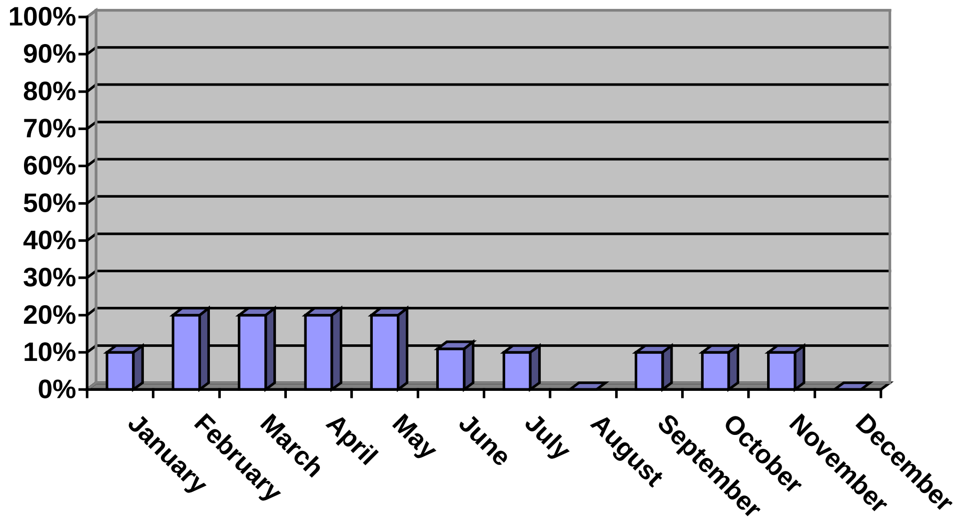


Figure 6. Percentage likelihood of sooty terns being present on Farallon de Medinilla based on monthly surveys from 1998 to 2007 (S. Vogt, pers. comm.). Surveys were not conducted in June 1999.

Attachment 1

Observers - Curt Kessler, Wildlife Biologist, USFWS, Honolulu, HI, Jess Omar, Conservation Officer, Saipan, CNMI, Joshua Fisher, Biologist, USFWS, Honolulu, HI.

Field note; Dead seabirds floating off Aguiguan (Goat Island), Commonwealth of the Northern Mariana Islands.

- Brown booby (*Sulu leucogaster*) – August 11-15, 2008 – Collected one dead adult female on August 11 and noted two others (both adult females) floating in the waters near Aguiguan Island, CNMI. Birds appeared to have been dead for two to three days judging from the smell. Another 3 sick and 8 dead brown boobies were observed by the boat crew during that week. Two or three sick brown boobies were observed on rocks along the Aguiguan coast on August 15. These birds appeared lethargic and unable to fly. Brown boobies do nest on Aguiguan Island (est. min. 50 pairs and could be over 100 pairs). Nearest islands with colonies: Rota – 50 miles, FDM – 85 miles.

- Red-footed booby (*Sula sula*) – August 26, 2008 - Observed 10-20 dead birds floating on the ocean on the west side of Aguiguan Island, CNMI. At least 10 birds were approached in order to identify and collect specimens. Most birds appeared to have been dead for at least three days based on smell. Only one bird was collected. Both adults and juveniles were observed dead. Red footed boobies do nest on Aguiguan Island in small numbers (est. 20 pairs). Nearest islands with colonies : Rota – 50 miles, FDM – 85 miles.

2.4.3 MICRONESIAN MEGAPODE ON TINIAN AND AGUIGUAN

Micronesian Megapode (*Megapodius laperouse*). Photo by Scott Vogt.

Prepared by: **Curt Kessler and Fred Amidon, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI**

INTRODUCTION

The Micronesian megapode (*Megapodius laperouse*) is a pigeon-sized bird in the family Megapodiidae, an old-world family restricted to the Australasian region and best known for its unusual reptile-like behavior of burying its eggs rather than incubating them as do all other birds. The Mariana Islands subspecies (*M. laperouse laperouse*), called sasangat in Chamorro and sasangal in Carolinian, was once found throughout the Mariana Islands but has since been extirpated or reduced in numbers particularly on limestone islands with human populations. The reasons for the disappearance from these islands are not entirely understood, but it is suspected that alien predators, loss of habitat, past egg-collecting, and over-hunting are factors (USFWS 1998). Currently, Micronesian megapodes are known or believed to occur on Aguiguan, Tinian, Saipan, Farallon de Medinilla (FDM), Sarigan, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, and possibly Uracus in the Mariana archipelago. They were extirpated from Guam and Rota around the turn of the century (USFWS 1998) and may have been extirpated from Anatahan due to volcanic activity in 2005. The U.S. Fish and Wildlife Service (USFWS) listed this species as endangered throughout its range in 1970 (USFWS 1970). Populations appear to be stable or possibly increasing in the unpopulated volcanic northern islands of the CNMI (Division of Fish and Wildlife 2000a-f, Martin *et al.* 2008, Vogt 2008). Currently a cooperative effort between the Commonwealth of the Northern

Mariana Islands – Division of Fish and Wildlife (DFW), Northern Islands Mayor's Office (NIMO), USFWS, and the U.S. Navy (USN) is underway to restore habitat in the northern islands and assess status for this species as outlined in the Micronesian Megapode Recovery Plan (USFWS 1998). For additional information on life history and recovery objectives, see the Micronesian Megapode Recovery Plan.

The original type specimen for *Megapodius laperouse* was collected on Tinian during the Uranie expedition in 1820. At the time, megapodes were reported as uncommon, and they seem to have declined steadily until 1945, when no megapodes were reported on the island (Baker 1951). Megapodes were observed on Tinian again in the late 1970's and have been observed periodically since then (Wiles *et al*. 1987, O'Daniel and Krueger 1999, Witteman 2001). No breeding activity has been observed on Tinian, and the birds are thought to have migrated from Saipan or Aguiguan; however, Tinian has not been thoroughly searched for nests (Kessler, pers. observation). Megapode observations on Tinian are usually associated with limestone forest and cliff-line habitat in the Maga and Mt. Laso areas on Navy leased lands. Therefore, it is believed that this is an important habitat for the species on the island.

Megapodes have been found in consistently low numbers on Aguiguan based on reports from the 1930's, 1950's, 1980's, and 1990's (Takatsukasa 1932-1938, Owen 1974, Engbring *et al.* 1986). In 1982, Engbring *et al.* (1986) estimated that a population of at least 11 megapodes existed on Aguiguan. In 2000, Cruz *et al.* (2000) estimated that there were 51 megapodes on Aguiguan, and Esselstyn *et al.* (2003) estimated a population of 72 (range 34-149) megapodes in 2002.

The breeding biology of megapodes in the southern limestone islands is still a mystery, although both Aguiguan and Saipan are assumed to have breeding populations. Megapodes utilize burrow-nesting at sun-exposed beaches, cinder fields, geothermal sites, and between the roots of trees (decompositional heat) and mound-building (decompostional heat) for incubating their eggs (Glass and Aldan 1988, Elliott 1994, Wiles and Conry 2001). However, sandy beach habitat on Tinian and Saipan are very limited and heavily used for recreation, and non-existent on Aguiguan. Also, cinder fields and geothermal sites are only available in the northern islands. Therefore, rotting trees and mound-building are the likely egg incubation sites on these islands. However, this has not been confirmed, and further research is needed to identify this important aspect of the species' biology to conserve and protect the species.

Effective methods for surveying Micronesian megapodes have also not been identified. Traditionally, point-transect or variable circular plot methodology has been used to survey for birds on most of the Mariana islands (*e.g.*, Engbring *et al.* 1986). However, this method is not as effective for secretive species, like the Micronesian megapode, or rare species. Therefore several survey methods were undertaken in 2008 in an effort to compare methods and identify a standard survey methodology.

METHODS

Point-Transect Surveys

We conducted island-wide point-transect or variable circular plot surveys on Tinian and Aguiguan between June 14 and 19 and June 25 and 27, 2008, respectively. On Tinian, we sampled a total of 254 stations on 14 transects (Figure 1). Ten of the transects and 216 of the stations were surveyed previously in 1982 (Engbring *et al*. 1986) and 1996 (USFWS, unpublished data). Four additional transects were included in the 2008 surveys to increase the survey coverage of limestone forest habitat on the island. On Aguiguan, we sampled 80 stations on 5 transects (Figure 2). Four of the transects were previously surveyed in 1982 (Engbring *et al*. 1986), 1992 (Craig *et al*. 1992), 1995 (USFWS unpublished data), 2000 (Cruz *et al*. 2000), and 2002 (Esselstyn *et al*. 2003). An additional transect of 14 stations was sampled during the 2008 survey for a total of 80 stations. This additional transect was added to sample secondary forest and open field habitats and increase the areal coverage of the island. All stations along all transects on both islands were 150 meters apart.

All surveys were conducted by one observer and followed standard point-transect methods, consisting of 8-minute counts and estimation of horizontal distances to all birds heard and/or seen (see Reynolds *et al.* 1980 or Engbring *et al*. 1986 for details). Sampling conditions recorded included cloud cover, rain, wind, noise level, and habitat type, and these were later used as covariates in density calculations (see 2.4.1 General Land Birds for additional information). Counts commenced at sunrise and continued until 1100 hours and were conducted only under favorable weather conditions.

The point-transect technique requires 75-100 detections to model the detection function for each species effectively (Buckland *et al*. 2001). If sufficient detections were recorded, densities were calculated using the program DISTANCE (Thomas *et al*. 2006). For additional information on point-transect sampling and data analysis see 2.4.1 General Land Birds.

Playback Surveys

Playback surveys were conducted for Micronesian megapodes on Tinian and Aguiguan between August 13 and 18 and August 20 and 22, 2008, respectively. A total of 21 stations along 3 transects were sampled on Tinian (Figure 3 Attachment 1). Two of the transects were previously sampled during the point-transect survey in June 2008 (transects 11 and 12; Figure 1 and an additional transect was established for this survey. All stations were 150 meters apart and all transects were at least 300 meters apart. In order to maximize the likelihood of detections, all transects were established in limestone forest in the Mount Lasu and Maga areas where megapodes had been previously recorded (USFWS 1998, Vogt 2008). On Aguiguan, the transects and stations used for the point-transect sampling were also sampled for Micronesian megapode playback surveys.

All stations were sampled by a single observer. During the survey, digitally recorded Micronesian megapode calls obtained on Sarigan were broadcast. Pair duet and alert calls were played on an electronic game caller (Foxpro FX5 ™) for one minute at each station. The observer then measured and recorded the horizontal distances of all Micronesian megapodes heard and/or seen during a four minute survey period (one minute of playbacks and three minutes of observation). Leupold 9x32 mm RXB-IV Range Finding Binoculars (Leupold, Beaverton, OR) were used to assist with distance estimation. However, not all distance estimates were derived from range-finder estimates. Weather and habitat conditions were recorded at each station. Counts commenced at sunrise and continued until completed (typically prior to 1100 hours) and were conducted only under favorable weather conditions.

Similar to the analysis of point-transect data, densities would be calculated from playback data using the program DISTANCE (Thomas *et al*. 2006) if sufficient detections (75 – 100) were recorded during the survey and if the movement in response to the playback calls could be accounted for during population estimation. Responsive movements were not available, therefore, estimates from point-transect methods were unreliable. Following methods outlined by Reynolds and Snetsinger (2001), we calculated the likelihood of detecting a small population of Micronesian megapodes in the Mount Lasu and Maga regions of Tinian regions (the areas where megapodes were last observed on Tinian) to determine survey effectiveness (see 2.4.4 Nightingale Reed-warbler for additional information on this technique). The effective survey area was approximated by calculating the area around each survey station using the effective detection radius of the megapode using the program DISTANCE (Thomas *et al.* 2006). The expected range of the Micronesian megapode in the Mount Lasu and Maga regions was estimated using native limestone forest estimates from 2006 Forest Service data (Forest Service 2006).

Territory Mapping
Between August 12 and 21, 2008, four study plots were established on Aguiguan and sampled to estimate Micronesian megapode territory densities (Figure 2). All four plots were established in native limestone forest in areas where megapodes were observed previously to maximize the likelihood of recording megapodes. Each study plot consisted of a grid of points at 50 meter intervals developed using Hawth's Analysis Tools© 3.27 in ArcMap 9.2 (ESRI, Redlands, CA). All points were downloaded into Garmin 76CSx (Garmin International, Inc., Olathe, KS) Global Positioning System (GPS) units as waypoints to assist with mapping. GPS tracks from each unit were also recorded during each survey and downloaded into ArcMap 9.2 to identify the effective search area.

Each plot was surveyed in the morning (0600-1200) and afternoon (1500-1800) over several days by one or several surveyors. All Micronesian megapode detections were marked on a map of the study plot using symbols for movements and activities outlined by Bibby *et al.* (2000) and/or recorded in a field notebook with GPS waypoints. These locations were then transferred to a master map of each study plot in ArcMap 9.2.

Micronesian megapode territory densities were determined by counting the number of pairs within each study plot and dividing the total number of territories by the size of the plot. Territories which overlapped the edge of the plot were included as half territories (Bibby *et al.* 2000). The presence of a territory was determined through a combination of visual observations of pairs and territorial behaviors. In addition, efforts were made to capture, band, and collect feather and blood samples from Micronesian megapodes in and outside of the study plot. We used unique combinations of color bands to facilitate territory mapping efforts and future efforts to obtain survival estimates. Feather and blood samples were collected for potential genetic analysis. The boundary of each study plot was defined as the outer points in the study plot grid. These were typically associated with cliff lines and forest edges.

RESULTS

Tinian

No Micronesian megapodes were detected during point-transect or playback surveys on Tinian. Search effort for point-transect surveys totaled 90 hours with approximately 26 percent of the time (23 hours) spent surveying native limestone forest. Search effort for the playback survey totaled 11 hours, all in native limestone forest. The effective detection radius of the megapode was 38 m ± 4m, based on an analysis of the Aguiguan playback survey data, while the effective search area and expected range of the megapode in the Mount Lasu and Maga regions was 9 ha and 71 ha, respectively. Therefore, the likelihood of detecting a megapode if the population in the Mount Lasu and Maga regions was two megapodes was estimated to be 24 percent. However, we believe this may be an underestimate. Based on our observations during playback surveys and color-banding of megapodes on Aguiguan, playbacks typically elicited a response from the majority of the territory holders in the area (see Aguiguan below). Therefore, it is likely that we would have detected megapodes in the area if they were present.

Aguiguan

One hundred four person-hours were spent territory mapping in the four study plots, which translated to approximately 2 person hours per hectare. In addition, 16 Micronesian megapodes were captured and color-banded in and outside the study plots (Table 2). Approximately 80 percent of the birds captured were paired. A total of 15 territories was identified. The average territory density per hectare was 0.27 (± 0.03 Standard Deviation (SD)), and territory size in limestone forest 3.76 ha (± 0.40 SD), respectively (Table 3). If we assume densities in our sampling plots are representative of megapode densities in all native forest areas occupied by megapodes (280 ha; see Table 3 in 2.1 Vegetation Surveys), we estimate there could be up to 75 Micronesian megapode territories on Aguiguan in this habitat. This estimate excluded the limestone forest along the southeast coast of Aguiguan where no megapodes were detected during the 1982, 1995, 2000, 2002, and 2008 point-transect and 2008 playback surveys, as well as secondary forest habitats, which are used by Micronesian megapodes, but were not sampled during the territory mapping.

Fifteen Micronesian megapodes were detected on Aguiguan during the point-transect surveys in June 2008 (Table 1). Unfortunately, there were insufficient detections to calculate densities. To estimate the proportion of megapodes present that were detected during the point-transect survey, we compared detections at stations that overlapped with our study plots (n = 17). If the megapodes detected during the August territory mapping were present in the same areas during the June point-transect survey, then the point-transect survey detected approximately 17 percent (number of birds detected per station/ number of birds territory mapped per station) of the population.

Forty Micronesian megapodes were detected on Aguiguan during the playback surveys in August 2008 (Table 1). The number of detections and stations occupied by megapodes was more than double the number of detections during the June 2008 point-transect survey (Table 1), indicating that playback surveys may be more effective than point-transect surveys for megapodes. Unfortunately, insufficient detections were recorded to estimate megapode densities using this method. In addition, observations reported by the playback surveyors indicate that Micronesian megapodes were moving in response to the playbacks which may bias detection distance estimates (Buckland *et al.* 2006). This movement will need to be assessed to properly calibrate future playback surveys (P.M. Gorresen, pers. comm. 2008). Also, comparing the playback detections at stations which overlapped the territory mapping plots (n = 17) indicates approximately 50 percent of the megapodes present were detected. We believe that this is an underestimate because prior to the survey three of the birds in the plots were captured using playbacks and banded which may have reduced their subsequent responsiveness to the playbacks. If we assume these birds would have responded and were detected, approximately 67 percent of the megapodes present would have been detected.

No evidence of Micronesian megapode breeding was recorded during the surveys despite efforts to locate potential nest sites. In addition, no juveniles or recently hatched birds were observed during the surveys. Finally, morphometrics, band numbers, and color-band combinations for all megapodes caught and banded are summarized in Table 2. Blood and feather samples of each individual caught during banding were collected and are stored at the Burke Museum of Natural History and Culture, University of Washington, Seattle, Washington.

DISCUSSION

In conclusion, we estimate that there could be up to 75 megapode territories on Aguiguan. However, because this study was intended to be a pilot study the megapode study plots were placed in areas known to be occupied by megapodes. Therefore, densities in these study plots may not reflect megapode densities across the island and extrapolating from these estimates should be done with caution. Previous estimates for the island by Engbring *et al.* (11 megapodes; 1986), Cruz *et al.* (51 megapodes; 2000), and Esselstyn *et al.* (72 megapodes; 2003) were much lower than the 75 territories estimated from the study plots in this study. In general, the number of detections per station recorded during the point-transect survey on Aguiguan was also similar to those reported in previous surveys (Table 1). This may indicate that the number of detections, and potentially the population, has been relatively stable since 1982. If the population has been stable over this time period then the megapode population may be less than 75 territories.

No Micronesian megapodes were recorded on Tinian, in spite of extensive surveys. This is consistent with previous surveys where detections were sporadic (Wiles et al. 1987, O'Daniel and Krueger 1999, Witteman 2001, Vogt 2008). Due to the sporadic nature of these detections we cannot rule out the possibility that megapodes may yet be present on Tinian in low numbers and may utilize the native forest habitats elsewhere on the island.

One potential reason for the sporadic nature of the detections on Tinian is inter-island movements and factors limiting population growth on the island. Movement between islands is documented for megapodes in Palau (Pratt *et al*. 1980), and the Micronesian megapode seems capable of crossing the water gaps between the islands in the Mariana archipelago (the maximum distance between islands is 60 miles, minimum distance is 3 miles, average is 36 miles). This is especially true for Tinian which is only 3 miles from Saipan and 6 miles from Aguiguan. If megapodes dispersed from Aguiguan or Saipan, they would likely end up on Tinian. However, a population on Tinian may not be able to persist on the island due to predation (*e.g.*, feral cats (*Felis cattus*)) or some other potential limiting factor (*i.e.*, limited breeding habitat).

Micronesian megapode home range size and territoriality are poorly known. It is obvious that they defend some type of area as evidenced by a pair's quick and agitated response to played-back recordings of duetting pairs during this study. However, we believe they may be defending food resources and not nesting habitat based on the lack of observations of nesting activity. Our average territory size estimate from the territory mapping was 3.8 ha compared with reported territory sizes ranging from 1 ha (Glass and Aldan 1988) to <10 ha (Lemke 1984) in the Mariana Islands. We believe that territory size likely varies with habitat conditions. Our observations on Aguiguan and reports from other islands in the archipelago (Lemke 1984, Glass and Aldan 1988, Vogt 2008; Kessler, pers. observation) indicate that closed canopy forest with a moist or wet substrate is probably richer foraging habitat than open forest with a dry substrate; territories in the former habitat are likely to be smaller than territories in the latter. This was especially evident on Aguiguan where megapodes were more common in areas with well developed canopies and wetter conditions (Kessler, pers. observation)

Survey efforts for Micronesian megapodes yielded mixed results. The point-transect survey method yielded few detections and was not found to be effective on Tinian and Aguiguan. This result could reflect low numbers of birds and infrequent vocalizations. However, if megapode detection data can be obtained and pooled from point-transect surveys that were conducted under the same survey conditions it may be possible to develop detection models to estimate densities for surveys with insufficient detections (P.M. Gorresen, pers. comm. 2008).

Playback surveys were found to substantially increase the number of detections. However, the results may be biased by megapodes moving closer to the station, in response to the playback, before being detected. In addition, not all individuals present may have been detected and a minimum number of detections are needed to effectively estimate densities. Therefore, it may not be applicable for estimating densities in small populations where detections are expected to be low. Biases associated with playbacks can be corrected using data on bird movements in response to playbacks (*e.g.*, Klavitter and Marzluff 2007). However, this may prove challenging for megapodes without radio telemetery work due to the difficulty in detecting individuals even with playbacks.

Territory mapping, in conjunction with color-banding and playbacks, could be an effective survey tool. However, establishing and surveying plots is difficult and time consuming, and territory densities can vary between and within habitat types. Multiple study plots are needed to account for this variability which increases the survey effort. This may prove to be difficult on remote islands without sufficient logistical support and time to establish and conduct the surveys.

Mark-resight estimates were not tested during this study. However, megapode responses to banding and playbacks during this study do provide some insight into the effectiveness of this technique. In general, banded birds were shy and difficult to resight after being caught and handled. If sufficient time is available to allow the birds to recover from being handled, this technique could be utilized.

Clearly, more work is needed to develop an effective megapode survey tool that can be used to compare populations across the species' entire range. Playbacks may prove to be the most effective tool if the response of megapodes to playbacks can be fully evaluated. Alternatively, a combination of intensive territory mapping and playback surveys may prove to be an effective method.

No evidence of megapode breeding on Aguiguan was recorded during this study. Megapodes use a variety of nesting strategies (Glass and Aldan 1988, Wiles and Conry 2001) and it is speculated that mound building or burrowing in decomposing trees might be the methods utilized on Aguiguan. However, mounds have yet to be identified despite unverified reports of small mound-like structures on the island (USFWS 1998). In the absence of nesting mounds, we hypothesize that decomposing trees and/or tree roots are the mostly likely method of incubation on the island. Efforts to locate nests in these substrates in August 2008 were not successful. However, the birds may not have been breeding at that time. Therefore, additional work is still needed to identify the breeding strategy of Micronesian megapodes on Aguiguan and the other southern islands.

Although important questions remain unanswered, the following information will assist land managers concerned with the development of the U.S. Marines Corp (USMC) training area on Tinian:

- No megapodes pairs were detected on Navy leased lands in 2008.
- Megapodes may immigrate into the area based on past survey observations.
- Megapodes will most likely be found in limestone forest areas and cliff-line habitat.
- Their territories, once they become established, would be approximately 3.5 ha.
- They would likely seek old growth limestone forest or forest strand beach habitat for nesting.
- The most practical way to detect if a pair is present is through the use of playbacks.

The areas on Navy lands that were used in the past by megapodes are the tracts of native forest at Mt. Lasu and Maga (USFWS 1998, Vogt 2008), and these areas could again be occupied by megapodes. This cliff-line forest habitat will be in direct conflict with USMC Safety Danger Zone's (SDZ's) which will require the backdrop protection of the cliffs for various weapon ranges. Unfortunately there are few areas of this native habitat left on Tinian (Figure 1), and these are found primarily on the land leased by the Navy. Those areas of cliff line will be the contention point of any weapons range proposals due to the rarity of this habitat and its importance to native species.

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Table 1. Number of stations sampled, number of stations where Micronesian megapodes were detected, number of megapodes detected, percent occupancy of stations, and megapodes per station for point-transect (PT) and playback (PB) surveys conducted on Aguiguan. Number of stations occupied were not available for 1992, 2000, and 2002.

Year	Month	Survey Type	Stations Sampled	Stations Occupied	Number Detected	Percent Occupancy	Birds per Station
1982	June	PT	66	8	14	9.1	0.16
1992	May	PT	66	UNK	11	UNK	0.17
1995	June	PT	66	12	16	18.2	0.24
2000	April	PT	66	UNK	12	UNK	0.18
2002	March	PT	66	UNK	16	UNK	0.24
2008	June	PT	80	11	15	13.8	0.19
2008	August	PB	80	24	40	30.0	0.50

Table 2. Band number, color band combination, morphology, and pair status for Mirconesian megapodes banded on Aguiguan in August 2008. Color band combinations are read from top to bottom and include yellow (Y), green (G), black (K), red (R), purple (P), white (W), blue (B), and a U.S. Fish and Wildlife Service aluminum band (A).

Bird	Date	Band #	Left Leg	Right Leg	Weight (g)	Wing (mm)	Tail (mm)	Tarsus (mm)	Culmen (mm)	Status
1	13 Aug	1096-96501	Y/Y	Y/A	373	191	65	53	22	Single
2	14 Aug	1096-96502	Y/G	Y/A	381	192	65	57	18	Paired with Bird 3
3	14 Aug	1096-96503	Y/K	Y/A	378	179	56	58	19	Paired with Bird 2
4	14 Aug	1096-96504	R/R	R/A	446	183	64	52	19	Single
5	14 Aug	1096-96505	R/W	R/A	343	176	60	53	20	Single
6	14 Aug	1096-96506	P/P	P/A	398	182	69	65	19	Paired with Bird 7
7	14 Aug	1096-96507	P/W	P/A	436	190	61	54	24	Paired with Bird 6
8	19 Aug	1096-96508	R/Y	R/A	346	189	53	57	20	Pair with unbanded
9	19 Aug	1096-96509	G/G	G/A	428	190	62	56	19	Pair with unbanded
10	20 Aug	1096-96510	B/B	B/A	366	185	62	52	18	Paired with Bird 11
11	20 Aug	1096-96511	B/R	B/A	358	190	72	53	21	Paired with Bird 10
12	20 Aug	1096-96512	R/K	R/A	421	-	-	-	-	Pair with unbanded
13	20 Aug	1096-96513	R/G	R/A	358	186	55	57	21	Pair with unbanded
14	21 Aug	1096-96514	B/W	R/A	365	192	68	54	17	Pair with unbanded
15	21 Aug	1096-96515	B/G	R/A	330	182	59	56	22	Pair with unbanded
16	21 Aug	1096-96516	K/R	G/A	375	160	72	60	20	Pair with unbanded

Table 3. Micronesian megapode territory densities (territories/ha) in four limestone forest plots on Aguiguan in August 2008.

Plot	Plot Size (ha)	Number of Territories	Territory Size	Density
1	12.84	3	4.28	0.23
2	10.03	3	3.34	0.30
3	19.25	5	3.85	0.26
4	14.28	4	3.57	0.28
		Mean (± Standard Deviation)	3.76 (± 0.40)	0.27 (± 0.03)

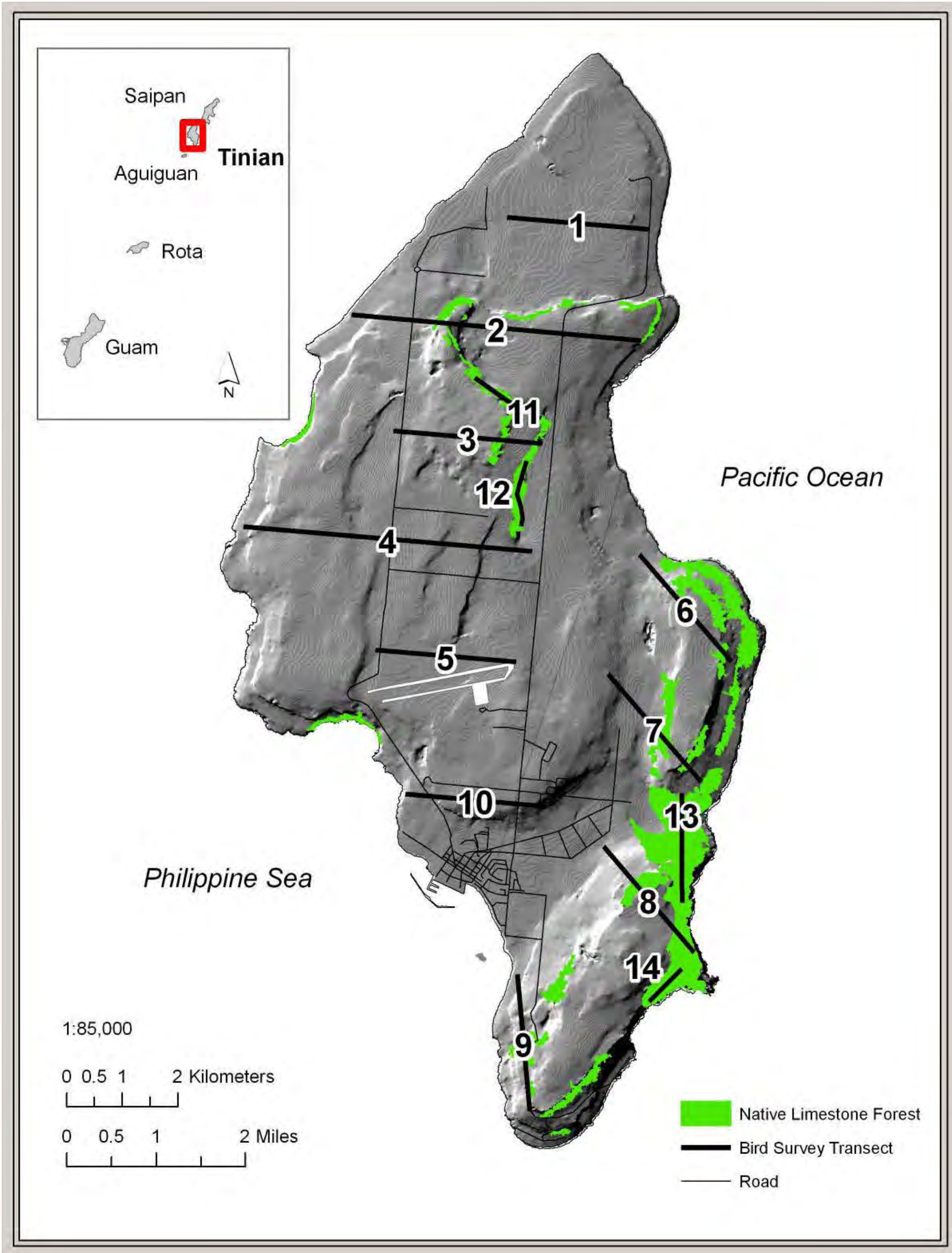

Figure 1. Island of Tinian showing the survey transects and native limestone forest.

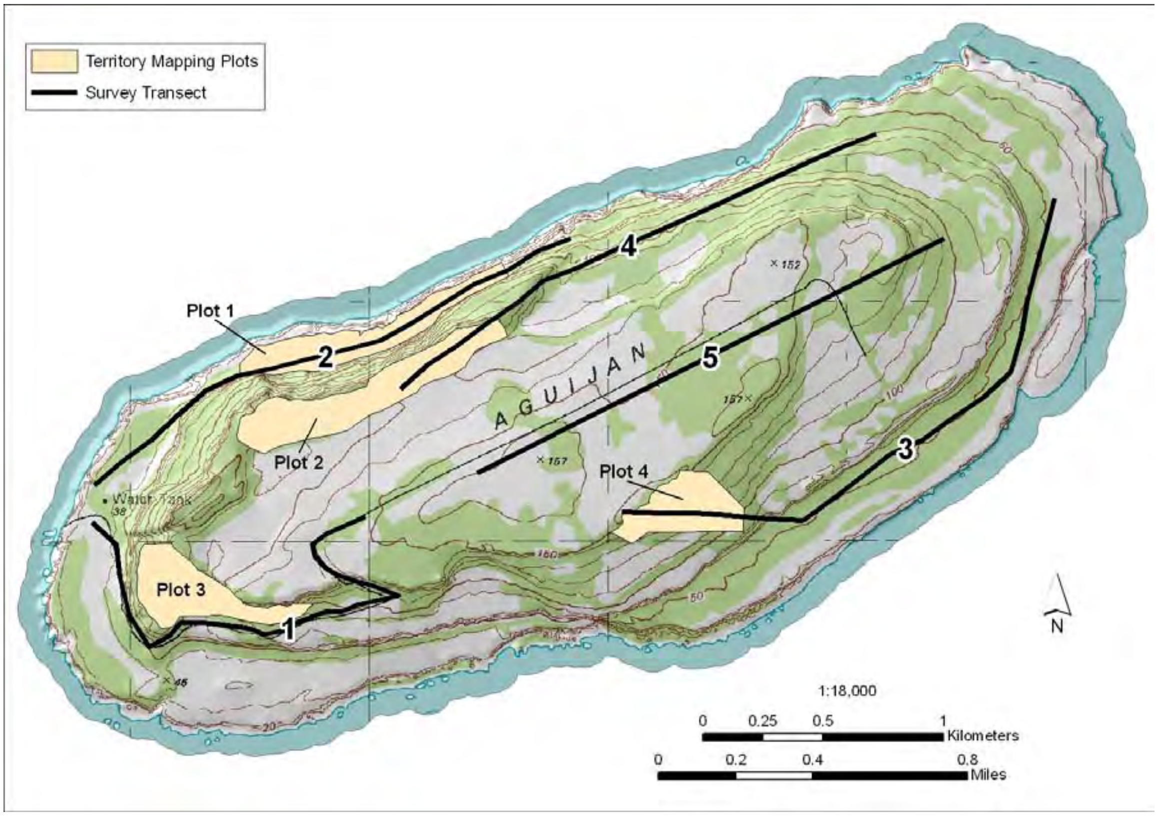

Figure 2. Survey transects and territory mapping plots surveyed on the island of Aguiguan in 2008.

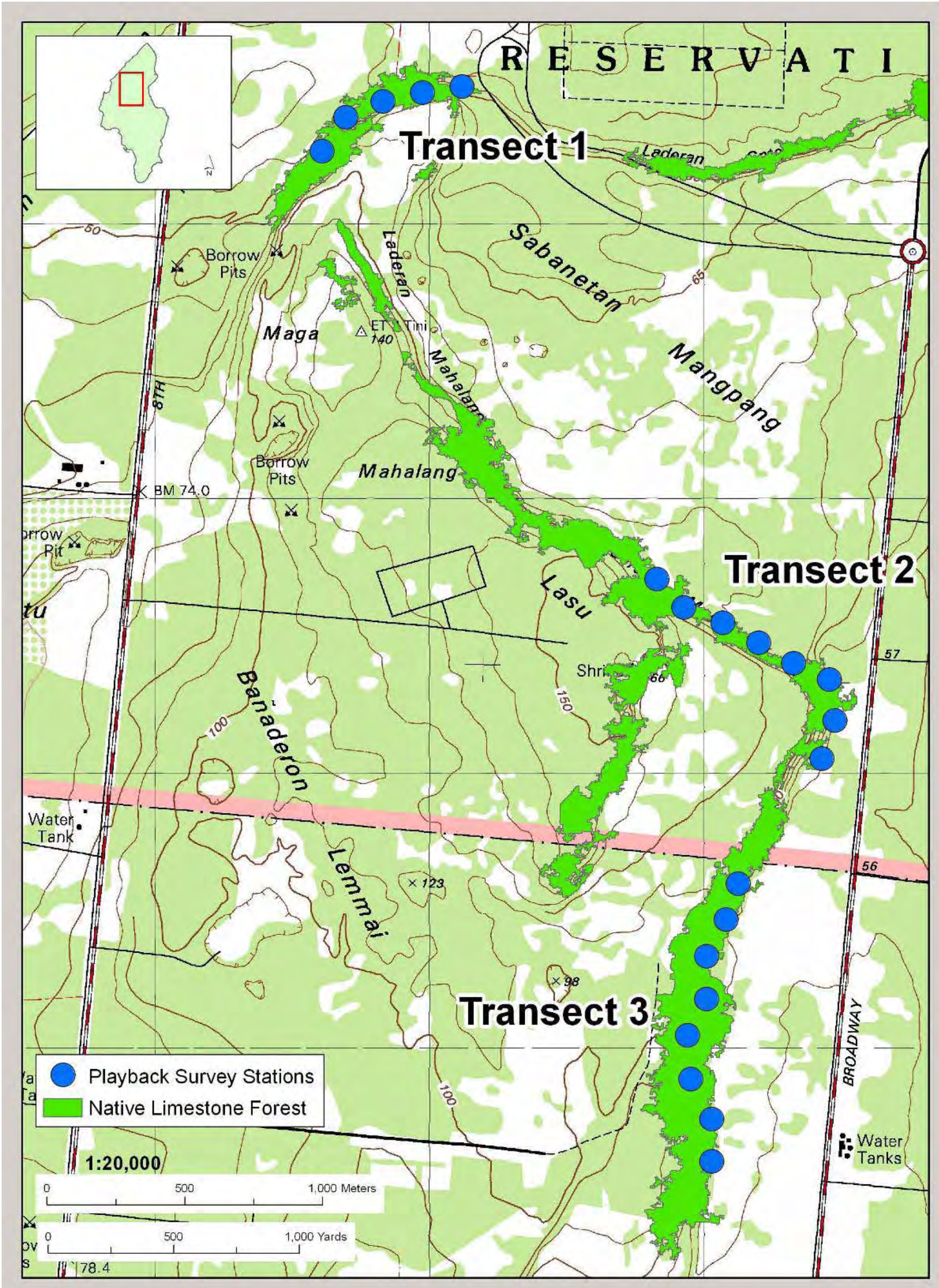

Figure 3. Playback survey stations and native limestone forest in the Mount Lasu and Maga regions of Tinian.

Attachment 1. UTM coordinates for the Micronesian megapode playback survey transects on the island of Tinian. All coordinates are in WGS84 UTM Zone 5 North. Stations along transect 3 correspond with transect 12 of the point-transect survey (see section 2.4.1 General Landbirds on Tinian and Aguiguan Attachment 1)

Transect	Station	Latitude	Longitude
1	1	352116.51	1665499.20
1	2	351972.25	1665476.71
1	3	351693.23	1665386.83
1	4	351607.22	1665263.67
1	5	351828.95	1665445.23
2	1	353474.33	1663190.50
2	2	353427.50	1663052.17
2	3	353454.51	1663339.75
2	4	353323.66	1663398.40
2	5	353196.90	1663473.75
2	6	353066.19	1663546.83
2	7	352923.87	1663602.55
2	8	352825.12	1663706.10
3	1	353122.99	1662596.49
3	2	353078.71	1662466.68
3	3	353007.30	1662332.00
3	4	353006.92	1662176.79
3	5	352938.08	1662044.09
3	6	352949.16	1661885.87
3	7	353025.32	1661739.87
3	8	353026.24	1661586.31

2.4.4 NIGHTINGALE REED-WARBLER ON AGUIGUAN

Male Nightingale Reed-warbler.
Photo by Scott Vogt.

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INTRODUCTION

The endangered nightingale reed-warbler (*Acrocephalus luscinia*), known in the Chamorro language as *ga'ga'karisu* (bird of the reeds) on Saipan, is a medium-sized, yellowish, long-billed passerine (USFWS 1998). It was federally listed as endangered in 1970 (USFWS 1970).

The nightingale reed-warbler belongs to the Old World reed-warbler group (Sylviinae: *Acrocephalus*), which is widespread from Europe through Australasia (Watson *et al*. 1986). The nightingale reed-warbler is endemic to the Mariana Islands and is known historically from five islands in the archipelago: Guam, Aguiguan, Saipan, Alamagan, and Pagan. In addition, the nightingale reed-warbler occurred prehistorically on Tinian (Steadman 1995). Currently, three subspecies of the nightingale reed-warbler are recognized: (1) *A. l. luscinia* on Guam, Saipan, and Alamagan; (2) *A. l. nijoi* on Aguiguan; and (3) *A. l. yamashinae* on Pagan (Pratt *et al*. 1987, Watson *et al*. 1986). Previously, Yamashina (1942) recognized four subspecies: (1) *A. l. luscinia* on Guam; (2) *A. l. hiwae* on Saipan and Alamagan; (3) *A. l. nijoi* on Aguiguan; and (4) *A. l. yamashinae* on Pagan. Mitochondrial DNA analysis provides some evidence that nightingale reed-warblers from Guam and Saipan do not fall out as sister taxa and that Guam birds fall outside the clade (a group of living organisms including all descendants sharing specific genetic traits of a common ancestor) of other Pacific Island *Acrocephalus* and therefore may be descended from a different continental ancestor (Beth Slikas, *in litt*. 2000).

The nightingale reed-warbler is believed extirpated from 3 islands. It has been extirpated, by unknown factors, from Guam since the late 1960s (Engbring *et al.* 1986, Reichel *et al.* 1992, Tenorio and Associates 1979). On Aguiguan, Engbring *et al*. (1986) report 3 probable records of nightingale reed-warblers during their 1982 surveys, though none were recorded on the counts. Several incidental observations of nightingale reed-warblers were also made during the survey team's visit 1-4 June 1982; and therefore, based on this information, they made a liberal estimation of 15 birds on the island (Engbring *et al*. 1986). Glass (1987) reported on 10 observations of nightingale reed-warblers, one made in 1984 and the other nine in February 1987. Following that report, the species was thought to be extirpated from Aguiguan (Reichel *et al.* 1992), but two singing males were observed in 1992 (Craig and Chandran 1992), and one was observed in 1993 (Lusk 1993). The last observation of nightingale reed-warblers on Aguiguan occurred in 1995 (USFWS 1998). Focused survey efforts in 2000 and 2002 failed to detect nightingale reed-warblers (Cruz *et al*. 2000, Esselstyn *et al*. 2003). The Pagan subspecies was extirpated from Pagan, presumably due to volcanic activity or habitat loss from overgrazing between the 1960s and 1981 (Glass 1987).

Based on the best current available information, between 2,769 to 3,596 pairs of nightingale reed-warblers are likely distributed over two islands: Saipan (2,596 pairs), and Alamagan (173-1,000 pairs) (DFW 2000; Camp *et al*. in review). Additional information on the nightingale reed-warbler can be obtained from Craig (1992), the recovery plan (USFWS 1998), and Mosher (2006).

The present surveys were conducted in June and August of 2008 to search for the nightingale reed-warbler on Aguiguan where they may have been extirpated. The information from these surveys will help us better understand the status of the species in the Mariana Islands.

METHODS

Study Area – The island of Aguiguan is part of the Commonwealth of the Northern Mariana Islands (CNMI). It is the second smallest (7 km^2), uninhabited limestone island in the archipelago and is found off the southwest coast of Tinian (Figure 1; Engbring *et al*. 1986). Because of the large number of feral goats (*Capra hircus*) on the island, Aguiguan is usually referred to locally as "Goat Island." Human activities (*e.g.*, commercial agriculture and timber harvesting) on the island have extensively altered the vegetation. In 1982, about 47 percent of native forest remained, and the remainder was about 4 percent secondary (mixed introduced and native) vegetation, 43 percent open field, and around 5 ha of tangantangan (*Leucaena leucocephala*) forest (Engbring *et al*. 1986). Based on a recent land cover assessment, the island is currently around 49 percent native forest, 14 percent secondary vegetation, 23 percent open field, 6 percent tangantangan, and 4 percent coastal strand (See 2.1 Vegetation Surveys).

Observer Training – Observers with previous experience surveying for birds in the Mariana Islands were given distance calibration and bird vocalization training in different habitats prior to the actual surveys.

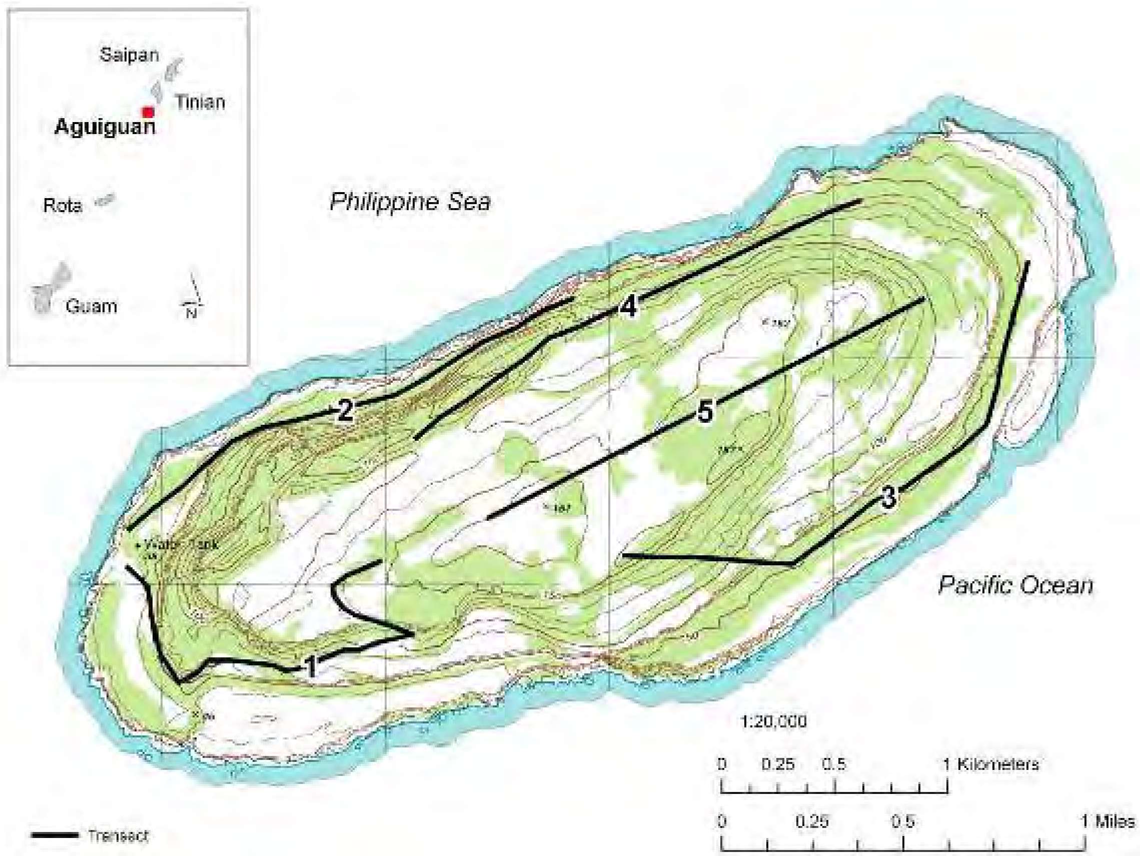

Figure 1. The island of Aguiguan, CNMI, showing the survey transects 1 -5.

Survey Methodology – Island-wide point surveys (or variable circular plot (VCP) surveys) were conducted for forest birds 25 to 27 June, 2008, and directed surveys using playbacks for the nightingale reed-warbler were conducted 20 to 22 August, 2008, on Aguiguan. Five transects with a total of 80 stations were surveyed (Figure 1; Camp *et al*. 2009). VCP surveys followed standard point-transect methods, consisting of 8-minute counts at each station (150 m apart) and estimation of the horizontal distance to each bird heard or seen (See Reynolds *et al*. 1980, Engbring *et al*. 1986 for details). Counts commenced at sunrise and continued to 1100 hours and were conducted under favorable weather conditions.

The same transects used for the VCP surveys were used for the directed surveys. A taped vocalization of a male nightingale reed-warbler singing was played for one minute at each station. Following the recording, the observers looked and listened for nightingale reed-warblers for three minutes. Weather and habitat sampling conditions were recorded at each station during both surveys. Counts commenced at sunrise and continued until 1100 hours, and were conducted under favorable weather conditions. Survey effort was recorded in hours as the difference between the start and end times for each survey (sunrise to 1100).

Following Reynolds and Snetsinger (2001), we calculated detection probabilities to estimate the likelihood of extirpation of the nightingale reed-warbler on Aguiguan. Scott *et al*. (1986) calculated the probability (p) of detecting one bird from a randomly distributed population of n individuals as:

$$p = 1 - \left(1 - \frac{a}{A}\right)^{n}$$

The effective search area (a; 125.9 hectares (ha)) was approximated by calculating the area for the effective detection radius (EDR) of the nightingale reed-warbler (71 meters; R. Camp, USGS-BRD, pers. comm. 2008) using ArcMap 9.2 (ESRI, Redlands, CA) and XTools Pro 5.2.0 (Data East, LLC, Novosibirsk, Russia). A, the last known range of the nightingale reed-warbler on Aguiguan, was estimated as the total forested habitat (native, secondary, and tangantangan) available on the island (479 ha; see Table 3, 2.1, Vegetation Surveys). We started with 15 birds as the hypothetical population size, n, as 15 was the last estimated number of birds on Aguiguan (Engbring *et al*. 1986).

Using Reed's (1996) modification of Guyann *et al*.'s (1985) statistical methods to infer extinction, we also calculated the minimum number of visits,

$$N_{min} = \frac{\ln \alpha}{\ln(1 - p)}$$

N_{min} needed for 95% (α=0.05) and 99% (α=0.01) probability of detection. N is the number of independent visits made to search for the species. We defined one visit as 10 hours of search effort.

RESULTS

No nightingale reed-warblers were detected during VCP counts or during the directed nightingale reed-warbler searches. One vocalization recorded during the directed surveys and thought perhaps to be a nightingale reed-warbler was later definitively identified as a golden white-eye (*Cleptornis marchei*). Search effort totaled 47 hours for the June and August 2008 surveys on Aguiguan. We determined the probability of detecting nightingale reed-warblers for various population sizes (n), starting with a population of 15, the population estimated by Engbring *et al*. (1986) in 1982. The likelihood of detecting 1 nightingale reed-warbler if the population was 15 during the 2008 surveys was 99 percent (Table 1) while the likelihood of detecting one nightingale reed-warbler if the population on Aguiguan was two was 46 percent (Table 1). In addition, if the population was two nightingale reed-warblers, 5 visits (95 percent probability) would be needed to achieve a 95 percent likelihood of detecting a reed-warbler compared to our 4.7 visits made, therefore, we cannot infer extirpation based on our 2008 survey effort.

One observer noted that several endemic species apparently responded (*i.e.*, approach observer playing tape or to sing) to playbacks of the nightingale reed-warbler, in particular the golden white-eye, whose song sounds similar (Glass 1987). Rufous fantails (*Rhipidura rufifrons*), bridled white eyes (*Zosterops conspicillatus*), Micronesian starlings (*Aplonis opaca*), and Micronesian myzomela (*Myzomela rubratra*) were also noted by this observer to occasionally respond to the playbacks. The CNMI Division of Fish and Wildlife (DFW; Esselstyn *et al*. 2003) also noted that golden white-eyes and Micronesian starlings respond to nightingale reed-warbler playbacks during surveys.

Table 1. Detection probability (DP) for one nightingale reed-warbler from a population of *n* birds randomly distributed across the known range.

Nightingale Reed-warbler Population (*n*)	DP	N_{min} for DP =95%	N_{min} for DP =99%
15	0.99	.65	1.01
10	0.95	.98	1.51
5	0.78	1.96	3.02
2	0.46	4.91	7.55

DISCUSSION

Although we cannot infer extirpation of the nightingale reed-warbler on Aguiguan at this time, the population would have to have been two or less birds in order not to have been detected during the 2008 surveys. It should be noted that some rare Hawaiian birds have been rediscovered after they were presumed extinct (Reynolds and Snetsinger 2001). Additional search effort could increase our confidence in the possibility of extirpation of this species or could lead to detections if it is still present. For example, additional searches could be established in areas of Aguiguan that were not covered during the 2008 surveys.

It should be noted that the DFW conducted surveys along the 4 Engbring *et al*. (1986) transects on Aguiguan in 2000 and again in 2002 (Cruz *et al*. 2000, Esselstyn *et al*. 2003) and also failed to detect nightingale reed-warblers. It has been suggested that the birds detected during the Craig and Chandran (1992) surveys were actually young birds colonizing from Saipan, and that the subspecies designation of nightingale reed-warblers on Aguiguan is not valid (Craig and Chandran 1992, Esselstyn *et al*. 2003). The additional search effort needed should be made, and if the species is extant, efforts should be made to preserve what may be a unique island subspecies. If however, nightingale reed-warblers have been extirpated on Aguiguan, the opportunity then exists to reintroduce birds there from either Saipan or Alamagan. In fact, one of the objectives in the nightingale reed-warbler recovery plan is the establishment of at least three additional populations, with emphasis on islands where they used to occur (USFWS 1998). Reintroductions to Aguiguan, will increase population numbers and species distribution and contribute to the delisting goals for this species. A plan to reintroduce nightingale reed-warbler should first be developed and should include information on habitat restoration and preservation as well as limiting factors for the birds.

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2.4.5 TINIAN MONARCH SURVEYS

Tinian Monarch (*Monarcha takatsukasae*). Photo by Eric VanderWerf.

Prepared by: **Fred Amidon, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI. Point-transect methods, results, tables, and figures, with some modifications, from Camp *et al.* (2009) (Appendix 3.1).**

INTRODUCTION

The Tinian monarch (*Monarcha takatsukasae*), or Chuchurican Tinian in the Chamorro language, is a small (15 centimeter) forest bird in the monarch flycatcher family (Monarchidae)(Baker 1951). The monarch currently is found only on the island of Tinian, but examination of museum specimens by Peters (1996) suggested a now extirpated population may have occurred on the island of Saipan, just north of Tinian. The monarch also was reported from the tiny island of Aguiguan just south of Tinian in the early 1950s, but some authorities discount this report as an error (Engbring *et al*. 1986).

The monarch inhabits a variety of forest types on Tinian, including native limestone forest dominated by *Ficus* spp., *Mammea odorata*, *Guamia mariannae*, *Cynometra ramiflora*, *Aglaia mariannensis*, *Premna obtusifolia*, *Pisonia grandis*, *Ochrosia mariannensis*, *Neisosperma oppositifolia*, *Intsia bijuga*, *Melanolepis multiglandulosa*, *Eugenia* spp., *Pandanus* spp., *Artocarpus* spp., and *Hernandia* spp., secondary vegetation consisting primarily of *Casuarina equisetifolia* and the non-natives *Acacia confusa*, *Albizia lebbeck*, *Cocos nucifera*, and *Delonix regia*, with some native species mixed in, like *Melanolepis multiglandulosa* and *Aidia cochinchinensis*, and nearly pure stands of introduced *Leucaena leucocephala* (tangantangan) (Engbring *et al*. 1986, Falanruw *et al.* 1989, USFWS 1996).

The first island-wide survey for the species took place in May 1982 using the point-transect or variable circular plot method. From that survey the population was estimated to be 39,338 birds and Tinian monarchs were found distributed throughout the island in all forest types (Engbring *et al*. 1986). A second survey of the Tinian monarch population took place in August and September 1996 using the same transects and methods as in 1982 (see Figure 1). The 1996 survey estimated the monarch population at 55,721 birds (Lusk *et al*. 2000), which was significantly higher than the estimate of 39,338 birds from 1982 found by Engbring *et al*. (1986). The 1996 survey also found that vegetation density had increased significantly in all forest types since 1982. Lusk *et al*. (2000) hypothesized that the increase in the monarch population was related to increases in density of vegetation in both native and introduced forest habitats, which may have been related to a decrease in grazing pressure.

The Tinian monarch was listed as endangered in 1970 (35 FR 8491) under the authority of the Endangered Species Conservation Act of 1969 (16 U.S.C. 668cc). The Tinian monarch was reclassified from endangered to threatened on April 6, 1987 (52 FR 10890), and on September 21, 2004, the monarch was removed from the Federal List of Endangered and Threatened Wildlife (69 FR 56367). A post-delisting monitoring plan was developed in 2005 (USFWS 2005) and was initiated in 2006 (USFWS 2008). Currently, the Tinian monarch is listed as threatened/endangered by Commonwealth of the Northern Mariana Islands and vulnerable by the World Conservation Union (IUCN 2008).

In 2008, the Department of Defense contracted the U.S. Fish and Wildlife Service's Pacific Islands Fish and Wildlife Office to conduct terrestrial and marine surveys on Tinian and Aguiguan. The following report outlines the survey results from June 2008 point-transect or variable circular plot surveys and Tinian monarch territory mapping in August 2008. The point-transect section is a summary of Camp *et al.* (2009; Appendix 3.1) with some modifications.

METHODS

Point-Transect Surveys

Between 27 April and 8 May 1982 Engbring *et al.* (1986) sampled a total of 216 stations on 10 transects during an island-wide survey of the island of Tinian (Figure 1). All transects were at least 300 meters apart and all stations along each transect were 150 meters apart (Engbring *et al.* 1986). These transects were resurveyed during both the 1996 (28 August – 1 September) and 2008 (14 – 19 June) surveys. An additional 4 transects were sampled during the 2008 survey for a total of 254 stations. The 4 additional transects were included to increase the number of stations in native limestone forest and to improve density estimates for the Tinian monarch (Table 1). These transects were also at least 300 m from the nearest transect and all stations were 150 meters apart.

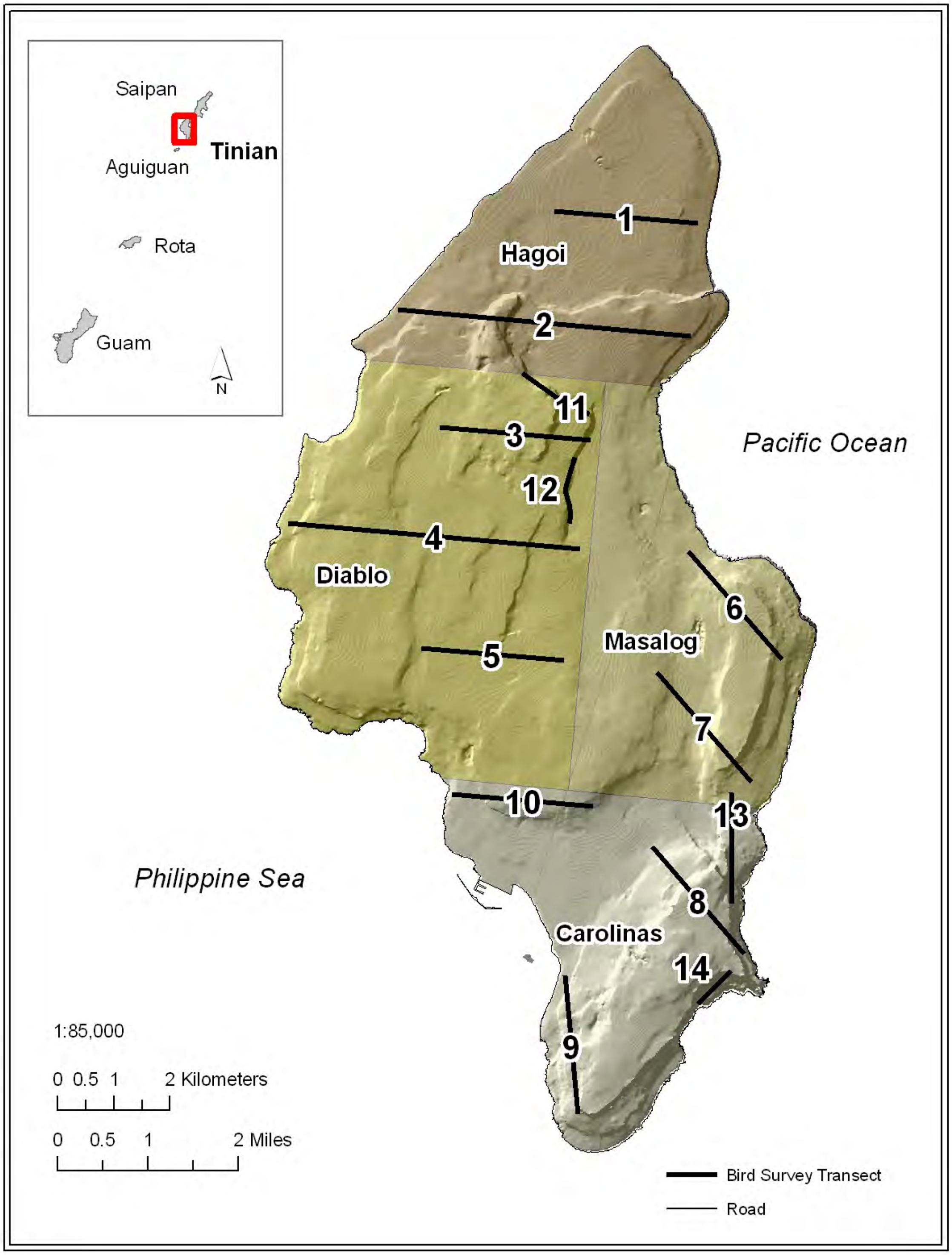

Figure 1. Island of Tinian showing the survey transects and regions (as defined by Engbring *et al.* 1986). Transects 1-10 were counted during all three surveys, and transects 11-14 were established and counted during the 2008 survey.

Table 1. Tinian monarch detections by habitat type in 1982 and estimated number of stations need to produce density estimates with 10%, 20% and 30% coefficients of variation.

			Coefficient of Variation		
Habitat	Stations	Detection	10%	20%	30%
Limestone Forest	14	35	120	30	13
Secondary Forest	67	198	102	25	11
Tangantangan	95	207	138	34	15

All surveys followed standard point-transect methods, consisting of 8-minute counts where horizontal distances to all birds heard and/or seen were measured and recorded (see Engbring *et al*. 1986 for details). Sampling conditions recorded included cloud cover, rain, wind, noise level, and habitat type, and these were later used as covariates in density calculations (see below). Counts commenced at sunrise and continued up to 1100 hours and were conducted only under favorable conditions.

Two observers surveyed each station in 1982, and one observer surveyed the stations in 1996 and 2008. Only data from one counter was used for each station from the 1982 surveys for this analysis and the counters were identified based on their experience and survey proficiency. Engbring *et al*. (1986) analyzed bird detections from all observers to estimate bird densities. For our analysis, we used detections from only one observer to recalculate densities for the 1982 Tinian survey, thus matching the 1996 and 2008 survey effort. Calculating densities from only one of the counters is a conservative approach and ensures sampling independence. This approach approximately halved the number of birds detected; however, our density estimates were generally greater than, but otherwise similar to, those of Engbring *et al*. (see Table 8; 1986). On Tinian the 95% confidence intervals bracketed Engbring *et al*.'s estimates for all but five birds—Mariana Fruit-Dove, Micronesian Honeyeater, Tinian Monarch, Rufous Fantail, and Bridled White-eye. Differences may have resulted from analytical procedures such as selecting different truncation distances, selecting different models to estimate densities, and analytical advances in distance sampling (see Johnson *et al*. 2006), in addition to estimating densities using detections from only one of the counts.

Population status was calculated as densities (birds/km^2) and number of birds (density by habitat type multiplied by habitat type area). Density was calculated using the program DISTANCE (Thomas *et al*. 2006) from species-specific global detection functions where data were post-stratified by survey in the stratum layer. Data were right-truncated to facilitate model fitting (Buckland *et al*. 2001), and the model with the lowest Akaike Information Criterion (AIC) was used to select the detection function that best approximated the data. Candidate models included half-normal and hazard-rate detection functions with expansion series of order two (Buckland *et al*. 2001). Sampling covariates were modeled in the multiple-covariate distance engine of DISTANCE (Thomas *et al*. 2006, Marques *et al*. 2007). Covariates (sampling conditions and survey year) were used to generate the global detection function when the best approximating model was improved by four or more AIC units. Variances and confidence intervals were derived by log-normal based methods. Survey-specific density by station values were generated for the population trends analyses (see below) from the global detection function using the post-stratification by sample option in the stratum layers annual estimates and regional estimates.

Area of habitat types came from Engbring *et al*. (1986) and recent vegetation cover estimates (see 2.1 Vegetation Survey). The area of habitat types was not available for the 1996 Tinian survey; therefore, we used the area by habitat types from Engbring *et al*. to calculate the 1996 numbers of birds. This may slightly underestimate the population size if there was more secondary forest in 1996 than 1982. The agriculture habitat type (combined agroforestry and cultivated habitat type classifications) was not used to calculate numbers of birds because the area of this habitat is very small relative to the island (< 2%), the area of the agriculture habitat type has declined (190 ha in 1982 to 174 ha in 2008; see 2.1 Vegetation Surveys), and only two stations were located in the agriculture habitat type, thus it was under-sampled.

Change in density among the three annual estimates on Tinian was assessed with repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, NC). Repeated measures ANOVA was also used to assess change in bird densities within regions among the three annual estimates. To stabilize the error variances, densities by station were log transformed after a constant of 1 was added (to avoid ln(0)). Stations were treated as the random factor, and we assumed the variance-covariance structure was a compound symmetry, homogeneous variance model (Littell *et al*. 1996). The degrees of freedom were adjusted using the Kenward-Roger adjustment statement and a Tukey's adjustment was used to control alpha = 0.05 for multiple-comparison procedures. Differences by habitat for Tinian Monarch from the 2008 survey were compared using a one-way ANOVA (PROC MIXED) with the same options as those used in the repeated measures models. The agriculture habitat was dropped from this analysis because only two stations were sampled within the habitat.

Territory Mapping
Between August 4 and 29, 2008, four study plots were established and sampled to estimate Tinian monarch territory densities (Figure 2). Two study plots were established in areas designated as secondary forest and two plots were established in areas designated as tangantangan thicket. Each plot was situated so that it straddled a minimum of two survey stations on transects sampled during the June 2008 point-transect survey to compare territory density estimates with point-transect survey results. Because of the patchy nature of these forest types and the goal of establishing the plot along an established transect, the locations of each plot were not randomly selected.

Each study plot consisted of a series of cut trails and stations marked at 50 meter increments to assist with territory mapping. Each plot was surveyed in the morning (0600-1200) and afternoon (1500-1800) over several days by teams of surveyors. Initially, efforts were undertaken to survey the entire plot during one morning or afternoon survey station. However, due to the amount of bird activity and size of the study plots it was not feasible to cover the plot adequately using this method. Therefore, each survey team focused on a portion of the study plot and multiple survey teams were often employed to increase survey coverage and to obtain dual observations of territorial pairs.

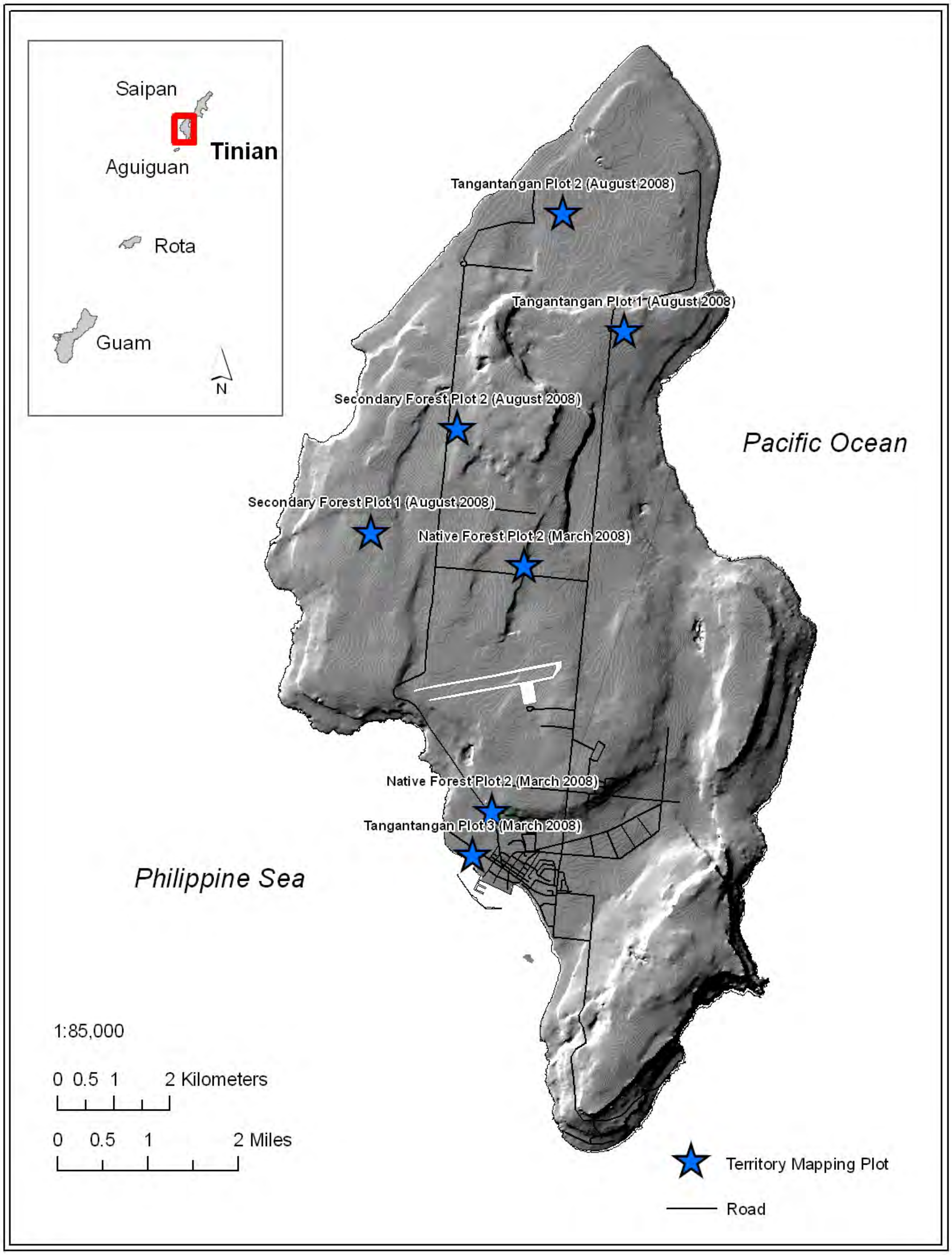

Figure 2. Island of Tinian showing the locations of the territory mapping plots sampled in March and August 2008.

All Tinian monarch detections were marked on a map of the study plot using symbols for movements and activities outlined by Bibby *et al.* (2000). These locations were then transferred to a master map of the study plot created with ArcMap 9.2 (ESRI, Redlands, CA). The locations of all nests found in the study plot were recorded with a Garmin etrex or 76CSx unit (Garmin International, Inc., Olathe, KS) Global Positioning System (GPS) unit and downloaded to ArcMap 9.2. Survey coverage and effort was also tracked using the track function of the GPS units which were downloaded to ArcMap 9.2 daily.

Tinian monarch territory densities were determined by counting the number of Tinian monarch pairs within each study plot and dividing the total number of territories by the size of the plot. Territories which overlapped the edge of the plot were included as half territories (Bibby *et al.* 2000). The presence of a territory was determined through a combination of visual observations of pairs or family groups, active nests, and territorial behaviors (*e.g.*, singing, territorial defense). In addition, simultaneous observations of birds and nesting activity by multiple observers were used whenever possible to confirm the presence of adjacent territories. The boundary of each study plot was defined as the outer east and west transects and ends of each north and south running transect. On average a buffer between 20 and 50 meters around each plot was surveyed based on the GPS tracks.

Territory density estimates for two limestone forest plots and an additional tangantangan thicket plot were obtained from the post-delisting monitoring results obtained in March 2008 (USFWS 2008). Territories in these study plots were delineated based on observations of individually marked birds in each study plot.

RESULTS AND DISCUSSION

Point-Transect Surveys

A total of 361 Tinian monarchs were detected during the June 2008 survey and the population was estimated to be approximately 38,000 individuals (Table 2). This population estimate represents a significant decline from our estimates for the 1982 and 1996 surveys (Table 2). In addition, densities of Tinian monarchs in the Diablo region declined significantly between 1982 and 2008 (Figure 3).

Table 2. Population density (birds/km^2 ± SE, with 95% CI) and abundance (density times the area of Tinian; 101.01 km^2; with 95% CI) estimates for Tinian monarchs from three point transect surveys. The 1982 and 1996 data were reanalyzed using current analysis procedures (see Methods above).

Year	Density	Abundance
1982	634.5 ± 37.88 (564.3–713.4)	60,898 (49,484–75,398)[1]
1996	705.7 ± 43.96 (624.3–797.6)	62,863 (50,476–78,758)[2]
2008	431.3 ± 30.75 (374.9–496.2)	38,449 (29,992–49,849)

1. 39,338 (35,161–43,515), Engbring *et al.* (1986) – Estimate from original report
2. 55,721 (48,345–63,495), Lusk *et al.* (1986) – Estimate from original report

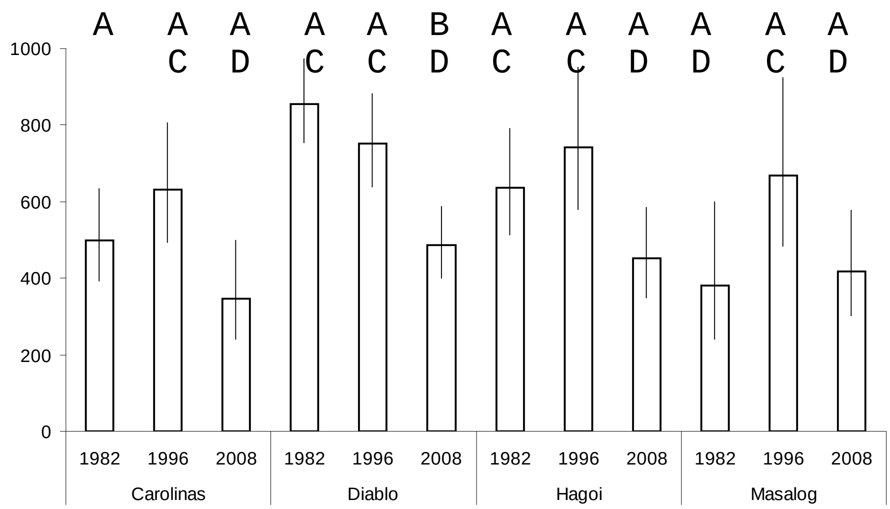

Figure 3. Density estimates (birds/km^2 and 95% CI) for Tinian monarchs by region and year from three point-transect surveys. Differences of least squares means were assessed with repeated measures ANOVA. Comparisons, within region by year, that share the same letter are not significantly different at the 0.05 level, adjusted for multiple comparisons (see 2.4.1 General Land Birds).

Tinian monarchs were recorded in all of the land cover types sampled on Tinian, but their densities were not distributed evenly among these land cover types (Table 3). Based on the 2008 survey, the greatest monarch densities were observed in limestone forest, secondary forest, and tangantangan thicket. The smallest densities were found in open field and urban/residential habitats. Monarch densities in limestone and secondary forests were greater than those in open field and urban/residential, but not different from densities in tangantangan thicket (Table 3).

Table 3. Tinian Monarch density estimates (birds/ha), standard error (SE), and 95% confidence intervals (Lower and Upper 95% CI) by habitat in 2008 based on point-transect sampling.

Habitat	Estimate	SE	L 95% CI	U 95% CI
Agriculture	1.75	1.75	*	*
Limestone Forest	6.41	0.74	5.09	8.05
Open Field	2.83	0.64	1.81	4.44
Secondary Forest	5.82	0.54	4.84	7.01
Tangantangan Thicket	4.36	0.47	3.52	5.39
Urban/Residential	1.50	1.04	0.32	6.94

*Sample size was insufficient to estimate reliable confidence intervals.

Engbring *et al.* (1986) and Lusk *et al*. (2000) both calculated lower Tinian Monarch abundance than our estimates for 1982 and 1996, respectively (Table 2). In addition, the estimate of 35,846 (± 2,211 SE) Tinian monarchs for 1982 by Lusk *et al*. (2000) is also lower than our estimate and the estimate by Engbring *et al.* (1986). These changes are due to differences between the analytical procedures, specifically differences in the model selected and advances within program DISTANCE. For example, Lusk *et al*. (2000) did not extrapolate densities to abundance for 2,375 ha of open fields, although monarchs were detected in this habitat. After dropping densities from the open fields and adjusting for this area difference, our densities resulted in 48,424 birds, an estimate that fell within their 95% CI. This difference is easily accounted for in differences between our methods, specifically differences in the model selected and advances within program DISTANCE. Lusk *et al*. (2000) calculated their density estimate from a half-normal model with polynomial adjustments and an effective detection radius (EDR) of just over 34 m. We estimated the EDR at 30.18 m from a hazard-rate detection function (without adjustments) and incorporating observers as a covariate, where the smaller EDR resulted in greater densities. Lastly, Lusk *et al*. (2000) used program VCPADJ (Fancy 1997) and a previous version of DISTANCE (Laake *et al*. 1994) to standardize the survey conditions and estimate densities. The updated version of DISTANCE (Thomas *et al*. 2006) we used incorporates all of the modeling in one program and uses an improved technique to account for differences in sampling conditions (Thomas *et al*. 2006, Marques *et al*. 2007).

Territory Mapping

A total of 680 person hours was spent territory mapping in the four study plots established in August 2008 which translated to approximately 24 person hours per hectare. Active breeding (*e.g.*, nest building, chick rearing, and family groups) was observed on all plots. A total of 65.5 territories were identified and territory densities ranged from 1.7 to 2.9 territories per hectare (Table 4). When compared with the territory mapping results in March 2008, territory densities were highest in limestone forest followed by secondary forest and then tangantangan thickets. Densities in tangantangan thickets were the most variable with densities overlapping estimates for secondary forest plots (Table 4). The lowest density was found in tangantangan plot 2 which was located off of the northfield runway (Figure 2).

Table 4. Tinian monarch territory density estimates (territories/ha) in limestone forest, secondary forest and tangantangan thickets in 2008 based on territory mapping. See USFWS (2008) for methods used to survey plots in March 2008.

Habitat	Plot	Plot Size (ha)	Number of Territories	Density	Survey Month
Limestone Forest	1	1.91	15	7.8	March
	2	2.42	18	7.5	March
Secondary Forest	1	6.47	18.5	2.9	August
	2	5.72	14	2.5	August
Tangantangan Thicket	1	8.59	21	2.4	August
	2	6.90	12	1.7	August
	3	3.26	8	2.5	March

The results from 2008 were similar to the three study plots surveyed in 1995 (USFWS 1996). That study reported 6.41 (95% CI: 5.09 – 8.05) birds per hectare in limestone forest and 5.82 (95% CI: 4.84 – 7.01) and 4.36 (95% CI: 3.52 – 5.39) birds per hectare in secondary forest and tangantangan thicket, respectively (USFWS 1996). The limestone forest plot in the 1995 study coincides with limestone forest plot 2, also known as the Airport Mitigation Plot, in the 2008 survey while the tangantangan plot in the 1995 study was near tangantangan plot 2 in this study. These results indicate that territory densities may be consistent over time as similar densities were reported in the two survey periods. However, results for different plots in the same habitat and between habitats can be variable.

One potential source of this variability is the disturbance history of each study plot. Tangantangan plot number 2 was located between two of the old runways built during World War II. This area was likely leveled and had all of its topsoil removed as part of runway construction. This site also had the lowest densities of Tinian monarch territories and the lowest recorded nesting activity. The two plots in limestone forest appear to have not been developed before, during, and after the war and had the highest Tinian monarch territory densities. The remaining plots all experienced some level of agricultural or military development based on 1945 aerial photographs. Tangantangan plot 3 is located on the site where a sugar refinery was constructed and destroyed during the war. Secondary forest plot 1 was likely an agricultural field prior to the war but had structures built on it near the end of the war. Both tangantangan plot 1 and secondary forest plot 2 were both agricultural fields prior to the war and were not developed after the war.

Another potential source of variability is the presence of broadleaved trees in the understory. Information from the 1995 Tinian monarch study indicates that nests are typically associated with native trees in the understory (USFWS 1996). Observations made during this survey also indicate that understory composition may be important to Tinian monarch breeding. In addition, habitat sampling along bird survey transects on Tinian by Vogt (2009; see Appendix 3.2) showed a positive correlation between Tinian monarch detections and tree diversity. This study also found that Tinian monarch detections were higher in mixed forest than areas dominated by tangantangan. Unfortunately, due to the nature of the survey and time limitations we were unable to assess this relationship further during the 2008 study. Further work on this subject is warranted.

The point-transect survey included the entire island and sampled a wide range of habitats. Therefore, the variability in density estimates in study plots should be incorporated within the point-transect estimates. To compare the two estimates we multiplied the territory density in each plot by two to estimate the minimum number of birds per hectare in the plot. We then compared these estimates to the point-transect density estimates and found that the confidence intervals for the point-transect estimates included the density estimates for the tangantangan and secondary forest plots (Table 3). This helps confirm the robustness of the point-transect estimates in these habitat types. However, the density estimates for the study plots were well outside the confidence intervals of the point-transect estimate for limestone forest. Both plots were located in thin stretches of native forest so Tinian monarchs may be more concentrated in these areas. To assess if the width of the native forest was a factor we classified all stations in native forest as either thin ($\leq$ 300 meters wide, n = 30) or wide (>300 meters wide, n = 24) native forest stations. We then compared detections for each station type and found that Tinian monarch detections were significantly higher on stations in thin stretches of native forest (2.50 $\pm$ 0.26) than stations in wide stretches of native forest (0.83 $\pm$ 0.26) (two sample T-test, T = -5.06, P<0.001, df = 51). Therefore, Tinian monarch densities may be higher in thinner stretches of native forest which may account for the higher densities in our territory mapping plots. However, it should be noted that the wide stretches of native forest that were sampled were all along the southeast coast of the island (transect 13 and 14 and the southern end of transect 8; Figure 1). In general, the terrain in this region was very rugged and the habitat quality in this area may differ from the other patches of native forest on the island. Therefore, further work is needed to determine why densities may differ among the patches of native forest.

Conclusions and Management Recommendations
The Tinian monarch population currently consists of approximately 40,000 individuals and has experienced a population decline since 1982 and 1996. The cause of the Tinian monarch population decline is uncertain. Tinian monarchs are primarily associated with forested habitats and the availability of these habitats have increased or remained stable since 1982 (see 2.1 Vegetation Surveys). In addition, other forest bird species, like the rufous fantail, have increased since 1982 (see General Land Birds). Therefore, gross changes in forest cover seem an unlikely cause of the decline. The quality of the forested habitat may have changed, for example we noted heavy cover on invasive vines in our secondary forest study plots, which may have reduced density of monarchs these areas could sustain. The decline may also be related to non-habitat factors as well. Observations of pox-like lesions on some individuals during color-banding may indicate that disease may be playing a role in the decline. Introduced predators, like rats, could also be impacting Tinian monarch populations.

Though habitat loss does not appear to be major in the decline of Tinian monarch, the loss of important habitat to the species is expected to further endanger this endemic species. Territory mapping and point-transect estimates indicate forested areas, especially native limestone forest, are important to the long-term conservation of this species. However, the value of each habitat type may be dependent on quantity of native trees in the understory. Therefore, we recommend the following management and research activities:

1. Avoid impacts to the remaining native limestone forest areas as these provide important habitat to the Tinian monarch and serve as seed sources for native forest restoration in adjacent habitats;
2. Actively restore native forest through planting of native trees in the understory of secondary forest and tangantangan habitats;
3. Convert open fields to native forest or potentially secondary forest;
4. Evaluate Tinian monarch habitat selection in native limestone forest, secondary forest, and tangantangan habitats;
5. Evaluate the potential impact of avian disease and predation on Tinian monarch populations; and
6. Prevent the introduction of brown treesnakes to Tinian.

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2.5 MAMMAL SURVEYS

2.5.1 RODENTS ON TINIAN

Suncus murinus. **Photo by Curt Kessler.**

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INTRODUCTION

The following report is a synopsis of a much larger report entitled: Systematic Rodent Monitoring; A Study of the Introduced Small Mammals of the Mariana Islands, by Wiewel *et. al.* 2008. Only those findings pertanent to the island of Tinian are presented here. Please reference the full document for further explanations of methods and results for the islands of Tinian, Saipan, Rota, and Guam (Appendix 3.3).

Introduced small mammals often have detrimental effects on island ecology (Atkinson 1985, Towns *et al.* 2006). Direct effects of introduced small mammals include competition with, or predation on, various amphibian (Worthy 1987, Towns and Daugherty 1994), avian (Fisher and Baldwin 1946, Wirtz 1972, Recher and Clark 1974, Atkinson 1977, Martin *et al.* 2000, Smith *et al.* 2006), invertebrate (Bremner *et al.* 1984; Kuschel and Worthy 1996; Brook 1999, 2000; Carlton and Hodder 2003; Priddel *et al.* 2003), mammalian (Daniel 1990, Goodman 1995, Pascal *et al.* 2005), and reptilian species (Whitaker 1973; Newman 1994; Towns 1994; Towns and Daugherty 1994; Cree *et al.* 1995; Hoare *et al.* 2007a,b), often resulting in population declines or even extirpation. Introduced small mammals may also suppress plant recruitment by consuming bark, flowers, foliage, fruits, seeds, or seedlings (Allen *et al.* 1994; Campbell and Atkinson 1999, 2002; McConkey *et al.* 2003; Wilson *et al.* 2003); in extreme cases this recruitment suppression can result in local extirpation (Campbell and Atkinson 1999, 2002). Less apparent but equally important indirect effects include disruption of island trophic systems (Fritts and Rodda 1998, Towns 1999) and nutrient cycling (Fukami *et al.* 2006), modification of vegetative community structure and successional patterns

(Campbell and Atkinson 1999, 2002; Athens *et al.* 2002), and creation of novel vectors and reservoirs for diseases and parasites of both animals (Pickering and Norris 1996, Martina *et al.* 2006) and humans (Chanteau *et al.* 1998, Lindo *et al.* 2002, Bitam *et al.* 2006, Jiang *et al.* 2006). However, our understanding of these effects is limited by incomplete knowledge of small mammal distribution, density, and biomass on many islands. Such information is especially critical in the Mariana Islands, where introduced small mammals are keystone prey for the introduced brown treesnake (*Boiga irregularis*) and small mammal density is inversely related to the effectiveness of brown treesnake control and management tools, such as mouse-attractant traps.

In an effort to address these concerns, we deployed mark-recapture livetrapping methodology to determine introduced small mammal distribution, density, and biomass at 3 sites on Tinian. We sampled one site each of grassland, *Leucaena* forest, and native limestone forest. In addition, we conducted snaptrapping at these sites following livetrapping, which allowed direct comparison between these sampling methods as well as estimates in indices generated from them. Livetrapping and snaptrapping occurred between April 2005 and June 2007.

Based on a review of available data the introduced small mammal community of the Mariana Islands consists of 5 or 6 species (with possible additional subspecies), ranging from the earliest introduction, *Rattus exulans*, which occurred no later than A.D. 1000–1200 (Steadman 1999) to the most recent introduction, *Suncus murinus*, first captured on Guam in 1953 (Peterson 1956). Later introductions include *Mus musculus*, first reported on Guam in 1819 (Freycinet 2003), and *R. norvegicus*, first reported on Saipan in the late 1800's (Kuroda 1938 cited by Wiles *et al.* 1990). Regarding the polytypic species *M. musculus*, it is not clear which, or how many, subspecies (*M. m. musculus*, *M. m. domesticus*, or *M. m. castaneus*; Musser and Carleton 2005) have been introduced. It is notable that Prager *et al.* (1998) found *M. m. castaneus* on Tinian, although this identification was based on genetic analysis of a single speciment. Two additional species, *R. rattus* and *R. tanezumi*, have been documented in the Mariana Islands (Baker 1946, Johnson 1962, Yosida *et al.* 1985), although their current status is unclear. The complex taxonomic history of these closely related species (Musser and Carleton 2005), which were only recently separated based on karyotypic differences (*R. rattus*: 2n = 38; *R. tanezumi*: 2n = 42) as well as biochemical and morphological features (Schwabe 1979, Baverstock *et al.* 1983), complicates the investigation of historic introductions and current distribution. Additional confusion arises from the limited hybridization observed in both laboratory (Yosida *et al.* 1971) and wild (Baverstock *et al.* 1983) populations, which led Baverstock *et al.* (1983:978) to conclude that *R. rattus* and *R. tanezumi* "…are best considered as incipient species. Where they meet, they may introgress, become sympatric without interbreeding, or one may replace the other depending upon the prevailing biological conditions."

METHODS

For a complete description of the study site selection and small mammal sampling protocols used during this research (described below), please refer to Wiewel (2005).

Study Site Selection

We sampled 3 sites on Tinian (Figure 1) between April 2005 and June 2007 (Table 1). Study sites were identified using a 1:25,000 scale topographical map (U.S. Geological Survey 1999) and 1:20,000 scale vegetation maps (Falanruw *et al.* 1989). Sites were evaluated based on habitat type, available area of relatively homogeneous habitat, and land ownership status. Selected sites represented the 3 major habitat types of the southern Mariana Islands: native limestone forest, grassland, and *L. leucocephala*-dominated secondary forest.

Table 1. Introduced small mammal sampling site coordinates and dates on Tinian, 2005–2007. Coordinates indicate the site centroid, and are presented in decimal degrees (WGS 84, UTM Zone 55 North).

Site	Habitat	Dates Sampled	Latitude	Longitude
KAST	grassland	Oct 24–28, 2005	14.951	145.651
ABLE	*Leucaena* forest	Nov 7–11, 2005	15.076	145.640
LSUS	native forest	Oct 31–Nov 4, 2005	15.043	145.629

Small Mammal Sampling

Due to the uncertainty surrounding the status of *R. rattus* and *R. tanezumi* in the Mariana Islands, we collected genetic material from all captured *Rattus* to allow determination of species identification and distribution. Until samples are processed, however, we will use the more recognized term *R. rattus* to refer to the combined sample of unidentified *Rattus* species.

At each site, mark-recapture livetrapping was conducted for 5 consecutive nights on an 11 × 11 grid with 12.5 m intervals between each trap station (grid area = 1.56 ha). A single standard-length folding Sherman live trap (229 × 89 × 76 mm; H.B. Sherman Traps, Inc., Tallahassee, FL) was placed at each trap station (n = 121) and a single Haguruma wire mesh live trap (approximately 285 × 210 × 140 mm; Standard Trading Co., Honolulu, HI) was placed at every other trap station (n = 36). Closed traps were placed on the grid a minimum of 2 nights prior to the beginning of sampling to provide an opportunity for small mammals to acclimate to their presence. Traps were placed on the ground and, whenever possible, located next to or beneath clumps of grass, downed woody debris, or rocks to provide shelter from sun and rain. Traps were baited with a mixture of peanut butter, oats, and food-grade paraffin (Wiewel 2004) and were checked beginning at 0730–0800 each day. Traps were closed during the day to minimize trap mortality. Traps were reopened at approximately 1600 and rebaited as necessary to ensure bait freshness.

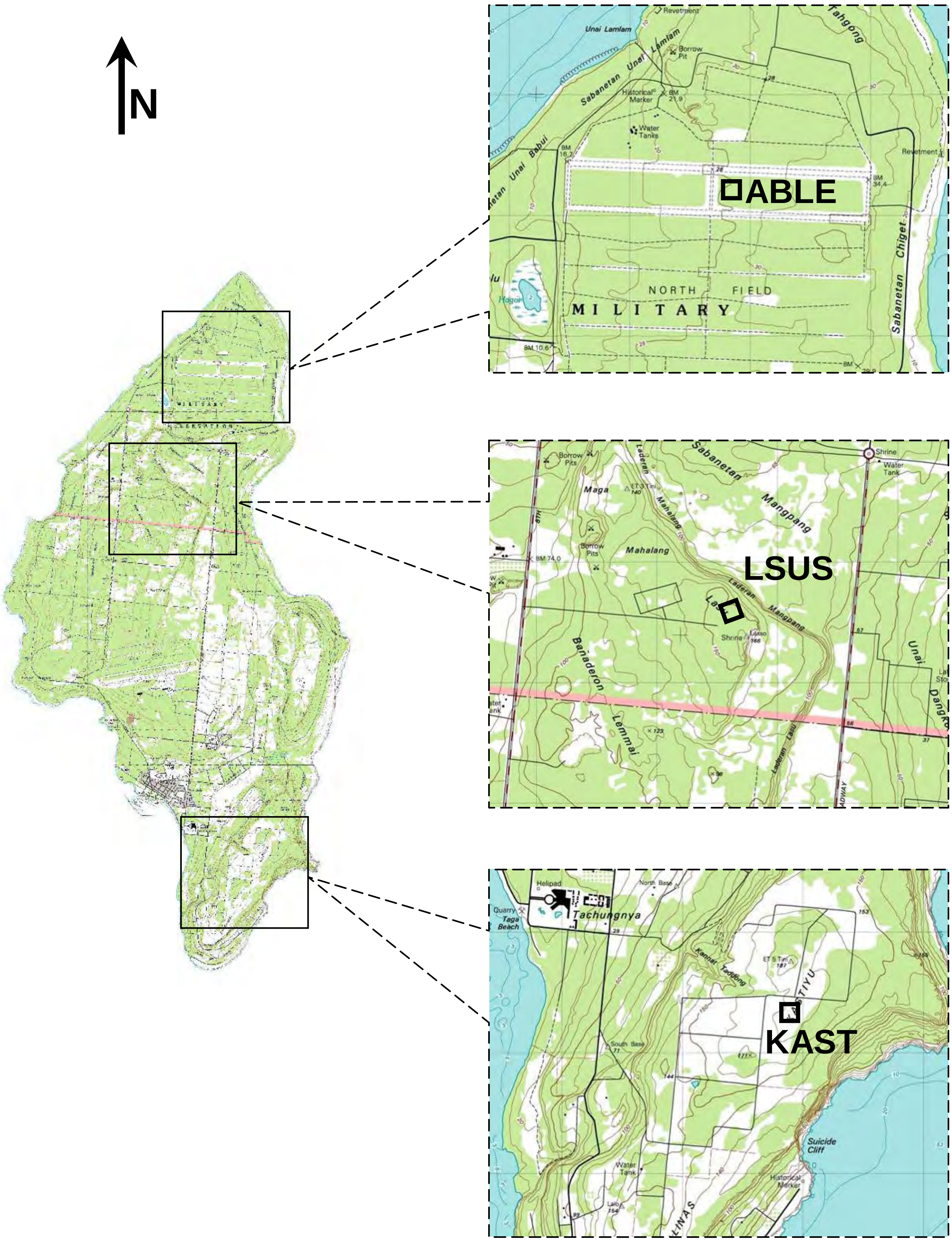

Figure 1. Introduced small mammal sampling locations on Tinian, Mariana Islands, 2005–2007. Sampling grids are delineated with bold squares, which represent an area of 125 m^2 (1.56 ha). See Table 1 for site coordinates, sampling dates, and habitat classifications.

Captured animals were examined and measured to determine species, sex, age, reproductive status, mass (g), head-body length (mm), tail length (mm), right hind foot length (mm), right ear length (mm), and testes length (mm; if applicable). Captured individuals were uniquely marked in each ear with numbered metal ear tags (*M. musculus* and *S. murinus*: small ear tags produced by S. Roestenburg, Riverton, UT; *Rattus* species: #1005-1, National Band and Tag Co., Newport, KY). Recaptured animals were examined to determine tag number. All capture, handling, and marking techniques followed guidelines approved by the American Society of Mammalogists (Gannon *et al.* 2007) and the U.S. Geological Survey Animal Care and Use Committee (Fort Collins Science Center).

Each site was also sampled with 5 consecutive nights of snaptrapping during the week following livetrapping. Results of snaptrapping are described elsewhere; however, data collected during snaptrapping were included in the calculation of both body condition index (a covariate used in mark-recapture abundance estimation) and mean maximum distance moved (used in density estimation).

Data Analysis

We estimated density and biomass separately for each species. First, we generated site-specific estimates of abundance using estimated capture and recapture probability modeled from livetrapping data. Because these estimates had no associated area component, our second step was to estimate the effective trapping area for each site with reference to each species' mean maximum distance moved between captures. Third, we estimated density as abundance/ effective trapping area. Fourth, we determined mean body mass based on measurements of captured animals at each site. Fifth, for each site we estimated biomass as the product of site-specific density and site-specific mean body mass. Finally, we created variance-covariance matrices to separately calculate the variances of density and biomass estimates. For a more detailed explanation of data analysis please refer to the original document (Appendix 3.3).

RESULTS

We captured a total of 241 *Rattus rattus*, 167 *Suncus nurinus*, 9 *Mus musculus*, and 1 *Rattus norvegicus* on Tinian (Table 2). No *Rattus exulans* were captured at the three sites sampled.

Density Estimates

R. rattus mean maximum distance moved on Tinian were 14.5 ± 1.3 m, 95% CI = 11.9–17.1; n = 180. When combined with the nominal grid area of 1.56 ha, these mean maximum distance moved estimates resulted in effective trapping areas of 1.95 ha and mean *R. rattus* density estimates of 73.0/ha (n = 3) on Tinian (Table 3).

S. murinus mean maximum distance moved varied primarily between habitats, and was greatest in grassland (29.2 ± 2.7 m, 95% CI = 23.7–34.7; n = 48), followed by mixed habitat (19.3 ± 3.2 m, 95% CI = 12.7–25.9; n = 25), *Leucaena* forest (16.3 ± 1.4 m, 95% CI = 13.6–19.0; n = 68), and native forest (14.2 ± 3.5 m, 95% CI = 6.4–22.0; n = 12).

Mean estimated density was 52.8/ha (n = 2) in *Leucaena* forest, 24.2/ha (n = 2) in native forest, 20.2/ha (n = 2) in mixed habitat, and 9.7/ha (n = 2) in grassland (Table 3).

Table 2. *Mus musculus*, *Rattus exulans*, *R. norvegicus*, *R. rattus*, and *Suncus murinus* individuals captured (M_{t+1}) and total captures ($n_.$) during mark-recapture livetrapping in grassland, *Leucaena* forest, mixed, and native forest habitats on Tinian, 2005–2007. Blank entries indicate zero captures.

		M. musculus		*R. exulans*		*R. norvegicus*		*R. rattus*		*S. murinus*	
Site	Habitat	M_{t+1}	$n_.$	M_{t+1}	$n_.$	M_{t+1}	$n_.$	M_{t+1}	$n_.$	M_{t+1}	$n_.$
KAST	grassland	9	12			1	1	106	132	11	11
ABLE	*Leucaena* forest							55	81	93	113
LSUS	native forest							80	92	43	43

Table 3. *Rattus rattus*, *Suncus murinus*, and *Mus musculus* density estimates ($\hat{D}$; animals/ha), standard errors (SE), and 95% confidence intervals (95% CI) in grassland, *Leucaena* forest, mixed, and native forest habitats on Tinian, 2005–2007. Blank entries indicate zero captures, and therefore zero estimated density.

		R. rattus			*S. murinus*			*M. musculus*		
Site	Habitat	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI	$\hat{D}$	SE	95% CI
Tinian										
KAST	grassland	99.9	17.9	64.8–135.0	8.9	2.5	4.0–13.8	8.2	2.7	2.9–13.5
ABLE	*Leucaena* forest	44.0	7.3	29.7–58.3	73.7	20.1	34.3–113.1			
LSUS	native forest	75.1	13.6	48.4–101.8	32.8	9.6	14.0–51.6			

M. musculus mean maximum distance moved on Tinian were 11.7 ± 8.7 m, 95% CI = 0–28.0; n = 3. When combined with the nominal grid area of 1.56 ha, these mean maximum distance moved estimates resulted in effective trapping areas of 1.87 ha for Tinian. These model-averaged effective trapping areas produced mean *M. musculus* density estimates of 2.6/ha (n = 3) on Tinian (Table 3).

Biomass Estimates

R. rattus, *S. murinus*, and *M. musculus* varied dramatically in morphology, with mean *R. rattus* mass being much greater (121.9 ± 1.8 g, 95% CI = 118.3–125.5; n = 707) than mean *S. murinus* mass (25.7 ± 0.4 g, 95% CI = 25.0–26.5; n = 298) or mean *M. musculus* mass (12.5 ± 0.2 g, 95% CI = 12.1–12.9; n = 154). *R. rattus* biomass was markedly greater than *S. murinus* or *M. musculus* biomass across sampled habitats (Table 4). Mean estimated *R. rattus* biomass was 11.6 kg/ha. The mean estimated *S. murinus* biomass was 1.9 kg/ha. When evaluating biomass across habitats on Tinian, mean *R. rattus* biomass was greatest in grassland, with a maximum estimate of 11.6 kg/ha in this habitat. In other habitats, mean estimated *R. rattus* biomass was roughly half that estimated for grassland, although maximum biomass estimates exceeded 8 kg/ha in both mixed habitat and native forest. In contrast to *R. rattus*, mean estimated *S. murinus* biomass was lowest in grassland and highest in *Leucaena* forest on Tinian, with a maximum estimate of 1.9 kg/ha in this habitat. Mean estimated *M. musculus* biomass was greatest in grassland on Tinian, with a maximum estimate of 0.4 kg/ha in this habitat.

Table 4. *Rattus rattus*, *Suncus murinus*, and *Mus musculus* biomass estimates ($\hat{Biom}$; kg/ha), standard errors (SE), and 95% confidence intervals (95% CI) in grassland, *Leucaena* forest, mixed, and native forest habitats on Guam, Rota, Saipan, and Tinian, 2005–2007. Blank entries indicate zero captures, and therefore zero estimated biomass.

		R. rattus			*S. murinus*			*M. musculus*		
Site	Habitat	$\hat{Biom}$	SE	95% CI	$\hat{Biom}$	SE	95% CI	$\hat{Biom}$	SE	95% CI
Tinian										
KAST	grassland	11.57	2.11	7.43–15.71	0.16	0.05	0.06–0.26	0.11	0.04	0.03–0.19
ABLE	*Leucaena* forest	5.09	0.88	3.37–6.81	1.87	0.52	0.85–2.89			
LSUS	native forest	8.78	1.63	5.59–11.97	0.83	0.25	0.34–1.32			

DISCUSSION

Three species, *R. rattus*, *S. murinus*, and *M. musculus*, were commonly captured during this study. Two additional species, *R. exulans* and *R. norvegicus*, were captured infrequently and in very low numbers (Table 2). Of these species, *R. rattus* attains the greatest density and biomass in grasslands on Tinian when compared to the other southern limestone islands of Guam (2.42, SE = 0.58), Rota (9.80, SE = 1.62), and Saipan (4.13, SE = 0.83) (Wiewel *et al.* 2008). Maximum estimates of *R. rattus* density on Tinian are 2–3 times greater than the highest known historic values from Guam and also greater than estimates from other tropical Pacific islands, including Pohnpei (4.0–8.5/ha; Strecker 1962), Majuro (11.3/ha; Strecker 1962), Eniwetok (19.9/ha; Jackson 1967), and the Galapagos (0.2–18.9/ha; Clark 1980). Indeed, the peak densities observed during this study are suggestive of population irruptions. Conversely, the fact that high density *R. rattus* populations were observed across habitats, islands, and time is not indicative of an irruptive event, and instead suggests that high density *R. rattus* populations may be fairly common to Tinian. Comparable (and even higher) densities have been recorded for *R. exulans* on small relatively competitor- and predator-free islands. On Kure Atoll, Wirtz (1972) documented a mean *R. exulans* density of 111.2/ha during monthly sampling from March 1964 to May 1965, with monthly estimates ranging from 49.4/ha to 185.3/ha. Similarly, on Tititiri Matangi Island, New Zealand, Moller and Craig (1987) estimated peak *R. exulans* densities of 130 ± 20/ha in grassland and 101 ± 12/ha in forest during regular sampling from February 1975 to May 1977.

S. murinus is generally less common than *R. rattus* in the Mariana Islands. The low mass of *S. murinus* (in relation to *R. rattus*) resulted in *S. murinus* biomass estimates that were only 1–37% of the estimated *R. rattus* biomass for the same site. Overall, *S. murinus* density exceeded 30/ha. On Tinian, *S. murinus* density and biomass were greater in forest than grassland, with the highest values occurring in *Leucaena* forest. In general, our estimates of *S. murinus* density are comparable to historic values from Guam (25.4/ha, Barbehenn 1969, 1974; 19.1/ha, Savidge 1986) and more recent estimates from Saipan (16.7–27.3/ha, S. Vogt unpublished data). Our estimates are also similar to values obtained for the islands of Ile aux Aigrettes (29.2/ha) and Ile de la Passe (20/ha), located off the coast of Mauritius in the Indian Ocean (Varnham *et al.* 2002). However, our maximum estimated *S. murinus* density of 73.7/ha greatly exceeds known values, and could indicate an irruptive potential for this species in the Mariana Islands.

M. musculus is a relatively minor component of the introduced small mammal community from a biomass standpoint, with estimates ranging from 0.01–0.45 kg/ha. However, *M. musculus* capture probability may have been negatively influenced by *R. rattus* activity (Brown *et al.* 1996, Weihong *et al.* 1999). To investigate this possibility, we added site-specific *R. rattus* density to the top *M. musculus* model in a post-hoc MARK analysis. As anticipated, *R. rattus* density had a negative effect on *M. musculus* capture probability ($\beta = -0.008 \pm 0.006$, 95% CI = -0.019–0.003), although this effect was weak as demonstrated by the 95% CI that asymmetrically overlapped zero. Nonetheless, the trend of decreasing *M. musculus* capture probability with increasing *R. rattus* density suggests that this relationship warrants further investigation and should be considered during sampling design and data analysis. For example, the use of multiple trap types may decrease the likelihood of capture probability suppression of non-dominant species (Brown *et al.* 1996, Weihong *et al.* 1999, Gragg 2004). There was an indication of habitat specialization for *M. musculus*, as maximum density and biomass occurred at grassland and mixed habitat sites with patchy vegetative growth and exposed soil. Baker (1946:398) noted a similar preference for “open grass and brush land” and areas where “limestone soils are exposed” on Guam. Similar habitat preferences for this species have been noted for other tropical Pacific islands (Nicholson and Warner 1953, Berry and Jackson 1979).

When interpreting these (and other) density and biomass estimates, it is essential to recognize the potential for temporal variability in introduced small mammal populations. For example, annual sampling at a single site on Guam demonstrated significant temporal variation in *R. rattus* density and biomass, which increased from 2.6/ha and 0.4 kg/ha in 2005 to 15.3/ha and 2.9 kg/ha in 2006. In 2007, 10 days of livetrapping (1570 trap nights) at this site yielded zero captures. Note that this sampling occurred at the same time each year (early May–early June) and therefore represents annual temporal variability. It is also possible that introduced small mammal density and biomass exhibit intra-annual temporal variability in the Mariana Islands. One slight complication is that this site is used for an ongoing, long-term brown treesnake population study (Rodda *et al.* 2007) and is surrounded by a snake- and ungulate-proof fence (i.e., brown treesnakes can not enter or exit and ungulates are excluded), suggesting that the site is not directly comparable with other forested areas on Guam. For example, the exclusion of introduced ungulates has resulted in rapid and dramatic shifts in vegetation structure and composition compared to the surrounding landscape (M. Christy, unpublished data). Nonetheless, the temporal variability in *R. rattus* density and biomass observed at this site suggests that introduced small mammal density and biomass may fluctuate greatly over relatively short time spans in the Mariana Islands. The potential for temporal variability should always be considered when interpreting density and biomass estimates, which are merely a snapshot of a dynamic population.

Implications for Mariana Island Ecology and Brown Treesnake Control and Management

Although little direct evidence currently exists for the Mariana Islands, it seems likely that the high-density introduced small mammal populations documented during this research have negative effects on native fauna and flora, and that introduced species (including small mammals) have modified Mariana Island ecosystems and ecosystem function (Fritts and Rodda 1998). In recent years, researchers have noted apparent declines of several avian species in the Mariana Islands, including the bridled white-eye (*Zosterops rotensis*; Amidon 2000, Fancy and Snetsinger 2001) and Mariana crow (*Corvus kubaryi*; Plentovich *et al.* 2005, U.S. Fish and Wildlife Service 2005) on Rota and the Micronesian megapode (*Megapodius laperouse*) and Mariana fruit dove (*Ptilinopus roseicapilla*) on Saipan (Craig 1999). Numerous hypotheses, including predation by introduced species (e.g., *Rattus*, black drongos, and feral cats), avian diseases or parasites, pesticides, and habitat degradation associated with land-use changes or typhoon damage, have been considered (Craig 1999, Amidon 2000, Fancy and Snetsinger 2001, Plentovich *et al.* 2005, U.S. Fish and Wildlife Service 2005, Ha *et al.* in prep). While predation by black drongos, diseases, and pesticides have largely been ruled out and habitat degradation is increasingly seen as an important factor in avian declines (e.g., Fancy and Snetsinger 2001, Ha *et al.* in prep), the role of introduced small mammals remains unclear. Predation by introduced *Rattus* species is often rejected as a cause of recent avian declines because ≥1 *Rattus* species have been present in the Mariana Islands for at least 1000 years. However, this rejection does not account for differential effects of various *Rattus* species on birds (Atkinson 1985, Thibault *et al.* 2002, Towns *et al.* 2006), as *R. exulans* (the earliest introduction to the Mariana Islands; Steadman 1999) is generally considered least detrimental to avian species. Perhaps more importantly, the potential impact of *R. rattus* or *R. tanezumi* on avian species is unknown, and the uncertainty surrounding the status and distribution of *R. diardii*, *R. rattus*, and *R. tanezumi* in the Mariana Islands further complicates matters. Further, temporal shifts in the presence or abundance of *Rattus* species may obscure their role in avian declines. High-density introduced small mammal populations on Rota, Saipan, and Tinian might also impact avian species through dietary competition, especially during the dry season when certain food items may become scarce. Food competition for invertebrate and reptile foods could be especially problematic for nesting birds, as these high protein prey items are required for nestlings.

Predation by introduced small mammals may also have direct negative effects on invertebrate or reptile populations in the Mariana Islands. Although *Rattus* species are often implicated in invertebrate and reptilian declines (Whitaker 1973; Bremner *et al.* 1984; Cree *et al.* 1995; Priddel *et al.* 2003; Hoare *et al.* 2007a,b), the insectivorous *S. murinus* may be more problematic for these taxa in the Mariana Islands. *S. murinus* has been implicated in the decline of native invertebrates and reptiles on Mauritius and nearby islands (Varnham *et al.* 2002). On Guam, Barbehenn (1974) commented that no skinks were observed during hundreds of hours of small mammal trapping during the peak of the *S. murinus* irruption in the early 1960's, which contrasts with the current abundance and visibility of skinks on Guam. More recently, Fritts and Rodda (1998) noted large differences in mean skink density between Saipan, where *S. murinus* was common (2200 skinks/ha), areas on Guam with few *S. murinus* (8850 skinks/ha), and areas on Guam where both *S. murinus* and brown treesnakes were excluded (13,200 skinks/ha). Similarly, Rodda and Fritts (1992) implicated *S. murinus* in the decline of the pelagic gecko (*Nactus pelagicus*), when they found that this gecko was common on Rota, where *S. murinus* was absent, but highly localized (Guam) or rare or possibly extinct (Saipan and Tinian) on islands with high past or current *S. murinus* populations.

Recent research suggests that introduced small mammals have important impacts on the effectiveness of brown treesnake control efforts, which are highly dependent on traps using live, domestic mice (*M. musculus*) as attractants. These traps are placed around ports, airports, and other cargo-handling facilities on Guam, as well as in locations vulnerable to accidental brown treesnake introductions, such as Rota, Saipan, and Tinian. Mouse-attractant traps are also commonly deployed during the response to snake sightings in brown treesnake-free locations. However, research conducted on Guam suggests that brown treesnake trap capture rates are inversely related to introduced small mammal density. For example, Rodda *et al.* (2001) found a strong correlation ($r^2 = 0.90$) between brown treesnake trap capture rates and indices of small mammal density and documented a 7-fold increase in brown treesnake capture rates in areas of very low small mammal density on Guam. Similarly, Gragg *et al.* (2007) documented a 22–65% increase in brown treesnake trap capture probability after reducing rodent populations with localized rodenticide application. These findings suggest reduced effectiveness of mouse-attractant traps on Tinian, Rota, and Saipan. Further, the majority of brown treesnake control and eradication tools currently being developed and evaluated, such as various acetaminophen delivery devices (Savarie *et al.* 2001), also rely on mouse-based attractants and will likely be subject to the same reduction in effectiveness in areas of high introduced small mammal density.

A second, though perhaps less obvious, effect of introduced small mammals on brown treesnake control and management relates to their impact on island trophic systems and predator-prey relationships. On Guam, introduced prey species, including small mammals, skinks, and geckos, were abundant and widespread at the time of brown treesnake introduction following World War II (Baker 1946, Fritts and Rodda 1998). Because these introduced prey species evolved with various predators, they were better able to persist under brown treesnake predation than the predator-naïve native species of Guam. In so doing, introduced prey species supported a high-density brown treesnake population, even as native avian and reptilian species declined. By the time brown treesnake predation pressure began to reduce introduced prey densities and brown treesnake density also began to decline because of food limitations, many native species were already extinct. Unfortunately, the high introduced small mammal density and biomass documented on the island of Tinian during this research suggests that a similar scenario could develop on this island should a brown treesnake population become established.

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2.5.2 RODENTS ON AGUIGUAN

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INTRODUCTION

Aguiguan (spelled Aguijan on USGS maps) is a small (720 ha) currently-uninhabited island south of Tinian, Mariana Islands. *Rattus exulans* arrived on inhabited Aguiguan around 1000 AD, as evidenced by numerous subfossil deposits of rat bones in cultural strata (Steadman 2006). The island had a small and perhaps intermittent human population until all residents were removed by Spanish authorities in 1695, after which the island remained uninhabited until 1936 (Butler 1992). For four years prior and during World War II, the Japanese developed all tillable parts of the island for sugarcane production, but farming ceased and all inhabitants were repatriated to Japan at the conclusion of the war (Bowers 2001). Presumably, the resident rats would have benefitted from the abandoned sugarcane and cessation of rat control efforts. However, in the decade following the war four scientific expeditions specifically noted the scarcity of rats on the island. The first three expeditions (Enders 1949; Owen 1952 cited in Davis 1954; Peterson 1954 cited in Davis 1954) found no evidence of rats, although it is unclear how much effort they put into the search. Over a three-week period Davis (1954) conducted both visual and trap searches, using a variety of baits, yet captured zero rats and observed only two despite high visibility in the goat-overbrowsed understory. Scientists did not visit the island again until 1983 when the rats were seen frequently (Kosaka et al. 1983). A panoply of recent studies provided trap capture rates for the relatively numerous rats, but these neither quantified the absolute abundance of the rats nor obtained genetic samples with which the species of rat could be verified (Campbell 1995, Cruz et al. 2000, Esselstyn et al. 2003).

Wiewel et al. (2009, in press) recently developed robust mark-recapture methods for quantifying absolute population densities of rats in the Mariana Islands. The analytical protocol used by Wiewel et al. (in press) accommodates neophobia (the tendency of rats to avoid novel objects such as traps) sex, reproductive status, size, body condition, trap shyness, a variety of weather covariates such as rain and wind, and unique local factors such as island identity. We sought to replicate Wiewel et al.'s methodology (with minor modifications) on Aguiguan, and thereby quantify the absolute density of a population that had become legendary over the past three decades for high rat abundance. Furthermore, genetic material obtained during the Wiewel et al. study of large Mariana Islands (Guam, Rota, Tinian, and Saipan) showed that the local large rat species was neither of the two species suspected (*R. rattus* or *R. tanezumi*), but an unexpected clade of rats originating in insular southern Asia (*R.* cf. *diardii*; sensu Robins et al. 2007). However, the rat on Aguiguan is considerably smaller than those on the adjacent islands of Guam, Rota, Tinian, and Saipan, and is believed to be *R. exulans*. Because recent morphological and genetic examination of the nominal *R. exulans* population elsewhere in the Pacific (Wake Island) revealed the presence of both *R. exulans* and a stunted form of *R. tanezumi* (P. Dunlevy, WS, pers. comm.), we collected morphological and genetic material from all rats captured during mark-recapture sampling on Aguiguan to confirm species identity. The technical details of the genetic work will be reported elsewhere. In this report we will provide the genetic findings and the absolute population density estimate obtained by mark-recapture.

MATERIALS AND METHODS

Between 22 July and 1 August 2008, we conducted rodent mark-recapture sampling on Aguiguan for 11 consecutive nights on an 11 × 11 grid with 12.5 m intervals between each trap station (nominal grid area = 1.56 ha). Sampling occurred in native forest with an understory of *Guamia mariannae*; other vegetation present included *Pisonia grandis, Ficus prolixa, and Leucaena leucocephala* with a trapping substrate of soil and limestone. The trap grid was located near the western end of the island on the top plateau (grid centriod: N latitude 14.854 and E longitude 145.552).

We placed a single standard-length folding Sherman live trap (229 × 89 × 76 mm; H.B. Sherman Traps, Inc., Tallahassee, FL) at each trap station (*n* = 121). In addition, a single Haguruma wire mesh live trap (approximately 285 × 210 × 140 mm; Standard Trading Co., Honolulu, HI) was placed at every other trap station (*n* = 36); thus the Hagarumas were spaced 25 m apart in a regular grid overlaying the Sherman grid. Closed and unbaited traps were placed on the grid 21 July 2009, one night prior to the beginning of sampling to provide an opportunity for rodents to acclimate to their presence.

We placed traps on the ground and, whenever possible, positioned them to provide shelter from sun and rain. To enhance trap success, we primarily baited traps with 1) a mixture of peanut butter, oats, and food-grade paraffin, or 2) coconut meat. Approximately equal amounts of these bait items were offered on the grid each night.

We checked traps beginning at 0730–0800 each day and closed them during the day to minimize trap mortality. We reopened traps at approximately 1600 and re-baited as necessary to ensure bait freshness. We used the method described by Nelson and Clark (1973) to account for sprung traps when calculating sampling effort.

We examined and measured captured animals to determine species, sex, age, reproductive status, mass (g), head-body length (mm), tail length (mm), right hind foot length (mm), right ear length (mm), and testes length (mm; if applicable). Captured individuals were uniquely marked in each ear with numbered metal ear tags (#1005-1, National Band and Tag Co., Newport, KY). Recaptured animals were examined to determine tag number. All capture, handling, and marking techniques followed guidelines approved by the American Society of Mammalogists (Gannon et al. 2007) and the U.S. Geological Survey Animal Care and Use Committee (USGS Fort Collins Science Center). We collected DNA samples by pulling several guard hairs (and their associated follicles) from all captured rats. Genetic materials were stored in a dry envelope. Five randomly-selected follicles were analyzed following the cytochrome oxidase I procedure outlined in Robins et al. (2007).

Abundance estimates were generated in Program MARK 4.3 (White and Burnham 1999) using the conditional likelihood closed capture-recapture model developed by Huggins (1989, 1991). Our analysis followed an information-theoretic approach involving model selection and multi-model inference. Model selection was based on Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002). Models were considered competitive with the top-ranked model when $\Delta AIC_c \leq 2.0$ (Burnham and Anderson 2002). To provide a robust abundance estimate, we model-averaged abundance estimates based on Akaike weights (w_i; Burnham and Anderson 2002) and included the entire model set except for models with nonsensical standard errors for β estimates (e.g., $\beta = -11.6$, $SE(\beta) = 42.6$), which were removed prior to model averaging abundance estimates.

We initiated our modeling efforts by evaluating six specific time structures to address suspected trap neophobia. Our neophobia models allowed capture probability to vary during the first three (Step3), five (Step5), and seven (Step7) sampling occasions, while holding capture probability constant for remaining sampling occasions. We also allowed neophobia to linearly diminish (i.e., capture probability increase linear) over the first three (Ramp3), five (Ramp5), and seven (Ramp7) sampling occasions, while holding capture probability constant for remaining sampling occasions. Our motivation for these models came from literature accounts of neophobia for introduced *Rattus* spp. (Temme and Jackson 1979, Inglis et al. 1996, and Clapperton 2006), neophobia lasting four days (two days trap exposure plus two days trapping) for *R.* cf. *diardii* in the southern Mariana Islands (Wiewel et al. 2009), and from trap results of *R. exulans* on Rota (rats were not trapped until five days of trap experience; Wiewel et al. 2008). We used the neophobia structure with the greatest support, along with individual and environmental covariates, and behavior (b) to define the global model. Using the global model, we then proceeded through a series of more parsimonious models. Covariates under consideration included sex, age (adult or juvenile), body condition index, head-body length (length), body size, and rain amount (during the past 24 hour period [rain24] and the cumulative rainfall effects over the past 48 hour period [rain48]). Rain amount was a quantitative measure of total rainfall (mm) measured at the trap grid center. We calculated body condition index as the ratio between the observed and expected mass of an individual, where expected mass was determined from a linear regression of ln mass vs. ln length. Body size was a species-specific composite variable created from a principal components analysis (Proc FACTOR, SAS Institute, 2003) of mass, length, tail length, hind foot length, and ear length measured for each captured individual. We evaluated this variable only in the global model in place of length. We used the variable (size or length) with the greatest support to build subsequent models. We assessed covariate importance by evaluating their slope estimates and 95% confidence intervals, where covariates with 95% confidence intervals not overlapping zero were considered influential on capture probability. Burnham and Anderson (2002:167) recommend the use of summed Akaike weights to evaluate the relative importance of covariates when a balanced model set is used (e.g., in our analysis each variable appeared in 11 models). We computed a relative importance measure for each variable by summing Akaike weights over every model in which that variable appeared. All estimates are presented as mean ± 1 SE.

We calculated *R. exulans* density by dividing the model-averaged abundance estimates by effective trapping area (ETA), where ETA equaled the total area encompassed by the trapping grid (1.56 ha) plus a boundary strip of ½ the mean maximum distance moved (MMDM) between captures for individuals captured two or more times (Wilson and Anderson 1985).

RESULTS

Rats were specifically uniform in morphology from Aguiguan and genetic analysis (n = 5) of the mtDNA cytochrome oxidase I gene region indicated that all hair follicle samples were that of *R. exulans* (S. J. Oyler-McCance and J. St. John, unpublished data).

We captured 48 *R. exulans* (33 females and 15 males) in 1,668 adjusted trap nights (1,727 total trap nights). Of these, 46 individuals were included in a mark-recapture analysis (2 escaped before they could be marked). We had 14 recaptures of 12 individuals. Of the 46 individuals used in the analysis, 42 were adults and 4 were juveniles. Average mass was 63.3 ± 2.54 g (95% CI = 58.4–68.3, n = 46).

R. exulans capture and recapture probability were best explained by models allowing neophobia to diminish linearly (i.e., capture probability increased linearly) until occasion 7 with additive effects of cumulative rainfall over the past 48 hours (rain48) and sex (Table 1). Capture probability increased slightly with increasing rainfall over a two day period ($\beta = 0.04 \pm 0.02$, 95% CI = -0.01, 0.08; Figure 1). The covariates ordered by estimated importance are sex, length, condition index, and age, as portrayed by the summed weights of 0.70, 0.34, 0.29, and 0.28, respectively (an importance value ≥ 0.5 indicates that the variable is important to the process being investigated [Barbieri and Berger 2004]). Females were much more likely to be captured than males after initial trap occasions ($\beta = -1.74 \pm 1.03$, 95% CI = -3.77, 0.30; Figure 2).

Mean maximum distance moved was 35.2 ± 5.8 m (95% CI = 23.8–46.7; n = 12). When combined with the nominal grid area of 1.56 ha, these MMDM estimates resulted in an effective trap area of 2.57 ha. The model-averaged *R. exulans* abundance estimate generated from our models equaled 141 ± 106 rats (95% CI 46-350). Average *R. exulans* density was calculated to be 55 individuals/ha.

DISCUSSION

Unlike the rat population on Wake Island, morphological examination indicated that only one species was present, and the DNA testing confirmed that all were *R. exulans*. This agrees with the subfossil material (Steadman 2006), and thus it is unlikely that temporal fluctuations in Aguiguan rat abundance were due to changing rat species composition, though a double replacement (*R. exulans* > unknown *Rattus* spp. > *R. exulans*) cannot be excluded with the data available.

The best estimate of rat density for Aguiguan was 55/ha, a value that is high without being exceptional. There are no firm *R. exulans* population density estimates for other localities in the Mariana Islands, and for western Micronesia we have located only the relative abundances of Strecker (1962) on Pohnpei Island. Using removal trapping Strecker (1962) obtained trapping success rates of 13-79% (mostly around 45%), which far exceeds the 3% mean capture rates we observed. Atkinson and Moller (1990) give absolute *R. exulans* population densities for various Pacific islands (none within Micronesia) of 6-170/ha in grassland and10-80/ha in forest. Thus our point estimate (55/ha) would appear to be near the middle of the potential range.

The observed density is also moderate in comparison to values Wiewel et al. (2009) obtained for *R.* cf. *diardii* collected in the Marianas. The mean body mass for *R.* cf. *diardii* on nearby Tinian (130 g) was roughly twice that of the *R. exulans* we sampled on Aguiguan (63 g). Despite this, the range of best density estimates for the larger rat on Tinian ranged 44/ha (introduced forest) to 99.9/ha (grassland), with native forest being near the middle (75.1/ha). Thus the observed absolute population density of *R. exulans* on Aguiguan (55/ha) is best characterized as moderate, at least with reference to nearby islands in the Marianas chain.

This finding does not comport well with the subjective impression most biologists have regarding the apparent superabundance of rats on Aguiguan. For example, Rodda et al. (2009) reported an extraordinary rat sighting rate of 16.8 rats per hour when conducting visual surveys for lizards on Aguiguan. Rodda et al. (2009) suggest that high visibility associated with heavy goat grazing of understory vegetation was responsible for elevated visual detection rates of the relatively moderate number of rats present.

It is also possible that the rats on Aguiguan are less wary as a consequence of reduced human persecution (the island has not been permanently inhabited for >60 years). Lack of wariness might lead to a relatively high sighting rate. If the rats on Aguiguan were generally less wary as a consequence of generations without human persecution, however, one might expect them to exhibit little fear of novel human objects such as traps. Instead, we observed eight days (one day of trap exposure plus seven days of trapping) of neophobia, a duration without precedent in our studies of rats in the Mariana Islands (Wiewel et al. 2009, in press). The causes of high rat visibility on Aguiguan in the face of only moderate rat density remain to be elucidated.

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use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Table 1. Model selection results for mark-recapture modeling of capture (*p*) and recapture (*c*) probability for *R. exulans* data collected on Aguiguan, 2008. Results include the relative Akaike's Information Criterion corrected for small sample size (ΔAIC_c), and Akaike weight (w_i), and number of model parameters (*K*). See text for abbreviations used in model names.

Model	ΔAIC_c	w_i	*K*
Ramp7 + rain48 + sex	0.00	0.206	4
Ramp7 + rain48 + sex + length	1.13	0.117	5
Ramp7 + rain48 + sex + age	1.79	0.084	5
Ramp7 + rain48 + sex + body condition	1.85	0.082	5
Ramp7 + rain48	2.56	0.057	3
Ramp7 + rain48 + sex + length + body condition	2.78	0.051	6
Ramp7	2.98	0.046	2
Ramp7 + rain48 + sex + age + length	3.06	0.045	6
Ramp7 + b	3.28	0.040	3
Ramp7 + rain48 + sex + age + body condition	3.73	0.032	6
Ramp7 + rain48 + sex + age + length + body condition	4.09	0.027	7
Ramp7 + b + rain48	4.21	0.025	4
Ramp7 + rain48 + body condition	4.26	0.025	4
Ramp7 + b + rain48 + sex + age + length + body condition	4.32	0.024	8
Ramp7 + rain24	4.37	0.023	3
Ramp7 + sex + age + length + body condition	4.49	0.022	6
Ramp7 + rain48 + age	4.57	0.021	4
Ramp7 + rain48 + length	4.58	0.021	4
Ramp7 + rain24 + sex + age + length + body condition	5.91	0.011	7
Ramp7 + rain48 + length + body condition	6.30	0.009	5
Ramp7 + rain48 + age + body condition	6.30	0.009	5
Ramp7 + rain48 + age + length	6.53	0.008	5
Step5	7.39	0.005	2
Ramp7 + rain48 + age + length + body condition	8.35	0.003	6
Ramp5	8.39	0.003	2
Step5 + b	9.29	0.002	3
Ramp5 + b	9.83	0.002	3
Step7	10.98	0.001	2
Step3	19.48	0.000	2
Ramp3	19.76	0.000	2

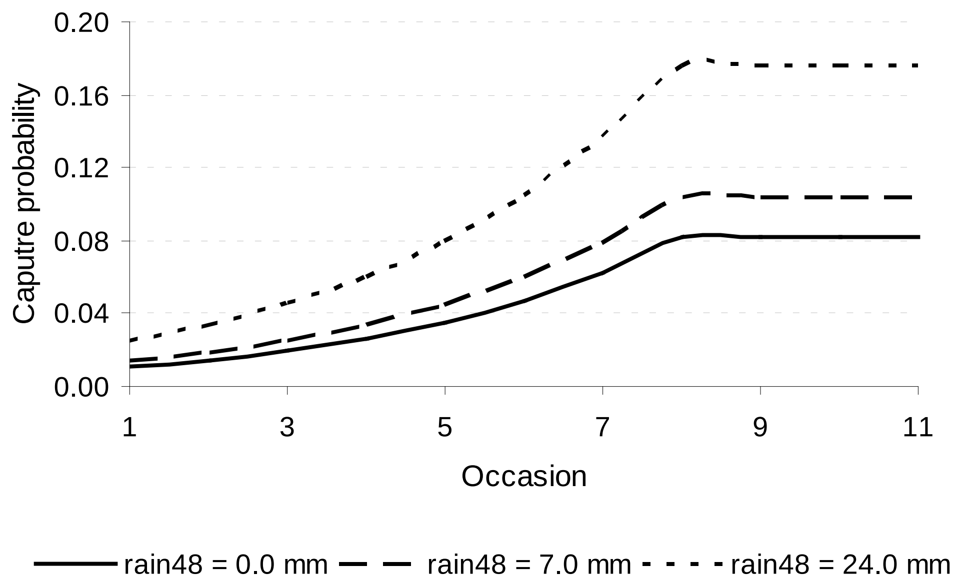

Figure 1. Cumulative rainfall effects over the past 48 hours (rain48) for female *Rattus exulans* on capture probability under three scenarios of no rainfall, the average cumulative rainfall value of 7.0 mm specified for each occasion, and the maximum cumulative rainfall of 24.0 mm specified for each occasion. A similar additive effect was seen in males but is not illustrated in this figure.

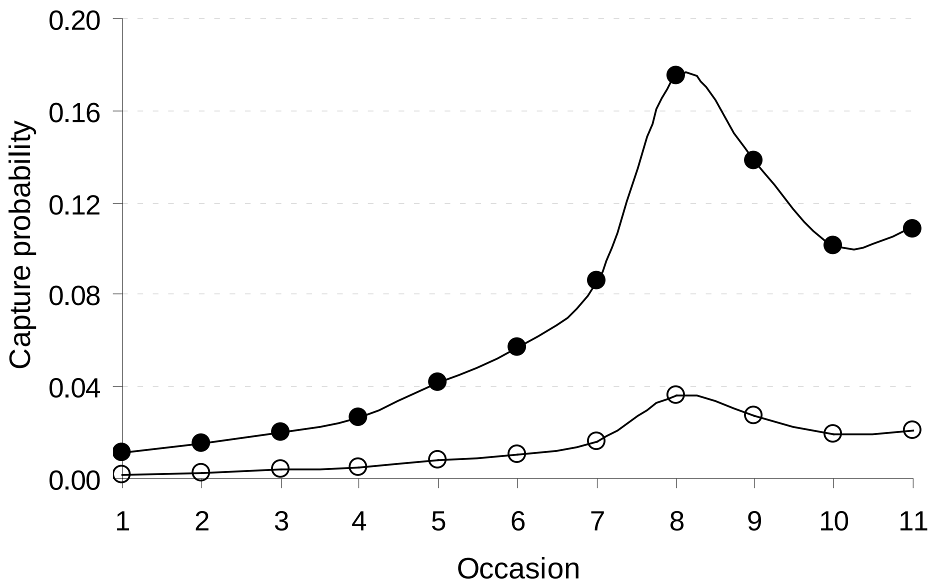

Figure 2. Effect of neophobia (reduced capture probability during occasions 1 through 7) and sex (female = •, male = ○) on *Rattus exulans* capture probability. Model also includes cumulative rainfall effects over the last 48 hours, which has a slightly positive effect on capture probability.

2.5.3 MARIANA FRUIT BAT ON TINIAN AND AGUIGUAN

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INTRODUCTION

Surveys for the Mariana fruit bat or fanihi (*Pteropus mariannus mariannus*) were conducted on the islands of Aguiguan and Tinian in 2008. Once common throughout the Mariana archipelago, fruit bats in the southern islands continue to be hunted and impacted by foraging habitat loss and numbers remain low (reviewed in U.S. Fish and Wildlife Service 2005). Bats have been occasionally sighted on Tinian and a small number of bats are resident on Aguiguan. This report provides an estimate of current numbers on Aguiguan and Tinian and reviews the findings of earlier surveys.

METHODS

Estimations of island-wide bat numbers were made using direct colony counts and station counts. Bats sleep during the day in canopy emergent trees solitarily or in colonial aggregations that may be spread over several acres. Colonial roosts are typically in locations that are difficult for people to reach, such as on cliffs or in remote forest areas. Direct colony counts were made during the day at a single colonial roost and at dusk when bats were leaving to forage. Station counts for solitary bats were conducted at dawn or dusk as bats depart or return from foraging (Utzurrum *et al.* 2003). Locations for station counts were selected for wide and unimpeded views of forests that would likely serve as roost sites for bats.

Tinian surveys were conducted February-August 2008 at sites used in earlier surveys and in new locations (Wheeler 1980, Wiles *et al*. 1989, Krueger andO'Daniel 1999, Cruz *et al*. 2000). Surveys were conducted on Aguiguan July 19-23, 2008. The minimum number of animals observed at each site was recorded. Low light, lack of distinctive markings, and the observers distance from the animals make individual recognition difficult. For each bat seen, the direction it flew and the location where it was lost from sight was noted. If a bat was subsequently seen that could have been the same individual returning to the site or leaving a tree where it had roosted, it was noted but not included in the tally.

RESULTS

Tinian

No bat colonies were observed on Tinian so no direct colony counts were conducted. Eight separate station counts were conducted at seven locations. No bats were observed during station counts or opportunistically.

Aguiguan

Thirteen station counts were conducted at eight different sites and a single colonial roost was counted, yielding an island-wide estimate of 40-60 bats.

A sprawling colonial roost was located at the base of a cliff on the northeastern side of the island. The site was visited mid-day, but we were unable to find a vantage point to see the roost without disturbing the bats. A dispersal count was conducted with three observers positioned along the cliff edge above the roost area. We counted 25 to 28 bats dispersing through the forest beneath us. *Pisonia grandis, Ficus* sp., *Premna serratifolia, Casurina equisetifolia* and other unidentified species were used as roosts by individual bats.

Twelve to 15 individual bats were also seen at 6 stations with another 4 bats seen en route to the count locations. The northeastern end of the island was monitored from a cliff-edge overlook. This site was surveyed at dawn on three mornings. Two to 6 bats were observed using and/or roosting in the area. Repeated observations of a bat scent marking the same branch at 0545 on successive mornings were likely of the same individual.

We observed solitary bats during the day on several occasions: 4 bats were sighted in the late afternoon flying above *Casurina equisetifolia* trees on the central plateau, and solitary bats flew from diurnal roost sites on 2 occasions when we walked underneath the tree. Solitary bats encountered in the forest and seen during the day indicate that bats were dispersed throughout the forest.

The combined total from the station and roost count was 39 to 47 individual bats. Taking into consideration bats observed in counts as well as those encountered in the forest, a minimum estimate for the island is 40 bats. Given the areas not covered during the surveys, it is reasonable to assume that an additional 20 bats may be present, giving an island-wide estimate of 40 to 60 bats.

DISCUSSION

In the last 29 years, few bats have been observed during surveys on Tinian although island residents report occasionally seeing bats (T. Castro, E. Masaga and F. Muna, pers. comm.). During surveys in 1979 two bats were observed in the Kastiyu forest and an island-wide estimate of 25 to 100 was calculated based on available forest habitat (Wheeler 1980). In 1983-1984 bats were sighted three times on Tinian and the number estimated island-wide was less than 25 individuals (Wiles *et al.* 1989). Surveys in 1994-1995 recorded no bats, but two incidental sightings were reported from other locations on Tinian (Krueger and O'Daniel 1999). No bats were sighted during two surveys in 2000 and 2001 (Cruz *et al.* 2000, Johnson 2001). In June 2005, approximately five bats were seen in the cliff-line forest during a routine forest bird survey of the Maga bird transect (S. Vogt, pers. comm.).

Bats occasionally have been seen in flight between Saipan, Tinian and Aguiguan. A group of approximately 50 bats was seen flying over the ocean toward Tinian from the southern part of Saipan in 2001 (L. Bulgrin, pers. comm.). On two occasions in 2008 single bats were watched as they flew from Aguiguan over the channel towards Tinian (C. Kessler, pers. comm.). One bat was seen during the day (0930), the other was seen at 2200 using nightvision goggles, and both were lost from sight when far over the channel. Travel between the islands may be natural dispersal movements or the result of disturbances caused by hunting (Wiles and Glass 1990).

Surveys on Aguiguan have shown a small but widely fluctuating number of bats in the past 54 years. The amount of time spent on the island, knowledge of likely colonial roost sites, survey locations, methods and analysis have differed among these surveys. In spite of the varied methods, it is clear that the number of bats on Aguiguan has remained low.

Early surveys in 1954 reported bats flushing on several occasions from the forest on the northeast lower terrace (Davis 1954). Surveys in 1983 and 1984 reported only one or two bats seen each trip, and less than 10 bats were thought to be present (Pratt and Lemke 1984). A 1987 survey located a colony of approximately 24 bats and estimated roughly 40 bats on island (Reichel *et al.* 1987). A minimum of 200 bats were estimated in 1988 based on a colony of approximately 60 and sighting of at least 136 bats foraging one evening (Reichel *et al.* 1988). The increase was attributed to immigration from another island. A maximum of 30 bats was estimated in 1989 and in 1992 (Rice and Reichel 1989, Craig and Chandran 1992). In 1995, a colonial roost of approximately 100 bats was located and added to solitary bats in flight for an island-wide estimate of 200 (Worthington and Taisacan 1995). In 2000, an island-wide estimate of 150 to 200 was based on approximately 63 bats observed, 23 solitary and two colonial roosts each with roughly 20 individuals (Cruz *et al.* 2000). The 2002 survey estimated 40-60 bats based on observations of 29 solitary individuals and no colonial roosts (Esselstyn *et al.* 2003).

During 1975 -1981, the Commonwealth of the Northern Mariana Islands (CNMI) legally exported 16,495 bats to the Guam to supply market demand (Wiles 1992). During these six years, 1,366 bats were exported from Tinian (50-433 annually). It is likely that many of these bats originated on Aguiguan (Wiles *et al.* 1989). The legal exporting of bats was curtailed in 1989 when fruit bats were included in the Convention of International Trade in Endangered Species (CITES). Fruit bats were listed as a threatened/endangered species by the CNMI government in 2000 (Berger *et al.* 2005), and were Federally listed as threatened in the CNMI in 2005 (USFWS 2005).

Ample time has passed since the CNMI government listed bats as a protected species (8 years ago and 19 years since exportation was banned) for bats to have recovered such that they could be legally hunted. This has not happened; poaching has continued unchecked. When hunting pressure has been reduced on other islands, fruit bat numbers have rapidly increased. Bats were extensively hunted in Palau during the 1980s when an estimated 2,000-5,000 *P. mariannus pelewensis* were killed annually (Wiles *et al.* 1997). Within ten years of cessation of commercial hunting for export to Guam, bats became common (Wiles *et al.* 1997). Fruit bats on Tutuila (American Samoa) declined from ca 12,000 to

1,500-2,500 from overhunting after cyclones in the early 1990s (Craig *et al*. 1994). Hunting was restricted, and within ten years, bats had increased to 7,000-8,000 (Utzurrum *et al.* 2006). As Saipan is the most comparable of the southern CNMI islands to Tutuila in size and habitat. It seems reasonable that Saipan could support several thousand bats, Tinian and Aguiguan could support hundreds.

Consumer demand for fruit bats remains the driving force for illegal hunting, preventing the recovery of bats in the southern islands of the CNMI. Bats were reported to sell for $50 on Tinian in 2008 and $140 on Saipan in 2006. The value of bats on Guam is beyond a monetary value with payment made by in-kind favors. Without immediate support from leading government officials and law enforcement, fruit bats will be extirpated from the southern Mariana Islands.

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2.5.4 SHEATH-TAILED BAT ON AGUIGUAN

Compiled by: Thomas J. O’Shea and Ernest W. Valdez. U.S. Geological Survey, Fort Collins Science Center, Colorado

Note: This is the Executive summary section of Assessment for Pacific Sheath-tailed Bats (*Emballonura semicaudata rotensis*) on Aguiguan, Commonwealth of the Northern Mariana Islands. For the entire document please refer to Appendix 3.3

Executive Summary

The subspecies of the Pacific sheath-tailed bat that once occurred throughout the Mariana Islands (*Emballonura semicaudata rotensis*) has not been well studied biologically, despite its declining status. It is a small insectivorous bat, and in the Mariana Islands it is known only to roost in caves. All available data indicate that it now occurs only as a single remnant population on Aguiguan. Overall the species is categorized as Endangered by the International Union for the Conservation of Nature and Natural Resources. The subspecies is protected by the Commonwealth of the Northern Mariana Islands (CNMI) law, and is considered a Category 3 candidate for listing under the U.S. Endangered Species Act. This categorization under U.S. law is based on the imminence and magnitude of threats, but further actions have not had the highest priority possible in part because the remaining population on Aguiguan has been considered to be a subspecies of a more widely found species. However, a thorough, modern quantitative morphometric and molecular genetic analysis is needed to verify if the subspecific level in the taxonomic hierarchy is accurate or if full species designation may be warranted for the population in the Marianas Islands.

In this report we document results from a biological assessment for Pacific sheath-tailed bats carried out in 2008 on Aguiguan and Tinian, CNMI. The field work was done by a team consisting of a former Guam Division of Aquatic and Wildlife Resources biologist with past experience surveying for this species and four bat biologists from the U.S. Geological Survey (USGS) Fort Collins Science Center and the USGS Pacific Island Ecosystems Research Center. The assessment consisted of determining present abundance and use of caves on Aguiguan by these bats and interpreting these data in comparison with a synthesis of the literature and past unpublished data; establishing baseline site occupancy models of spatial foraging habitat use through monitoring of ultrasonic echolocation calls; determining basic aspects of diet through analysis of fecal material; sampling bats through capture to obtain new data on reproduction and body size, as well as to collect samples for future genetic analysis; and determining characteristics of temperature and humidity in caves. We conducted a review of specimens available in research museums, and obtained samples from guano deposits that may be useful in analysis for contaminants in comparison with analysis of guano from other islands where these bats have become extinct. We also conducted a limited survey for the presence of these bats on Tinian.

Our report summarizes previously unpublished results on numbers of Pacific sheath-tailed bats roosting in caves on Aguiguan in 1995 and 2003, and compares past results with findings from new surveys conducted in 2008. Overall, we examined the abundance, roosting behavior, and distribution of Pacific sheath-tailed bats on Aguiguan by searching caves and hollow trees for roosting bats during the day. Counts of bats at caves show that a small population of Pacific sheath-tailed bats continues to exist on Aguiguan, with a

range of 359 - 466 individuals counted at five of 41 caves in 2008. Comparison with past counts suggests that this population has increased over the last 13 years. Bats appeared to prefer roosting in larger caves and displayed fidelity toward five of the seven roosts found occupied in the study. Occupied caves were larger than most unoccupied caves but had similar conditions of temperature and humidity. In 2008 one cave consistently housed the largest colony, with a range of 308–382 bats counted, whereas counts at other occupied caves on Aguiguan yielded 1–64 individuals. Slight variability occurred in replicate counts on different dates during the 2008 survey. We found no evidence of hollow tree trunks being used as roosts. It is possible that a small number of colonies of these bats may remain undiscovered at inaccessible caves on Aguiguan.

Evaluation of trends in colony sizes of cave bats throughout the world generally relies on count data that are uncalibrated index values, which can be difficult to interpret. Therefore this assessment also sought to utilize a recently developed quantitative approach to establish a baseline site occupancy model of spatial occurrence of foraging Pacific sheath-tailed bats on Aguiguan. This method uses detection of bat ultrasonic calls to assess presence absence of foraging bats at night in relation to various habitat attributes. Thirty one echolocation stations were deployed across Aguiguan between 25 June and 14 July 2008. Twenty one of the 31 stations recorded ultrasonic pulses from sheath tailed bats over a period of 19 days, with 35,858 calls recorded. Ten percent of the calls were characterized as peak activity, 40% as moderate activity, and 50% as brief passes. Analyses show that peak activity and occurrence is related to canopy cover, vegetation stature, and distance to known roosts. Native limestone forest is preferred foraging habitat. Echolocation calls of Pacific sheath-tailed bats were characterized for the first time, and search phase calls were similar to those of other emballonurid bats that use a narrow bandwidth and short pulse duration to forage in cluttered vegetation.

There has been no prior information on the food habits of the Pacific sheath-tailed bat anywhere in the species' range. Herein we reported on new findings from analysis of fecal material from this bat on Aguiguan. We collected and analyzed 200 fecal pellets of bats from two roosts (Guano Cave and Crevice Cave). The diet of the Pacific sheath-tailed bat was diverse, but mostly consisted of small-sized prey ranging from 1.7 to 6.4 mm in length. Overall hymenopterans (ants, wasps, and bees), lepidopterans (moths), and coleopterans (beetles) were the three major food items in the diet of bats from both roosts. However, the ranking of volumes of each insect order consumed varied between roosts. At Guano Cave, hymenopterans made up 64% of the diet, followed by coleopterans (10%), and lepidopterans (8%). At Crevice Cave, lepidopterans made up 45% of the diet, followed by hymenopterans (41%), and coleopterans (10%). Within Hymenoptera, most of the prey items belonged to ichneumondoidea (parasitoid wasps), followed by formicids (ants belonging to Formicinae and Ponerinae; i.e., trap jaw ants). Because alates (= winged adults) of ants and termites (isopterans) found in fecal samples generally have wings only when they are reproductive or establishing new colonies, it is likely that Pacific sheath-tailed bats take advantage of seasonal food sources. In other areas the occurrences of these winged forms are often present during the onset of rains; we sampled guano at the onset of the rainy season on Aguiguan (late June to early July). Lepidopterans, specifically microlepidopterans, likely were another seasonally abundant prey item. Silken fungus beetles and leaf beetles identified in the guano appear to be forest dependent species and were a consistent component of the bats' diet. Not only do these and other prey items indicate that these bats forage mainly in forest habitat during late June and early July, but that they also capture prey near (above and below) the canopy. From these diet analyses, we categorize the Pacific sheath-tailed bat as an aerial insectivore or hawker, similar to other emballonurids around the world.

We also collected various other samples and obtained information on the biology and natural history of Pacific sheath-tailed bats on Aguiguan. We used standard means to capture Pacific sheath-tailed bats in mist nets while they dispersed or foraged through the forest, but these attempts were largely unsuccessful because these bats were highly maneuverable and easily avoided mist nets on close approach. We successfully captured 12 adult bats and one attached suckling young by using hand nets on bats in flight in the forest, or mist nets set in or near caves used as roosts. Both methods have logistical problems and limitations: in addition to the high maneuverability of the bats precluding use of mist nets in standard configurations, considerable time is required to accrue multiple captures using hand nets. Caves where bats roost are co-occupied by endangered Mariana swiftlets. Thus capturing bats at caves has the potential to disturb both the bats and the swiftlets. We found that these bats can be very sensitive to initial handling, but stress can be reduced by placing bats individually in cloth bags promptly after capture and before examining them. We determined body mass, length of forearm, and reproductive condition of the 12 adult bats. In addition to qualitative features of skull morphology, length of forearm has been given as a characteristic distinguishing between some subspecies of *E. semicaudata*. However, these new forearm measurements show that there is considerable overlap in body size between *E. semicaudata rotensis* and the other three subspecies of Pacific sheath-tailed bats. We also collected small wing biopsies from12 bats prior to release for some basic preliminary genetic analyses to ascertain genetic diversity of the population on Aguiguan and the depth of division of this subspecies based on comparison with published data on genetics of *E. s. semicaudata* from Fiji. This work will be carried out by USGS geneticists in 2009. We also prepared two museum voucher specimens of *E. s. rotensis*, increasing the number of known specimens from the Mariana Islands available in United States museums from two to four. We reviewed the literature and queried a limited number of online databases to compile updated information on specimens of Pacific sheath-tailed bats that might be available for taxonomic study. Considerable numbers of specimens including other subspecies are available worldwide (over 380), and about 22 additional specimens from the Marianas Islands (including Guam) are housed in museums in France and Japan. Expanded study of museum specimens and comparative genetic analyses are needed to fully ascertain the systematic status of the Pacific sheath-tailed bat population on Aguiguan.

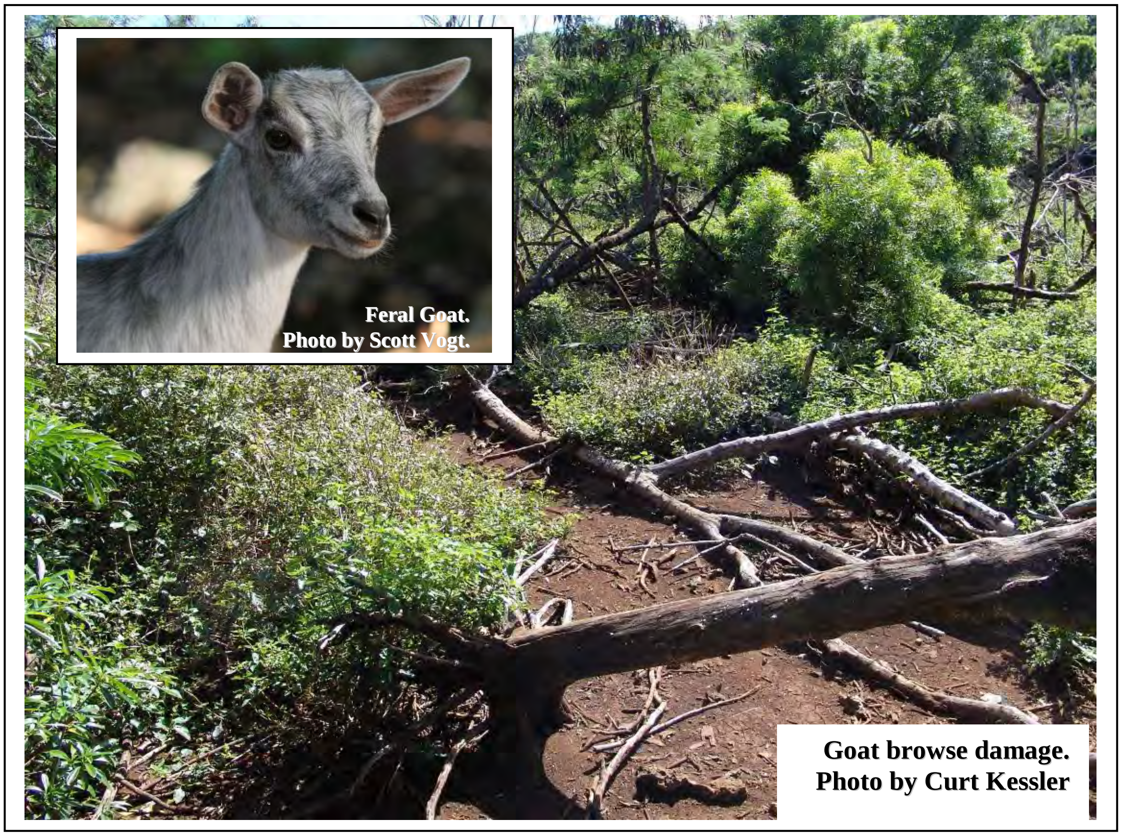
There is limited information on reproduction in Pacific sheath-tailed bats in the CNMI or elsewhere. Six female bats captured by Wiles and others on Aguiguan late in the rainy season of 2003 were apparently not reproductive. In contrast, seven of the eight female bats we captured in June and July 2008 were either pregnant or lactating. We also observed 11 pups at roosts in caves during June and July 2008; all were singletons. None of the bats we captured were volant young of the year. The presence of reproductive females and pups or embryos in June and July but no volant young suggests the hypothesis that Pacific sheath-tailed bats on Aguiguan may have a diffuse seasonality in reproduction, such that the period of late gestation, lactation, and maturation of young coincides with the late June to early November rainy season. We observed one large embryo in a female dissected in June 2008, as was also observed in a female dissected by Lemke in June 1984. These dissections and the observations of 11 apparent singleton pups suggest a litter size of one. If reproduction occurs only once per year and litter size is one, then the capacity for population growth in Pacific sheath-tailed bats will be very limited. All bats that we captured at caves in 2008 and by others in years past were females, whereas 4 bats captured at dusk dispersing along a steep rocky hillside, not near any known colony, were males. This suggests that perhaps males may form bachelor colonies apart from roosts occupied primarily by females, as is known for other Old World species in the genus Emballonura. Elaborate social behavior patterns were also suggested by the audible communication sounds produced by bats that we observed foraging and dispersing through the forest and flying into caves.

The scientific literature includes speculation that the extinction of Pacific sheath-tailed bats on other islands may have been attributable at least in part to past use of organochlorine insecticides. However, there is no chemical or toxicological evidence that bears directly on this speculation. Analyses based on other species of insectivorous bats have shown that concentrations of organochlorine insecticides in bat guano can provide diagnostic evidence of mortality and population declines. Aguiguan has been mostly uninhabited since the use of organochlorines became widespread elsewhere in the world. Thus guano samples from sheath-tailed bats on Aguiguan could provide comparative baselines with which to compare contamination of guano from islands where these bats have become extinct (e.g. Guam). Therefore we used contaminant free sampling approaches to obtain guano at 3 different depth levels (i.e., surface, 10 and 20 cm below surface) from two areas of a guano pile beneath roosting bats at Guano Cave. These samples are stored in the USGS laboratory at the Fort Collins Science Center and can be made available for future chemical analysis. However, because this guano was deposited over many years, the material also likely includes particles of guano from Mariana swiftlets. The degree of mixing of guano from these two sources should be estimated using microscopic techniques prior to chemical analysis.

Pacific sheath-tailed bats are only known from Tinian based on prehistoric deposits in caves. During the last 4 days and nights of our study we made an effort to document the presence of Pacific sheath-tailed bats on Tinian using echolocation detectors. We also queried knowledgeable individuals, and watched for bats and listened for audible calls during the echolocation surveys. We felt that our best chance for success in documenting bats on Tinian would be echolocation-based sampling in limestone forest areas because of their heavy use of this habitat for foraging on Aguiguan. We deployed two monitoring stations that sampled continuously all night long, both set out for one night in a forest in the Mount Lasso area and for a second night in the Kastiyu Forest. We also sampled for one night at each of these sites using ad hoc walking transects and echolocation detectors during the first part of the night, corresponding to peak times of bat echolocation activity on Aguiguan. No bats were detected. However, this survey was far from exhaustive and additional effort using echolocation detectors over wider areas of forest and searches of caves will be needed to rule out the possibility that a small remnant population of these bats may still exist on Tinian. Similar echolocation detector based surveys would also be useful on two other islands in the CNMI (Anatahan and Maug) where tentative sightings were reported in the early 1980s but never subsequently confirmed.

A number of considerations for future activities stem from the findings of this assessment. These are best characterized as activities related to management for conservation, monitoring, and research. Considerations for management for conservation include limiting disturbance of and access to caves used by roosting bats; and increasing the extent of native limestone forest, decreasing existing stands of invasive plants, and eliminating or avoiding actions that would reduce the amount of native limestone forest on Aguiguan. Considerations for future monitoring of sheath-tailed bats on Aguiguan include periodic monitoring of numbers of bats utilizing key caves, and monitoring the use of foraging habitat with echolocation detectors and site occupancy models. Considerations for research include searching the more inaccessible areas on Aguiguan for the presence of additional colonies that may occupy caves requiring technical climbing and caving skills to reach; increasing the foundation of ecological knowledge of this species pertinent to its conservation and management, including investigations into seasonal aspects of reproduction, roosting, and foraging biology; conducting a modern analysis of the taxonomic status of *Emballonura semicaudata* and its subspecies using combined quantitative morphometric and molecular genetic approaches; and further assessing the possible occurrence of Pacific sheath-tailed bats on Tinian and other islands.

2.5.5 FERAL GOATS ON TINIAN AND AGUIGUAN



Feral Goat.
Photo by Scott Vogt.

Goat browse damage.
Photo by Curt Kessler

Prepared by: **Curt Kessler, U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, HI.**

INTRODUCTION

Browsing by feral goats (*Capra hircus*) on Aguiguan is altering the spectacular old growth limestone forest leading to replacement with invasive plant species, primarily lantana (*Lantana camara*). This process has two major components that compound the problem over time thus accelerating the forest loss. First, the goats eat all seedlings from most native trees which halts the natural regeneration of limestone forest. This also allows non-palatable invasive plant species such as lantana to colonize and form a monoculture. Second, as canopy trees die and are not replaced, the open canopy allows more solar heating of the forest floor, drying out the soil and destroying the forest floor microclimate. This drying stresses the trees and reduces the trees' ability to survive the dry seasons. As more trees die over time the dry areas increase, which accelerates the cycle until a drought period when massive tree die-offs can occur (Kessler 2002a). Though currently uninhabited, the forest on Aguiguan has been significantly altered by human activities (Engbring *et al*. 1986) and recovery of the forest is unlikely to occur without the removal of the goats. Between 1989 and 1990, an effort was made to eradicate goats from Aguiguan. During that time, 158 goats were removed leaving an estimated 40 goats on the island (Rice 1991). Unfortunately the eradication program did not continue and the goat population has increased since that time. Until recently, there was no feral goat population established on Tinian.

METHODS AND RESULTS

Aguiguan is approximately 720 hectares (ha). Based on site visits during November 2006 and June-September 2008 (C. Kessler, USFWS, pers. comm.), previous surveys of Aguiguan (Lemeke 1984, Esselstyn *et al*. 2003), the current condition of the vegetation on the island, as well as findings from Sarigan and Anatahan (Kessler 2002b, Worthington *et al*. 2001), Aguiguan is estimated to have about 1,440 goats or 2 per hectare. Recent hunting might have reduced this number slightly, but the population is still likely over 1,000 goats.

DISCUSSION

The Mariana Islands possess a very fertile ecology. Introduced, feral, and invasive species usually thrive on these islands due to the mild climate, plentiful rain, and continual growing season. The island of Tinian was known in the early 1800's as an island overrun by feral livestock. However that changed in the early 1900's and until recently Tinian has had no feral ungulates. The neighboring island of Aguiguan however, is known as Goat Island and has had feral goats for the last 50 years and maybe much longer. In 1989, an attempt to remove the goats was undertaken by CNMI-DFW which reduced the goats to under 100 (Rice 1991) but the effort was halted due to political concerns. Since that time the goat population has recovered and is at or near the capacity of the island (Kessler pers. obs.).

Feral goats in the Marianas have an average density of 2 goats/ha. (DFW 1985, Esselstyn *et al*. 2003, Kessler 2001). On Aguiguan, Lemke estimated 1,000 goats in 1984 and Esselstyn estimated 1,143 individuals (range 943 to 2,117) in 2002; both surveys used transect survey methods. The current estimate of the Aguiguan goat population is still within these ranges and evidence supports that goats are severely impacting the native forest.

Aguiguan would be a relatively easy island to eradicate goats from due to its small size and close proximity to Tinian. It is estimated that with a budget of $500,000 that the goats could be removed in 2-3 months. Currently there is opposition to the eradication of goats from the Tinian Mayor's Office. For the past 60 years, Aguiguan has been a place to hunt and gather resources for the residents of Tinian, and goats are considered one of these resources. However, it is suspected that if Aguiguan was leased, that this opposition would evaporate. Especially if the island would begin to produce cash revenue through tourism as well as provide traditionally cultural native species for consumption. Aguiguan is the only limestone island with most of the original species intact including old growth forest. Based on a recent land cover assessment, the island is currently around 49 percent native forest (See Section 2.1, Vegetation Surveys on Tinian and Aguiguan).

Goats have recently been transported from Aguiguan to Tinian as per instructions of the Mayor of Tinian. These goats, which anecdotal accounts put a total at 200 individuals, were released into the native forest on Tinian public lands to propagate. A survey around the coast on October 11, 2008 confirmed at least 20 goats at Puntan Kastiyu (14°56'53.90"N 145°39'53.38"E). It appeared that this herd is already creating trails, accelerating erosion, and impacting the native vegetation on the hillside. If public hunting of goats was allowed on Tinian then the threat of overpopulation might be negated.

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3.0 APPENDICES

3.1 STATUS AND TRENDS OF THE LAND BIRD AVIFAUNA ON TINIAN AND AGUIGUAN, MARIANA ISLAND

3.2 SYSTEMATIC RODENT MONITORING: A STUDY OF THE SMALL MAMMALS IN THE MARIANA ISLANDS

3.3 ASSESSMENT FOR PACIFIC SHEATH - TAILED BATS (*EMBALLONURA SEMICAUDATA ROTENSIS*) ON AGUIGUAN, COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

APPENDIX 3.1

STATUS AND TRENDS OF THE LAND BIRD AVIFAUNA ON TINIAN AND AGUIGUAN, MARIANA ISLANDS

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Keywords: abundance estimation; Aguiguan; bird counts; Mariana Islands; point-transect sampling; Tinian; trends

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Abstract

Avian surveys were conducted on the islands of Tinian and Aguiguan, Marianas Islands, in 2008 by the U.S. Fish and Wildlife Service to provide current baseline densities and abundances and assess population trends using data collected from previous surveys. On Tinian, during the three surveys (1982, 1996, and 2008), 18 species were detected, and abundances and trends were assessed for 12 species. Half of the 10 native species—Yellow Bittern (*Ixobrychus sinensis)*, White-throated Ground-Dove (*Gallicolumba xanthonura*), Collared Kingfisher (*Todiramphus chloris*), Rufous Fantail (*Rhipidura rufifrons*), and Micronesian Starling (*Aplonis opaca*)—and one alien bird—Island Collared-Dove (*Streptopelia bitorquata*)—have increased since 1982. Three native birds—Mariana Fruit-Dove (*Ptilinopus roseicapilla*), Micronesian Honeyeater (*Myzomela rubratra*), and Tinian Monarch (*Monarcha takatsukasae*)—have decreased since 1982. Trends for the remaining two native birds—White Tern (*Gygis alba*) and Bridled White-eye (*Zosterops saypani*)—and one alien bird—Eurasian Tree Sparrow (*Passer montanus*)—were considered relatively stable. Only five birds—White-throated Ground-Dove, Mariana Fruit-Dove, Tinian Monarch, Rufous Fantail, and Bridled White-eye—showed significant differences among regions of Tinian by year. Tinian Monarch was found in all habitat types, with the greatest monarch densities observed in limestone forest, secondary forest, and tangantangan (*Leucaena leucocephala*) thicket and the smallest densities found in open fields and urban/residential habitats. On Aguiguan, 19 species were detected on one or both of the surveys (1982 and 2008), and abundance estimates were produced for nine native and one alien species. Densities for seven of the nine native birds—White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Rufous Fantail, Bridled White-eye, Golden White-eye (*Cleptornis marchei*), and Micronesian Starling—and the alien bird—Island Collared-Dove—were significantly greater in 2008 than 1982. No differences in densities were detected between the two surveys for White Tern and Micronesian Honeyeater. Three native land birds—Micronesian Megapode (*Megapodius laperouse*), Guam Swiftlet (*Collocalia bartschi*), and Nightingale Reed-Warbler (*Acrocephalus luscinia*)—were either not detected during the point-transect counts or the numbers of birds detected were too small to estimate densities for either island. Increased military operations on Tinian may result in increases in habitat clearings and the human population, which would expand human dominated habitats, and declines in some bird populations would be likely to continue or be exacerbated with these actions. Expanded military activities on Tinian would also mean increased movement between Guam and Tinian, elevating the probability of transporting the Brown Tree Snake (*Boiga irregularis*) to Tinian.

Introduction

The Department of Defense (DOD) has proposed expanding military operations in the Mariana Islands. To determine the future impacts of military operations on bird populations on these islands, the DOD contracted the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, to coordinate avian surveys on the islands of Tinian and Aguiguan in the Commonwealth of the Northern Mariana Islands (CNMI). The survey data will be used to establish population baseline information to compare with any later change in status and distribution of the birds.

Current avian population estimates were calculated for the whole island for both Tinian and Aguiguan, and by regions for Tinian Island. These estimates were compared with results from a previous survey of both islands that was undertaken in 1982 by Engbring *et al*. (1986), yielding trends spanning 27 years. On Tinian, trends in bird populations across the island and within regions were compared from three surveys: the 1982 Engbring *et al*. survey, a survey in 1996 by the U.S. Fish and Wildlife Service (unpublished data, Lusk *et al*. 2000), and again in 2008. Aguiguan was surveyed in 1982 and 2008, and end-point comparisons were used to assess population changes. Particular attention was given to assess the status of the Tinian Monarch. Formerly listed as an endangered species, the monarch was delisted on September 21, 2004 (69 FR 65367) and is being monitored by the Fish and Wildlife Service through field surveys of distribution and abundance and tracking of land use and development on Tinian.

Methods

Survey area

Tinian

Tinian is the second largest of the CNMI islands at 101.01 km^2 (15^o 00` N, $145^o$ 35` E). The island consists of low-lying plateaus and a gentle limestone ridge dominated by Puntan Carolinas (elevation 196 m). The vegetation of Tinian currently consists of mixed second-growth forests, grassy savannas, and introduced forests, most of which are tangantangan (*Leucaena leucocephala*) thickets (Engbring *et al*. 1986). The little native vegetation that remains on Tinian (5%; Engbring *et al*. 1986) has been greatly altered by centuries of human use and non-native species and is basically confined to a few cliffs and adjacent steep limestone slopes (Engbring *et al*. 1986).

Aguiguan

Aguiguan is a small, uninhabited island located 8 km southwest of Tinian (7.09 km^2; 14^o 51` N, $145^o$ 33` E). It is made up of several concentric plateaus bounded by steep scarps, and the top most plateau is about 150 m in elevation. Like other CNMI islands, the vegetation on Aguiguan has been extensively altered by human activity, so the available native forest is limited. In addition, the island has a large feral goat (*Capra hircus*) population which continues to alter the native forest.

Bird surveys

On Tinian, the baseline survey conducted between 27 April and 8 May 1982 sampled a total of 216 stations on 10 transects with representative island-wide coverage across geography and habitats (Engbring *et al*. 1986; Figure 1). Placement of transects was random-systematic (Engbring *et al*. 1986). These transects were located and resurveyed during both the 1996 (28 August – 1 September) and 2008 (14 – 19 June) surveys. An additional four transects were sampled during the 2008 survey for a total of 254 stations (transect 11 – 9 stations; transect 12 – 9 stations; transect 13 – 14 stations; and transect 14 – 5 stations). The four transects were added to increase the sampling of native limestone forest and improve density estimates for Tinian Monarch.

On Aguiguan, an island-wide survey consisting of 66 stations on four transects (random-systematic placement) was conducted on 2 and 3 June 1982, and a partial survey (transects 1 and 2 only) was conducted on 10 and 11 March 1982 (Engbring *et al*. 1986; Figure 2). Data from only the June survey were used in this study because all stations were sampled and the survey month coincides with the 2008 survey. All four transects were located and resurveyed during the 2008 (25 – 27 June) survey. An additional transect of 14 stations was sampled during the 2008 survey for a total of 80 stations. This transect was added to increase the numbers of bird detected and to sample the top most plateau; however, placement of this transect on the plateau was random.

All surveys followed standard point-transect methods, consisting of 8-minute counts, where horizontal distances to all birds heard and/or seen were measured and recorded (see Engbring *et al*. 1986 for details). Sampling conditions recorded included cloud cover, rain, wind, noise level, and habitat type, and these were later used as covariates in density calculations (see *Population status* below). Counts commenced at sunrise and continued up to four hours and were conducted only under prescibed conditions.

Stations were surveyed by two observers in 1982 and one observer in 1996 and 2008. Data from only one counter were used for each station from the 1982 Tinian surveys, and the best counters were identified based on their experience and survey proficiency. Engbring *et al*. (1986) analyzed bird detections from all observers to estimate bird densities. For our analysis, we used detections from only one observer to recalculate densities for the 1982 Tinian survey, thus matching the 1996 and 2008 survey effort. Calculating densities from only one of the counters is a conservative approach and ensures sampling independence. This approach approximately halved the number of birds detected; however, our density estimates were generally greater than, but otherwise similar to, those of Engbring *et al*. (see their Table 8; 1986). On Tinian the 95% confidence intervals bracketed Engbring *et al*.'s estimates for all but four birds—Mariana Fruit-Dove, Tinian Monarch, Rufous Fantail, and Bridled White-eye. Differences may have resulted from analytical procedures such as selecting different truncation distances, selecting different models to estimate densities, and analytical advances in distance sampling (see Johnson *et al*. 2006), in addition to estimating densities using detections from only one of the counts (Tinian only). Data from both counters were used to estimate 1982 densities on Aguiguan because it was a small data set, and the sampling effort was adjusted appropriately.

Population status

Population status was calculated as density (birds/km^2) and number of birds (density by habitat type multiplied by habitat type area). Density was calculated using the program DISTANCE, version 5.0, release 2 (Thomas *et al*. 2006) from species-specific global detection functions, where data were post-stratified by survey. Data were right-truncated to facilitate model fitting (Buckland *et al*. 2001:16). Candidate models included half-normal and hazard-rate detection functions with expansion series of order two (Buckland *et al*. 2001:361, 365). Sampling covariates were modeled in the multiple-covariate distance engine of DISTANCE (Thomas *et al*. 2006, Marques *et al*. 2007). The model with the lowest Akaike Information Criterion (AIC) was used to select the detection function that best approximated the data. Covariates (sampling conditions, habitat types, and survey year) were used to generate the global detection function when the best approximating model was improved by four or more AIC units (Appendix 1). Variances and confidence intervals were derived by log-normal based methods. Survey-specific, density-by-station values were generated for the population trends analyses (see *Population trends* below) from the global detection function using the post-stratification-by-sample option. Area of habitat types came from Engbring *et al*. (1986) and U.S. Fish and Wildlife Service (2008). The area of habitat types was not available for the 1996 Tinian survey; therefore, we used the area by habitat types from Engbring *et al*. to calculate the 1996 numbers of birds. This may slightly underestimate the population size if there was more secondary forest in 1996 than 1982. Agriculture habitat type (combined agroforestry and cultivated habitat type classifications) was not used to calculate numbers of birds because the area of this habitat is very small relative to the island (< 2%), the area of the agriculture habitat type has declined (190 ha in 1982 to 174 ha in 2008; U.S. Fish and Wildlife Service 2008), and insufficient numbers of stations were established in the agriculture habitat type to produce reliable density estimates (1 in 1982, 4 in 1996, and 2 in 2008), thus it was under-sampled. In addition, coastal and urban/residential habitat types were inconsistently and under-sampled (coastal: 3 stations in 1982, 1 in 1996, and 0 in 2008; urban/residential: 0 stations in 1982 and 1996, and 7 in 2008), and were not used in calculating population estimates. On Aguiguan, the 1982 estimates of the area of habitat types were not reliable; therefore, numbers of birds were calculated only for the 2008 survey.

Population trends

Change in bird density among the three annual estimates on Tinian was assessed with repeated measures analysis of variance (ANOVA: PROC MIXED; SAS Institute Inc., Cary, NC). To stabilize the error variance, density-by-station values were ln(density+1) transformed. Repeated measures ANOVA was also used to assess change in bird density within regions among the three annual estimates. Stations were treated as the random factor, and because the number of repeated measures was too small to fit a covariance model, we assumed the variance-covariance structure was a compound symmetry, homogeneous-variance model (Littell *et al*. 1996). Degrees of freedom was adjusted using the Kenward-Roger adjustment statement, and a Tukey's adjustment was used to control experiment-wise alpha = 0.05 for multiple-comparison procedures. A further analysis was conducted to assess differences by habitat type for Tinian Monarch from the 2008 survey using a one-way ANOVA (PROC MIXED) with the same options as those used in the repeated measures models. The agriculture habitat was dropped from this analysis because only two stations were sampled within the habitat during the 2008 survey.

End-point comparisons of the Aguiguan bird densities were compared using a two-sample *z*-test. Comparing density estimates using *z*-tests is the recommended method (L. Thomas, pers. comm.) and is an extension of the method listed in Buckland *et al*. (2001:353).

Results

Tinian

A total of 18 species was detected during one or more of the three surveys on Tinian (Table 1). Sufficient numbers of individuals were detected for 10 native and two alien species to calculate density and abundance estimates. Bridled White-eye and Rufous Fantail were the most abundant birds, whereas White-throated Ground-Dove and Yellow Bittern were the least abundant birds (Table 2). Half of the 10 native species—Yellow Bittern, White-throated Ground-Dove, Collared Kingfisher, Rufous Fantail, and Micronesian Starling—have increased since 1982 (Table 3, Figure 3). Three native birds—Mariana Fruit-Dove, Micronesian Honeyeater, and Tinian Monarch—have decreased in the same period. Although these declines were not linear (Figure 3), the overall changes between 1982 and 2008 were significant (Table 3). Trends for the remaining two native birds—White Tern and Bridled White-eye—were considered relatively stable. The alien bird—Island Collared-Dove—increased since 1982 or remained relatively stable, respectively (Tables 2 and 3, Figure 3). Although Eurasian Tree Sparrow densities increased 98% from 2 to 110 birds/km^2 between 1982 and 2008, their densities were not estimated well enough to make strong conclusions, and we conclude they have remained relatively stable.

Only 5 birds—White-throated Ground-Dove, Mariana Fruit-Dove, Tinian Monarch, Rufous Fantail, and Bridled White-eye—showed significant differences among regions by year (Table 4, Appendix 2). Between 1982 and 2008, White-throated Ground-Dove densities increased in the Diablo and Hagoi regions, and Rufous Fantail densities increased in the Carolinas and Masalog regions (Figure 4). Mariana Fruit-Dove densities declined in the Carolinas, and Tinian Monarch and Bridled White-eye densities declined in the Diablo region. In addition, densities of 3 birds—White Tern, Micronesian Honeyeater, and Micronesian Starling—differed by year and region but the year-region interaction was insignificant (Table 4, Figure 4, Appendix 2). White Tern densities were greater in Diablo than in Hagoi, but densities in those regions were not different from densities in the Carolinas and Masalog. Densities of Micronesian Honeyeater were greater in the Carolinas and Diablo regions than in the Hagoi and Masalog regions. Micronesian Starling densities were lower in Masalog than in the other regions.

Tinian Monarch densities have declined both temporally (survey year comparisons) and spatially (regional comparisons). We also tested for differences in Tinian Monarch densities among the different habitat types. Tinian Monarchs were found in all habitat types, but their densities were not distributed evenly among the habitats (Figure 5). Based on the 2008 survey, the greatest monarch densities were observed in limestone forest, secondary forest, and tangantangan thicket. The smallest densities were found in open field and urban/residential habitats. Monarch densities in limestone and secondary forests were greater than those in open field and urban/residential habitat but not different from densities in tangantangan thicket (Table 5, Appendix 3).

We used the coefficient of variation (CV=SE/density) to evaluate Tinian Monarch estimator certainty by comparing the variability in densities calculated with and without the newly established transects. During the 2008 survey, 37 stations were sampled on four new transects. All of the stations were in limestone forest habitat, except that two stations on transect 13 were located in tangantangan thicket habitat. Both of these habitats contain high densities of Tinian Monarch (Table 5). Incorporating the new transects increased the precision of monarch estimates in limestone forest habitat by more than 50% compared to estimates from just the original transects (Table 6). Sampling the new transects helped to improve precision in monarch densities by 15% in the Carolinas and Diablo regions, and most of the improvement was in estimates from the Carolinas Region. Overall, the precision of the island-wide monarch estimate was increased by almost 9%.

Aguiguan

A total of 19 species was detected on the Aguiguan surveys (Table 7). Sufficient numbers of individuals were detected for nine native and one alien species to calculate density and abundance estimates. Bridled White-eye was the most abundant bird at over 44,000 birds on the small 7 km^2 island, and Collared Kingfisher and Island Collared-Dove were the least abundant birds (Table 8). Densities for seven of the nine native birds—White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Rufous Fantail, Bridled White-eye, Golden White-eye, and Micronesian Starling—were significantly greater in 2008 than 1982 (Table 8, Figure 6). No differences in densities were detected between the two surveys for White Tern and Micronesian Honeyeater. Densities of the alien Island Collared-Dove had increased significantly between 1982 and 2008.

Trends Across Islands

Densities have increased or remained stable for 84% (21 of 25 populations) of the nine native land bird species shared between Saipan (Camp *et al*., in press) and one or both of the islands covered in this study (Table 9). White-throated Ground-Dove and Micronesian Starling populations increased on all three islands. Yellow Bittern, Collared Kingfisher, and Bridled White-eye populations either increased or remained stable. Change in the status of the Mariana Fruit-Dove, Micronesian Honeyeater, Rufous Fantail, and Golden White-eye populations was mixed among the islands.

Discussion

Island Trends

Abundances of half of the 10 native birds on Tinian— Yellow Bittern, White-throated Ground-Dove, Collared Kingfisher, Rufous Fantail, and Micronesian Starling—and seven of nine native birds on Aguiguan—White-throated Ground-Dove, Mariana Fruit-Dove, Collared Kingfisher, Rufous Fantail, Bridled White-eye, Golden White-eye, and Micronesian Starling—have increased since the 1982 survey. In addition, three native birds on both islands have remained stable—White Tern on both islands, Bridled White-eye on Tinian, and Micronesian Honeyeater on Aguiguan. Large increases in densities of Yellow Bittern, Rufous Fantail, and Micronesian Starling on Tinian, and Rufous Fantail on Aguiguan support increasing their status classification. Changes in the other birds were not sufficient to warrant reclassification. Reichel and Glass (1991) listed Yellow Bittern as rare, and now at more than 1,600 birds the species can be considered uncommon—observing them in representative habitat is not certain but likely. Rufous Fantail and Micronesian Starling on Tinian may be considered abundant. Abundances of about 86,000 and 30,000 birds, respectively, make finding them in large numbers within representative habitat a certainty. Likewise, Rufous Fantail on Aguiguan may be considered abundant at more than 6,400 birds. Alien birds—Island Collared-Dove and Eurasian Tree Sparrow—densities increased on both islands and Tinian, respectively, and both species may be categorized as common or abundant.

No species had declined on Aguiguan, whereas Mariana Fruit-Dove, Micronesian Honeyeater, and Tinian Monarch declined on Tinian. Relatively large numbers of these birds remain on Tinian (> 3,000 individuals), and changes to their abundance status are unwarranted. However, declines for these native species are a concern, especially for the Tinian Monarch, which is endemic to Tinian and listed as threatened by the CNMI and vulnerable by the IUCN. Likely causes for these declines include predation and habitat loss/degradation. One possible explanation for increases in Aguiguan birds has been extensive expansion of secondary forest and brush habitats. About half of the island was cleared for agriculture during the 1930s and 1940s, and those fallow fields are now dominated by *Lantana camara* and other alien plants, and secondary forest (Figure 7). Forests currently cover about 70% of the island, and an additional 20% of the island is occupied primarily by *L. camara* fields, providing habitat for birds.

Trends Across Islands

The U.S. Fish and Wildlife Service conducted a land bird survey on Saipan in 2007 and assessed population trends (Camp *et al*., in press). Comparing trends among the neighboring Mariana Islands of Tinian, Aguiguan, and Saipan provides an index of the species' regional trends. The carnivorous birds—Yellow Bittern and Collared Kingfisher—increased or remained stable. Densities of Yellow Bittern have increased on Tinian and Saipan, but the species is found in very low numbers on Aguiguan. In fact, no birds were detected on count during the 2008 Aguiguan survey, although one was seen along a transect (APM, pers. obs.), and only one bird was detected during the 1982 survey. Yellow Bittern inhabit swamps, marshes, and other grassy habitats, and secondary forest, and bittern may be absent from Aguiguan because very little grass-dominated habitat now occurs on this island. In contrast, bittern may be increasing on Tinian and Saipan where grassy and open habitats have increased.

Trends among the fruit-eating birds—White-throated Ground-Dove and Mariana Fruit-Dove—were mixed, and the pattern does not appear to correspond to increases in human populations. Micronesian Starling, a largely frugivorous species, increased on all three islands. Camp *et al*. (in press) speculated that fruit-eating birds on Saipan may have benefited from the expansion of scarlet gourd (*Coccinia grandis*). This alien, smothering vine, also occurs on Tinian but only locally and has not formed dense canopies. Scarlet gourd is not reported from Aguiguan. Thus, it is likely that scarlet gourd is does not account for much of the increases in the fruit-eating bird populations on Tinian and Aguiguan. Another explanation is that there may be different patterns of hunting across the islands that account for the mixed trends. For example, people have traditionally hunted White-throated Ground-Dove and Mariana Fruit-Dove; however, it is not legal to hunt these doves but current hunting prevalence is unknown.

The insectivorous Rufous Fantail increased on Tinian and Aguiguan but decreased on the more densely human-populated Saipan. Trends for birds with diets including insects, nectar, and fruits were mixed. The Aguiguan population of Bridled White-eye may have increased in response to expansion of secondary forest and lantana field habitats. Habitat change and increased human populations may not be strong enough drivers to effect Bridled White-eye populations on Saipan and Tinian. Golden White-eye is known from the recent fossil record to have formerly occurred on Tinian, where it is now extinct (Craig 1999). The species was detected in large numbers on Aguiguan, and the population there has more than doubled (529 to 1,293 birds/km^2) between 1982 and 2008. Craig (1996, as cited in Craig 1999) estimated Golden White-eye densities on Saipan at about 1,200 birds/km^2, an estimate that roughly matches the 1997 point-transect density (Camp *et al*., in press). The current Golden White-eye densities on Aguiguan were almost twice that reported from Saipan (1,300 and 700 birds/km^2, respectively), and their trends were in opposite directions—increasing on Aguiguan and decreasing on Saipan (Camp *et al*., in press). The Golden White-eye decline on Saipan may be a result of increasing human populations and habitat loss/degradation, whereas these factors are not affecting the population on uninhabited Aguiguan.

Generally, the birds on Tinian, Aguiguan, and Saipan are doing comparatively well for insular species. This is surprising given that nearly all of the native forests on Tinian and Saipan have been lost and that all habitats on Aguiguan suffer from heavy browsing by feral goats and forest regeneration is thus severely selective. Recent surveys on Rota showed that seven of eight bird trends have declined (Amar *et al*. 2008). The only bird to increase on Rota was the Micronesian Starling, which has also increased on the other three islands. Similar to our findings, Amar *et al*. conclude that the loss of forests or the spread of scarlet gourd does not fully explain bird population trends on Rota. Likewise, large-scale climate change, increases in human populations on Rota, Saipan, and Tinian, and Malathion insecticide spraying do not appear to be consistent drivers of bird trends. The status of Brown Tree Snake on Rota, Tinian, and Aguiguan is unknown, but reports of sightings are very rare. Brown Tree Snakes have been frequently sighted on Saipan

(Rodda and Savidge 2007). However, declines in the bird populations do not follow the geographic pattern of snakes spreading across an island, as they did on Guam (Savidge 1987). Further research is needed to identify the causative agents of population change in these four islands.

Rare Species and Those Not Appropriate for Point-Transect Sampling
Three native land birds—Micronesian Megapode, Guam Swiftlet, and Nightingale Reed-Warbler—were either not detected during the point-transect counts or the numbers of birds detected were too few to estimate densities. Point-transect methods may not be appropriate for the very rare megapode and reed-warbler, and the behavior of the swiftlet violates modeling assumptions. A remnant population of a few Micronesian Megapode may persist on Tinian (Wiles *et al*. 1987, U.S. Fish and Wildlife Service 1998a), although no individuals were detected during any of the three point-transect surveys. Wiles *et al*. (1987) speculated that the megapode population on Tinian may originate from birds being brought in by humans or possibly dispersing from nearby populations on Aguiguan or Saipan. Aguiguan supports a small Micronesian Megapode population (U.S. Fish and Wildlife Service 1998a), and about equal numbers of birds were detected during the 1982 and 2008 surveys (14 and 15 birds, respectively). During the 1982 survey on Aguiguan, four Nightingale Reed-Warbler incidental sightings were recorded, but not during the 8-min counts (Engbring *et al*. 1986). The reed-warbler has not been observed on Aguiguan since the mid-1990s and may be extirpated on Aguiguan (U.S. Fish and Wildlife Service 1998b, Esselstyn *et al*. 2003). The Nightingale Reed-Warbler was not detected by the 2008 survey, either during counts or incidentally. The Guam Swiftlet historically occurred on Tinian but is extinct on the island (U.S. Fish and Wildlife Service 1991, Cruz *et al*. 2008); no swiftlets were detected during the three point-transect surveys. Cruz *et al*. (2008) noted that the Aguiguan swiftlet population has probably remained fairly stable between 1987 and 2002; however, it is notable that the numbers of birds detected in 2008 were only 17% of those detected in 1982 (27 and 157 birds, respectively). This apparent decline was further supported by the drop in numbers of birds detected at roosting cave counts between 1985 and 1997-2002 (Cruz *et al*. 2008).

The 1996 White Tern estimate on Tinian was markedly lower than from the other surveys. It is likely that the low tern estimate was an artifact of when the survey was conducted and not an actual change in the tern population. The original survey in 1982 and the most recent 2008 survey occurred early in the year and early in the breeding season (although terns can breed in all months of the year; Niethammer and Patrick-Castilaw 1998), whereas the 1996 survey was conducted in late August and after the breeding season. When not nesting, most individuals spend extended periods at sea (Niethammer and Patrick-Castilaw 1998); therefore portions of the population in 1996 were outside the sampling frame. In addition, the 1996 survey focused on passerines, and not all tern detections may have been recorded (FAA, pers. comm.).

Tinian Monarch concerns
Lusk *et al*. (2000) calculated the 1996 Tinian Monarch abundance at about 55,700 birds, which is 11% less than our estimate of 62,900 birds. This change is due to differences between the analytical procedures. For example, Lusk *et al*. (2000) did not extrapolate

densities to abundance for 2,375 ha of open fields, although monarchs were detected in this habitat. After dropping densities from the open fields and adjusting for this area difference, our densities resulted in 48,424 birds, an estimate that fell within their 95% CI. This difference is easily accounted for in differences between our methods, specifically differences in the model selected and advances within program DISTANCE. Lusk *et al*. (2000) calculated their density estimate from a half-normal model with polynomial adjustments and an effective detection radius (EDR) of just over 34 m. We estimated the EDR at 30.18 m from a hazard-rate detection function (without adjustments) and incorporating observers as a covariate, where the smaller EDR resulted in greater densities. Lastly, Lusk *et al*. (2000) used program VCPADJ (Fancy 1997) and a previous version of DISTANCE (Laake *et al*. 1994) to standardize the survey conditions and estimate densities. The updated version of DISTANCE (Thomas *et al*. 2006) we used incorporates all of the modeling in one program and uses an improved technique to account for differences in sampling conditions (Thomas *et al*. 2006, Marques *et al*. 2007).

Estimator certainty usually declines with decreasing density estimates; however, this pattern was not observed for the 2008 Tinian Monarch estimate. There was an almost 3-fold decrease in estimator certainty for the 2008 estimate than that observed for either the 1982 or 1996 estimates. Variability in monarch densities on the new transects was substantially less than that observed on the entire set of original transects and the subset of original transects within the same regions. In the two regions where additional transects were sampled—Carolinas and Diablo—variability in the Tinian Monarch density diverged (see Appendix 2). Variability in the monarch density in the Diablo region remained low even though densities declined. In contrast, uncertainty increased 4-fold in the Carolinas region. The additional stations sampled during the 2008 survey in the Carolinas region reduced variability to the Tinian Monarch estimate, but estimator certainty was poorer than in previous surveys. Adding stations to the limestone forest habitat improved estimator certainty by 50%. Thus, additional stations may be needed to further improve estimator certainty. Allocation of stations for monitoring Tinian Monarch should consider additional sampling in habitats with uncertain estimates including agriculture (CV>100%), urban/residential (CV=69%), and lastly in open field habitat where 23% CV is adequate for trends monitoring. Also, additional sampling could be allocated in the Carolinas region to help reduce the almost 50% CV.

The U.S. Fish and Wildlife Service (2005) post-delisting plan for the Tinian Monarch identified the loss of habitat as a primary threat. The USFWS identified limestone and secondary forests and tangantangan thicket as quality habitat for the monarch (densities of 30.7, 7.7, and 6.0 birds/ha, respectively). Monach densities in 2008 declined dramatically by 79% in limestone forests and substantially by 24% and 27% in secondary forest and tangantangan thicket, respectively, from those reported by U.S. Fish and Wildlife Service (2005). We also show that the monarch population declined over the 27-year period, and the decline between 1996 and 2008 may be attributed to reduced bird density in open field habitat. Continued monitoring of the Tinian Monarch will be necessary to track its long-term survival, especially when the species is faced with population declines, threats such as the potential invasion of the Brown Tree Snake, and habitat lost to the increasing development of Tinian Island.

Bird Monitoring for Conservation on Tinian

The current status of the Brown Tree Snake on Tinian is unknown, but there have been several reports of snakes from Tinian and other CNMI islands (Colvin *et al*. 2005). Interdiction measures to prevent the introduction and establishment of snakes are crucial for the survival of CNMI land birds. If established, the Brown Tree Snake will decimate the avifauna (Savidge 1987, Wiles *et al*. 2003). Military operations are likely to increase traffic between Guam and Tinian, increasing the probability of transporting Brown Tree Snake to Tinian.

Military operations are likely to result in increases in the human population and land use conversion, which will expand human dominated habitats. Between 1980 and 2000, the human population on Tinian increased 309 % from 866 to 3,540 people, respectively (CNMI Department of Commerce 2001). Human increases were concentrated in and around the main settlement, San Jose, and not in the northern two-thirds of the island leased by the military. Humans have predominantly increased in the Carolinas region (which includes much of San Jose), where both alien birds and four native birds—Yellow Bittern, Collared Kingfisher, Rufous Fantail, and Micronesian Starling—increased. In contrast, Tinian Monarch, a native bird typically associated with forests, especially limestone forests, declined in the Carolinas region where housing, roads, and services have expanded. These bird trend patterns could well continue or be exacerbated by increasing military actions.

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Wiles, G.J., Beck, R.E. and Amerson, A.B. (1987) The Micronesian Megapode on Tinian, Mariana Islands. `Elepaio 47:1-3.

Figure 1. Island of Tinian showing the survey transects and regions (as defined by Engbring et al. 1986). Transects 1-10 were counted during all three surveys, and transects 11-14 were established and counted during the 2008 survey.

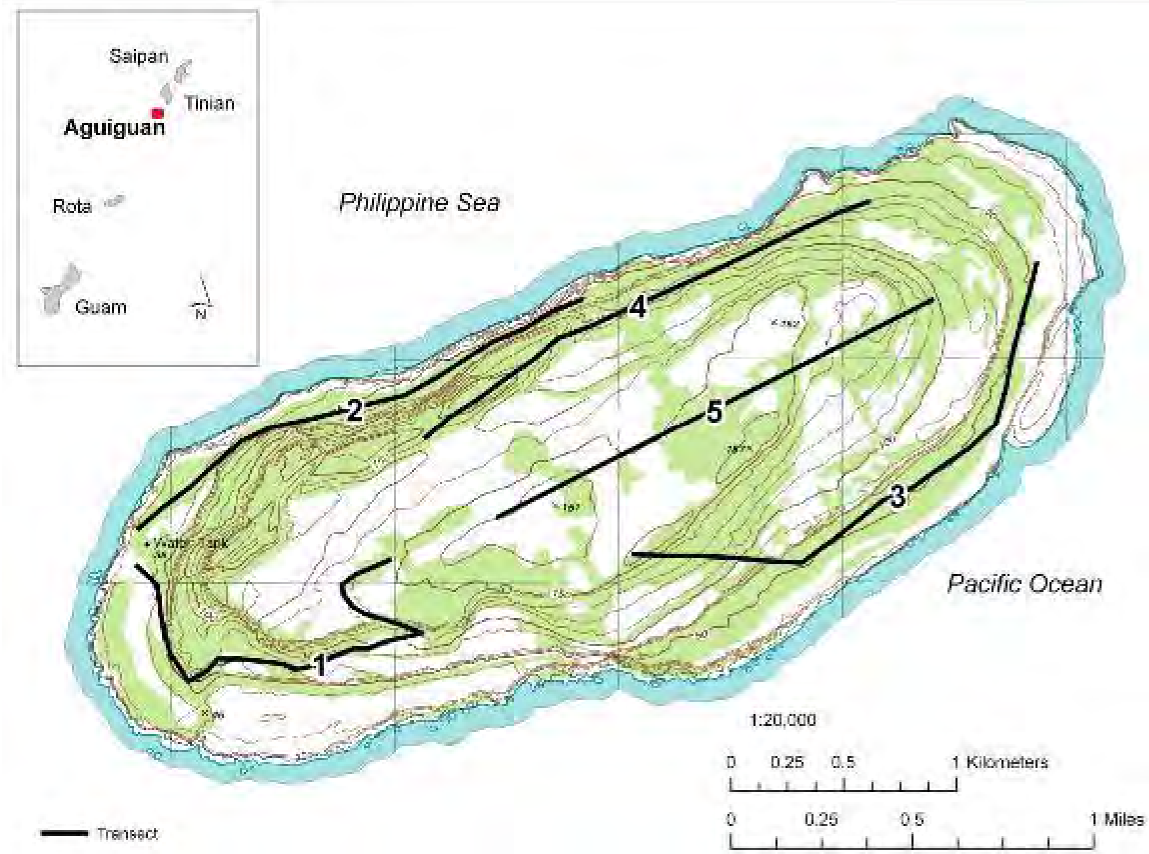
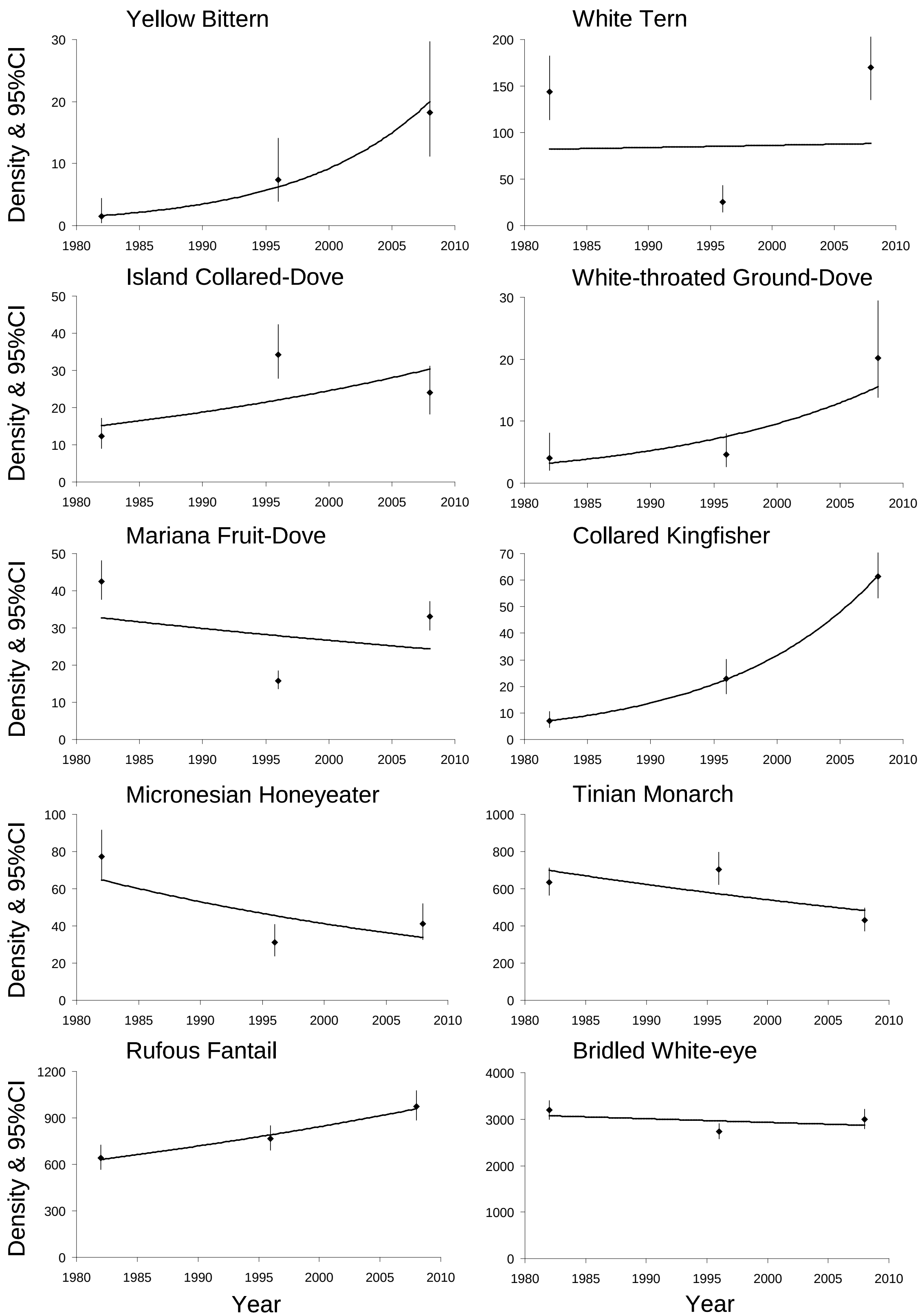


Figure 2. Island of Aguiguan showing the survey transects. Transects 1-4 were counted during both the 1982 and 2008 surveys, whereas transect 5 was established and counted during the 2008 survey.


Yellow Bittern
White Tern
Island Collared-Dove
White-throated Ground-Dove
Mariana Fruit-Dove
Collared Kingfisher
Micronesian Honeyeater
Tinian Monarch
Rufous Fantail
Bridled White-eye
Density & 95%CI
Year

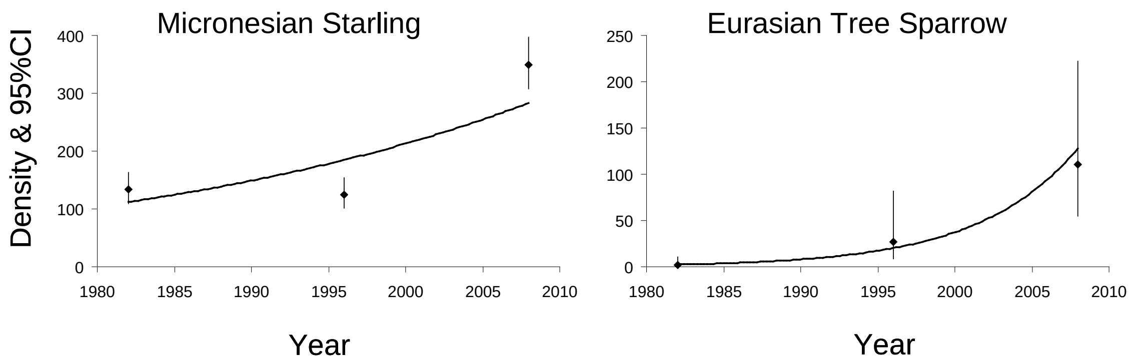
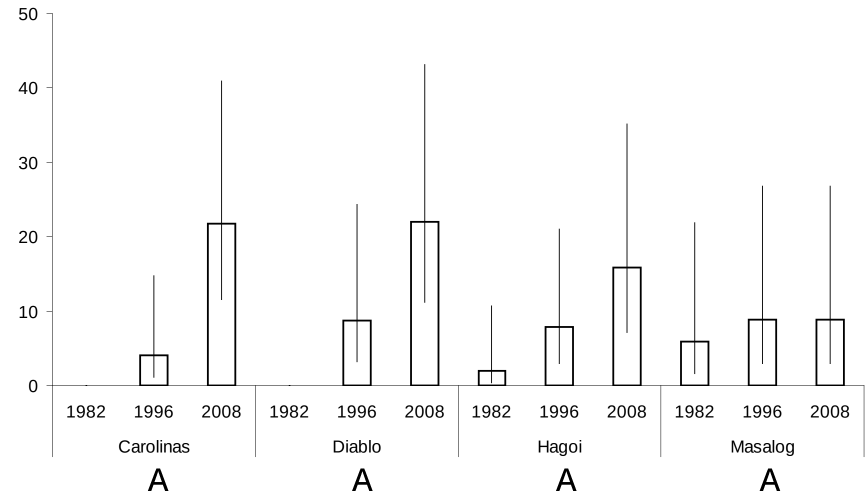
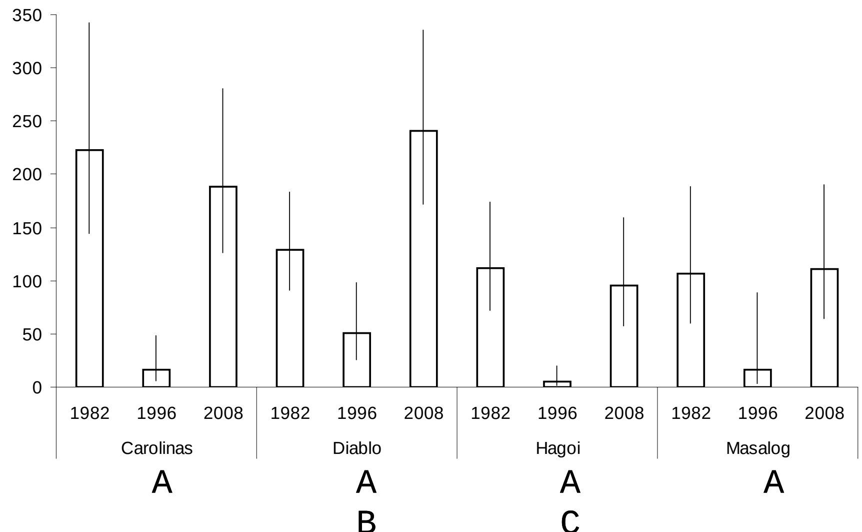


Figure 3. Density estimates (birds/km2 and 95% CI) for native and alien Tinian land birds from three point-transect surveys. Densities were fitted with a line from an exponential model to illustrate population trends.

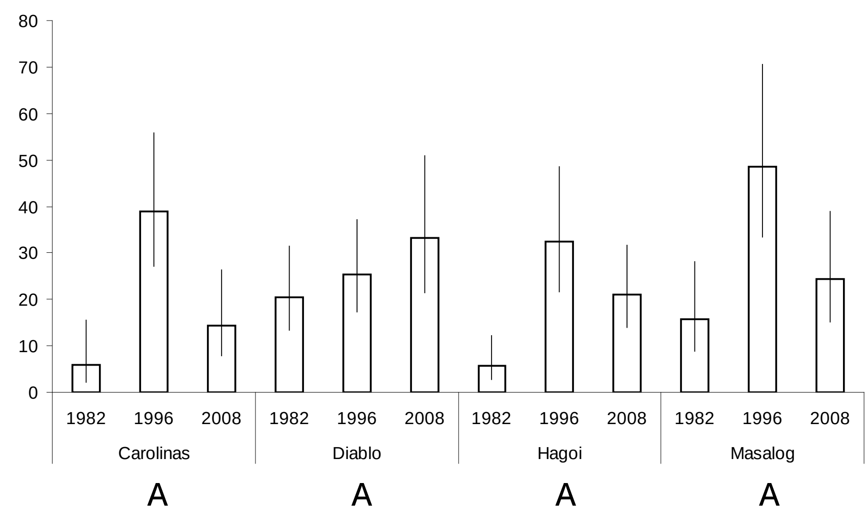
Yellow Bittern



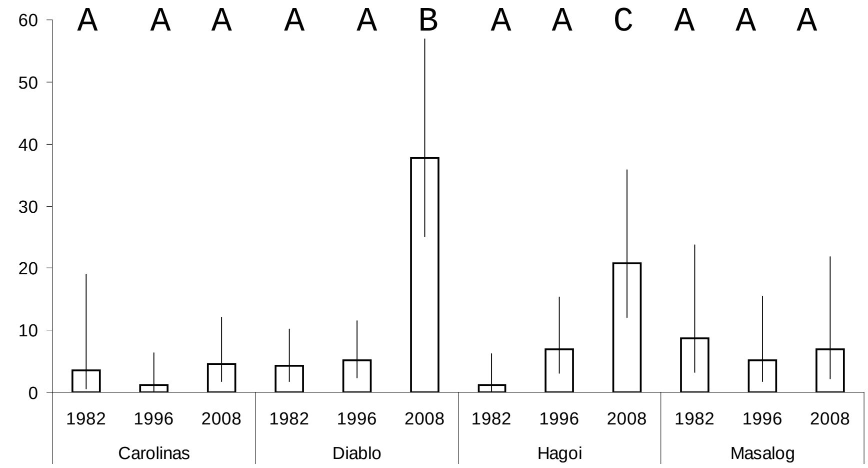
White Tern



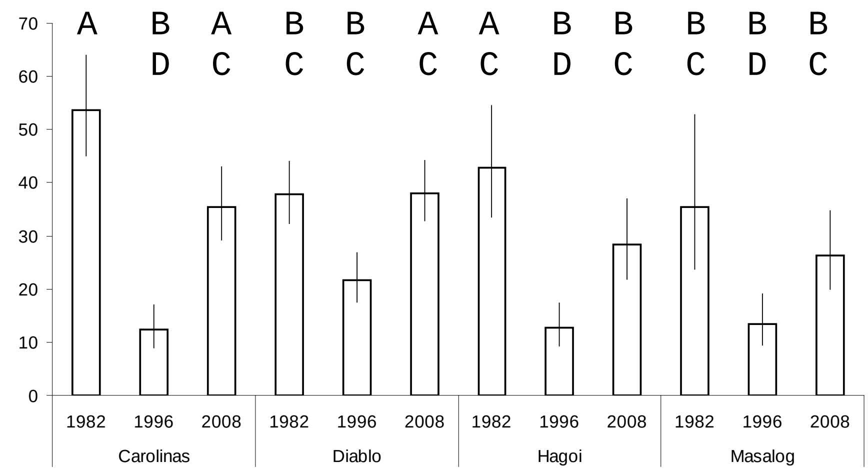
Island Collared-Dove



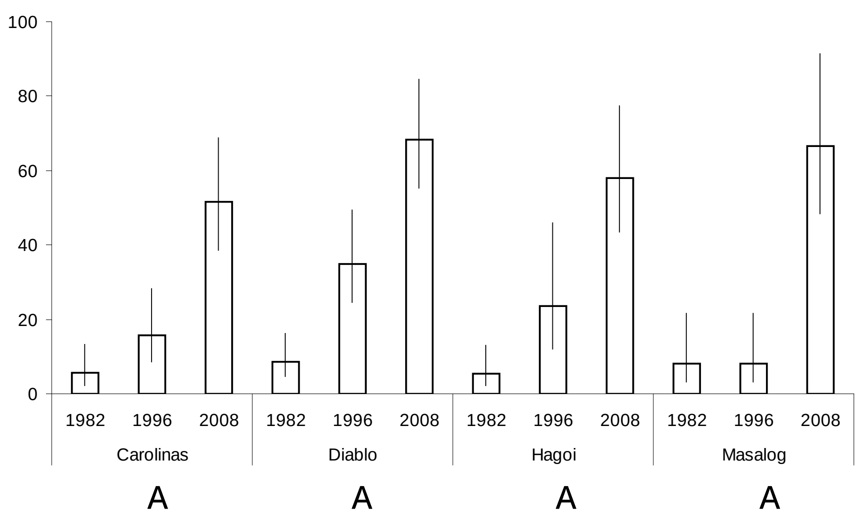
White-throated Ground-Dove



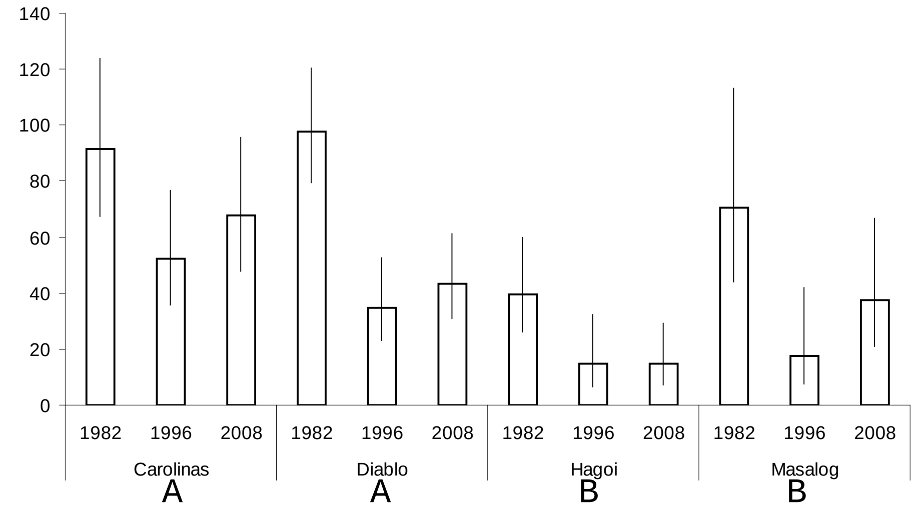
Mariana Fruit-Dove



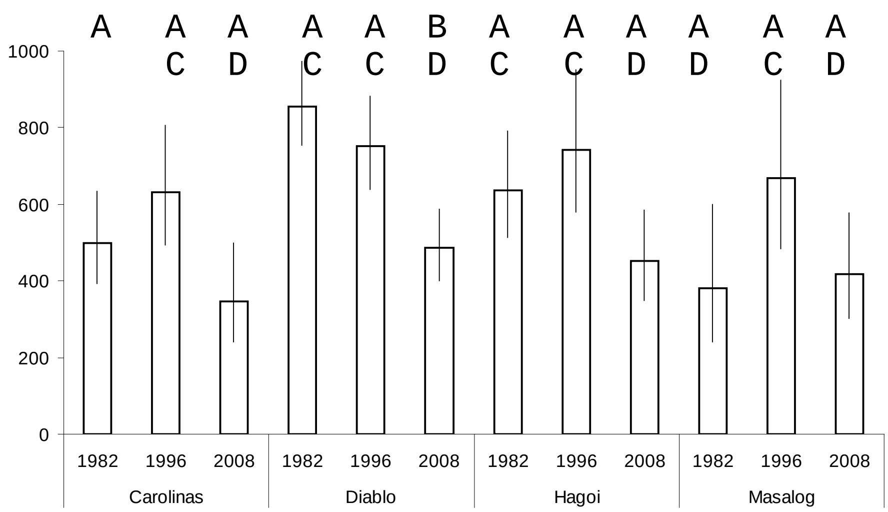
Collared Kingfisher



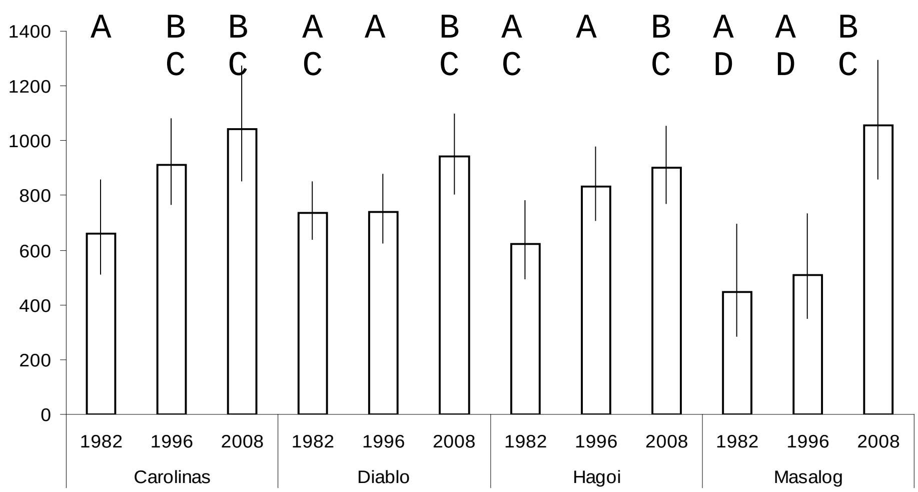
Micronesian Honeyeater



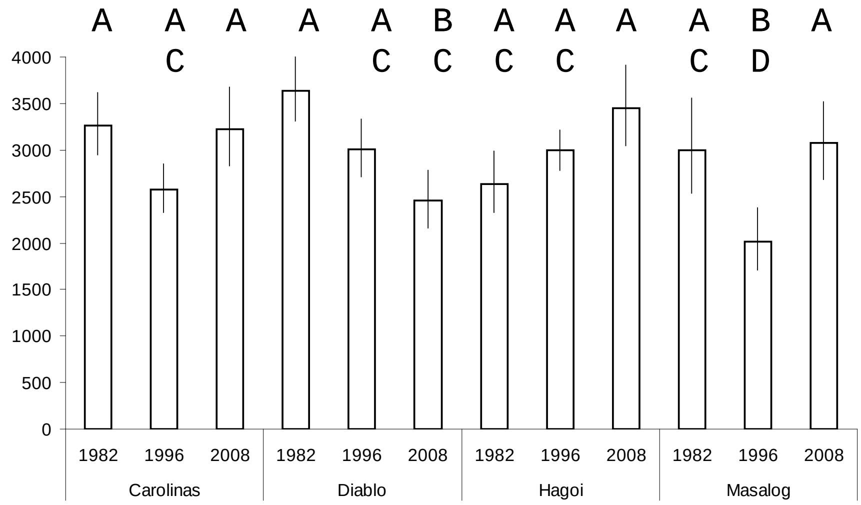
Tinian Monarch



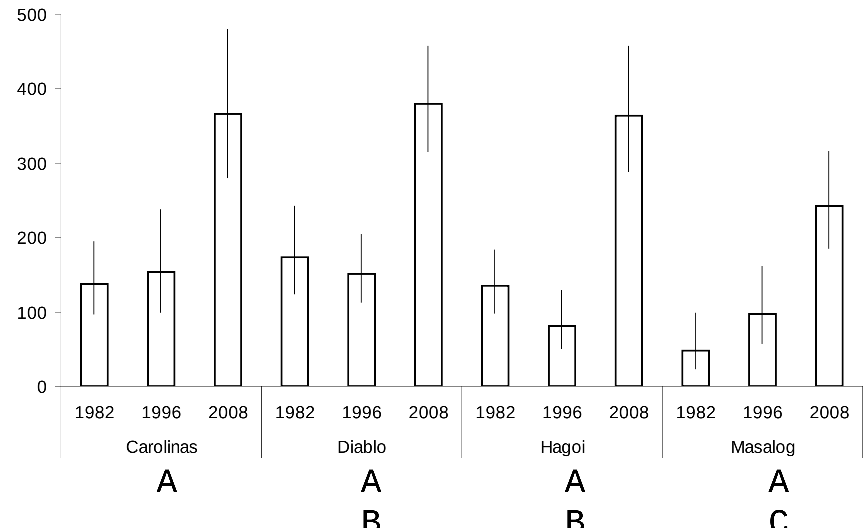
Rufous Fantail



Bridled White-eye



Micronesian Starling



Eurasian Tree Sparrow

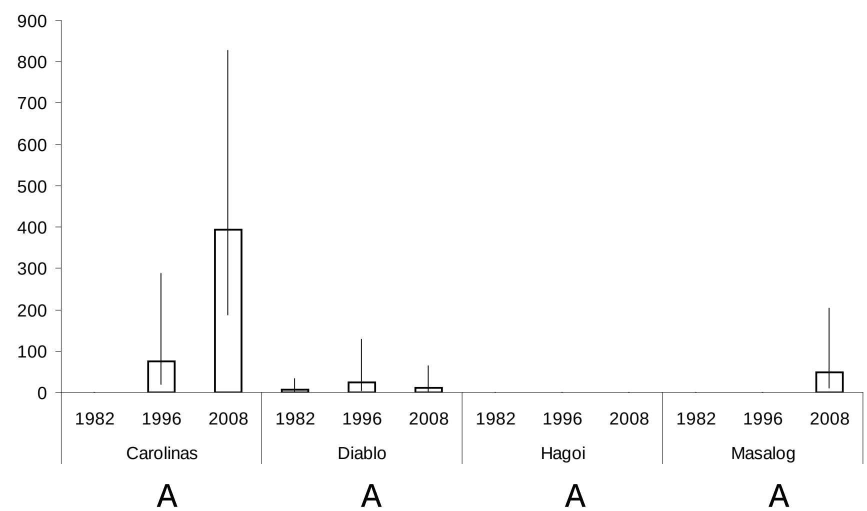


Figure 4. Density estimates (birds/km^2 and 95% CI) for native and alien Tinian land birds by region and year from three point-transect surveys. Differences of least squares means were assessed with repeated measures ANOVA (see Appendix 2 for details). Comparisons that share the same letter are not significantly different at the 0.05 level, adjusted for multiple comparisons. Comparisons below species name are year within region results (i.e., significant year, region and interaction effects), whereas comparisons below x-axis indicate fixed effects results (i.e., region or interaction effects were not significant).

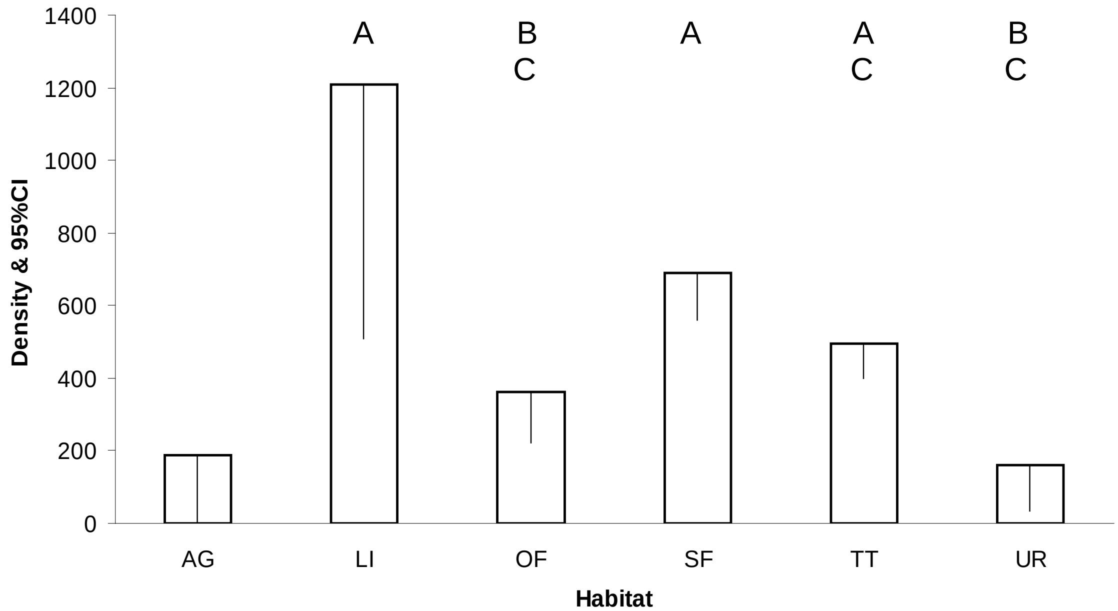


Figure 5. Density estimates (birds/km^2 and lower 95% CI) for the Tinian Monarch from all 14 transects sampled during the 2008 point-transect survey (data from all 14 transects). Habitat types are AG – agriculture, LI – limestone forest, OF – open field, SF – secondary forest, TT – tangantangan thicket, and UR – urban/residential. Differences of least squares means were assessed with a 1-way ANOVA. Agriculture habitat was dropped from this analysis and coastal habitat was not sampled in 2008 (see Methods). Comparisons that share the same letter are not significantly different at the 0.05 level, adjusted for multiple comparisons. Monarch densities in limestone and secondary forests were greater than those in open field and urban/residential.

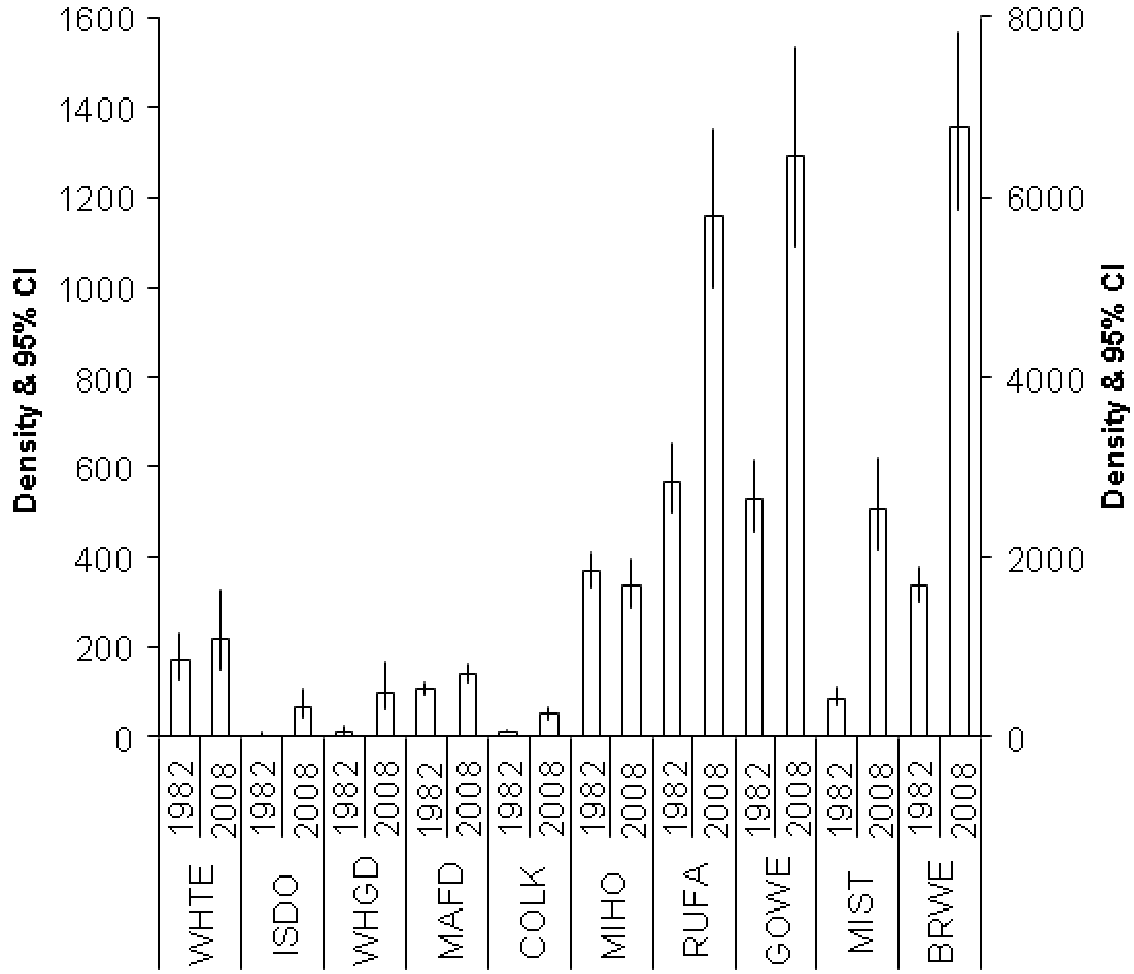


Figure 6. Density estimates (birds/km^2 and 95% CI) for native and alien Aguiguan land birds from two point-transect surveys. The primary y-axis is for the first nine species, and the secondary y-axis is for Bridled White-eye. Species codes are WHTE – White Tern; ISDO – Island Collared-Dove; WHGD – White-throated Ground-Dove; MAFD – Mariana Fruit-Dove; COLK – Collared Kingfisher; MIHO – Micronesian Honeyeater; RUFA – Rufous Fantail; GOWE – Golden White-eye; MIST – Micronesian Starling; and BRWE – Bridled White-eye.

Vegetation Changes in Central Aguiguan

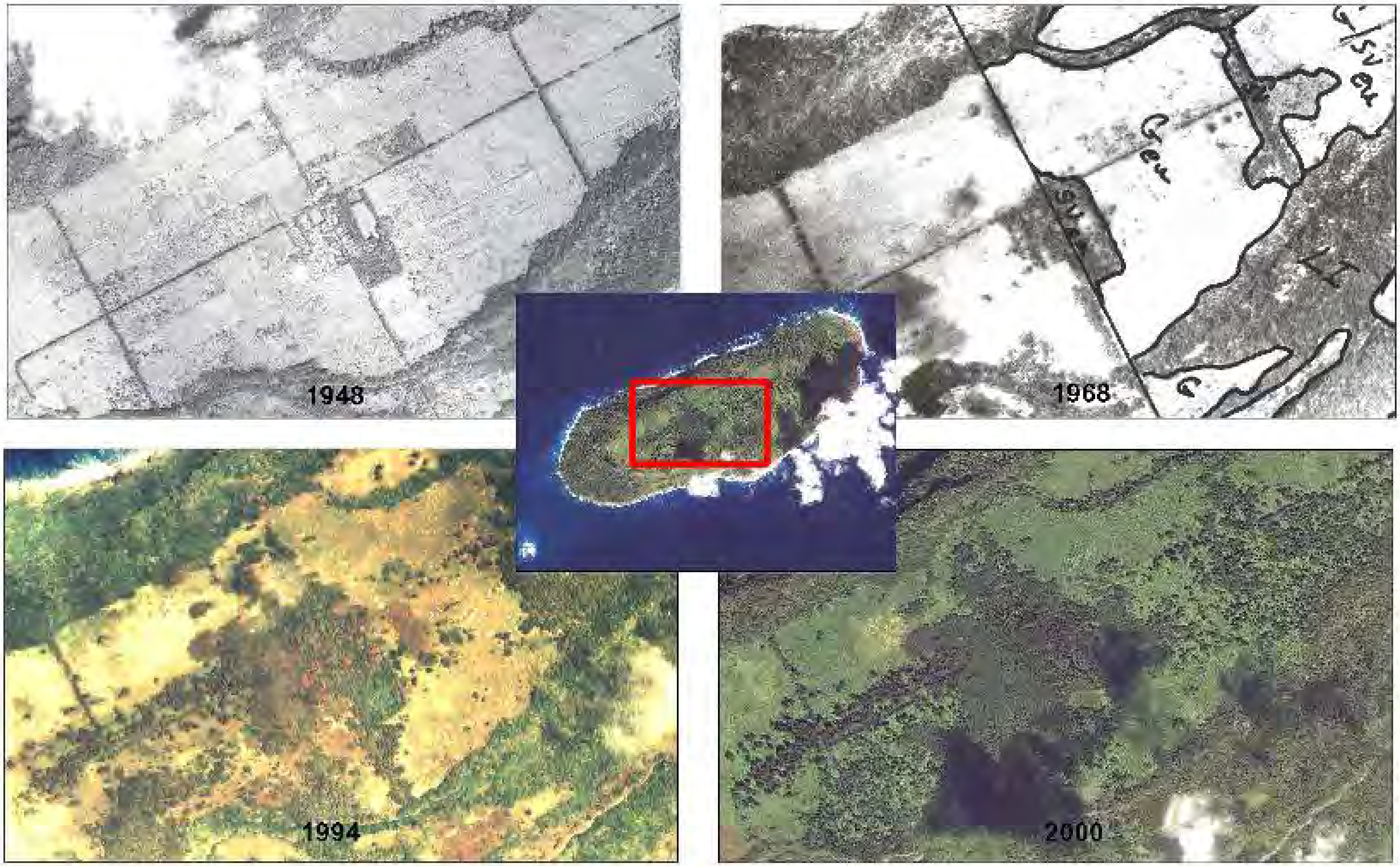


Figure 7. Vegetation changes in central Aguiguan, as shown by a series of aerial photos of center of the island. About half of the island was cleared for agriculture during the 1930s and 1940s (represented in the 1948 photo). Agriculture halted after WWII, and the fallow fields were dominated by grass (labeled G in the 1964 photo, and represented in yellow in the 1994 photo). Secondary forest expanded into the fallow fields and is represented in dark green in the bottom two photos. By 2000, the non-native shrub *Lantana camara* had replaced the grass in the fallow fields, and is represented in light green in the 2000 photo. One of the few remaining patches of grass is visible in the 2000 photo (just below the right corner of the central panel).

Table 1. List of birds detected from three different point-transect surveys on Tinian. In 1982 and 1996, 216 stations were sampled on 10 transects, and in 2008 254 stations were sampled on 14 transects. The number of stations occupied (# Stns Ocpd) and birds detected (# Dect), and indices of percent occurrence (% Occ) and birds per station (BPS), were calculated. Nomenclature generally follows the AOU checklist and Reichel and Glass (1991) with updates. Density estimates were produced for birds in bold.

		1982				1996				2008			
Species	Scientific Name	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS
Red Junglefowl	*Gallus gallus*	45	105	20.8	0.49	0	0	0.0	0.00	45	77	17.7	0.30
White-tailed Tropicbird	*Phaethon lepturus*	0	0	0.0	0.00	0	0	0.0	0.00	3	5	1.2	0.02
Yellow Bittern	*Ixobrychus sinensis*	10	10	4.6	0.05	16	18	7.4	0.08	34	38	13.3	0.15
Pacific Reef-Egret	*Egretta sacra*	1	1	0.5	<0.01	1	1	0.5	<0.01	0	0	0.0	0.00
Pacific Golden-Plover	*Pluvialis fulva*	1	1	0.5	0.00	0	0	0.0	0.00	3	11	1.2	0.04
Ruddy Turnstone	*Arenaria interpres*	0	0	0.0	0.00	0	0	0.0	0.00	1	1	0.4	<0.01
Brown Noddy	*Anous stolidus*	0	0	0.0	0.00	0	0	0.0	0.00	1	1	0.4	<0.01
White Tern	*Gygis alba*	128	344	59.3	1.59	22	52	10.2	0.24	122	322	48.0	1.27
Island Collared-Dove	*Streptopelia bitorquata*	51	66	23.6	0.31	136	256	63.0	1.19	79	116	31.1	0.46
White-throated Ground-Dove	*Gallicolumba xanthonura*	13	16	6.0	0.07	23	23	10.6	0.11	64	82	25.2	0.32
Mariana Fruit-Dove	*Ptilinopus roseicapilla*	189	623	87.5	2.88	150	240	69.4	1.11	212	462	83.4	1.82
Collared Kingfisher	*Todiramphus chloris*	150	294	69.4	1.36	124	285	57.4	1.32	190	374	74.8	1.47
Micronesian Honeyeater	*Myzomela rubratra*	131	236	60.6	1.09	60	96	27.8	0.44	87	125	34.3	0.49
Tinian Monarch	*Monarcha takatsukasae*	187	539	86.6	2.50	173	500	80.1	2.31	178	361	70.1	1.42
Rufous Fantail	*Rhipidura rufifrons*	202	786	93.5	3.64	188	502	87.0	2.32	235	686	92.5	2.70
Bridled White-eye	*Zosterops saypani*	216	2,222	100.0	10.29	216	1,770	100.0	8.19	253	2,024	99.6	7.97

Micronesian Starling	*Aplonis opaca*	177	513	81.9	2.38	106	226	49.1	1.05	215	614	84.7	2.42
Eurasian Tree Sparrow	*Passer montanus*	1	1	0.5	<0.01	3	13	1.4	0.06	13	62	5.1	0.24

Table 2. Population density and abundance estimates for native and alien Tinian land birds from three point-transect surveys. Data from Engbring et al. (1986) transects only. First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: bird abundance (sum of density by habitat type times the area of habitat types) with 95% CI. Agriculture, coastal and urban/residential habitat types were dropped for calculating bird abundance due to small sample size.

Species	1982	1996	2008
Yellow Bittern	1.5 ± 0.89 (0.5–4.4)	7.4 ± 2.49 (3.9–14.1)	18.2 ± 4.56 (11.2–29.6)
	127 (30–550)	764 (270–2,302)	1,695 (835–3,575)
White Tern	144.1 ± 17.24 (113.9–182.2)	25.3 ± 7.01 (14.8–43.2)	169.9 ± 19.66 (135.4–213.2)
	13,980 (9,349–21,512)	2,846 (1,121–7,300)	15,147 (10,067–23,041)
Island Collared-Dove	12.4 ± 2.04 (9.0–17.1)	34.3 ± 3.67 (27.8–42.3)	23.9 ± 3.24 (18.4–31.2)
	1,093 (642–2,024)	3,291 (2,296–4,777)	2,198 (1,374–3,648)
White-throated Ground-Dove	4.1 ± 1.45 (2.0–8.0)	4.6 ± 1.30 (2.7–8.0)	20.2 ± 3.91 (13.8–29.5)
	434 (136–1,421)	440 (174–1,147)	1,827 (1,045–3,226)
Mariana Fruit-Dove	42.6 ± 2.64 (37.7–48.1)	15.8 ± 1.23 (13.6–18.4)	33.1 ± 1.96 (29.4–37.1)
	3,909 (3,185–4,826)	1,539 (1,155–2,065)	3,029 (2,506–3,677)
Collared Kingfisher	7.0 ± 1.46 (4.7–10.5)	22.9 ± 3.28 (17.3–30.3)	61.3 ± 4.33 (53.3–70.4)
	570 (305–1,130)	2,268 (1,329–3,883)	5,439 (4,212–7,090)
Micronesian Honeyeater	77.2 ± 6.79 (64.9–91.7)	31.2 ± 4.26 (23.9–40.8)	41.3 ± 4.86 (32.8–52.0)
	7,859 (5,877–10,700)	2,847 (1,684–4,838)	3,716 (2,458–5,667)
Tinian Monarch	634.5 ± 37.88 (564.3–713.4)	705.7 ± 43.96 (624.3–797.6)	431.3 ± 30.75 (374.9–496.2)
	60,898 (49,484–75,398)	62,863 (50,476–78,758)	38,449 (29,992–49,849)
Rufous Fantail	641.2 ± 39.30 (568.4–723.3)	766.3 ± 40.85 (690.1–851.0)	975.0 ± 48.26 (884.6–1,074.6)
	58,336 (48,119–71,134)	67,191 (55,510–82,000)	86,112 (72,786–102,594)
Bridled White-eye	3,190.9 ± 101.79 (2,996.8–3,397.6)	2,731.9 ± 81.96 (2,575.5–2,897.8)	2,997.2 ± 105.80 (2,795.8–3,213.0)
	302,477 (270,218–338,821)	253,407 (225,258–286,044)	270,785 (239,579–306,772)
Micronesian Starling	133.9 ± 13.53 (109.8–163.3)	125.1 ± 13.34 (101.5–154.2)	349.5 ± 22.47 (308.0–396.6)
	11,543 (7,994–17,041)	10,841 (7,270–16,296)	30,088 (23,633–38,565)

Eurasian Tree Sparrow	2.1 ± 2.07 (0.4–10.7)	26.7 ± 16.42 (8.7–81.5)	110.2 ± 40.54 (54.7–222.2)
	155 (29–817)	1,244 (232–6,662)	2,111 (429–10,666)

Table 3. Repeated measures analysis of variance results for trends in Tinian land bird densities among years. Data from Engbring et al. (1986) transects only, excluding stations from agriculture, coastal and urban/residential habitat types. Trends are denoted as increasing (▲), decreasing (▼), or stable (▬). Significant changes are marked in bold. Degrees of freedom for the differences of least squares means (Diff LSM) are 398.

		Fixed Effects		Diff LSM								
				82-96			82-08			96-08		
Species	Trend	$F_{2,398}$	*p*	Est (SE)	*t*	Adj-*p*	Est (SE)	*t*	Adj-*p*	Est (SE)	*t*	Adj-*p*
Yellow Bittern	▲	13.57	<0.001	-0.04 (0.02)	-1.86	0.153	-0.10 (0.02)	-5.14	<0.001	-0.07 (0.02)	-3.29	0.003
White Tern	▬	43.18	<0.001	0.47 (0.06)	7.55	<0.001	-0.06 (0.06)	-0.91	0.634	-0.53 (0.06)	-8.46	<0.001
Island Collared-Dove	▲	16.22	<0.001	-0.14 (0.03)	-5.66	<0.001	-0.09 (0.03)	-3.38	0.002	0.06 (0.03)	2.28	0.060
White-throated Ground-Dove	▲	27.87	<0.001	<0.01 (0.02)	-0.42	0.906	-0.12 (0.02)	-6.67	<0.001	-0.11 (0.02)	-6.24	<0.001
Mariana Fruit-Dove	▼	64.54	<0.001	0.19 (0.02)	10.92	<0.001	0.05 (0.02)	2.73	0.018	-0.14 (0.02)	-8.19	<0.001
Collared Kingfisher	▲	87.05	<0.001	-0.11 (0.03)	-3.79	<0.001	-0.36 (0.03)	-12.84	<0.001	-0.26 (0.03)	-9.05	<0.001
Micronesian Honeyeater	▼	31.76	<0.001	0.27 (0.04)	7.59	<0.001	0.20 (0.04)	5.90	<0.001	-0.06 (0.04)	-1.69	0.209
Tinian Monarch	▼	10.65	<0.001	-0.09 (0.09)	-0.97	0.597	0.31 (0.09)	3.42	0.002	0.40 (0.09)	4.39	<0.001
Rufous Fantail	▲	19.55	<0.001	-0.24 (0.09)	-2.75	0.017	-0.54 (0.09)	-6.24	<0.001	-0.30 (0.09)	-3.49	0.002
Bridled White-eye	▬	5.26	0.006	0.16 (0.05)	3.24	0.004	0.07 (0.05)	1.42	0.330	-0.09 (0.05)	-1.81	0.166
Micronesian Starling	▲	67.87	<0.001	0.04 (0.07)	0.57	0.836	-0.64 (0.07)	-9.79	<0.001	-0.68 (0.07)	-10.36	<0.001
Eurasian Tree	▬	0.96	0.384	-0.02	-0.78	0.713	-0.03	-1.38	0.352	-0.01	-0.60	0.822

Sparrow	(0.02)	(0.02)	(0.02)

Table 4. Repeated measures analysis of variance results for year, region, and year-region interaction fixed effects in Tinian land bird densities. Data from Engbring et al. (1986) transects only. Dash indicates interaction test not conducted because one or both main effects results were non-significant. Differences of least squares means for the significant fixed effects (bold for interaction, italics for region) are presented in Appendix 2 and summarized in Figure 3.

	Fixed Effects					
	Year		Region		Interaction	
Species	$F_{2,392}$	*P*	$F_{3,196}$	*P*	$F_{6,392}$	*P*
Yellow Bittern	10.17	<0.001	0.20	0.899	—	—
White Tern	40.78	<0.001	4.15	0.007	1.71	0.116
Island Collared-Dove	19.67	<0.001	1.47	0.224	—	—
White-throated Ground-Dove	16.98	<0.001	5.19	0.002	6.60	<0.001
Mariana Fruit-Dove	66.10	<0.001	5.99	<0.001	3.76	0.001
Collared Kingfisher	81.67	<0.001	2.17	0.093	—	—
Micronesian Honeyeater	25.99	<0.001	10.89	<0.001	1.73	0.113
Tinian Monarch	8.94	<0.001	7.61	<0.001	3.10	0.006
Rufous Fantail	28.31	<0.001	5.23	0.002	6.63	<0.001
Bridled White-eye	9.29	<0.001	6.04	<0.001	11.58	<0.001
Micronesian Starling	62.05	<0.001	3.60	0.014	1.43	0.200
Eurasian Tree Sparrow	1.29	0.276	1.36	0.256	—	—

Table 5. One-way ANOVA and multiple comparisons results of Tinian Monarch densities by habitat types from the 2008 survey (data from all 14 transects). Agriculture habitat type was dropped from the analysis due to small sample size; only 2 survey stations were sampled. Significance was assessed at the alpha 0.05 level using Tukey's adjustment for multiple comparisons with 247 degrees of freedom (highlighted in bold). Habitat codes are LI – limestone forest; OF – open field; SF – secondary forest; TT – tangantangan thicket; and UR – urban/residential.

Fixed Effect	Num DF	Den DF	*F* Value	Pr > *F*
Habitat	4	247	6.24	<0.001

Habitat	Habitat	Estimate	Error	*t* Value	Adj *P*
LI	**OF**	0.76	0.203	3.75	**0.002**
LI	SF	0.01	0.173	0.04	1.000
LI	TT	0.31	0.165	1.85	0.348
LI	**UR**	1.11	0.382	2.91	**0.032**
OF	**SF**	-0.75	0.194	-3.89	**0.001**
OF	TT	-0.46	0.187	-2.43	0.111
OF	UR	0.35	0.392	0.89	0.900
SF	TT	0.30	0.154	1.94	0.298
SF	**UR**	1.10	0.377	2.93	**0.030**
TT	UR	0.80	0.374	2.15	0.201

Table 6. Measures of precision in Tinian Monarch 2008 densities for newly established transects, the original transects, the original transects in the same regions, and transects in limestone forest habitat[1].

Group	Density	SE	CV	Increased Precision
Original & New Transects	4.87	0.316	6.48	
Original Transects	4.51	0.32	7.09	8.6%
Limestone Forest Original & New Transects	6.41	0.735	11.48	
Limestone Forest Original Transects	4.97	1.152	23.20	50.5%
Carolinas & Diablo Regions Original & New Transects	5.03	0.392	7.80	
Carolinas & Diablo Regions Original Transects	4.46	0.409	9.18	15.0%
Carolinas Region Original & New Transects	3.73	0.544	14.56	
Carolinas Region Original Transects	3.62	0.661	18.23	20.1%
Diablo Region Original & New Transects	6.07	0.507	8.36	
Diablo Region Original Transects	5.07	0.488	9.62	13.1%

[1] New transects include 35 stations located in limestone forest and 2 stations in tangantangan thicket habitats, and were pooled for this analysis.

Table 7. List of birds detected from the 1982 and 2008 point-transect surveys on Aguiguan. In 1982, 66 stations were sampled on 4 transects (88 counts; several stations were counted more than once), and in 2008, 80 stations were sampled in 5 transects. The number of stations occupied (Stns Ocpd), birds detected (# Dect), indices of percent occurrence (% Occ), and birds per station (BPS) were calculated. Nomenclature generally follows the AOU checklist and Reichel and Glass (1991) with updates. Density estimates were produced for birds in bold. Scientific names are provided in superscript.

	1982				2008			
Species	# Stns Ocpd	# Dect	% Occ	BPS	# Stns Ocpd	# Dect	% Occ	BPS
Micronesian Megapode	8	14	9.1	0.16	11	15	13.8	0.19
White-tailed Tropicbird	1	1	1.1	0.01	—	—	—	—
Red-tailed Tropicbird[1]	8	13	9.1	0.15	—	—	—	—
Great Frigatebird[2]	1	2	1.1	0.02	—	—	—	—
Yellow Bittern	1	1	1.1	0.01	—	—	—	—
Brown Noddy	14	20	15.9	0.23	—	—	—	—
Black Noddy[3]	31	75	35.2	0.85	1	1	1.2	0.01
White Tern	54	218	61.4	2.48	34	84	42.5	1.05
Sooty Tern[4]	1	1	1.1	0.01	—	—	—	—
Island Collared-Dove	9	16	10.2	0.18	28	50	35	0.63
White-throated Ground-Dove	10	18	11.4	0.20	25	37	31.2	0.46
Mariana Fruit-Dove	87	757	98.9	8.60	75	240	93.8	3.00
Guam Swiftlet	26	157	29.6	1.78	9	27	11.2	0.34
Collared Kingfisher	56	154	63.6	1.75	53	101	66.2	1.26
Micronesian Honeyeater	87	745	98.9	8.47	74	174	92.5	2.18
Rufous Fantail	84	453	95.5	5.15	77	219	96.2	2.74
Golden White-eye	83	444	94.3	5.05	74	268	92.5	3.35
Bridled White-eye	88	823	100.0	9.35	77	758	96.2	9.48
Micronesian Starling	71	207	80.7	2.35	69	167	86.2	2.09

[1] = *Phaethon rubricauda*
[2] = *Fregata minor*

[3] = *Anous minutus*
[4] = *Onychoprion fuscatus*

Table 8. Population density and abundance estimates for native and alien Aguiguan land birds from two point-transect surveys. First row: mean density (birds/km^2 ± SE, with 95% CI). Second row: 2008 bird abundance (density by habitat times the habitat area) with 95% CI. Significance was assessed at the alpha 0.05 level using two-sample *z*-test (highlighted in bold). Change was defined as increasing (▲), decreasing (▼), or not significantly different (▬).

Species	1982	2008	*z* Value	*P*	Change
White Tern	169.6 ± 27.0 (124.2–231.6)	218.8 ± 44.2 (147.3–325.1)	-0.95	0.341	▬
		1,214 (604–3,651)			
Island Collared-Dove	4.4 ± 1.8 (2.0–9.7)	66.9 ± 16.7 (41.1–108.8)	-3.72	<0.001	▲
		307 (151–658)			
White-throated Ground-Dove	13.1 ± 4.8 (6.6–26.3)	100.2 ± 26.5 (59.9–167.6)	-3.23	0.001	▲
		484 (260–953)			
Mariana Fruit-Dove	107.5 ± 6.5 (95.4–121.1)	141.0 ± 10.8 (121.3–164.0)	-2.67	0.008	▲
		818 (604–1,170)			
Collared Kingfisher	13.1 ± 2.0 (9.7–17.8)	50.3 ± 6.6 (38.9–65.0)	-5.39	<0.001	▲
		347 (184–1,186)			
Micronesian Honeyeater	368.3 ± 19.6 (331.8–408.7)	336.2 ± 27.1 (286.7–394.1)	-0.96	0.337	▬
		2,128 (1,564–3,046)			
Rufous Fantail	568.8 ± 39.6 (496.0–652.2)	1.157.9 ± 89.3 (995.0–1,347.5)	-6.41	<0.001	▲
		6,429 (4,765–13,666)			
Golden White-eye	529.1 ± 40.6 (455.1–615.2)	1,292.6 ± 111.9 (1,089.7–1,533.4)	-6.41	<0.001	▲
		7,496 (4,983–17,387)			
Bridled White-eye	1,685.6 ± 102.3 (1,495.7–1,899.6)	6,771.2 ± 490.2 (5,867.6–7,814.1)	-10.15	<0.001	▲
		44,293 (32,246–63,031)			
Micronesian Starling	86.5 ± 10.9 (67.6–110.7)	505.2 ± 52.7 (411.5–620.3)	-7.78	<0.001	▲
		3,531 (1,902–12,374)			

Table 9. Comparison of density (birds/km2 and 95% confidence intervals) and change in the status of nine native land bird populations from the most recent point-transect surveys (Tinian and Aguiguan 2008, Saipan 2007) by island. A "—" denoted the species was not detected on the island. Changes are denoted as increasing (▲), decreasing (▼), or stable (▬). Results for Saipan are from Camp *et al*. (in press).

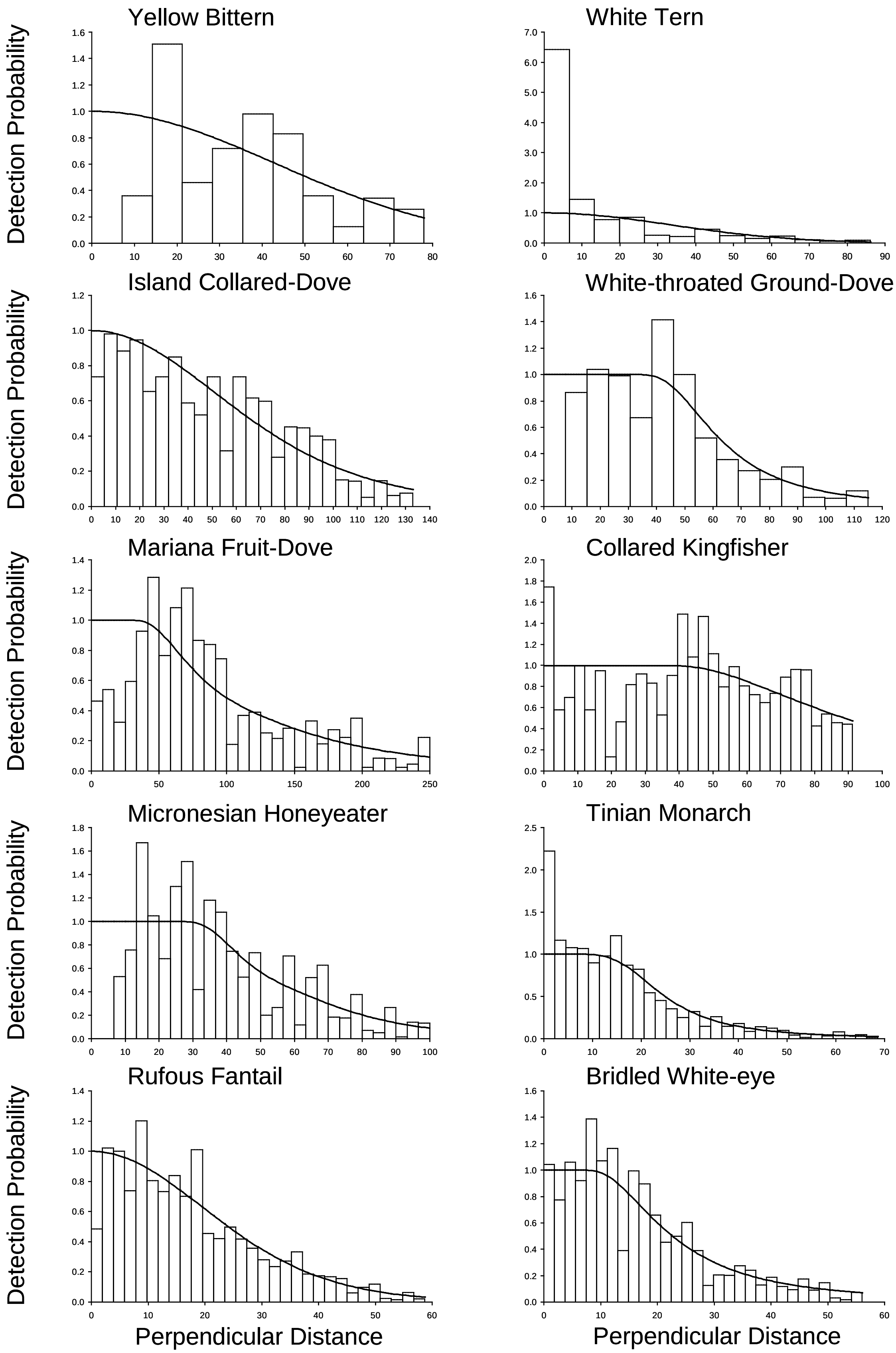
	Tinian		Aguiguan		Saipan	
Species	Density (95% CI)	Change	Density (95% CI)	Change	Density (95% CI)	Change
Yellow Bittern	18.2 (11.2–29.6)	▲	—		11.4 (4.8–21.2)	▲
White-Throated Ground-Dove	20.2 (13.8–29.5)	▲	100.2 (59.9–167.6)	▲	100.5 (77.1–127.9)	▲
Mariana Fruit-Dove	33.1 (29.4–37.1)	▼	141.0 (121.3–164.0)	▲	65.5 (53.0–79.8)	▬
Collared Kingfisher	61.3 (53.3–70.4)	▲	50.3 (38.9–65.0)	▲	25.8 (16.8–39.1)	▬
Micronesian Honeyeater	41.3 (32.8–52.0)	▼	336.2 (286.7–394.1)	▬	482.3 (383.5–651.5)	▲
Rufous Fantail	975.0 (884.6–1,074.6)	▲	1,157.9 (995.0–1,347.5)	▲	469.1 (394–1,601.5)	▼
Golden White-Eye	—		1,292.6 (1,089.7–1,533.4)	▲	711.8 (534.8–975.3)	▼
Bridled White-eye	2,997.2 (2,795.8–3,213.0)	▬	6,771.2 (5,867.6–7,814.1)	▲	4,713.3 (3,982.7–5,488.9)	▬
Micronesian Starling	349.5 (308.0–396.6)	▲	505.2 (411.5–620.3)	▲	161.9 (96.8–257.5)	▲

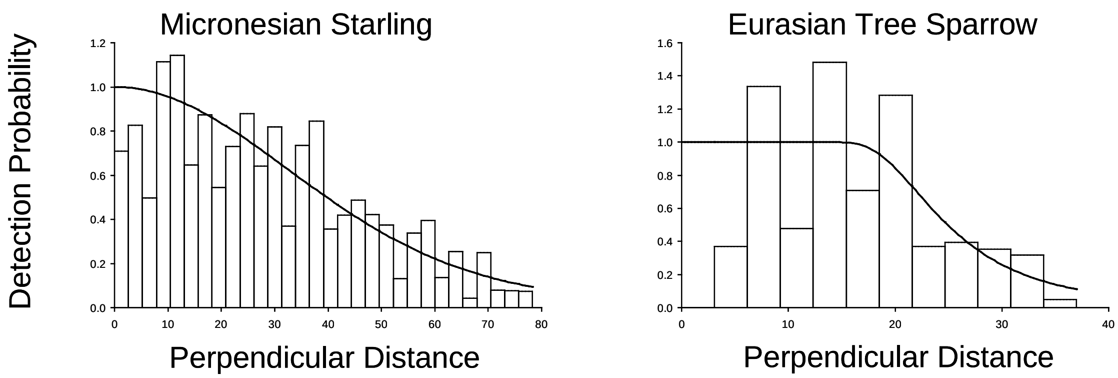
Appendix 1. Species data and models.

A. Detection function parameters used to derive population densities for each species on Tinian.

Species	Truncation	Key Model	Adjustment Terms	Covariates
Yellow Bittern	78.0	Half normal	None	None
White Tern	92.7	Half normal	None	None
Island Collared-Dove	133.0	Half normal	None	Observer
White-throated Ground-Dove	115.0	Hazard rate	None	None
Mariana Fruit-Dove	250.0	Hazard rate	None	Observer
Collared Kingfisher	91.2	Hazard rate	None	Observer
Micronesian Honeyeater	100.0	Hazard rate	None	Year
Tinian Monarch	68.6	Hazard rate	None	Observer
Rufous Fantail	58.7	Half normal	None	Observer
Bridled White-eye	56.0	Hazard rate	None	Observer
Micronesian Starling	78.3	Half normal	None	Observer
Eurasian Tree Sparrow	37.0	Hazard rate	None	None

C. Histograms of bird detections used to calculate population estimates on Tinian. The best fit lines for these data were modeled with program DISTANCE.

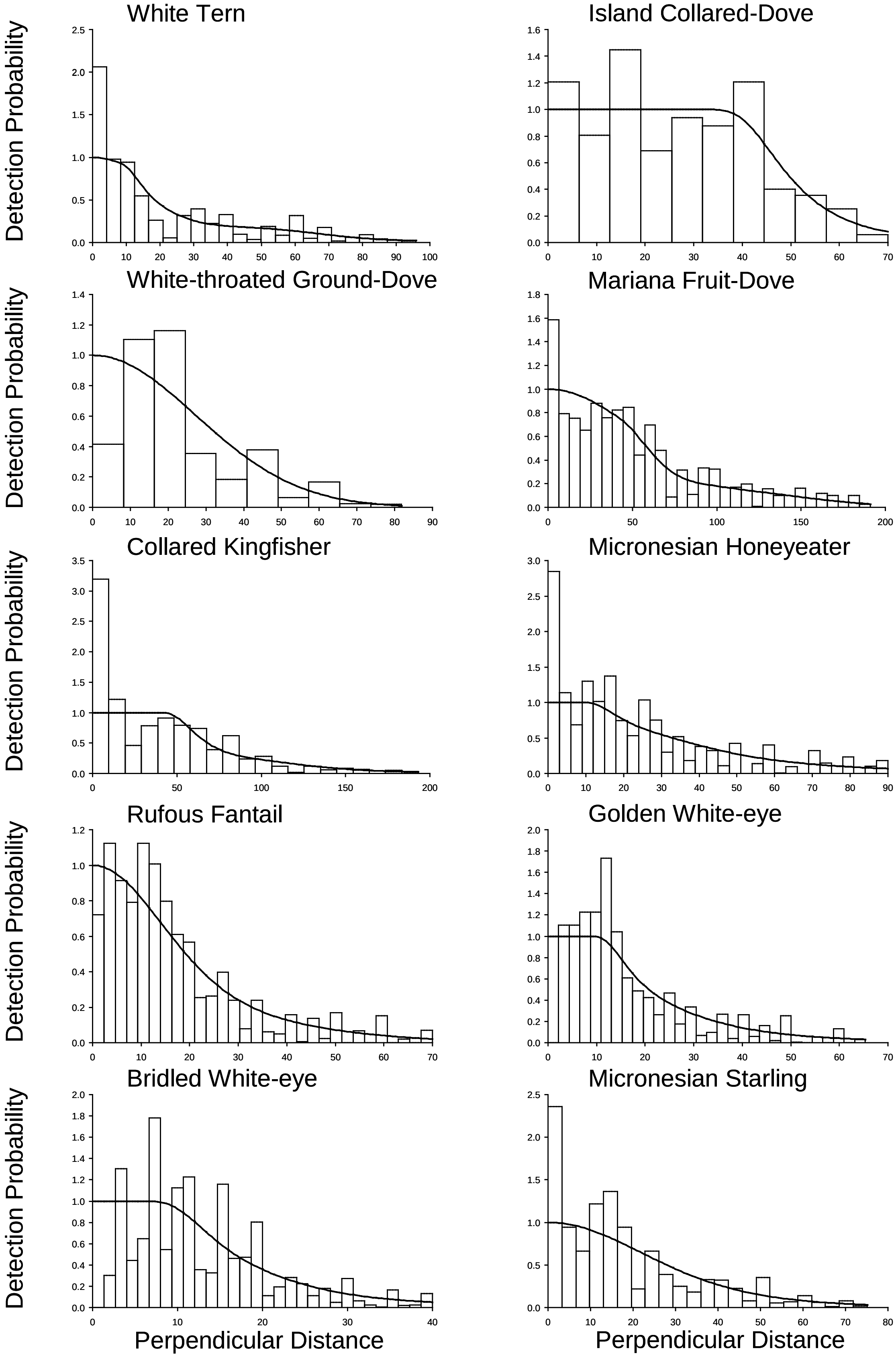



Micronesian Starling
Eurasian Tree Sparrow
Detection Probability
Perpendicular Distance
Perpendicular Distance

D. Detection function parameters used to derive population densities for each species on Aguiguan.

Species	Truncation	Key Model	Adjustment Terms	Covariates
White Tern	95.8	Half normal	Cosine (2,3)	Observer
Island Collared-Dove	70.0	Hazard rate	None	None
White-throated Ground-Dove	81.8	Half normal	None	None
Mariana Fruit-Dove	191.0	Hazard rate	Cosine (2)	Observer
Collared Kingfisher	193.0	Hazard rate	None	Year
Micronesian Honeyeater	90.0	Hazard rate	None	Observer
Rufous Fantail	70.0	Hazard rate	None	Observer
Golden White-eye	65.3	Hazard rate	None	Observer
Bridled White-eye	40.0	Hazard rate	None	Cloud
Micronesian Starling	75.1	Half normal	None	Observer

E. Histograms of bird detections used to calculate population estimates on Aguiguan. The best fit lines for these data were modeled with program DISTANCE.



Appendix 2. Results from region and year analyses for Tinian land birds.

A) Density estimates (birds/km^2), standard error (SE), and 95% confidence intervals (Lower and Upper 95% CI) by region and year.

Yellow Bittern

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	0.0	0.00	0.0	0.0
	1996	4.0	2.92	1.1	14.8
	2008	21.8	7.10	11.6	40.9
Diablo	1982	0.0	0.00	0.0	0.0
	1996	8.8	4.81	3.2	24.3
	2008	22.0	7.69	11.2	43.1
Hagoi	1982	2.0	2.01	0.4	10.7
	1996	7.9	4.10	3.0	21.0
	2008	15.8	6.59	7.1	35.1
Masalog	1982	5.9	4.27	1.6	21.9
	1996	8.9	5.25	3.0	26.8
	2008	8.9	5.25	3.0	26.8

White Tern

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	222.6	48.36	144.7	342.2
	1996	16.7	9.48	5.8	48.2
	2008	188.4	37.91	126.4	280.7
Diablo	1982	129.3	22.75	91.3	183.0
	1996	50.5	17.20	26.1	97.7
	2008	240.4	40.57	172.2	335.5
Hagoi	1982	112.0	24.79	72.2	173.5
	1996	5.5	3.83	1.5	19.4
	2008	95.6	24.72	57.4	159.1
Masalog	1982	106.5	30.64	60.1	188.6
	1996	16.4	16.40	3.0	88.9
	2008	110.6	29.96	64.5	189.7

Island Collared-Dove

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	5.8	3.01	2.2	15.4
	1996	38.8	7.08	27.0	55.7
	2008	14.3	4.45	7.8	26.3
Diablo	1982	20.4	4.48	13.3	31.4
	1996	25.4	4.91	17.3	37.1
	2008	33.1	7.27	21.5	51.0
Hagoi	1982	5.7	2.24	2.7	12.2
	1996	32.4	6.65	21.6	48.6
	2008	21.0	4.34	13.9	31.6
Masalog	1982	15.7	4.58	8.8	28.0
	1996	48.6	9.06	33.5	70.6
	2008	24.3	5.75	15.1	39.0

White-throated Ground-Dove

Region	Year	Estimate	SE	L 95%CI	U 95%CI

Carolinas	1982	3.5	3.58	0.7	19.0
	1996	1.2	1.19	0.2	6.3
	2008	4.6	2.35	1.8	12.0
Diablo	1982	4.3	1.96	1.8	10.2
	1996	5.1	2.15	2.3	11.4
	2008	37.7	7.94	25.0	56.9
Hagoi	1982	1.2	1.17	0.2	6.2
	1996	7.0	2.88	3.1	15.4
	2008	20.9	5.79	12.1	35.8
Masalog	1982	8.7	4.60	3.2	23.7
	1996	5.2	3.02	1.8	15.5
	2008	7.0	4.27	2.2	21.8

Mariana Fruit-Dove

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	53.7	4.72	45.1	64.0
	1996	12.4	1.98	9.0	17.0
	2008	35.4	3.44	29.2	43.0
Diablo	1982	37.8	2.94	32.4	44.1
	1996	21.7	2.32	17.6	26.9
	2008	38.0	2.85	32.8	44.1
Hagoi	1982	42.8	5.19	33.6	54.5
	1996	12.8	1.99	9.4	17.4
	2008	28.4	3.77	21.8	37.0
Masalog	1982	35.4	7.04	23.8	52.8
	1996	13.4	2.33	9.5	19.0
	2008	26.3	3.64	19.9	34.8

Collared Kingfisher

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	5.5	2.52	2.3	13.2
	1996	15.7	4.72	8.7	28.3
	2008	51.6	7.47	38.7	68.9
Diablo	1982	8.7	2.76	4.7	16.1
	1996	34.8	6.13	24.6	49.3
	2008	68.3	7.33	55.2	84.5
Hagoi	1982	5.4	2.48	2.3	13.0
	1996	23.5	8.07	12.1	45.9
	2008	57.9	8.41	43.4	77.4
Masalog	1982	8.1	4.14	3.1	21.5
	1996	8.1	4.14	3.1	21.5
	2008	66.5	10.47	48.5	91.4

Micronesian Honeyeater

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	91.3	14.03	67.3	123.9
	1996	52.4	10.06	35.8	76.7
	2008	67.6	11.77	47.8	95.5
Diablo	1982	97.8	10.21	79.6	120.3
	1996	34.8	7.26	23.1	52.5
	2008	43.5	7.52	30.9	61.2
Hagoi	1982	39.7	8.25	26.3	59.9

	1996	14.7	6.00	6.7	32.3
	2008	14.7	5.21	7.4	29.3
Masalog	1982	70.5	16.66	44.0	113.1
	1996	17.6	7.86	7.4	41.8
	2008	37.5	10.85	21.1	66.6

Tinian Monarch

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	498.2	59.84	392.1	633.1
	1996	630.7	77.83	493.1	806.7
	2008	346.6	63.26	241.2	498.1
Diablo	1982	856.3	55.40	753.3	973.3
	1996	750.9	61.05	639.1	882.3
	2008	485.4	46.84	400.8	587.8
Hagoi	1982	637.6	69.30	513.3	791.9
	1996	742.8	92.48	579.6	952.0
	2008	451.9	58.83	348.6	585.7
Masalog	1982	380.7	86.11	242.0	598.9
	1996	668.5	107.43	483.8	923.8
	2008	417.8	66.85	302.8	576.5

Rufous Fantail

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	661.9	85.71	511.2	857.0
	1996	910.1	78.08	766.9	1079.9
	2008	1042.1	104.31	853.5	1272.4
Diablo	1982	735.8	52.83	638.1	848.5
	1996	740.8	63.56	624.8	878.4
	2008	941.1	73.59	805.8	1099.0
Hagoi	1982	622.5	70.41	496.8	780.2
	1996	832.3	66.17	710.3	975.4
	2008	900.0	70.38	770.1	1051.7
Masalog	1982	446.6	98.39	287.2	694.6
	1996	507.5	93.23	350.8	734.3
	2008	1055.6	106.93	860.5	1295.0

Bridled White-eye

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	3266.8	167.26	2949.0	3618.8
	1996	2575.7	129.82	2328.6	2849.1
	2008	3226.9	210.72	2831.7	3677.1
Diablo	1982	3638.8	174.30	3308.4	4002.1
	1996	3005.3	155.07	2712.0	3330.2
	2008	2452.9	153.80	2165.2	2778.8
Hagoi	1982	2637.7	162.75	2331.4	2984.2
	1996	2993.9	108.38	2785.5	3218.0
	2008	3452.9	216.50	3045.8	3914.5
Masalog	1982	3000.8	251.17	2533.1	3554.7
	1996	2014.2	165.16	1706.3	2377.6
	2008	3072.7	204.33	2686.2	3514.8

Micronesian Starling

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	137.1	23.93	96.9	194.0
	1996	153.5	33.59	99.5	236.8
	2008	365.9	49.47	279.5	479.1
Diablo	1982	173.2	29.13	124.2	241.5
	1996	151.3	22.61	112.5	203.4
	2008	380.2	35.28	316.3	456.9
Hagoi	1982	134.5	20.97	98.6	183.5
	1996	80.7	19.21	50.4	129.2
	2008	363.2	42.03	288.4	457.5
Masalog	1982	48.4	17.42	23.9	98.3
	1996	96.9	24.71	58.2	161.2
	2008	242.2	31.92	185.7	315.8

Eurasian Tree Sparrow

Region	Year	Estimate	SE	L 95%CI	U 95%CI
Carolinas	1982	0.0	0.00	0.0	0.0
	1996	75.2	56.71	19.6	288.4
	2008	393.8	151.68	187.6	826.7
Diablo	1982	6.1	6.13	1.1	32.3
	1996	24.3	24.53	4.6	129.1
	2008	12.1	12.27	2.3	64.5
Hagoi	1982	0.0	0.00	0.0	0.0
	1996	0.0	0.00	0.0	0.0
	2008	0.0	0.00	0.0	0.0
Masalog	1982	0.0	0.00	0.0	0.0
	1996	0.0	0.00	0.0	0.0
	2008	49.2	39.24	11.9	203.8

B) Comparison of densities by region and year using repeated measures ANOVA for eight species with significant main effects (Table 4). Effect codes are Yr – year, Reg – region, and Y*R – interaction between year and region main effects.

White Tern

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	0.4920	0.0649	392	7.58	<.001
Yr		1982		2008	-0.0298	0.0649	392	-0.46	0.890
Yr		1996		2008	-0.5218	0.0649	392	-8.04	<.001
Reg	Carolina		Diablo		-0.0054	0.0795	196	-0.07	1.000
Reg	Carolina		Hagoi		0.2214	0.0855	196	2.59	0.050
Reg	Carolina		Masalog		0.1707	0.0947	196	1.80	0.275
Reg	Diablo		Hagoi		0.2268	0.0749	196	3.03	0.015
Reg	Diablo		Masalog		0.1761	0.0852	196	2.07	0.168
Reg	Hagoi		Masalog		-0.0507	0.0909	196	-0.56	0.944

White-throated Ground-Dove

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	-0.0042	0.0181	392	-0.23	0.971
Yr		1982		2008	-0.0934	0.0181	392	-5.16	<.001
Yr		1996		2008	-0.0891	0.0181	392	-4.93	<.001
Reg	Carolina		Diablo		-0.0845	0.0225	196	-3.75	0.001
Reg	Carolina		Hagoi		-0.0433	0.0242	196	-1.79	0.282
Reg	Carolina		Masalog		-0.0264	0.0268	196	-0.98	0.759
Reg	Diablo		Hagoi		0.0412	0.0212	196	1.94	0.214
Reg	Diablo		Masalog		0.0581	0.0241	196	2.41	0.079
Reg	Hagoi		Masalog		0.0169	0.0257	196	0.66	0.913
Yr*Reg	Carolina	1982	Diablo	1982	-0.0081	0.0355	576	-0.23	1.000
Yr*Reg	Carolina	1982	Hagoi	1982	0.0156	0.0382	576	0.41	1.000
Yr*Reg	Carolina	1982	Masalog	1982	-0.0416	0.0423	576	-0.98	0.998
Yr*Reg	Carolina	1982	Carolina	1996	0.0136	0.0380	392	0.36	1.000
Yr*Reg	Carolina	1982	Diablo	1996	-0.0148	0.0355	576	-0.42	1.000
Yr*Reg	Carolina	1982	Hagoi	1996	-0.0320	0.0382	576	-0.84	1.000
Yr*Reg	Carolina	1982	Masalog	1996	-0.0177	0.0423	576	-0.42	1.000
Yr*Reg	Carolina	1982	Carolina	2008	-0.0211	0.0380	392	-0.56	1.000
Yr*Reg	Carolina	1982	Diablo	2008	-0.2381	0.0355	576	-6.70	<.001
Yr*Reg	Carolina	1982	Hagoi	2008	-0.1210	0.0382	576	-3.16	0.072
Yr*Reg	Carolina	1982	Masalog	2008	-0.0273	0.0423	576	-0.64	1.000
Yr*Reg	Diablo	1982	Hagoi	1982	0.0238	0.0335	576	0.71	1.000
Yr*Reg	Diablo	1982	Masalog	1982	-0.0335	0.0381	576	-0.88	0.999
Yr*Reg	Diablo	1982	Carolina	1996	0.0217	0.0355	576	0.61	1.000
Yr*Reg	Diablo	1982	Diablo	1996	-0.0067	0.0288	392	-0.23	1.000
Yr*Reg	Diablo	1982	Hagoi	1996	-0.0239	0.0335	576	-0.71	1.000
Yr*Reg	Diablo	1982	Masalog	1996	-0.0096	0.0381	576	-0.25	1.000
Yr*Reg	Diablo	1982	Carolina	2008	-0.0130	0.0355	576	-0.37	1.000
Yr*Reg	Diablo	1982	Diablo	2008	-0.2299	0.0288	392	-7.99	<.001
Yr*Reg	Diablo	1982	Hagoi	2008	-0.1129	0.0335	576	-3.37	0.039
Yr*Reg	Diablo	1982	Masalog	2008	-0.0192	0.0381	576	-0.50	1.000

Yr*Reg	Hagoi	1982	Masalog	1982	-0.0572	0.0406	576	-1.41	0.962
Yr*Reg	Hagoi	1982	Carolina	1996	-0.0020	0.0382	576	-0.05	1.000
Yr*Reg	Hagoi	1982	Diablo	1996	-0.0304	0.0335	576	-0.91	0.999
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.0476	0.0345	392	-1.38	0.966
Yr*Reg	Hagoi	1982	Masalog	1996	-0.0334	0.0406	576	-0.82	1.000
Yr*Reg	Hagoi	1982	Carolina	2008	-0.0368	0.0382	576	-0.96	0.998
Yr*Reg	Hagoi	1982	Diablo	2008	-0.2537	0.0335	576	-7.57	<.001
Yr*Reg	Hagoi	1982	Hagoi	2008	-0.1366	0.0345	392	-3.97	0.005
Yr*Reg	Hagoi	1982	Masalog	2008	-0.0429	0.0406	576	-1.06	0.996
Yr*Reg	Masalog	1982	Carolina	1996	0.0552	0.0423	576	1.30	0.978
Yr*Reg	Masalog	1982	Diablo	1996	0.0268	0.0381	576	0.70	1.000
Yr*Reg	Masalog	1982	Hagoi	1996	0.0096	0.0406	576	0.24	1.000
Yr*Reg	Masalog	1982	Masalog	1996	0.0239	0.0422	392	0.57	1.000
Yr*Reg	Masalog	1982	Carolina	2008	0.0205	0.0423	576	0.48	1.000
Yr*Reg	Masalog	1982	Diablo	2008	-0.1965	0.0381	576	-5.16	<.001
Yr*Reg	Masalog	1982	Hagoi	2008	-0.0794	0.0406	576	-1.95	0.724
Yr*Reg	Masalog	1982	Masalog	2008	0.0143	0.0422	392	0.34	1.000
Yr*Reg	Carolina	1996	Diablo	1996	-0.0284	0.0355	576	-0.80	1.000
Yr*Reg	Carolina	1996	Hagoi	1996	-0.0456	0.0382	576	-1.19	0.989
Yr*Reg	Carolina	1996	Masalog	1996	-0.0313	0.0423	576	-0.74	1.000
Yr*Reg	Carolina	1996	Carolina	2008	-0.0347	0.0380	392	-0.91	0.999
Yr*Reg	Carolina	1996	Diablo	2008	-0.2517	0.0355	576	-7.08	<.001
Yr*Reg	Carolina	1996	Hagoi	2008	-0.1346	0.0382	576	-3.52	0.024
Yr*Reg	Carolina	1996	Masalog	2008	-0.0409	0.0423	576	-0.97	0.998
Yr*Reg	Diablo	1996	Hagoi	1996	-0.0172	0.0335	576	-0.51	1.000
Yr*Reg	Diablo	1996	Masalog	1996	-0.0029	0.0381	576	-0.08	1.000
Yr*Reg	Diablo	1996	Carolina	2008	-0.0063	0.0355	576	-0.18	1.000
Yr*Reg	Diablo	1996	Diablo	2008	-0.2233	0.0288	392	-7.75	<.001
Yr*Reg	Diablo	1996	Hagoi	2008	-0.1062	0.0335	576	-3.17	0.070
Yr*Reg	Diablo	1996	Masalog	2008	-0.0125	0.0381	576	-0.33	1.000
Yr*Reg	Hagoi	1996	Masalog	1996	0.0143	0.0406	576	0.35	1.000
Yr*Reg	Hagoi	1996	Carolina	2008	0.0109	0.0382	576	0.28	1.000
Yr*Reg	Hagoi	1996	Diablo	2008	-0.2061	0.0335	576	-6.15	<.001
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.0890	0.0345	392	-2.58	0.293
Yr*Reg	Hagoi	1996	Masalog	2008	0.0047	0.0406	576	0.12	1.000
Yr*Reg	Masalog	1996	Carolina	2008	-0.0034	0.0423	576	-0.08	1.000
Yr*Reg	Masalog	1996	Diablo	2008	-0.2204	0.0381	576	-5.78	<.001
Yr*Reg	Masalog	1996	Hagoi	2008	-0.1033	0.0406	576	-2.54	0.317
Yr*Reg	Masalog	1996	Masalog	2008	-0.0096	0.0422	392	-0.23	1.000
Yr*Reg	Carolina	2008	Diablo	2008	-0.2170	0.0355	576	-6.10	<.001
Yr*Reg	Carolina	2008	Hagoi	2008	-0.0999	0.0382	576	-2.61	0.277
Yr*Reg	Carolina	2008	Masalog	2008	-0.0062	0.0423	576	-0.15	1.000
Yr*Reg	Diablo	2008	Hagoi	2008	0.1171	0.0335	576	3.50	0.026
Yr*Reg	Diablo	2008	Masalog	2008	0.2108	0.0381	576	5.53	<.001
Yr*Reg	Hagoi	2008	Masalog	2008	0.0937	0.0406	576	2.31	0.474

Mariana Fruit-Dove

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	0.1941	0.0175	392	11.11	<.001
Yr		1982		2008	0.0522	0.0175	392	2.99	0.008
Yr		1996		2008	-0.1418	0.0175	392	-8.12	<.001
Reg	Carolina		Diablo		0.0185	0.0214	196	0.86	0.824
Reg	Carolina		Hagoi		0.0551	0.0230	196	2.39	0.082
Reg	Carolina		Masalog		0.0965	0.0255	196	3.78	0.001
Reg	Diablo		Hagoi		0.0366	0.0202	196	1.82	0.269
Reg	Diablo		Masalog		0.0780	0.0230	196	3.40	0.005
Reg	Hagoi		Masalog		0.0414	0.0245	196	1.69	0.332
Yr*Reg	Carolina	1982	Diablo	1982	0.1129	0.0341	578	3.31	0.047
Yr*Reg	Carolina	1982	Hagoi	1982	0.0836	0.0367	578	2.28	0.495
Yr*Reg	Carolina	1982	Masalog	1982	0.1822	0.0406	578	4.48	0.001
Yr*Reg	Carolina	1982	Carolina	1996	0.3105	0.0367	392	8.47	<.001
Yr*Reg	Carolina	1982	Diablo	1996	0.2347	0.0341	578	6.88	<.001
Yr*Reg	Carolina	1982	Hagoi	1996	0.3066	0.0367	578	8.35	<.001
Yr*Reg	Carolina	1982	Masalog	1996	0.3030	0.0406	578	7.46	<.001
Yr*Reg	Carolina	1982	Carolina	2008	0.0922	0.0367	392	2.52	0.333
Yr*Reg	Carolina	1982	Diablo	2008	0.1105	0.0341	578	3.24	0.058
Yr*Reg	Carolina	1982	Hagoi	2008	0.1779	0.0367	578	4.85	0.000
Yr*Reg	Carolina	1982	Masalog	2008	0.2070	0.0406	578	5.09	<.001
Yr*Reg	Diablo	1982	Hagoi	1982	-0.0293	0.0322	578	-0.91	0.999
Yr*Reg	Diablo	1982	Masalog	1982	0.0693	0.0366	578	1.89	0.763
Yr*Reg	Diablo	1982	Carolina	1996	0.1976	0.0341	578	5.79	<.001
Yr*Reg	Diablo	1982	Diablo	1996	0.1218	0.0278	392	4.38	0.001
Yr*Reg	Diablo	1982	Hagoi	1996	0.1937	0.0322	578	6.03	<.001
Yr*Reg	Diablo	1982	Masalog	1996	0.1901	0.0366	578	5.20	<.001
Yr*Reg	Diablo	1982	Carolina	2008	-0.0207	0.0341	578	-0.61	1.000
Yr*Reg	Diablo	1982	Diablo	2008	-0.0024	0.0278	392	-0.08	1.000
Yr*Reg	Diablo	1982	Hagoi	2008	0.0650	0.0322	578	2.02	0.679
Yr*Reg	Diablo	1982	Masalog	2008	0.0941	0.0366	578	2.57	0.298
Yr*Reg	Hagoi	1982	Masalog	1982	0.0986	0.0390	578	2.53	0.326
Yr*Reg	Hagoi	1982	Carolina	1996	0.2270	0.0367	578	6.18	<.001
Yr*Reg	Hagoi	1982	Diablo	1996	0.1511	0.0322	578	4.70	0.000
Yr*Reg	Hagoi	1982	Hagoi	1996	0.2231	0.0333	392	6.71	<.001
Yr*Reg	Hagoi	1982	Masalog	1996	0.2194	0.0390	578	5.63	<.001
Yr*Reg	Hagoi	1982	Carolina	2008	0.0086	0.0367	578	0.23	1.000
Yr*Reg	Hagoi	1982	Diablo	2008	0.0270	0.0322	578	0.84	1.000
Yr*Reg	Hagoi	1982	Hagoi	2008	0.0943	0.0333	392	2.84	0.170
Yr*Reg	Hagoi	1982	Masalog	2008	0.1234	0.0390	578	3.17	0.072
Yr*Reg	Masalog	1982	Carolina	1996	0.1284	0.0406	578	3.16	0.073
Yr*Reg	Masalog	1982	Diablo	1996	0.0525	0.0366	578	1.44	0.956
Yr*Reg	Masalog	1982	Hagoi	1996	0.1245	0.0390	578	3.19	0.066
Yr*Reg	Masalog	1982	Masalog	1996	0.1208	0.0407	392	2.97	0.123
Yr*Reg	Masalog	1982	Carolina	2008	-0.0900	0.0406	578	-2.21	0.540
Yr*Reg	Masalog	1982	Diablo	2008	-0.0716	0.0366	578	-1.96	0.721
Yr*Reg	Masalog	1982	Hagoi	2008	-0.0043	0.0390	578	-0.11	1.000

Yr*Reg	Masalog	1982	Masalog	2008	0.0249	0.0407	392	0.61	1.000
Yr*Reg	Carolina	1996	Diablo	1996	-0.0758	0.0341	578	-2.22	0.534
Yr*Reg	Carolina	1996	Hagoi	1996	-0.0039	0.0367	578	-0.11	1.000
Yr*Reg	Carolina	1996	Masalog	1996	-0.0076	0.0406	578	-0.19	1.000
Yr*Reg	Carolina	1996	Carolina	2008	-0.2184	0.0367	392	-5.96	<.001
Yr*Reg	Carolina	1996	Diablo	2008	-0.2000	0.0341	578	-5.86	<.001
Yr*Reg	Carolina	1996	Hagoi	2008	-0.1327	0.0367	578	-3.61	0.018
Yr*Reg	Carolina	1996	Masalog	2008	-0.1035	0.0406	578	-2.55	0.314
Yr*Reg	Diablo	1996	Hagoi	1996	0.0719	0.0322	578	2.24	0.523
Yr*Reg	Diablo	1996	Masalog	1996	0.0683	0.0366	578	1.87	0.779
Yr*Reg	Diablo	1996	Carolina	2008	-0.1425	0.0341	578	-4.18	0.002
Yr*Reg	Diablo	1996	Diablo	2008	-0.1242	0.0278	392	-4.47	0.001
Yr*Reg	Diablo	1996	Hagoi	2008	-0.0568	0.0322	578	-1.77	0.834
Yr*Reg	Diablo	1996	Masalog	2008	-0.0277	0.0366	578	-0.76	1.000
Yr*Reg	Hagoi	1996	Masalog	1996	-0.0037	0.0390	578	-0.09	1.000
Yr*Reg	Hagoi	1996	Carolina	2008	-0.2145	0.0367	578	-5.84	<.001
Yr*Reg	Hagoi	1996	Diablo	2008	-0.1961	0.0322	578	-6.10	<.001
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.1288	0.0333	392	-3.87	0.007
Yr*Reg	Hagoi	1996	Masalog	2008	-0.0996	0.0390	578	-2.55	0.310
Yr*Reg	Masalog	1996	Carolina	2008	-0.2108	0.0406	578	-5.19	<.001
Yr*Reg	Masalog	1996	Diablo	2008	-0.1924	0.0366	578	-5.26	<.001
Yr*Reg	Masalog	1996	Hagoi	2008	-0.1251	0.0390	578	-3.21	0.063
Yr*Reg	Masalog	1996	Masalog	2008	-0.0960	0.0407	392	-2.36	0.439
Yr*Reg	Carolina	2008	Diablo	2008	0.0184	0.0341	578	0.54	1.000
Yr*Reg	Carolina	2008	Hagoi	2008	0.0857	0.0367	578	2.33	0.454
Yr*Reg	Carolina	2008	Masalog	2008	0.1148	0.0406	578	2.83	0.173
Yr*Reg	Diablo	2008	Hagoi	2008	0.0673	0.0322	578	2.09	0.627
Yr*Reg	Diablo	2008	Masalog	2008	0.0965	0.0366	578	2.64	0.262
Yr*Reg	Hagoi	2008	Masalog	2008	0.0292	0.0390	578	0.75	1.000

Micronesian Honeyeater

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	0.2518	0.0363	392	6.94	<.001
Yr		1982		2008	0.1876	0.0363	392	5.17	<.001
Yr		1996		2008	-0.0642	0.0363	392	-1.77	0.182
Reg	Carolina		Diablo		0.0323	0.0478	196	0.68	0.906
Reg	Carolina		Hagoi		0.2413	0.0514	196	4.70	<.001
Reg	Carolina		Masalog		0.1799	0.0569	196	3.16	0.010
Reg	Diablo		Hagoi		0.2090	0.0450	196	4.64	<.001
Reg	Diablo		Masalog		0.1476	0.0512	196	2.88	0.023
Reg	Hagoi		Masalog		-0.0615	0.0546	196	-1.13	0.674

Tinian Monarch

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	-0.1750	0.0925	392	-1.89	0.143
Yr		1982		2008	0.2156	0.0925	392	2.33	0.053
Yr		1996		2008	0.3905	0.0925	392	4.22	<.001

Reg	Carolina		Diablo		-0.4019	0.1180	196	-3.40	0.004
Reg	Carolina		Hagoi		-0.2164	0.1270	196	-1.70	0.324
Reg	Carolina		Masalog		0.1388	0.1406	196	0.99	0.757
Reg	Diablo		Hagoi		0.1854	0.1112	196	1.67	0.344
Reg	Diablo		Masalog		0.5406	0.1265	196	4.27	0.000
Reg	Hagoi		Masalog		0.3552	0.1349	196	2.63	0.045
Yr*Reg	Carolina	1982	Diablo	1982	-0.7112	0.1837	572	-3.87	0.007
Yr*Reg	Carolina	1982	Hagoi	1982	-0.3605	0.1976	572	-1.82	0.804
Yr*Reg	Carolina	1982	Masalog	1982	0.4406	0.2188	572	2.01	0.684
Yr*Reg	Carolina	1982	Carolina	1996	-0.3105	0.1942	392	-1.60	0.909
Yr*Reg	Carolina	1982	Diablo	1996	-0.4804	0.1837	572	-2.62	0.275
Yr*Reg	Carolina	1982	Hagoi	1996	-0.3738	0.1976	572	-1.89	0.764
Yr*Reg	Carolina	1982	Masalog	1996	-0.1663	0.2188	572	-0.76	1.000
Yr*Reg	Carolina	1982	Carolina	2008	0.2374	0.1942	392	1.22	0.987
Yr*Reg	Carolina	1982	Diablo	2008	-0.0871	0.1837	572	-0.47	1.000
Yr*Reg	Carolina	1982	Hagoi	2008	0.0120	0.1976	572	0.06	1.000
Yr*Reg	Carolina	1982	Masalog	2008	0.0689	0.2188	572	0.32	1.000
Yr*Reg	Diablo	1982	Hagoi	1982	0.3507	0.1731	572	2.03	0.675
Yr*Reg	Diablo	1982	Masalog	1982	1.1518	0.1969	572	5.85	<.001
Yr*Reg	Diablo	1982	Carolina	1996	0.4007	0.1837	572	2.18	0.564
Yr*Reg	Diablo	1982	Diablo	1996	0.2308	0.1473	392	1.57	0.920
Yr*Reg	Diablo	1982	Hagoi	1996	0.3374	0.1731	572	1.95	0.727
Yr*Reg	Diablo	1982	Masalog	1996	0.5449	0.1969	572	2.77	0.198
Yr*Reg	Diablo	1982	Carolina	2008	0.9486	0.1837	572	5.16	<.001
Yr*Reg	Diablo	1982	Diablo	2008	0.6241	0.1473	392	4.24	0.002
Yr*Reg	Diablo	1982	Hagoi	2008	0.7231	0.1731	572	4.18	0.002
Yr*Reg	Diablo	1982	Masalog	2008	0.7801	0.1969	572	3.96	0.005
Yr*Reg	Hagoi	1982	Masalog	1982	0.8011	0.2100	572	3.82	0.009
Yr*Reg	Hagoi	1982	Carolina	1996	0.0500	0.1976	572	0.25	1.000
Yr*Reg	Hagoi	1982	Diablo	1996	-0.1199	0.1731	572	-0.69	1.000
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.0133	0.1762	392	-0.08	1.000
Yr*Reg	Hagoi	1982	Masalog	1996	0.1942	0.2100	572	0.92	0.999
Yr*Reg	Hagoi	1982	Carolina	2008	0.5979	0.1976	572	3.03	0.105
Yr*Reg	Hagoi	1982	Diablo	2008	0.2734	0.1731	572	1.58	0.916
Yr*Reg	Hagoi	1982	Hagoi	2008	0.3725	0.1762	392	2.11	0.613
Yr*Reg	Hagoi	1982	Masalog	2008	0.4294	0.2100	572	2.05	0.662
Yr*Reg	Masalog	1982	Carolina	1996	-0.7511	0.2188	572	-3.43	0.032
Yr*Reg	Masalog	1982	Diablo	1996	-0.9210	0.1969	572	-4.68	0.000
Yr*Reg	Masalog	1982	Hagoi	1996	-0.8144	0.2100	572	-3.88	0.007
Yr*Reg	Masalog	1982	Masalog	1996	-0.6069	0.2158	392	-2.81	0.179
Yr*Reg	Masalog	1982	Carolina	2008	-0.2033	0.2188	572	-0.93	0.999
Yr*Reg	Masalog	1982	Diablo	2008	-0.5278	0.1969	572	-2.68	0.240
Yr*Reg	Masalog	1982	Hagoi	2008	-0.4287	0.2100	572	-2.04	0.664
Yr*Reg	Masalog	1982	Masalog	2008	-0.3717	0.2158	392	-1.72	0.857
Yr*Reg	Carolina	1996	Diablo	1996	-0.1699	0.1837	572	-0.92	0.999
Yr*Reg	Carolina	1996	Hagoi	1996	-0.0633	0.1976	572	-0.32	1.000
Yr*Reg	Carolina	1996	Masalog	1996	0.1442	0.2188	572	0.66	1.000

Yr*Reg	Carolina	1996	Carolina	2008	0.5479	0.1942	392	2.82	0.175
Yr*Reg	Carolina	1996	Diablo	2008	0.2234	0.1837	572	1.22	0.988
Yr*Reg	Carolina	1996	Hagoi	2008	0.3225	0.1976	572	1.63	0.896
Yr*Reg	Carolina	1996	Masalog	2008	0.3794	0.2188	572	1.73	0.851
Yr*Reg	Diablo	1996	Hagoi	1996	0.1066	0.1731	572	0.62	1.000
Yr*Reg	Diablo	1996	Masalog	1996	0.3141	0.1969	572	1.60	0.910
Yr*Reg	Diablo	1996	Carolina	2008	0.7177	0.1837	572	3.91	0.006
Yr*Reg	Diablo	1996	Diablo	2008	0.3932	0.1473	392	2.67	0.245
Yr*Reg	Diablo	1996	Hagoi	2008	0.4923	0.1731	572	2.84	0.166
Yr*Reg	Diablo	1996	Masalog	2008	0.5493	0.1969	572	2.79	0.188
Yr*Reg	Hagoi	1996	Masalog	1996	0.2075	0.2100	572	0.99	0.998
Yr*Reg	Hagoi	1996	Carolina	2008	0.6112	0.1976	572	3.09	0.088
Yr*Reg	Hagoi	1996	Diablo	2008	0.2867	0.1731	572	1.66	0.887
Yr*Reg	Hagoi	1996	Hagoi	2008	0.3857	0.1762	392	2.19	0.559
Yr*Reg	Hagoi	1996	Masalog	2008	0.4427	0.2100	572	2.11	0.617
Yr*Reg	Masalog	1996	Carolina	2008	0.4037	0.2188	572	1.85	0.792
Yr*Reg	Masalog	1996	Diablo	2008	0.0792	0.1969	572	0.40	1.000
Yr*Reg	Masalog	1996	Hagoi	2008	0.1783	0.2100	572	0.85	1.000
Yr*Reg	Masalog	1996	Masalog	2008	0.2352	0.2158	392	1.09	0.995
Yr*Reg	Carolina	2008	Diablo	2008	-0.3245	0.1837	572	-1.77	0.835
Yr*Reg	Carolina	2008	Hagoi	2008	-0.2254	0.1976	572	-1.14	0.993
Yr*Reg	Carolina	2008	Masalog	2008	-0.1685	0.2188	572	-0.77	1.000
Yr*Reg	Diablo	2008	Hagoi	2008	0.0991	0.1731	572	0.57	1.000
Yr*Reg	Diablo	2008	Masalog	2008	0.1561	0.1969	572	0.79	1.000
Yr*Reg	Hagoi	2008	Masalog	2008	0.0570	0.2100	572	0.27	1.000

Rufous Fantail

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	-0.2980	0.0868	392	-3.43	0.002
Yr		1982		2008	-0.6521	0.0868	392	-7.52	<.001
Yr		1996		2008	-0.3542	0.0868	392	-4.08	0.000
Reg	Carolina		Diablo		0.0887	0.1147	196	0.77	0.866
Reg	Carolina		Hagoi		0.0847	0.1234	196	0.69	0.902
Reg	Carolina		Masalog		0.4970	0.1367	196	3.64	0.002
Reg	Diablo		Hagoi		-0.0040	0.1081	196	-0.04	1.000
Reg	Diablo		Masalog		0.4082	0.1230	196	3.32	0.006
Reg	Hagoi		Masalog		0.4122	0.1312	196	3.14	0.010
Yr*Reg	Carolina	1982	Diablo	1982	-0.4308	0.1748	564	-2.46	0.366
Yr*Reg	Carolina	1982	Hagoi	1982	-0.1465	0.1881	564	-0.78	1.000
Yr*Reg	Carolina	1982	Masalog	1982	0.4411	0.2083	564	2.12	0.610
Yr*Reg	Carolina	1982	Carolina	1996	-0.7967	0.1821	392	-4.38	0.001
Yr*Reg	Carolina	1982	Diablo	1996	-0.2829	0.1748	564	-1.62	0.902
Yr*Reg	Carolina	1982	Hagoi	1996	-0.5348	0.1881	564	-2.84	0.166
Yr*Reg	Carolina	1982	Masalog	1996	0.2863	0.2083	564	1.37	0.968
Yr*Reg	Carolina	1982	Carolina	2008	-0.7584	0.1821	392	-4.17	0.002
Yr*Reg	Carolina	1982	Diablo	2008	-0.5752	0.1748	564	-3.29	0.050
Yr*Reg	Carolina	1982	Hagoi	2008	-0.6196	0.1881	564	-3.29	0.049

Yr*Reg	Carolina	1982	Masalog	2008	-0.7916	0.2083	564	-3.80	0.009
Yr*Reg	Diablo	1982	Hagoi	1982	0.2843	0.1648	564	1.73	0.856
Yr*Reg	Diablo	1982	Masalog	1982	0.8719	0.1874	564	4.65	0.000
Yr*Reg	Diablo	1982	Carolina	1996	-0.3659	0.1748	564	-2.09	0.628
Yr*Reg	Diablo	1982	Diablo	1996	0.1479	0.1381	392	1.07	0.996
Yr*Reg	Diablo	1982	Hagoi	1996	-0.1040	0.1648	564	-0.63	1.000
Yr*Reg	Diablo	1982	Masalog	1996	0.7171	0.1874	564	3.83	0.008
Yr*Reg	Diablo	1982	Carolina	2008	-0.3276	0.1748	564	-1.87	0.775
Yr*Reg	Diablo	1982	Diablo	2008	-0.1444	0.1381	392	-1.05	0.997
Yr*Reg	Diablo	1982	Hagoi	2008	-0.1887	0.1648	564	-1.15	0.992
Yr*Reg	Diablo	1982	Masalog	2008	-0.3608	0.1874	564	-1.92	0.743
Yr*Reg	Hagoi	1982	Masalog	1982	0.5875	0.1999	564	2.94	0.131
Yr*Reg	Hagoi	1982	Carolina	1996	-0.6502	0.1881	564	-3.46	0.030
Yr*Reg	Hagoi	1982	Diablo	1996	-0.1364	0.1648	564	-0.83	1.000
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.3883	0.1652	392	-2.35	0.443
Yr*Reg	Hagoi	1982	Masalog	1996	0.4328	0.1999	564	2.17	0.576
Yr*Reg	Hagoi	1982	Carolina	2008	-0.6120	0.1881	564	-3.25	0.056
Yr*Reg	Hagoi	1982	Diablo	2008	-0.4287	0.1648	564	-2.60	0.282
Yr*Reg	Hagoi	1982	Hagoi	2008	-0.4731	0.1652	392	-2.86	0.159
Yr*Reg	Hagoi	1982	Masalog	2008	-0.6451	0.1999	564	-3.23	0.060
Yr*Reg	Masalog	1982	Carolina	1996	-1.2377	0.2083	564	-5.94	<.001
Yr*Reg	Masalog	1982	Diablo	1996	-0.7240	0.1874	564	-3.86	0.007
Yr*Reg	Masalog	1982	Hagoi	1996	-0.9759	0.1999	564	-4.88	<.001
Yr*Reg	Masalog	1982	Masalog	1996	-0.1548	0.2024	392	-0.76	1.000
Yr*Reg	Masalog	1982	Carolina	2008	-1.1995	0.2083	564	-5.76	<.001
Yr*Reg	Masalog	1982	Diablo	2008	-1.0163	0.1874	564	-5.42	<.001
Yr*Reg	Masalog	1982	Hagoi	2008	-1.0606	0.1999	564	-5.31	<.001
Yr*Reg	Masalog	1982	Masalog	2008	-1.2326	0.2024	392	-6.09	<.001
Yr*Reg	Carolina	1996	Diablo	1996	0.5138	0.1748	564	2.94	0.132
Yr*Reg	Carolina	1996	Hagoi	1996	0.2618	0.1881	564	1.39	0.965
Yr*Reg	Carolina	1996	Masalog	1996	1.0830	0.2083	564	5.20	<.001
Yr*Reg	Carolina	1996	Carolina	2008	0.0382	0.1821	392	0.21	1.000
Yr*Reg	Carolina	1996	Diablo	2008	0.2215	0.1748	564	1.27	0.983
Yr*Reg	Carolina	1996	Hagoi	2008	0.1771	0.1881	564	0.94	0.999
Yr*Reg	Carolina	1996	Masalog	2008	0.0051	0.2083	564	0.02	1.000
Yr*Reg	Diablo	1996	Hagoi	1996	-0.2519	0.1648	564	-1.53	0.932
Yr*Reg	Diablo	1996	Masalog	1996	0.5692	0.1874	564	3.04	0.102
Yr*Reg	Diablo	1996	Carolina	2008	-0.4755	0.1748	564	-2.72	0.221
Yr*Reg	Diablo	1996	Diablo	2008	-0.2923	0.1381	392	-2.12	0.611
Yr*Reg	Diablo	1996	Hagoi	2008	-0.3366	0.1648	564	-2.04	0.663
Yr*Reg	Diablo	1996	Masalog	2008	-0.5087	0.1874	564	-2.71	0.223
Yr*Reg	Hagoi	1996	Masalog	1996	0.8211	0.1999	564	4.11	0.003
Yr*Reg	Hagoi	1996	Carolina	2008	-0.2236	0.1881	564	-1.19	0.990
Yr*Reg	Hagoi	1996	Diablo	2008	-0.0404	0.1648	564	-0.25	1.000
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.0847	0.1652	392	-0.51	1.000
Yr*Reg	Hagoi	1996	Masalog	2008	-0.2568	0.1999	564	-1.28	0.981
Yr*Reg	Masalog	1996	Carolina	2008	-1.0447	0.2083	564	-5.02	<.001

Yr*Reg	Masalog	1996	Diablo	2008	-0.8615	0.1874	564	-4.60	0.000
Yr*Reg	Masalog	1996	Hagoi	2008	-0.9058	0.1999	564	-4.53	0.001
Yr*Reg	Masalog	1996	Masalog	2008	-1.0779	0.2024	392	-5.33	<.001
Yr*Reg	Carolina	2008	Diablo	2008	0.1832	0.1748	564	1.05	0.996
Yr*Reg	Carolina	2008	Hagoi	2008	0.1389	0.1881	564	0.74	1.000
Yr*Reg	Carolina	2008	Masalog	2008	-0.0332	0.2083	564	-0.16	1.000
Yr*Reg	Diablo	2008	Hagoi	2008	-0.0443	0.1648	564	-0.27	1.000
Yr*Reg	Diablo	2008	Masalog	2008	-0.2164	0.1874	564	-1.15	0.992
Yr*Reg	Hagoi	2008	Masalog	2008	-0.1720	0.1999	564	-0.86	0.999

Bridled White-eye

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	0.1766	0.0464	392	3.81	0.001
Yr		1982		2008	0.0071	0.0464	392	0.15	0.987
Yr		1996		2008	-0.1695	0.0464	392	-3.65	0.001
Reg	Carolina		Diablo		0.1128	0.0523	196	2.16	0.139
Reg	Carolina		Hagoi		0.0699	0.0563	196	1.24	0.601
Reg	Carolina		Masalog		0.2577	0.0623	196	4.14	0.000
Reg	Diablo		Hagoi		-0.0429	0.0493	196	-0.87	0.820
Reg	Diablo		Masalog		0.1449	0.0561	196	2.58	0.051
Reg	Hagoi		Masalog		0.1878	0.0598	196	3.14	0.010
Yr*Reg	Carolina	1982	Diablo	1982	-0.0421	0.0878	587	-0.48	1.000
Yr*Reg	Carolina	1982	Hagoi	1982	0.2615	0.0945	587	2.77	0.198
Yr*Reg	Carolina	1982	Masalog	1982	0.2141	0.1046	587	2.05	0.661
Yr*Reg	Carolina	1982	Carolina	1996	0.2121	0.0974	392	2.18	0.566
Yr*Reg	Carolina	1982	Diablo	1996	0.1620	0.0878	587	1.84	0.792
Yr*Reg	Carolina	1982	Hagoi	1996	0.1099	0.0945	587	1.16	0.991
Yr*Reg	Carolina	1982	Masalog	1996	0.6562	0.1046	587	6.27	<.001
Yr*Reg	Carolina	1982	Carolina	2008	-0.0335	0.0974	392	-0.34	1.000
Yr*Reg	Carolina	1982	Diablo	2008	0.3972	0.0878	587	4.52	0.001
Yr*Reg	Carolina	1982	Hagoi	2008	0.0169	0.0945	587	0.18	1.000
Yr*Reg	Carolina	1982	Masalog	2008	0.0813	0.1046	587	0.78	1.000
Yr*Reg	Diablo	1982	Hagoi	1982	0.3037	0.0828	587	3.67	0.015
Yr*Reg	Diablo	1982	Masalog	1982	0.2563	0.0942	587	2.72	0.220
Yr*Reg	Diablo	1982	Carolina	1996	0.2542	0.0878	587	2.89	0.147
Yr*Reg	Diablo	1982	Diablo	1996	0.2041	0.0739	392	2.76	0.200
Yr*Reg	Diablo	1982	Hagoi	1996	0.1520	0.0828	587	1.84	0.797
Yr*Reg	Diablo	1982	Masalog	1996	0.6983	0.0942	587	7.42	<.001
Yr*Reg	Diablo	1982	Carolina	2008	0.0086	0.0878	587	0.10	1.000
Yr*Reg	Diablo	1982	Diablo	2008	0.4393	0.0739	392	5.95	<.001
Yr*Reg	Diablo	1982	Hagoi	2008	0.0590	0.0828	587	0.71	1.000
Yr*Reg	Diablo	1982	Masalog	2008	0.1235	0.0942	587	1.31	0.977
Yr*Reg	Hagoi	1982	Masalog	1982	-0.0474	0.1004	587	-0.47	1.000
Yr*Reg	Hagoi	1982	Carolina	1996	-0.0495	0.0945	587	-0.52	1.000
Yr*Reg	Hagoi	1982	Diablo	1996	-0.0996	0.0828	587	-1.20	0.989
Yr*Reg	Hagoi	1982	Hagoi	1996	-0.1517	0.0884	392	-1.72	0.860
Yr*Reg	Hagoi	1982	Masalog	1996	0.3946	0.1004	587	3.93	0.006

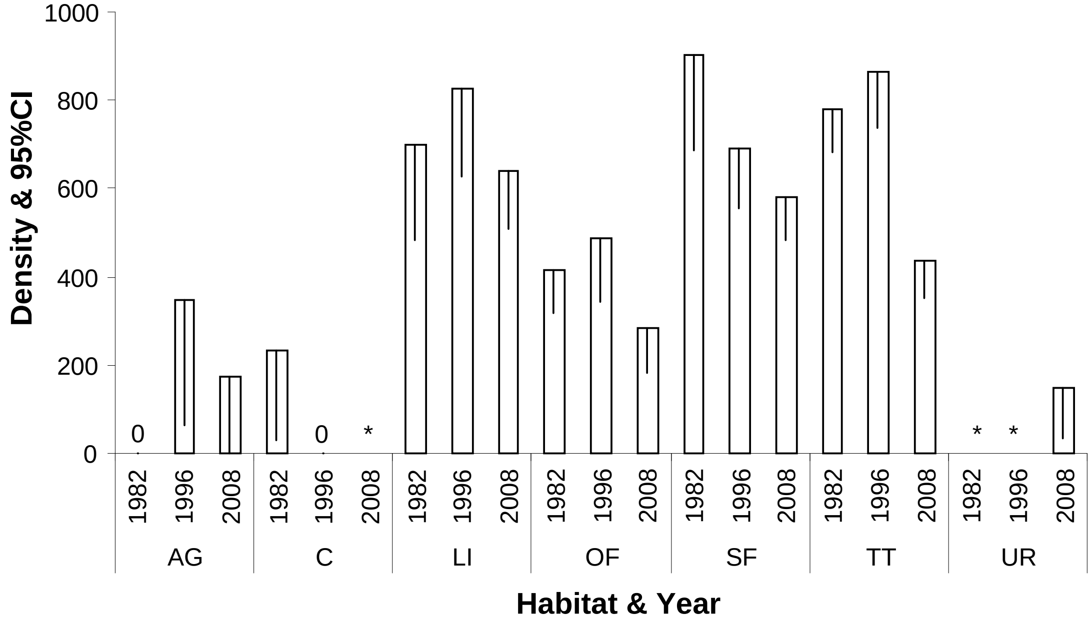
Yr*Reg	Hagoi	1982	Carolina	2008	-0.2950	0.0945	587	-3.12	0.081
Yr*Reg	Hagoi	1982	Diablo	2008	0.1357	0.0828	587	1.64	0.894
Yr*Reg	Hagoi	1982	Hagoi	2008	-0.2447	0.0884	392	-2.77	0.198
Yr*Reg	Hagoi	1982	Masalog	2008	-0.1802	0.1004	587	-1.79	0.820
Yr*Reg	Masalog	1982	Carolina	1996	-0.0021	0.1046	587	-0.02	1.000
Yr*Reg	Masalog	1982	Diablo	1996	-0.0522	0.0942	587	-0.55	1.000
Yr*Reg	Masalog	1982	Hagoi	1996	-0.1043	0.1004	587	-1.04	0.997
Yr*Reg	Masalog	1982	Masalog	1996	0.4420	0.1082	392	4.09	0.003
Yr*Reg	Masalog	1982	Carolina	2008	-0.2476	0.1046	587	-2.37	0.431
Yr*Reg	Masalog	1982	Diablo	2008	0.1831	0.0942	587	1.94	0.730
Yr*Reg	Masalog	1982	Hagoi	2008	-0.1972	0.1004	587	-1.96	0.717
Yr*Reg	Masalog	1982	Masalog	2008	-0.1328	0.1082	392	-1.23	0.987
Yr*Reg	Carolina	1996	Diablo	1996	-0.0501	0.0878	587	-0.57	1.000
Yr*Reg	Carolina	1996	Hagoi	1996	-0.1022	0.0945	587	-1.08	0.995
Yr*Reg	Carolina	1996	Masalog	1996	0.4441	0.1046	587	4.25	0.002
Yr*Reg	Carolina	1996	Carolina	2008	-0.2455	0.0974	392	-2.52	0.329
Yr*Reg	Carolina	1996	Diablo	2008	0.1851	0.0878	587	2.11	0.617
Yr*Reg	Carolina	1996	Hagoi	2008	-0.1952	0.0945	587	-2.07	0.648
Yr*Reg	Carolina	1996	Masalog	2008	-0.1307	0.1046	587	-1.25	0.985
Yr*Reg	Diablo	1996	Hagoi	1996	-0.0521	0.0828	587	-0.63	1.000
Yr*Reg	Diablo	1996	Masalog	1996	0.4942	0.0942	587	5.25	<.001
Yr*Reg	Diablo	1996	Carolina	2008	-0.1954	0.0878	587	-2.23	0.532
Yr*Reg	Diablo	1996	Diablo	2008	0.2352	0.0739	392	3.19	0.068
Yr*Reg	Diablo	1996	Hagoi	2008	-0.1451	0.0828	587	-1.75	0.842
Yr*Reg	Diablo	1996	Masalog	2008	-0.0806	0.0942	587	-0.86	0.999
Yr*Reg	Hagoi	1996	Masalog	1996	0.5463	0.1004	587	5.44	<.001
Yr*Reg	Hagoi	1996	Carolina	2008	-0.1433	0.0945	587	-1.52	0.935
Yr*Reg	Hagoi	1996	Diablo	2008	0.2874	0.0828	587	3.47	0.028
Yr*Reg	Hagoi	1996	Hagoi	2008	-0.0930	0.0884	392	-1.05	0.996
Yr*Reg	Hagoi	1996	Masalog	2008	-0.0285	0.1004	587	-0.28	1.000
Yr*Reg	Masalog	1996	Carolina	2008	-0.6897	0.1046	587	-6.59	<.001
Yr*Reg	Masalog	1996	Diablo	2008	-0.2590	0.0942	587	-2.75	0.206
Yr*Reg	Masalog	1996	Hagoi	2008	-0.6393	0.1004	587	-6.37	<.001
Yr*Reg	Masalog	1996	Masalog	2008	-0.5748	0.1082	392	-5.31	<.001
Yr*Reg	Carolina	2008	Diablo	2008	0.4307	0.0878	587	4.90	<.001
Yr*Reg	Carolina	2008	Hagoi	2008	0.0504	0.0945	587	0.53	1.000
Yr*Reg	Carolina	2008	Masalog	2008	0.1148	0.1046	587	1.10	0.995
Yr*Reg	Diablo	2008	Hagoi	2008	-0.3803	0.0828	587	-4.60	0.000
Yr*Reg	Diablo	2008	Masalog	2008	-0.3159	0.0942	587	-3.35	0.041
Yr*Reg	Hagoi	2008	Masalog	2008	0.0645	0.1004	587	0.64	1.000

Micronesian Starling

Effect	Region	Year	Region	Year	Estimate	SE	DF	*t* Value	Adj *P*
Yr		1982		1996	0.0097	0.0677	392	0.14	0.989
Yr		1982		2008	-0.6479	0.0677	392	-9.57	<.001
Yr		1996		2008	-0.6576	0.0677	392	-9.72	<.001
Reg	Carolina		Diablo		-0.0766	0.0877	196	-0.87	0.819

Reg	Carolina	Hagoi	0.0316	0.0944	196	0.34	0.987
Reg	Carolina	Masalog	0.2310	0.1045	196	2.21	0.124
Reg	Diablo	Hagoi	0.1082	0.0827	196	1.31	0.558
Reg	Diablo	Masalog	0.3076	0.0941	196	3.27	0.007
Reg	Hagoi	Masalog	0.1994	0.1003	196	1.99	0.196

Appendix 3. Break down of the Tinian Monarch population by habitat and year.



A) Plot of Tinian Monarch density estimates (birds/km^2) and lower 95% confidence interval by habitat and year from all transects (10 in 1982 and 1996, and 14 in 2008). Habitat types are AG – agriculture, C – coastal, LI – limestone forest, OF – open field, SF – secondary forest, TT – tangantangan thicket, and UR – urban/residential. No birds were detected in the agriculture habitat in 1982 or coastal habitat in 1996. No stations (indicated with *) were surveyed in the coastal habitat in 2008, and urban/residential habitat in 1996 and 2008.

B) Tinian Monarch density estimates (birds/km^2), standard error (SE), and 95% confidence intervals (Lower and Upper 95% CI) by habitat and year from all transects (10 in 1982 and 1996, and 14 in 2008). Habitat types are AG – agriculture, C – coastal, LI – limestone forest, OF – open field, SF – secondary forest, TT – tangantangan thicket, and UR – urban/residential. No birds were detected in the agriculture habitat in 1982 or coastal habitat in 1996. No stations (indicated with *) were surveyed in the coastal habitat in 2008, and urban/residential habitat in 1996 and 2008.

Habitat	Year	Estimate	SE	L 95%CI	U 95%CI
AG	1982	0.0			
	1996	349.4	201.96	63.561	1920.800
	2008	174.7	174.77	†	†
C	1982	232.9	116.66	30.770	1763.400
	1996	0.0			
	2008	*			
LI	1982	698.8	123.97	483.410	1010.200
	1996	825.9	111.49	625.330	1090.700
	2008	640.6	73.54	509.490	805.400
OF	1982	414.9	56.68	316.340	544.230
	1996	485.8	84.62	342.690	688.560
	2008	283.3	63.74	180.590	444.440
SF	1982	901.1	117.05	687.880	1180.400
	1996	691.2	76.45	553.930	862.540
	2008	582.4	54.28	483.960	700.740
TT	1982	778.2	51.52	682.940	886.810
	1996	863.2	68.80	737.510	1010.400
	2008	435.7	46.84	352.230	539.030
UR	1982	*			
	1996	*			
	2008	149.8	103.99	32.300	694.240

† Sample size was insufficient to estimate reliable confidence intervals.

C) Comparison of Tinian Monarch densities by habitat and year using repeated measures ANOVA from all transects (10 in 1982 and 1996, and 14 in 2008). Year and habitat fixed effects were significant but the year and habitat interaction was non-significant ($F_{8,623} = 0.62$, $p = 0.764$); therefore, only effects by habitat are presented here. Differences among years are presented in Table 4. Significant differences are highlighted in bold. Habitat types are LI – limestone forest, OF – open field, SF – secondary forest, and TT – tangantangan thicket; agriculture, coastal, and urban/residential (ACU) habitats were combined because insufficient numbers of stations were sampled in those habitats.

Effect	Num DF	Den DF	*F* Value	Pr > *F*
Habitat	4	645	15.04	<.0001

Effect	Effect	Estimate	Error	*t* Value	Adj *P*
ACU	**LI**	**-1.002**	**0.250**	**-4.00**	**<.001**
ACU	OF	-0.354	0.243	-1.45	0.592
ACU	**SF**	**-0.958**	**0.245**	**-3.91**	**<.001**
ACU	**TT**	**-0.999**	**0.236**	**-4.23**	**<.001**
LI	**OF**	**0.648**	**0.132**	**4.91**	**<.001**
LI	SF	0.044	0.134	0.33	0.998
LI	TT	0.003	0.118	0.03	1.000
OF	**SF**	**-0.604**	**0.119**	**-5.10**	**<.001**
OF	**TT**	**-0.645**	**0.100**	**-6.43**	**<.001**
SF	TT	-0.041	0.102	-0.40	0.995

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Appendix K - Aircraft Carrier

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Architect-Engineering Services for Environmental Planning Support
Strategic Forward Basing Initiatives and Related Technical Services and Activities
At Various Navy and Marine Corps Locations, Pacific Basin and Indian Ocean Areas
Contract No. N62742-06-D-1870
Amendment No. 0024

Dredged Material Upland Placement Study
Apra Harbor, Guam

Final Report

Prepared For:

Department of the Navy
Naval Facilities Engineering Command Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, Hawaii 96860-3134

May 2008

NAVFAC Naval Facilities Engineering Command PACIFIC DIVISION

TEC Inc. Joint Venture
A Joint Venture of TEC Inc., Earth Tech, Inc., and EDAW, Inc.

WESTON SOLUTIONS

Dredged Material Upland Placement Study
Apra Harbor, Guam

Final Report

Prepared For:

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May 2008

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LIST OF ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
ARG	Amphibious Readiness Group
ARPA	Archaeological Resources Protection Act
BMPs	Best Management Practices
CAA	Clean Air Act
CAD	Confined Aquatic Disposal
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CO	Carbon Monoxide
COMNAVREGMAR	Commander, U.S. Navy Region Marianas
CVN	Carrier Vessel Nuclear
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
CZMP	Coastal Zone Management Program
DMMP	Dredged Material Management Plan
DMPF	Dredged Material Processing Facility
DoD	Department of Defense
DON	Department of Navy
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
ER-M	Effects Range - Median
ESA	Endangered Species Act
ESQD	Explosive Safety Quantity Distance
FAA	Federal Aviation Administration
FWCA	Fish and Wildlife Coordination Act
FY	Fiscal Year
GEDA	Guam Economic Development Authority
GEPA	Guam Environmental Protection Agency
HHFP	Helber, Hastert, & Fee, Planners
HUD	U.S. Housing and Urban Development
LPC	limiting permissible criteria
MPRSA	Marine Protection, Research and Sanctuaries Act
MLLW	Mean Lower Low Water
MOU	Memorandum of Understanding
NAAQS	National Ambient Air Quality Standards
NAVFAC PAC	U.S. Naval Facilities Engineering Command, Pacific
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NO_X	Oxides of Nitrogen
O&M	Operations and Maintenance
ODMDS	Ocean Dredged Material Disposal Site
PCB	Polychlorinated biphenyls

PM_{10}	Particulate Matter 10 Microns or Less
PWC	United States Navy Public Works Center
RCRA	Resource Conservation and Recovery Act
RHA	Rivers and Harbors Act
SARA	Superfund Amendments and Reauthorization Act
SO_X	Oxides of Sulfur
SP	Solid Phase
SPP	Suspended Particulate Phase
SRF	Ship Repair Facility
T-AKE	Advanced Auxiliary Dry Cargo Ships
U.S.	United States
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
WRDA	Water Resources Development Act

UNITS OF MEASURE

a	acre
dBA	A-weighted decibels
cy	cubic yards
ft	feet
ha	hectare
km	kilometers
m	meters
m^2	square meters
m^3	cubic meters
mcy	million cubic meters
mi	miles
mm	millimeter
ppm	parts per million
sf	square foot
%	percent
µg/kg	microgram per kilogram

EXECUTIVE SUMMARY

A Phase I Dredged Material Management Plan (DMMP), Commander, United States [U.S.] Navy Region Marianas (COMNAVREGMAR), Guam (MEC Analytical System [MEC]-Weston Solutions Inc.[Weston] 2005), was developed to assist the Navy to complete the proposed construction dredging projects in an efficient, environmentally sound, logistical feasible and cost effective manner. The Phase I DMMP identified potential placement and beneficial use alternatives for the successful management of dredged material from planned construction dredging projects. In the three years following the development of the Phase I DMMP, changes to the Navy's waterfront functional plans and new mission preparedness objectives have subsequently required a review and update of the Phase I DMMP. This Upland Placement Study is essentially a revision, or update, to the Phase I DMMP developed by Weston in 2005. This study revisits each dewatering site and beneficial use alternative proposed in the Phase I DMMP, and addresses the viability of each alternative with respect to new dredging requirements and construction schedules. Recently developed waterfront functional plans for Sierra Wharf, Victor and Uniform Wharves, and feasibility studies for the construction of a Carrier Vessel Nuclear (CVN) capable berth (TEC Inc. JV 2008) were used to assist in the reevaluation of potential management alternatives.

Vessels with deep drafts, including scheduled operations with a Carrier Vessel Nuclear (CVN) 68 and CVN 78, and increased ship visits are anticipated for Apra Harbor (Helber, Hastert & Fee, Planners [HHFP] 2003b; TEC Inc. JV 2008). Maintenance and construction dredging will be required to accommodate these new, larger vessels and increased traffic.

To accommodate further operational needs, the Navy proposed two construction projects to increase design depths of Inner and Outer Apra Harbor (HHFP 2003b; TEC Inc. JV 2008-in progress). P-433, scheduled for Fiscal Year (FY)10, will dredge approximately 508,877 cubic yards (cy) (389,064 cubic meters [m^3]) of sediment along Sierra and Tango Wharves. The unscheduled CVN capable berth project is estimated to require between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3) of sediment to be dredged depending on which alternative CVN site is selected (Table ES-1). Together, the P-433 and CVN projects result in the need to manage an additional volume of 987,777 cy to 1,266,877 cy (755,209 m^3 and 968,597 m^3), depending on the final CVN alternative selected.[1]

Mechanical dredging is the recommended dredging method and has been used in past Guam dredging projects. While the production volume is considerably less than the volume dredged by other means (i.e., hydraulically), the nature of mechanically dredged material is better suited for the management alternatives described herein. As stated in the Phase I DMMP, a bulking factor of 10 percent (%) should be applied to dredged volume during mechanical dredging. Dredged volumes used in this report do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008-in progress).

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[1] Dredge volumes include a 2-foot overdredge.

Table ES-1. Estimated Future Construction Dredge Material Generation for U.S. Navy, Apra Harbor, Guam

Project	Year	Volume Requiring Management (cy)[1]
P-502	2008	98,300[2]
P-433	2010	508,877
CVN Wharf - Former SRF Parallel to Shore	Unscheduled	478,900[3]
CVN Wharf Alternative - Polaris Point Parallel to Shore		758,000[3]
CVN Wharf Alternative - Polaris Point Diagonal		672,400[3]

[1] Dredged volumes include a two feet (ft) overdredge allowance and no bulking factor.
[2] Dredged material to be placed in Orote Airfield CDF and is not included in the total dredged volume to be managed.
[3] Dredged volumes include channel, turning basin, and wharf.

In total, 27 dewatering sites were considered in the Phase I DMMP and reevaluated as part of this study. This study has determined that six dewatering sites and three beneficial use alternatives are considered to be logistically, technically, and economically feasible.

Six sites have been identified as potential dewatering site alternatives for dredged material resulting from P-433 and CVN (Figure ES-1):

1. Polaris Point - 44.3 acre (a) (17.9 hectare [ha]) site located on Polaris Point;
2. Field 5 - 53.2 a (21.5 ha) site located northwest of the Commissary, between and Marine Drive and Sumay Drive;
3. Commercial Port Field 1 - 36.9 a (14.9 ha) site located within Commercial Port property on Cabras Island;
4. Field 3 - 16.0 a (6.5 ha) site located south of the Navy Exchange Center and Commissary;
5. Field 4 - 26.6 a (10.8 ha) site located northwest of the Commissary, between Shoreline Drive and Marine Drive; and
6. PWC Compound - 27.8 a (11.3 ha) site located between Marine Drive and Sumay Drive at the former PWC Compound.

Polaris Point and Field 5 are large enough to accommodate the dredged material for both construction dredging projects (Table ES-2). All dewatering facilities have the capacity to store material from P-433, with the exception of Field 3. Field 3 must be used in conjunction with another alternative due to limited capacity. Dredging, rehandling, and placement costs are estimated to range from $88.10/cy (Field 5) to $119.05/cy (Commercial Port 1)[2].

Beneficial use includes a wide variety of options that utilize dredged material for a productive purpose. Beneficial uses of dredged material may make traditional placement of dredged material unnecessary or at least reduce the level of disposal. The beneficial use alternatives discussed in this report are identified as proposed projects in the Waterfront Function Plan (HHFP 2003b) and Ordnance Function Plan (HHFP 2003a), with the exception of the proposed Commercial Port expansion. Three beneficial use alternatives were evaluated: (1) magazine construction, (2) landfill daily cover, and (3) construction fill for Commercial Port expansion.

[2] Unit costs assume facilities are used to their maximum capacity.

Assuming that further geotechnical and chemical analyses prove the dredged material is suitable for all the identified beneficial uses, each of the alternatives are feasible and recommended.

Table ES-2. Greatest Capacity Design Specifics for Dewatering Facility Alternatives

	Field 3	Field 4	Field 5	PWC Compound	Commercial Port Field 1		Polaris Point
					East	West	
Site Area (a)	16.0	26.6	53.2	27.8	22.7	14.2	44.3
Dike Center Line Perimeter (ft)	2,965	5,600	7,000	5,000	4,600	4,750	5,900
Dike Width (ft)	8	8	12	12	12	12	12
Dike Elevation (ft)	18.5	16.00	26.00	19.00	15.00	6.25	31.00
Dredged Material Lift Height (ft)	16.50	14.00	24.00	17.00	13.00	4.25	29.00
Dike Volume (cy)	129,005	185,837	606,667	242,778	145,667	33,811	711,278
Internal Volume (cy)	296,915	414,968	1,453,237	519,684	330,428	63,554	1,361,372
Total Capacity (cy)	425,920	600,805	2,059,904	762,461	476,095	97,365	2,072,649
					573,459		
Sufficient Capacity for each individual project?	No	P-433	P-433 and CVN	P-433	P-433		P-433 and CVN
Sufficient Capacity for both projects?	No	No	Yes	No	No		Yes

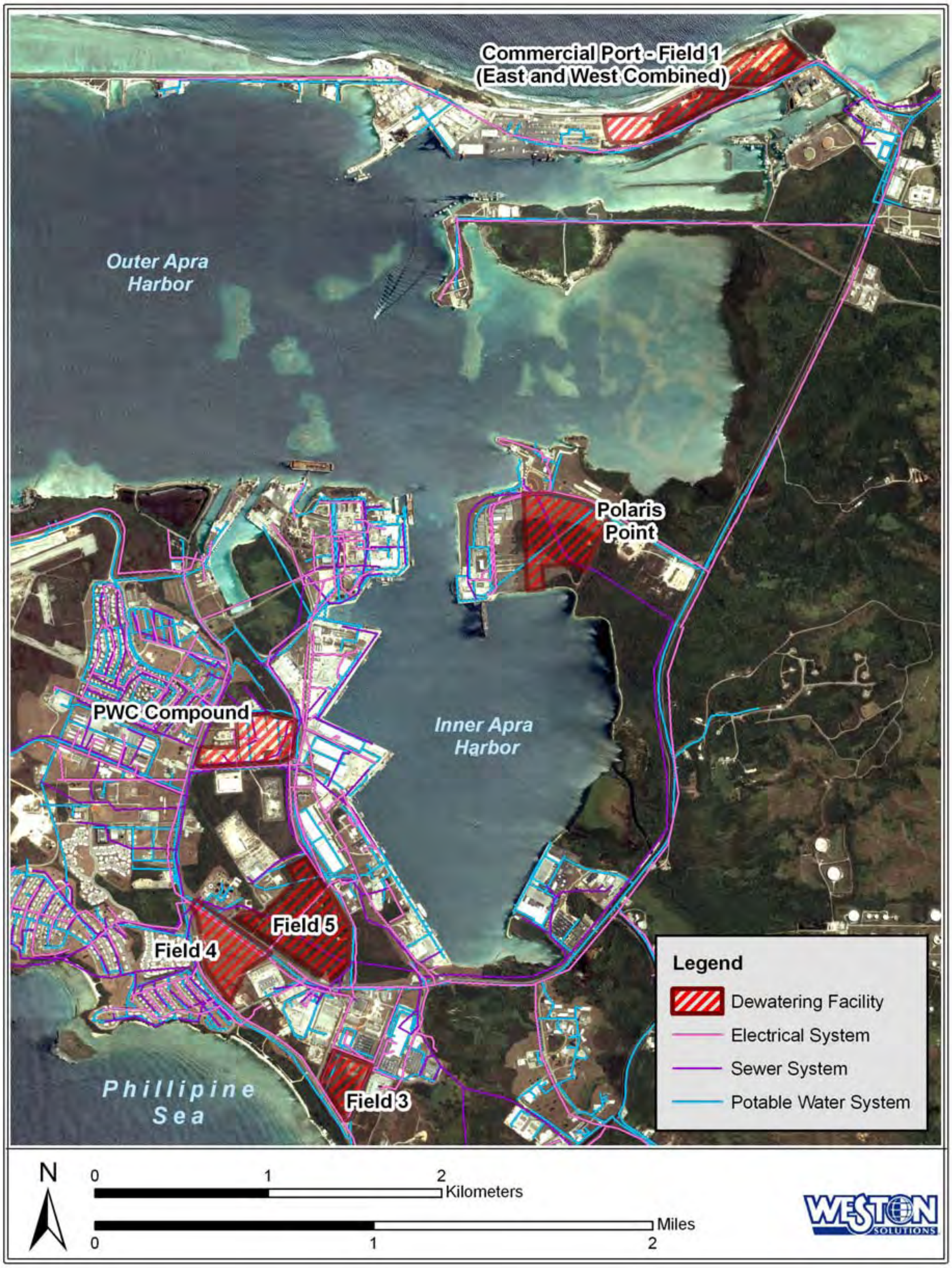

Figure ES-1. Location Map of Feasible Dewatering Sites.

Recommendations

Based on this preliminary evaluation, Polaris Point, Field 5, Field 4, Field 3, PWC Compound, and Commercial Port Field 1 are recommended for dewatering dredged material generated from the P-433 and CVN capable berthing projects. Polaris Point or Field 5 can be designed to accommodate the total volume from these construction projects. Due to their location and proximity to active areas within the base, PWC Compound and Fields 3, 4, and 5 have the potential to cause traffic and air quality impacts. These impacts are generally considered to be temporary and manageable. Construction and placement-related activities in PWC Compound, Field 4, or Commercial Port Field 1 may cause exterior noise levels within the adjacent housing complexes to temporarily exceed U.S. Housing and Urban Development (HUD) and Department of Defense (DoD) guidelines for residential areas. Construction and placement-related activities along the south end of Field 3 may cause noise levels at the adjacent beach to be elevated relative to the American National Standards Institute (ANSI) noise guideline for neighborhood parks.

Based on this preliminary evaluation, all feasible beneficial use alternatives are recommended assuming dewatered dredged material is chemically and geotechnically suitable. Utilizing dewatered dredged material for the Commercial Port expansion project would conserve other material resources for construction projects that have more rigorous geotechnical requirements (e.g., homogenization and sheer strength).

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1.0 PURPOSE AND NEED FOR ACTION

1.1 Introduction

The directive of the Commander of United States [U.S] Navy Region Marianas (COMNAVREGMAR) is to provide logistical and training support for U.S. Armed Forces and its Allies operating in the Western Pacific and Asia. A necessary component of the support program is to ensure adequate navigation depth for current and future operational requirements.

Apra Harbor, Guam is home to the Military Sealift Command, Maritime Prepositioning Ship Squadron 3, Submarine Squadron 15, and the U.S. Navy Public Works Center (PWC). The Military Sealift Command and the Maritime Prepositioning Ship Squadron are responsible for the sea transportation of equipment and supplies to deployed forces, and for maintenance and ship engineering support. Submarine Squadron 15 was created to improve the readiness of the Pacific submarine force and to provide logistical support, training, and maintenance (Global Security 2002). The PWC, Guam, is responsible for facility maintenance, utilities, environmental, transportation, engineering, and construction support.

An integral part of the Navy's mission and operational preparedness is to support forces transiting through and based in Apra Harbor, Guam. Vessels with deep drafts, including Carrier Vessel Nuclear (CVN) 68 and CVN 78, and increased ship visits are anticipated for Apra Harbor (Helber, Hastert & Fee, Planners [HHFP] 2003b; TEC Inc. JV 2008-in progress). Maintenance and construction dredging will be required to accommodate these new, larger vessels and increased traffic. Without dredging, the ability of the Navy to support its mission may be compromised. Consequently, management of Apra Harbor dredged material, in a manner consistent with the Navy's mission, is a high priority.

1.2 Background

The current design depths of Inner Apra Harbor are not sufficient to support proposed vessel berthing requirements. Current design depths for Inner Apra Harbor are -40 feet (ft) (-12.2 meters [m]) through the entrance to Inner Apra Harbor and adjacent to Alpha and Bravo Wharves, -35 ft (-10.7 m) in the north (along Mike - Tango Wharves and in the north-central and eastern portions) and -32 ft (-9.8 m) in the south (X-Ray to Uniform Wharves). Maintenance dredging was conducted in November 2003 for the first time since 1978. The 25-year hiatus in dredging activities resulted in a loss of approximately 5 ft (1.5 m) of navigation depth, due to sediment inputs from local streams and rivers and sediment transport from storms. The decreased navigation depth increases the potential risk of vessel groundings in Inner Apra Harbor. Beginning in 2003, maintenance dredging has resulted in approximately 160,000 cubic yards (cy) (122,336 cubic meters [m^3]) of dredged material being placed in confined dewatering facilities located within the Ship Repair Facility (SRF) and at Orote Airfield. Construction dredging was completed in 2007 as part of the P-431 project. P-431 increased the waters depths from -35 ft (-10.7 m) in the entrance channel and adjacent to Alpha and Bravo Wharves to -40 ft (-12.7 m). Construction dredging activities resulted in approximately 407,000 cy (311,174 m^3) of dredged material being placed in a dewatering facility located at Field 5.

To accommodate further operational needs, the Navy proposed three construction projects (identified as P-502, P-433, and an unscheduled project for the berthing of a CVN) to increase design depths of Inner and Outer Apra Harbor (HHFP 2003b; TEC Inc. JV 2008-in progress). Beginning fiscal year (FY) 2008, the first project (P-502) will dredge approximately 98,300 cy (75,156 m^3) along Kilo Wharf. The second project (P-433), scheduled for FY 2010, will dredge approximately 508,877 cy (389,064 m^3) of sediment along Sierra and Tango Wharves. The final proposed project (currently unscheduled and referred to herein as the CVN project), will dredge between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3), depending on the final site selected, in Outer Apra Harbor. A total volume of 987,777 cy to 1,266,877 cy (755,209 m^3 and 968,597 m^3) of material will need to be managed from these proposed construction projects. Dredged volumes include a two-ft overdredge allowance; however, they do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008 - in progress).

1.3 Purpose and Need

A Phase I Dredged Material Management Plan (DMMP), COMNAVREGMAR, Guam (MEC-Weston 2005), was developed to assist the Navy to complete the proposed construction dredging projects in an efficient, environmentally sound, logistical feasible and cost effective manner. The Phase I DMMP identified potential placement and beneficial use alternatives for the successful management of dredged material from planned construction dredging projects.

In the three years following the development of the Phase I DMMP, changes to the Navy's waterfront functional plans and new mission preparedness objectives have subsequently required a review and update of the Phase I DMMP. The purpose of this report is to reevaluate potential locations for dewatering facilities and beneficial use alternatives as presented in the Phase I DMMP, determine if any additional locations for dewatering facilities or beneficial use alternatives have become available in the three years since the Phase I DMMP study was completed, and provide sound management recommendations. In keeping with the Navy's sustainable planning policies, a key component of this study is to identify management alternatives that dewater the maximum amount of dewatered dredged material and minimize the acreage of Navy lands required, with little or no significant environmental impact.

Management of dredged material from these projects required the identification of feasible dewatering placement sites on the Naval Complex, and the potential beneficial use of the dewatered dredged material in planned construction projects. The evaluation of management alternatives (placement and beneficial use) included technical, logistical and economic feasibility, and consideration of the potential for environmental and social impacts. Each of these evaluative criteria is described below:

- <u>Technical Feasibility:</u> This criterion assessed the existing physical conditions and geotechnical considerations of each proposed management alternative. Based on the available data and certain assumptions regarding site conditions, (i.e., infiltration rates, bearing capacity, anticipated settlement, etc.) each alternative was assessed for consistency with the proposed use (e.g., dredged material dewatering and storage). Other general site conditions such as vegetative cover, shape of the site, and ability to develop the proposed alternative based on current and proposed land use were also considered. A site was rejected if it was not technically feasible to implement.

- Logistical Feasibility: Logistical feasibility included evaluations of the operational aspects of an alternative, such as capacity of the alternative to accommodate the projected volume of dredged material associated with each planned construction dredging project. Other factors included the ability to place construction or dredging equipment on site, access to and egress from the site, and schedule. Coordination will be necessary between dredged material management activities and naval operations. A site was rejected if it was not logistically feasible to implement.

- Economic Feasibility: This criterion focused on the cost of the alternative relative to the capacity volume of dredged material accommodated by the alternative. Unit costs used to derive cost estimates for each management alternative were standardized to provide equitable comparisons among potential alternatives. Alternative sites that required special construction efforts were evaluated by assessing the cost relative to the benefit gained in regards to capacity and beneficial use opportunities. A placement site or beneficial use alternative was rejected if estimated costs for one or more elements of the alternative were significantly higher (e.g., order of magnitude) than the range of costs normally encountered with the management of dredged material.

- Environmental Impacts: This criterion focused on the identification of potential environmental impacts resulting from the implementation of each alternative. A placement or beneficial use alternative was rejected if it had one or more impacts to sensitive resources or receptors that would likely be unacceptable or difficult to mitigate below a level of significance.

- Social Acceptability: This criterion focused on the identification of potentially adverse impacts to aesthetic resources, recreational uses, or to vehicle traffic patterns. A project alternative was rejected if it had one or more elements that would likely be unacceptable to naval personnel and/or residents of the Apra Harbor Naval Complex.

1.4 Regulatory Environment

Federal laws and regulations designed to protect the environmental, cultural, historical and coastal resources, and commerce in waters of the U.S. and its territories may be applicable to the dredging and placement activities described in this DMMP. The Navy will comply with laws and regulations that are relevant to dredging and subsequent management of dredged material, including those described below (Guam Environmental Protection Agency [GEPA] 2000, Lauter-Reinmann 1998, and Schroeder et al. 2001):

Clean Water Act (CWA) or Federal Water Pollution Control Act
The CWA established the basic structure for regulating discharges of pollutants into waters of the U.S. Section 404 of the CWA authorizes the Secretary of Army to issue permits for the discharge of dredged or fill material into U.S. waters. The U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (USEPA) are responsible for regulating the discharge of dredged or fill material, and to ensure such discharges do not adversely affect

waters of the U.S. The USACE is responsible for evaluating potential alternatives to discharge activities. The USEPA is responsible for environmental oversight of any USACE proposed disposal decision. Section 401 of the CWA indicates that activities resulting in discharge to waters of a state or territory must comply with all applicable state or territorial water quality standards. Guam's Water Quality Standards were recently revised and approved in 2001. Any discharge or runoff from dewatering facilities to waters of the U.S. would be regulated under the CWA.

Coastal Zone Management Act (CZMA) and Amendments
The CZMA was established to preserve, protect, develop and where possible, restore and enhance the Nation's coastal resources. States and territories are encouraged to develop coastal zone management programs (CZMPs) to manage economic growth in conjunction with the protection of natural resources, diminution of coastal hazards, improvement of water quality, and sustainable coastal development. The CZMA required that federal activities adhere to the policies established under each state's CZMP. A CZMP is in effect for Guam, and addresses coastal related issues involved with the construction dredging.

Endangered Species Act (ESA)
The ESA provides for the conservation of ecosystems that support threatened and endangered plant and animal species. The ESA allows for the determination and development of the threatened and endangered species list. The ESA protects threatened and endangered species by prohibiting federal agencies from authorizing, funding, or carrying out any action that would jeopardize such species, or destroy or modify its critical habitat. The U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) administer provisions under the ESA. Several endangered species inhabit areas within the Apra Harbor Naval Complex; consequently, identification and development of placement alternatives must consider applicable ESA requirements.

Fish and Wildlife Coordination Act (FWCA)
The FWCA provides that whenever the waters or channel of a body of water are modified by a federal agency, the agency must first consult with the USFWS, NMFS, and state or territorial agencies representing local fish and wildlife resources. The review agencies identify potential adverse impacts to wildlife resources and propose measures that would eliminate or reduce any possible damages or losses to those resources. Since dredging activities and potential nearshore placement alternatives are considered as part of this DMMP, coordination with these agencies may be required.

National Environmental Policy Act (NEPA)
The NEPA is a national policy for the protection of the environment. It is designed to prevent or eliminate damage to the environment and support the health and welfare of the individual. The NEPA is intended to develop the understanding of the ecological systems and natural resources important to the Nation, establish a process of environmental review and public notification for federal planning and decision making. The NEPA requires federal agencies to develop an environmental impact statement (EIS), which considers potential environmental impacts, unavoidable, adverse environmental effects, and project alternatives before a decision is made to implement a federal project.

Rivers and Harbors Act (RHA)
Section 10 of the RHA prohibits the building of wharves, piers, jetties, and other structures without approval from the USACE. Dredging activities (excavation) or dredged placement activities (fill) within navigable waters also requires the approval of the USACE.

Resource Conservation and Recovery Act (RCRA)
This Act controls the generation, transportation, treatment, storage and disposal of hazardous wastes. Guidelines for management of non-hazardous wastes are also provided. The USEPA is designated as the administrating agency of this Act. Beneficial use alternatives identified as part of this DMMP will require that materials be RCRA compliant.

Executive Order 13089 – Coral Reef Protection
Executive Order 13089 was established for the protection of U.S. coral reef ecosystems. It states that all Federal agencies conducting activities potentially affecting coral reef ecosystems within waters of the U.S. need to identify operations that may affect the coral reef ecosystems, use their jurisdiction to protect and enhance the conditions of the systems, and ensure that any actions authorized, funded, or implemented will not degrade the conditions required to sustain healthy coral reef ecosystems. Executive Order 13089 also provides for the implementation of measures needed to research, monitor, manage and restore affected coral reef ecosystems, including measures to reduce impacts from pollution, sedimentation and fishing. To protect the reef community, construction dredging activities will use best management practices (BMPs) to control the potential release of material that may lead to increases in suspended material into the water.

Magnuson-Stevens Fishery Conservation and Management Act
This Act was established to provide for the management of fish and other species within the Exclusive Economic Zone (EEZ) through Regional Fishery Management Councils. The Act requires national fishery conservation and management for the sustained participation of fishery dependent communities, and minimizes economic impacts to such communities. It also identifies overfished species and rebuilds those stocks, and identifies and protects essential fish habitat that may potentially be impacted by activities conducted under federal permits, licenses or other such authorities. This Act may be applicable to designated areas within the Apra Harbor Complex.

National Historic Preservation Act (NHPA)
The NHPA provides for a National Register of Historic Places to include districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, and culture. Section 106 of the National Historic Preservation Act requires Federal agencies to consider potential impacts on historic properties resulting from federal activities and provides for the Advisory Council on Historic Preservation a reasonable opportunity to comment on such activities. Goals of this act are to seek ways to avoid, minimize, or mitigate any adverse effects on historic properties. Placement site considerations must include NHPA guidance when historical resources are present.

Archaeological Resources Protection Act (ARPA)
The primary purpose of the ARPA is for the protection of archaeological resources (being at least 100 years or older), and sites that are on public or Indian lands, and to support the exchange of information between governmental authorities, the professional archaeological community,

and other stakeholders having collections of archaeological resources. The ARPA mandates that archaeological resources or sites may not be excavated, removed, damaged or altered. Placement site considerations include ARPA guidance when archaeological resources are present.

Several Acts listed by GEPA (2000) as pertaining to dredging activities on Guam do not apply to the proposed construction dredging within the Inner Apra Harbor discussed in this DMMP. Placement of dredged material into confined facilities does not require guidance by the Marine Protection, Research and Sanctuaries Act (MPRSA). The Inner Apra Harbor is under the authority and jurisdiction of the U.S. Navy and is not utilized for private commerce; therefore, the Merchant Marine Act is not applicable. Inner Apra Harbor is not a Superfund site; therefore, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) as amended by Superfund Amendments and Reauthorization Act (SARA) do not apply. In addition, the Toxic Substances Control Act does not apply because Polychlorinated biphenyls (PCB) concentrations in the material to be dredged are well below 50 parts per million (ppm). The Water Resource Development Act (WRDA) provides for the conservation of water resources, and is biennially renewed to authorize the USACE to perform specific actions leading to the improvement of rivers and harbors of the U.S. However, the proposed construction related dredging activities are not a component of current or any proposed WRDA legislation, therefore, WRDA would not apply.

Although the dredged material management alternatives discussed herein will occur almost entirely within Navy property (with the exception of the possible beneficial use of dredged material for the proposed Commercial Port Expansion), Guam laws and regulations may apply.

2.0 PROJECT DESCRIPTION AND DREDGING REQUIREMENTS

2.1 Description of Apra Harbor Naval Complex

The Apra Harbor Naval Complex comprises 4,575 acres (a) (1,852 hectares [ha]) on lands surrounding Apra Harbor. It is located on the west central coast of Guam, approximately 8 miles (mi) (12.8 kilometers [km]) southwest of Hagatna, the capital city (Figure 1). The naval complex consists of the Main Base, the Fuel and Supply Department, and the PWC. The development of the complex, including fast land creation and wharf construction following World War II, resulted in the division of Apra Harbor into an inner and outer harbor. The majority of Department of the Navy (DON) operations occur on lands bordering Inner Apra Harbor. The 750 ft (228 m) wide entrance to Inner Apra Harbor occurs at its northern end, between the lands occupied by the former SRF on the west and Polaris Point on the east. Inner Apra Harbor is approximately 0.8 mi (1.3 km) wide and 1.5 mi (2.4 km) long covering a total of 650 a (263 ha). Mangrove and wetland habitats, associated with the Aplacho and Atantano Rivers, are located along the eastern edge of Apra Harbor, while the southern and western boundaries of Inner Apra Harbor are developed and support Navy operations. The Naval Complex also encompasses Camp Covington and the Orote Peninsula.

Located within the Naval Complex are seven active wharves in Inner Apra Harbor and three active wharves in Outer Apra Harbor (Figure 2). The COMNAVREGMAR Waterfront Function Plan (HHFP 2003b) describes current activities for each of the Naval Complex's wharves. Alpha and Bravo Wharves, located on the southwest corner of Polaris Point, are designated as berths for submarines and the submarine tender USS Frank Cable (AS-40). The northwest corner of Polaris Point, facing Outer Apra Harbor, is the location of the "former" Charlie Wharf. The former SRF includes the wharves Lima, Mike, November, Oscar, Papa, and Quebec, and is currently leased to Guam Shipyard Inc. through the Guam Economic Development Authority (GEDA). Guam Shipyard Inc. uses this land to continue to provide ship repair, maintenance, and support to the Navy.[3] The general-purpose wharves Romeo, Sierra, Tango, Uniform, and Victor are located along the western side of Inner Apra Harbor. Uniform Wharf is currently not operational for naval berthing due to earthquake damage sustained in 1993; however, wharf improvements are planned for FY 2010 to provide "cold iron" berthing support for the Amphibious Readiness Group (ARG). The supply wharf, X-Ray, is located in the southeast corner of Inner Apra Harbor. Delta and Echo refueling wharves are located in Outer Apra Harbor adjacent to Dry Dock Island. Kilo Wharf is also located in the Outer Apra Harbor, on the Orote Peninsula, and is used for on-loading and off-loading of ammunitions from ordnance supply ships and occasional carrier berthing.

[3] The term "SRF" will be used throughout this report to maintain consistency with other existing documentation.

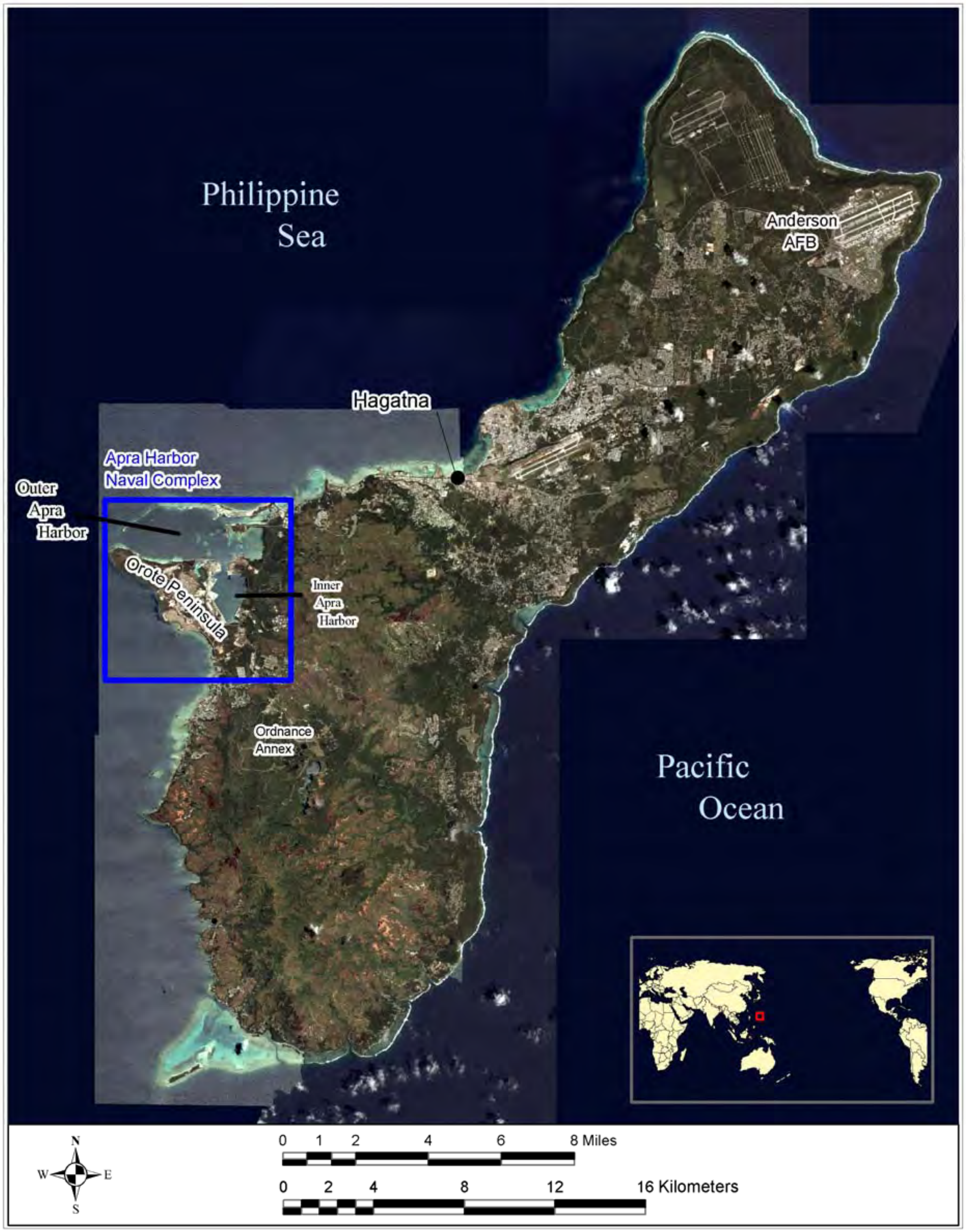

Figure 1. Guam General Vicinity Map.

Figure 2. Location of Navy Wharves throughout Inner and Outer Apra Harbor.

2.2 Dredging Requirements

Dredging is the removal of sediment in its natural or recently deposited state by mechanical or hydraulic means. The "dredging and disposal process" is defined as the excavation, transport, and placement of dredged material. Following excavation, dredged material can be transported from the dredging site to the placement site via the dredge itself, or by barge, pipeline, truck, rail, or a combination thereof. Placement sites may be located in open-water, nearshore, or upland locations. A comprehensive DMMP requires an examination of the compatibility between the dredging equipment and techniques used for excavation, the transport of the material from the dredging site to the placement area, and the management of the placement area. This document reevaluates dredging and transportation techniques, placement options and beneficial use alternatives as recommended in the Phase I DMMP with consideration for recent adjustments to the Navy's operational requirements.

2.2.1 Dredge Areas, Quantities and Characteristics

The COMNAVREGMAR Waterfront Function Plan (HHFP 2003b) detailed three separate project areas proposed for construction dredging and their associated design depths. These projects were identified as P-431, P-518, and P-436. As a result of these three projects, approximately 695,000 cy (531,366 m^3) of sediment was dredged. In the three years following the development of the Phase I DMMP, dredging associated with P-431 was successfully completed with approximately 407,000 cy (311,174 m^3) of dredge material being placed in an upland dewatering facility. Both P-518 and P-436, originally scheduled for FY 2007 and FY 2009, respectively, have been cancelled. However, additional dredging associated with several new projects has been identified. First, P-502, scheduled for FY 2008, requires 98,300 cy (75,156 m^3) of sediment to be dredged in association of the Kilo Wharf expansion (Table 1). It should be noted that an evaluation conducted by Moffatt and Nichol (2007) determined that the dredged material generated by the P-502 Kilo Wharf project can be placed in the existing Orote Airfield Confined Disposal Facility (CDF). Therefore, this material is not included in the total volume of dredged material to be managed herein. Second, P-433, scheduled for FY 2010, requires 508,877 cy (389,064 m^3) of sediment to be dredged in association with anticipated berthing requirements at Sierra Wharf. Third, an unscheduled project associated with the construction of a CVN capable berth requires between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3) of sediment to be dredged. P-439, also scheduled for FY 2010, does not require dredging in association with Uniform and Victor Wharves improvements. Together, the P-433 and CVN projects result in the need to manage an additional volume of 987,777 cy to 1,266,877 cy (755,209 m^3 and 968,597 m^3), depending on the final CVN alternative selected. Dredged volumes include a 2-ft overdredge allowance; however they do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008 – in progress).

Table 1. Estimated Future Construction Dredge Material Generation for U.S. Navy, Apra Harbor, Guam

Project	Year	Volume Requiring Management (cy)[1]
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[1] Dredged volumes include a 2 ft overdredge allowance and no bulking factor.
[2] Dredged material to be placed in Orote Airfield CDF and is not included in the total dredged volume to be managed.
[3] Dredged volumes include channel, turning basin, and wharf.

Dredged material from each of the proposed construction projects has been evaluated in accordance with three national testing manuals: *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual (Inland Testing Manual*; USEPA and USACE 1998), *Evaluation of Dredged Material Proposed for Disposal and Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual (Upland Testing Manual*; USACE 2003), and *Evaluation of Dredged Material Proposed for Ocean Disposal – Testing Manual (Ocean Testing Manual*; USEPA and USACE 1991).

P-502

Construction dredging at Kilo Wharf is proposed as Project P-502 in order to maintain the operational preparedness of the Navy to support new T-Class Combat Logistics Force ships (e.g., Advanced Auxiliary Dry Cargo Ships [T-AKE] and Ammunitions Ships) and to provide temporary mooring of larger transient vessels in Guam. This project was originally designed to extend the existing Kilo Wharf 285 ft (86.9 m) to the west and 115 ft (35.1 m) to the east, and deepen the extended areas to -56 ft (-17.1 m) mean lower-low water (MLLW). The Kilo Wharf design has been modified, eliminating the east expansion and extending the west expansion to 400 ft (121.9 m). The area fronting the wharf would be construction dredged to -45 ft (-13.7 m) MLLW with 2-ft (0.6-m) overdredge allowance (Figure 3). P-502 is scheduled for FY 2008 and will generate a cut volume of approximately 92,800 cy (70, 951 m^3) of dredged material in the vicinity of Kilo Wharf. Accounting for the 2-ft overdredge allowance, approximately 98,300 cy (75,158 m^3) of dredged material will be generated. The dredged material generated from the P-502 project was recommended for placement into the existing Orote Airfield CDF (Moffatt and Nichol 2007).

Results of the dredged material evaluations for P-502 were presented in both the *Dredged Material Management Plan: Sampling and Analysis of Sediments for Construction Dredging at Kilo Wharf – Final Report* (Weston and Belt Collins 2005) and *Dredged Material Sampling and Tier III Analysis Evaluation for Apra Harbor Projects (P-436, P-502, P-518), Guam – Final Report* (Weston 2007). The former report evaluated the potential environmental impacts P-502 project dredged material may have if placed in an upland dewatering facility. Potential

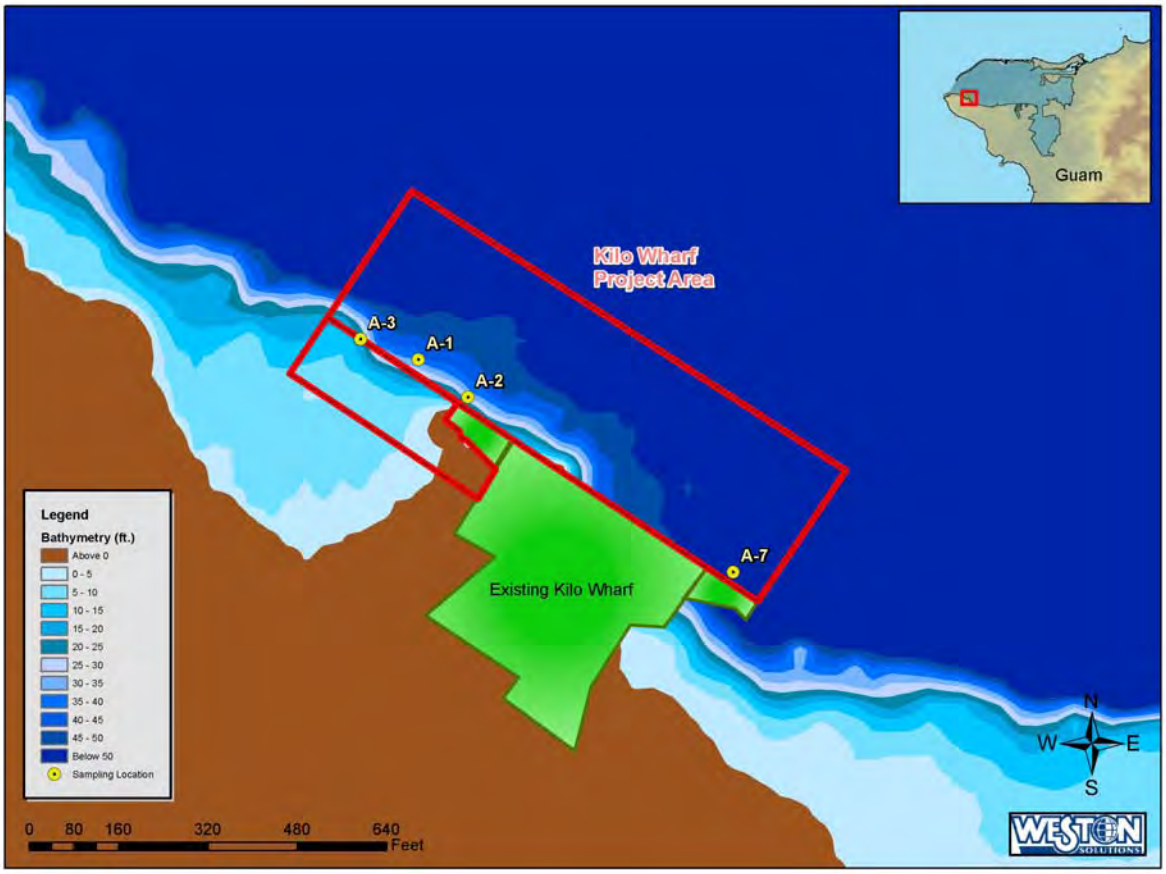


Figure 3. Dredge Footprint for P-502, Kilo Wharf, Outer Apra Harbor, Guam

environmental impacts included runoff associated with rain, leachate associated with foundation soils, effluent discharge from pore water, and excess carrier water and volatilization of volatile organics. The report indicated P-502 project dredged material was not expected to cause any adverse environmental impacts and was suitable for placement in the existing Orote Airfield and SRF dewatering facility sites, and the proposed Polaris Point, Commercial Port, Field 3 and Field 5 dewatering facility sites. The latter report (Tier III evaluation) evaluated the suitability of P-502 project dredged material for ocean disposal, assuming an Ocean Dredged Material Disposal Site (ODMDS) is designated for Guam. The report indicated P-502 project dredged material was suitable for ocean disposal.

P-433

Construction dredging along Sierra and Tango Wharves is proposed as part of Project P-433 in order to maintain the operational preparedness of the Navy to provide "cold iron" berthing for extended transient ships including those in the ARG and additional shore side support. The area along the wharves would be construction dredged to -38 ft MLLW (-11.6 m) with a 2-ft (0.6-m) overdredge allowance (Figure 4). P-433 is scheduled for FY 2010 and will generate a cut volume of approximately 246,264 cy (188,282 m^3) of dredged material in the vicinity of Sierra and Tango Wharves. Accounting for the 2-ft overdredge allowance, approximately 508,877 cy (389,064 m^3) of dredged material will be generated.

Figure 4. Dredge Footprint for P-433, Sierra Wharf, Inner Apra Harbor, Guam

Although dredged material evaluations have not been completed specifically under the P-433 project scope, the proposed P-433 dredge footprint is consistent with the proposed dredge footprint under the P-436 project scope. Results of the dredged material evaluations for P-436 were presented in the *Phase I Dredged Material Management Plan for Apra Harbor, Guam* (MEC-Weston 2005), *Dredged Material Long-Term Management Strategy: Phase II Guam, Evaluation of Environmental Effects for Dewatering and Management of Materials from MCON P-518 and P-436 – Final Report* (Weston 2005b), and the *Dredged Material Sampling and Tier III Analysis Evaluation for Apra Harbor Projects (P-436, P-502, P-518), Guam – Final Report* (Weston 2007).

Sediment chemistry results presented in Phase I were provided solely as a screening tool. The Phase I preliminary assessment determined that none of the analytes tested in the sample collected adjacent to Sierra Wharf exceeded the PWC Landfill acceptance criteria for daily cover.

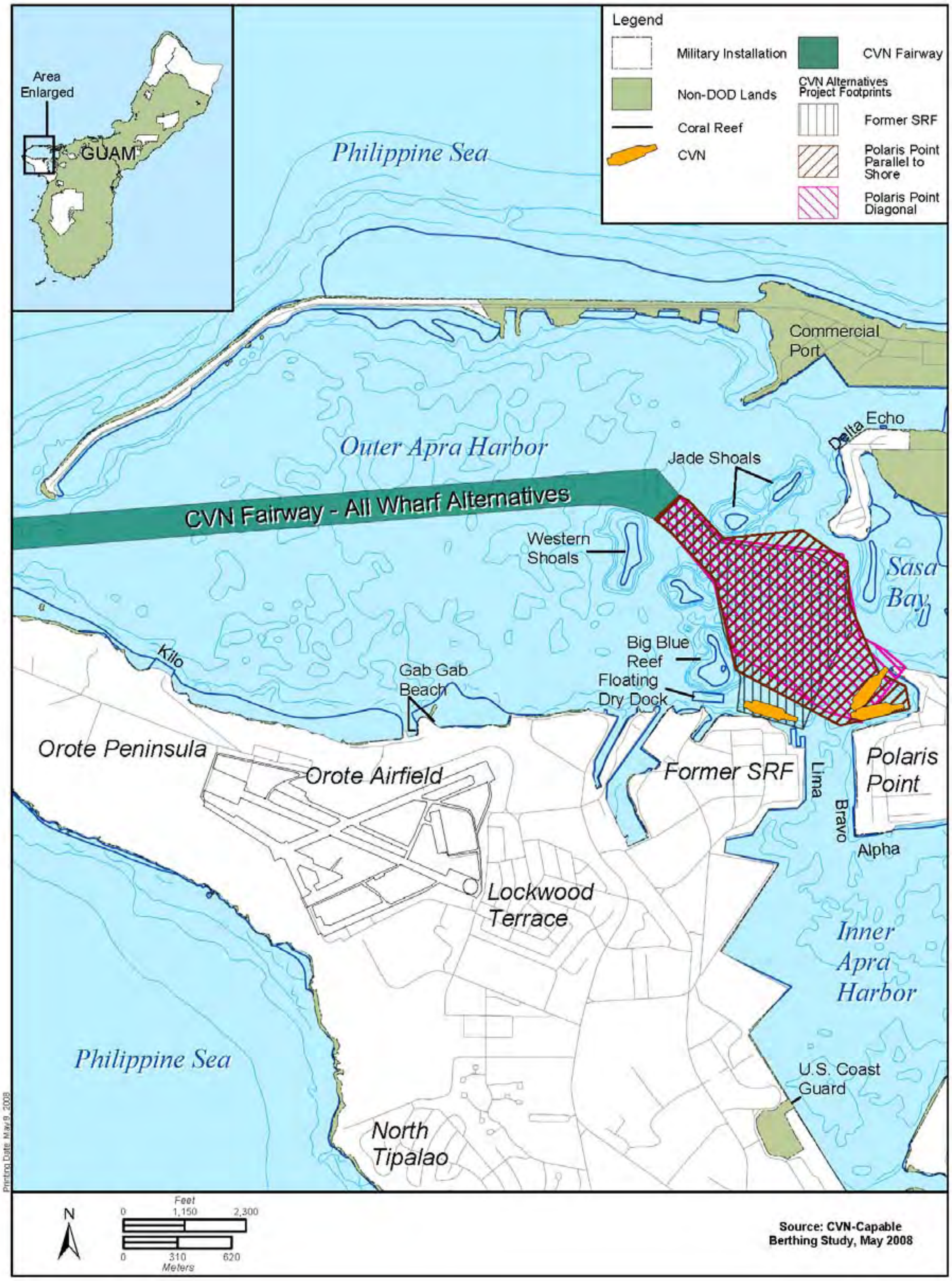
The Phase II report evaluated potential environmental impacts P-436 project dredged material may have if placed in an upland dewatering facility. Potential environmental impacts included runoff associated with rain, leachate associated with foundation soils, effluent discharge from pore water and excess carrier water, and volatilization of volatile organics. The report indicated P-436 project dredged material was not expected to cause any adverse environmental impacts with the exception of minimal detectable odors at all sites and potential volatized mercury exposures downwind of Field 3. With the implementation and enforcement of maximum exposure times for workers and residents downwind of Field 3, P-436 project dredged material was determined to be suitable for placement in the proposed Commercial Port, Field 3, and Field 5 dewatering facility sites.

The Tier III report evaluated the suitability of P-436 project dredged material for ocean disposal, assuming an ocean dredged material disposal site (ODMDS) is designated for Guam. The report indicated that the majority of P-436 project dredged material was suitable for ocean disposal. Proposed dredged material from an area fronting Oscar, Papa, Quebec, and Romeo Wharves did not meet the limiting permissible criteria (LPC) requirements for ocean disposal. It should be noted that this area is not within the proposed P-433 dredge footprint. Proposed dredged material immediately adjacent to Sierra Wharf was recommended for ocean disposal despite not meeting the LPC requirements for ocean disposal. This recommendation was made despite slight toxicity observed in only one amphipod solid phase (SP) test and based on the high survival of all test organisms in suspended particulate phase (SPP) tests, *Neanthes arenaceodentata* high survival in SP tests, relatively low contaminant concentrations, tissue concentrations below published relevant effects levels and low total PCB tissue concentrations (<20 microgram per kilogram [µg/kg]).

CVN Capable Berth

To accommodate the berthing of a CVN for 21-day visits to Apra Harbor, the Navy proposes construction dredging for the development of a deep water wharf at one of three alternative sites within the harbor, and along access fairways to the selected site. The selection of the appropriate site for the berthing of larger vessels will be based on engineering, environmental, regulatory, and economic feasibility.

Three wharf alternatives, or sites, have been identified for the potential construction of a deep water wharf in Apra Harbor, Guam. The sites are on either side of the entrance to Inner Apra Harbor. These include two sites on Polaris Point near the former Charlie Wharf (one parallel and one diagonal to shore) and one site at the former SRF site (Figure 5).



From TEC Inc. JV 2008-in progress

Figure 5. Dredge Footprint for CVN Alternatives, Outer Apra Harbor, Guam

The sites at Polaris Point are located in Outer Apra Harbor at the northern end of Polaris Point in a cove situated east of the Inner Harbor entrance channel. In one alternative, the berth would be parallel to the coastline; and in a second alternative the berth would be aligned diagonally from the northwest corner of Polaris Point to the point bounding the northern side of the cove. Steel sheet pile caisson foundations from the former wharf lay offshore from this site, and water depths in the area range from -20 to -80 ft (-6.1 to -24.4 m) MLLW. The dredge footprint for these two potential sites includes the area fronting the wharf, a turning basin northwest of the site, and an access fairway (CVN Fairway) trending to the northwest from the turning basin to Outer Apra Harbor. Dredging will occur to -49.5 ft (-15.1 m) MLLW in all areas with an additional 2-ftt overdredge allowance. Accounting for the 2-ft overdredge allowance, the Polaris Point – Parallel to Shore alternative will generate a volume of approximately 758,000 cy (579,533 m^3) of dredged material. Accounting for the 2-ft overdredge allowance, the Polaris Point–Diagonal alternative will generate a volume of approximately 672,400 cy (514,087 m^3) of dredged material.

The SRF site is located in Outer Apra Harbor, west of the Inner Harbor entrance channel and north of the former Navy SRF complex, which is currently the Guam Shipyard. Water depths in this area range from -20 to -73 ft (-6.1 to 22.3 m) MLLW, with the exception of a shallow reef that lies immediately north of the site. The dredge footprint for this potential site includes the area fronting the wharf, and similar turning basin and access fairway (CVN Fairway) identified for the Polaris Point sites. Like Polaris Point, if this site is selected, dredging will occur to -49.5 ft (-15.1 m) MLLW with a 2-ft overdredge allowance. Accounting for the 2-ft overdredge allowance, the Former SRF – Parallel to Shore alternative will generate a volume of approximately 478,900 cy (366,145 m^3) of dredged material.

Results of dredged material evaluations conducted in Outer Apra Harbor in support of the potential CVN berthing alternative were presented in the *Sediment Characterization for Construction Dredging at Charlie, Sierra and SRF Wharves, Apra Harbor, Guam – Final Report* (Weston 2006). The purpose of this report was to delineate the distribution and magnitude of chemicals of potential concern within material to be dredged from the three CVN alternative sites. The sediment chemistry results were compared to previous studies conducted within Apra Harbor (MEC-Weston 2005, Weston 2005a, Weston 2005b, Weston and Belt Collins 2006) to assist with the selection of appropriate management options (e.g., placement of material in a dewatering facility and eventual beneficial use) for sediment dredged during the deep water wharf (CVN capable berth) construction project. None of the Outer Apra Harbor samples representing proposed dredged material exceeded effects-range median (ER-M) values. ER-M values are a screening tool to assess potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analyses.

2.2.2 Dredging Methods

There are two general types of dredging operations: mechanical dredging and hydraulic dredging. The operations vary by the method used to loosen the material from its *in-situ* state and transport the material from the seafloor to the water surface. Mechanical dredging is typically conducted using a grab or bucket, such as a clamshell dredge. Hydraulic dredging is typically conducted using a cutter suction (pipeline) dredge or hopper dredge. It should be noted that dredged material from Apra Harbor may contain submerged ordnance and explosives.

Regardless of the selected dredging method, mechanical or hydraulic, BMPs will be required to appropriately screen for submerged ordnance and explosives (TEC JV, Inc. 2008-in progress).

The Phase I DMMP presents a detailed discussion comparing mechanical and hydraulic dredging techniques (MEC-Weston 2005). For the purposes of this study, the Phase I DMMP recommendation to use mechanical dredging was determined to be consistent with the current objectives and is summarized below.

2.2.2.1 Mechanical Dredging

Mechanical dredging is the recommended dredging method, and has been used in past Guam dredging projects. While the production volume is considerably less than the volume dredged by other means (i.e., hydraulically), the nature of mechanically dredged material is better suited for the management alternatives described herein. As stated in the Phase I DMMP, a bulking factor of 10% should be applied to dredged volume during mechanical dredging. Dredged volumes used in this report do not include a bulking factor to be consistent with other concurrent studies (TEC Inc. JV 2008 in progress). The dewatering time for mechanically dredged material is less than the dewatering time for hydraulically dredged material.

2.2.2.2 Hydraulic Dredging

Construction dredging within Inner Apra Harbor with a cutter suction dredge was not the recommended method for the Phase I DMMP due to the high volume of water and navigational constraints caused by the discharge line. The water content of hydraulically dredged material is much higher than that of mechanically dredged material. Production volume can range from four to six times the dredged volume (DON 2003). Upland placement of this volume will require more space and ocean disposal by dump scows will require more trips than mechanically dredged material. In addition, the pipeline used in cutter suction dredging may impede naval operations and potentially effect safe navigation within Inner Apra Harbor. Consequently, development and design of proposed alternatives included in this DMMP assume that material will not be hydraulically placed.

Again, high water content of hopper dredged materials would result in long dewatering times and larger dewatering areas. In addition, hopper dredging is typically used as an alternative to hydraulic cutterhead dredging when bottom dumping or when a large distance between the dredge site and placement area precludes the use of a cutterhead dredge. Neither situation is relevant to the construction dredging project in this DMMP. Consequently, design and development at proposed alternatives included in this DMMP do not include consideration for hopper dredging.

2.2.3 Dredged Material Rehandling

Rehandling is the process of loading, transporting, and offloading dredged material, and applies to upland placement alternatives. The process is highly dependent on the type of dredging method employed and the location of the placement area. Rehandling is often the most important factor in determining the economic feasibility of a dredging project since costs increase with the number of times dredged material is re-handled. Dredged material rehandling should be evaluated in the early stages of the planning process using the following criteria:

- Available Means of Rehandling
- Nature of Material (Wet/Dry)
- Annual Volume of Dredged Material
- Duration of Project
- Estimated Cost of Available Transport Modes
- Technical, Environmental, Legal, and Federal Agency Regulations (Herbich 2000)

For the purposes of this study, the recommendations made in the Phase I DMMP were determined to be consistent with the current objectives and are summarized below.

Several dredging scenarios involving various dredging, transport, and disposal methods were considered in the Phase I DMMP: (1) mechanical dredging and mechanical offloading upland; (2) mechanical dredging and hydraulic offloading upland; (3) hydraulic dredging and hydraulic offloading upland; (4) mechanical dredging and mechanical near-shore disposal; (5) hydraulic dredging and hydraulic near-shore disposal; and (6) mechanical dredging and in-water disposal.

Of the six dredging and rehandling scenarios considered, mechanical dredging and mechanical offloading for upland or near shore disposal were the most feasible based on dewatering site capacity, dewatering time, and environmental and navigational considerations and constraints. The increased volume of dredged material associated with hydraulic dredging and offloading required larger capacity placement facilities and produced larger volumes of decanted water that may have compromised marine resources in either Inner or Outer Apra Harbor. In addition, the increased water content associated with hydraulic dredging and offloading extended dewatering times, delaying the use of dredged material for beneficial use. The discharge line used in cutter suction dredging may have limited naval operations in Inner Apra Harbor during dredging activities. The navigational constraints imposed by the hydraulic discharge line may have also restricted naval operations and potentially increased navigational hazards within Inner Apra Harbor.

Mechanical dredging and offloading must consider interchange loading and unloading operations to accommodate the specific site needs in terms of efficiency and cost. This assessment utilizes the same assumptions as the Phase I DMMP; the dredged material will be offloaded from the scow at Alpha, Delta/Echo, or Uniform wharves. Alpha Wharf is a general-purpose wharf with 520 linear ft (158 m) of berth space. Delta/Echo Wharves are refueling and homeporting docks with 1,600 linear ft (488 m) of berth space. Uniform Wharf is a general-purpose wharf with 1,200 linear ft (366 m) of berth space.

2.2.4 Potential Dredged Material Management Alternatives

The dredged material management alternatives examined for the Phase I DMMP included the placement of material into confined placement, open-water placement, and contained aquatic disposal (CAD). Eventual beneficial use alternatives with the dewatered dredged material include bulkhead construction fill material, magazine/berm construction, landfill cover, and shoreline restoration. In total, 27 alternatives were considered in the Phase I DMMP and reevaluated as part of this study (Table 2; Figure 6). During the course of this study, it was determined that five dewatering sites and four beneficial use alternatives were considered to be logistically, technically, and economically feasible (highlighted in Table 2). Feasible dewatering facility alternatives are presented in Section 3.2. Feasible beneficial use alternatives are presented in Section 3.4.

2.2.4.1 Confined Placement (Dewatering Facilities)

Upland confined placement and nearshore confined placement were recommended management alternatives in the Phase I DMMP (MEC-Weston 2005). This study solely recommended the use of upland confined placement, or dewatering facilities for the temporary storage of dredged material. Conventional open water placement and contained aquatic disposal sites were and still remain infeasible management alternatives within the scope of this document because an ocean disposal site has not be designated. However, efforts are currently underway to designate an ODMDS in Guam. Dewatering facilities are engineered structures for containment of dredged material. Dewatering facilities are bound by confinement dikes or structures to enclose the disposal area, thereby isolating the dredged material from its surrounding environment. An upland dewatering facility consists of a fully diked facility located above the water line and out of wetland areas.

Dewatering facilities may be used for either coarse or fine-grained material. The material is placed into the facility either hydraulically or mechanically. Placing the material directly in to the facility from the dredging site through pipelines is the most economical method. The dredged material consists of a certain percentage of slurry when it is pumped into the facility. Depending on the placement method, slurry material initially deposited in the dewatering facility may occupy from 1.1 times (mechanical placement) to five to 10 times (hydraulic placement) its original volume due to water content. Design of the dewatering facility must account for this additional volume (production volume; Section 2.2.2.1) during the drying phase. Following placement, the finer sediments are allowed to consolidate, settle, and dewater. Water evaporates or percolates through the dike walls or into the ground. Facilities that use weirs to enable surface water to exit the facility must be designed with sufficient retention times to ensure adequate sediment settling will occur.

Dredged material placement within a dewatering facility has several benefits. Dewatering facilities can prevent or substantially reduce the amount of dredged material re-entering the environment when the facility is properly designed, operated, and maintained. Dewatering facilities can provide either a temporary or permanent storage location for dredged material that will naturally vegetate if left undisturbed. Finally, dewatering facilities can be used as processing and/or blending areas for beneficial use activities.

The size, design and cost of a dewatering facility are site-specific. Factors considered in the design of a dewatering facility include: the location, physical nature of sediments to be placed (e.g., grain size, organic content, etc.), physical nature of project footprint, chemical nature of sediments (contaminated vs. clean), volume of sediments to be stored, placement method, and the length of time material will be stored at the facility. Depending on the design, operation and maintenance (O&M) costs of the dewatering facility will vary.

The use of dewatering facilities is a long-term or short-term solution for the management of material dredged from Inner and Outer Apra Harbor. Material may be stored indefinitely in the facility or temporarily placed for dewatering prior to beneficial use.

2.2.4.2 Potential Beneficial Uses

Dredged material provides a manageable and valuable resource. As such, beneficial use is a desired management option. Beneficial use alternatives evaluated for the Phase I Guam DMMP included construction fill material, magazine construction, daily landfill cover, and shoreline restoration (MEC-Weston 2005). Factors that were considered in the evaluation of beneficial use alternatives included the identification of local needs and opportunities for beneficial use, geotechnical and sediment chemistry requirements, distance from the dredging site or dewatering site to the location of beneficial use, site accessibility, handling requirements, and capacity of beneficial use in relation to the volume of dredged material available.

This study reviewed the findings of the Phase I DMMP and determined four categories of beneficial use alternatives continues to provide feasible management option for Apra Harbor dredged material. These beneficial use alternatives include: construction fill material, magazine construction, daily landfill cover and shoreline restoration. Section 3.4 of this report or the Phase I DMMP (MEC-Weston 2005) presents a detailed discussion of these alternatives. For all of the beneficial use alternatives discussed in this report, the material must first be placed in an upland dewatering facility. After the material is sufficiently dry, the material would be available for beneficial use alternatives in planned construction activities.

Table 2. Summary of Dewatering Facility Options and Beneficial Use Alternatives

ID	Site	Capacity	Primary Constraints	Phase I DMMP Determination
Dewatering Facility Options				
1	Polaris Point Field	2,072,649 cy	Relocation of utilities, loss of recreational facilities, within Explosive Safety Quantity Distance (ESQD)	Feasible
2	Ordnance Annex - Near Main Gate	41,584 cy	Insufficient capacity, limited access, environmental	Infeasible
3	Ordnance Annex - Near Fena Reservoir	27,941 cy	Insufficient capacity, limited access, environmental	Infeasible
4	Field 1	54,539 cy	Transport distance, proximity to recreational land uses	Infeasible
5	Field 2	94,773 cy	Proximity to utilities, recreational land uses	Infeasible
6	Field 3	425,920 cy	Relocation of utilities	Feasible
7	Field 4	600,805 cy	Relocation of utilities	Feasible
8	Field 5	2,059,904 cy	Relocation of utilities, removal of abandoned structures	Feasible
9	PWC Compound	762,461 cy	Relocation of utilities, removal of abandoned structures	Feasible
10	Ship Repair Facility - Existing Site	16,000 cy	Insufficient capacity, removal of existing dredged material	Infeasible
11	Marina	17,381 cy	Insufficient capacity, limited access	Infeasible
12	Orote Airfield – Existing Site	71,900 cy	Removal of existing dredged material	Infeasible
13	Dry Dock Island	59,876 cy	No existing berthing or staging areas, limited access	Infeasible
14	Commercial Port - Field 1 (East and West Combined)	573,459 cy	Removal of limestone escarpment, limited staging areas	Feasible
15	Commercial Port - Field 2	730,721 cy	Loss of wetland habitat	Infeasible
Beneficial Use Alternatives				
A	Polaris Point - North Park and Beach Nearshore Placement/Fast Land	695,000 cy	Loss of marine habitat, incompatible with land use designation	Infeasible
B	Polaris Point - Charlie Wharf Rehabilitation	27,000 cy	Geotechnical suitability of dewatered material	Feasible
C	Polaris Point - Bravo Wharf Expansion	5,300 and 10,700 cy	Availability of dewatered material/coordinated schedule	Infeasible
D	Polaris Point - Alpha Wharf Nearshore Placement/Fast Land	152,500 cy	Loss of marine habitat, not planned	Infeasible
E	Ordnance Annex – Magazine Construction	89,450 cy	Geotechnical suitability of dewatered material, availability of dewatered material/coordinated schedule	Feasible
F	PWC Landfill – Daily Cover	18,200 - 22,620 cy/year	TCLP tests, availability of dewatered material/coordinated schedule	Feasible
G	Uniform Wharf Rehabilitation	5,000 cy	Availability of dewatered material/coordinated schedule	Infeasible
H	Ship Repair Facility – Abandoned Cove Nearshore Placement/Fast Land	42,667 cy	Loss of marine habitat	Infeasible
I	IR Landfill – Capping Material	4,000 cy	At capacity, no access	Infeasible
J	Kilo Wharf Expansion	40,000 cy	Limited landside access	Infeasible
K	Orote Peninsula – Magazine Construction	102,400 cy	No waterside access, environmental	Infeasible
L	Commercial Port Expansion	1,500,000 cy	Geotechnical suitability of dewatered material, availability of dewatered material/coordinated schedule	Feasible
	Highlighted Options = Feasible Alternatives			

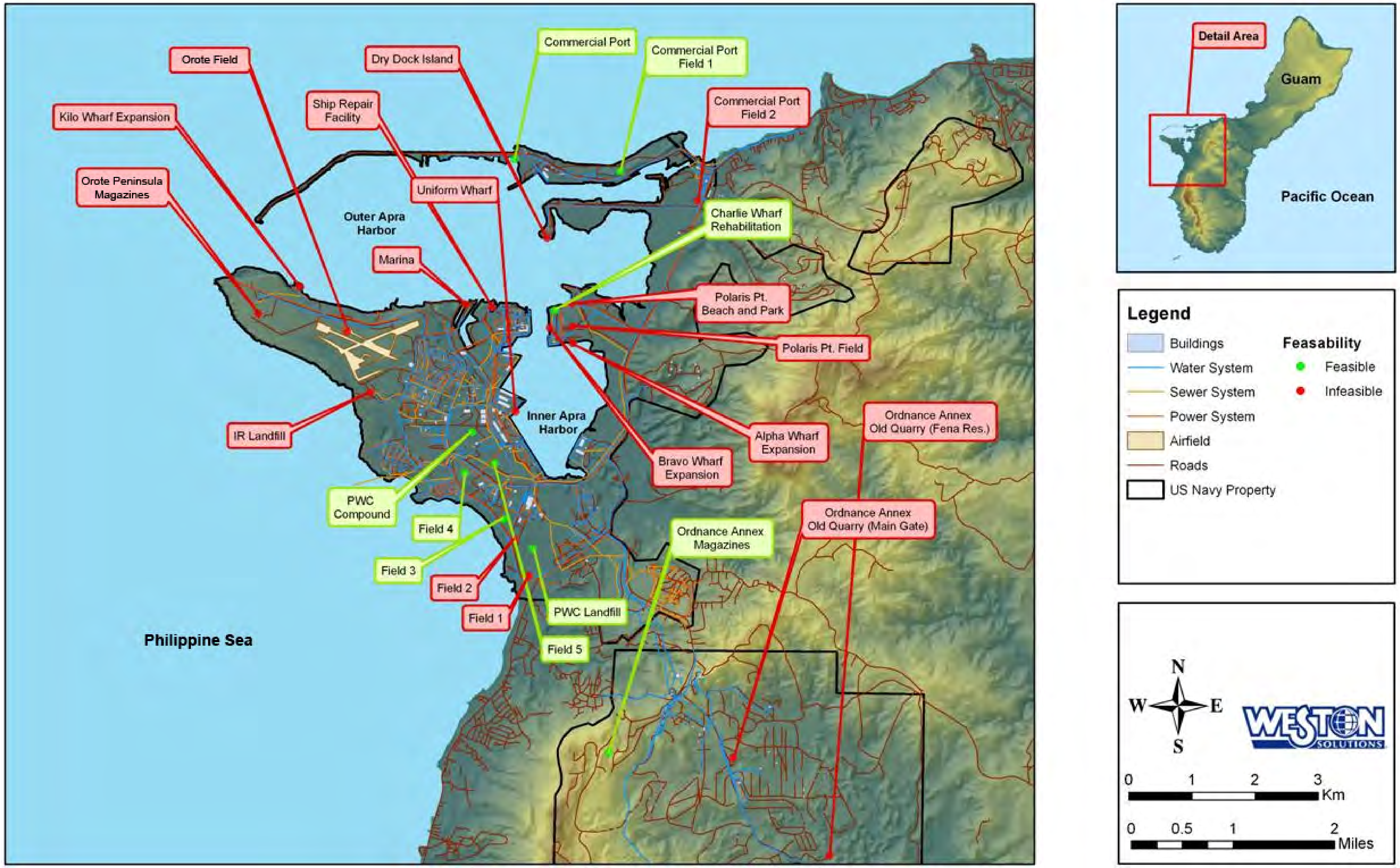


Figure 6. Overview Map of Potential Dewatering Facilities and Beneficial Use Alternatives, Apra Harbor Naval Complex, Guam

3.0 DESCRIPTION AND EVALUATION OF FEASIBLE ALTERNATIVES

This section provides an overview of dewatering and beneficial use alternatives determined to be feasible for the management of material from the proposed construction dredging projects P-433 and the selected CVN alternative. The proposed alternatives described in this chapter include dewatering sites where dredged material could be stored and allowed to dry, and potential beneficial use alternatives where dewatered dredged material could be used for planned construction projects, potential wharf expansion projects, or ongoing operations requiring fill or construction material (Figure 7). All feasible dewatering sites described in this study were considered as potential sources of material for all potential beneficial use alternatives. Alternatives that did not meet the purpose and need of the study were eliminated from further evaluation.

3.1 Formulation and Evaluation of Alternatives

This Upland Placement Study is essentially a revision, or update, to the Phase I DMMP developed by Weston in 2005. This study revisits each dewatering site and beneficial use alternative proposed in the Phase I DMMP and addresses the viability of each alternative with respect to new dredging requirements and construction schedules. Recently developed waterfront functional plans for Sierra Wharf, Victor, and Uniform Wharves and feasibility studies for the construction of a CVN capable berth (TEC Inc. JV 2008- in progress) were used to assist in the reevaluation of potential management alternatives.

Originally, the design and evaluation of potential dewatering site and beneficial use alternatives were based on multiple sources of information including data from preliminary reconnaissance surveys, an extensive literature review, and communications with Navy and other appropriate personnel (e.g., Commercial Port). The evaluation considered management strategies previously developed for Inner Apra Harbor (Olin-Estes et al. 2002); existing and future land uses of the Apra Harbor Naval Complex (HHFP 2003b); industry-accepted standards for dredged material management and beneficial use (e.g., USACE 1987) and the reasonableness of the alternatives from a technical and economic perspective (NEPA 1969 [42 United States Code (USC) §4321, et. Seq] as implemented by the Council on Environmental Quality regulations 40 Code of Federal Regulations [CFR] Parts 1500-1508).

As part of the alternative formulation process, a reconnaissance survey of the Apra Harbor Naval Complex was conducted in December 2003, which included interviews with COMNAVREGMAR and U.S. Naval Facilities Engineering Command, Pacific (NAVFAC PAC) personnel and visits to potential dewatering and beneficial use locations. The physical/chemical characteristics of sediments associated with the proposed construction dredging projects were used to evaluate the potential for environmental impacts (see Section 2.2.1).

This evaluation includes a description of capacity and costs associated with each alternative. Previous evaluation of the existing conditions of land use (air quality, soils [geology], waters [ground, surface, and marine], and biological and cultural resources) are detailed in the Phase I

DMMP (MEC- Weston 2005). The economical, technical, and logistical feasibility was evaluated at each alternative, along with environmental impacts and social considerations.

3.1.1 Assumptions

Evaluation of the alternatives required several universal assumptions regarding capacity requirements, construction schedules, dewatering times, and cost standards. Descriptions of the assumptions are as follows:

Capacity Assumptions
As discussed in the Phase I DMMP (MEC-Weston 2005) and to be consistent with other concurrent studies (TEC Inc. JV 2008- in progress), mechanical dredging is recommended for Inner Apra Harbor due to considerations based on the volume of dredged material to be managed, environmental, dewatering time, and navigational constraints. Mechanical dredging may increase the volume of cut material by 10% bulking factor; however, this is not included in capacity assumptions to be consistent with other concurrent studies (TEC Inc. JV 20008-in progress). A 2-ft overdredge allowance is factored into the capacity assumptions. As such, the anticipated volume of material requiring placement associated with each of the planned P-433 and the selected CVN alternative construction projects is 508,877 cy (389,064 m^3), and between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3), respectively. Greatest capacity is determined by the volume of the dike relative to the volume of material within the facility. The greatest capacity was determined to be at a dike height where the volume of the dike is approximately 50% of the volume of material within the facility. A description of the calculations used to determine volume of the facilities is provided in Appendix C of the Phase I DMMP (MEC-Weston 2005).

Construction Scheduling Assumptions
The duration of each of the construction dredging projects depends upon the volume of material to be dredged, production schedule, type of equipment, and number of vehicles in operation at the job site. Based on recent mechanical dredging operations in Apra Harbor using current dredge equipment available in Guam for the P- 431 project, the average dredging production rate is 800 cy (612 m^3) per day (personal communications with Black Construction, Guam). This rate was applied to the P-433 and the CVN alternative construction projects, assuming a seven day work week. The P-433 project (508,877 cy [389,064 m^3]) would take approximately 1.7 years to complete. The selected CVN alternative (between 478,900 cy and 758,000 cy [366,145 m^3 and 579,533 m^3]) would take approximately 1.6 to 2.6 years to complete. However, a larger dredge and crane operation is expected to be utilized for these dredge projects, costs associated with mobilizing a dredger from the continental U.S. have been included. It should be noted that scheduling may be delayed due to typhoons, especially between the months of January and July.

Dewatering Time Assumptions
After adequate drying time, dredged material will be available for potential beneficial use. Drying times will vary according to the size of the dewatering site, the height of dredged material within the site (herein referred to as "lift"), sediment characteristics, and environmental conditions. Passive or active dewatering technologies may be applied at each dewatering site to decrease drying times. Passive dewatering systems allow water to naturally evaporate into the atmosphere or drain into the soil. Active dewatering systems decrease drying time by diverting

water off the site or into a specially designed infiltration area. Estimates are based on observations of P-431 dredged material placed on Field 5. This material was dewatered within 2 to 10 months (personal communications with Black Construction, Guam) and therefore available for beneficial use soon after placement. Prior to beneficial use, a geotechnical evaluation must be conducted to confirm moisture content is adequate for the selected beneficial use.

Environmental Assumptions

Independent of each alternative, the material will have to be offloaded at a wharf. For dewatering site alternatives located in the northern part of Inner Apra Harbor or Outer Apra Harbor it is assumed that dredged material will be offloaded at Alpha Wharf or Delta/Echo Wharves; for dewatering site alternatives located in the southern part of Inner Apra Harbor it is assumed material will be offloaded at Uniform Wharf.

Noise levels from mechanical dredging and offloading 50 ft (15 m) from the source are estimated to range from 80 to 92 A-weighted decibels (dBA) (USEPA 1971, DON 2003) and levels are estimated to decrease by 6 dBA for each doubling of distance from the noise source. Buildings at Alpha, Delta/Echo and Uniform wharves are approximately 130 to 250 ft (40 to 75 m) from offloading areas; therefore, noise levels at those distances are estimated to range from 74 to 86 dBA outdoors and 54 to 71 dBA indoors (15 to 20 dBA less). These noise levels are similar to or slightly higher than acceptable noise levels for industrial lands. The Federal Aviation Administration (FAA) generally considers average outdoor noise levels equal to or less than 75 dBA acceptable; whereas, the Department of Defense (DoD) considers average outdoor noise levels up to 84 dBA acceptable with appropriate indoor noise reduction (DON 2003).

In order to utilize Uniform Wharf, maintenance and repairs may be required. Uniform Wharf has sustained significant earthquake damage that could prohibit prolonged use of a crane on the bulkhead. Recent dredging operations have used Uniform Wharf for offloading, rehandling, and transporting of dredged material. Consequently, Uniform Wharf may be sufficiently stable to permit similar operations of the planned construction projects. However, availability of Uniform Wharf may be limited due to upgrades scheduled in FY 2011 (MCON P-439).

Cost Assumptions

Preliminary costs estimates for the dredging and construction activities are provided by TEC Inc. and are consistent with other concurrent studies (TEC Inc. JV 2008 - in progress). Actual unit costs and mobilization/demobilization (mobe/demobe) costs may vary depending on several factors, including contractor availability, local skilled labor and labor rates, and construction schedule. Cost estimates for each dewatering alternative were standardized in order to compare amongst the alternatives. Costs are based on mechanical dredging and offloading for all dewatering site alternatives due to the infeasibility of hydraulic dredging as discussed in Section 2.2.2.

Dredging costs, consistent with TEC Inc. JV (2008-in progress), are estimated to be \$20.26/cy. Mobilization of dredge equipment is estimated to be \$9,208,320. Dredged material placement costs (\$40.52/cy) include preparing the wharf for offloading of dredged material by crane and the relocation and placement of dredged material at the dewatering site. Dredged material will be confined by earthen perimeter dikes built to an elevation that will accommodate the material generated for each project, plus a minimum of 2 ft freeboard. Crest widths range from 8 to 12 ft, depending upon the size of the facility. All of the dike will be constructed with on-site material by using previously placed dewatered dredged material. A rehandling cost to build the perimeter dike is estimated to be $16.50/cy. An additional cost for site preparation ($5,000/acre) is included. Indirect construction costs include geotechnical analysis, design and specifications, crust management plan, storm water management plan, infrastructure relocation, lighting and fencing, and miscellaneous job site costs need to be considered. An overall 10% contingency is included and is consistent with TEC JV (2008 –in progress).

3.1.2 Feasibility Evaluation Criteria

Alternatives were evaluated based on several criteria associated with their ability to meet the purpose and need, and include technical, logistical and economic feasibility, and environmental and social considerations. These criteria are described below.

Technical Feasibility
This criterion assesses the existing physical conditions and geotechnical considerations of each proposed management alternative. Based on the available data, site conditions such as infiltration rates, bearing capacity, and anticipated settlement were assessed for consistency with the requirements of the proposed management alternatives. Other general site conditions include vegetative cover, shape of the site, and the ability to develop the proposed alternative based on current and proposed land use. A management alternative was rejected if it was not technically feasible to implement.

Logistical Feasibility
This criterion focused on the operational aspects of an alternative, such as the ability of the site to accommodate the dredged material, the ability of the site to support placement of construction or dredging equipment, ingress and egress from the site, schedule, and coordination of dredged material management activities with naval operations. A project alternative was rejected if it was not logistically feasible to implement.

Economic Feasibility
This criterion focused on the cost of the alternative relative to the capacity volume of dredged material accommodated by the alternative. Unit costs used to build cost estimates for each dewatering alternative are consistent with the CVN study (TEC Inc. JV 2008 in progress) and were standardized in order to permit equitable comparison of the alternatives. Alternatives that required special construction efforts will need to be evaluated by assessing the cost relative to the benefit gained in regards to capacity and beneficial use opportunities.

Environmental Impacts
This criterion focused on the identification of potential environmental impacts from implementation of each alternative. A project alternative was rejected if it had one or more impacts to sensitive resources or receptors that would likely be unacceptable or difficult to mitigate below a level of significance.

Social Acceptability
This criterion focused on the identification of potentially adverse impacts to aesthetic and/or visual resources, recreational uses, and vehicle traffic patterns. A project alternative was rejected if it had one or more elements that would likely be unacceptable to the residents of the Naval Complex.

3.1.3 Purpose and Need Requirements

Dredging of Inner and Outer Apra Harbor is required to fulfill planned functions of the Apra Harbor Naval Complex in support of U.S. Armed Forces operating in the western Pacific. This study is being developed to provide for the management of the material that will be generated as a consequence of these dredging projects. In order to satisfy the purpose and need requirements, the dewatering alternatives evaluated must first provide for the anticipated volume of material generated from the proposed construction projects. Only those dewatering alternatives that provide sufficient capacity to accommodate material from all three projects together or for the total volume of any one project by itself were considered feasible. Additionally, it was necessary for all alternatives (dewatering and beneficial use) to be technically, logistically, and economically feasible with acceptable environmental and social impacts. If any one of the criteria was not met, the alternative was rejected from further consideration.

This evaluation is being conducted for the management of between 987,777 cy and 1,266,877 cy (755,209 m^3 and 968,597 m^3) of sediment to be generated from two projects (Table 3). The first, P-433, is scheduled for FY 2010 and requires 508,877 cy (389,064 m^3) of sediment to be managed upland in association with anticipated berthing requirements at Sierra Wharf. The second, an unscheduled project associated with the construction of a CVN capable berth, requires between 478,900 cy and 758,000 cy (366,145 m^3 and 579,533 m^3) of sediment to be managed. These volumes include a 2-ft overdredge allowance and no bulking factor.

Table 3. Volume of Material Requiring Management by Construction Project

	P-433	CVN Minimum volume Alternative	CVN Maximum volume Alternative	Total Volume (CVN min. plus P-433)	Total Volume (CVN max. plus P-433)
Dredge Volume with a 2 ft overdredge (cy)	508,877	478,900	758,000	987,777	1,266,877

3.2 Dewatering Facility Alternatives

All dewatering site alternatives maximize the available area of land to minimize lift heights and thereby reduce dredged material drying time. While smaller acreage alternatives may present fewer social and environmental impacts, these sites require higher dike elevations, greater lift heights, and longer drying times. Consequently, alternatives with the largest areas provide dewatered material for beneficial use in the least amount of time and are the most economical to construct.

The following dewatering facility sites were determined to be feasible management alternatives during the initial Phase I DMMP study (MEC-Weston 2005). Due to changes in planned construction projects, a re-evaluation of sites previously found suitable and unsuitable was conducted. Six previously recommended dewatering facilities were re-evaluated and are still considered to be viable management alternatives by their ability to meet current capacity needs. They include Polaris Point, Field 5, Commercial Port Field 1, Field 3, Field 4, and PWC. Existing dewatering facilities at Orote Airfield would be available for reuse if a beneficial reuse was identified for the dried dredged material. This study assumes a Orote Airfield will not have capacity.

Six sites have been identified as potential dewatering site alternatives for dredged material resulting from P-433 and CVN (Figure 7): (1) a 44.3 a (17.9 ha) site located on Polaris Point, referred to as Polaris Point Field; (2) a 53.2 a (21.5 ha) site located northwest of the Commissary, between and Marine Drive and Sumay Drive, referred to as Field 5; (3) a 36.9 a (14.9 ha) site located on Commercial Port property on Cabras Island, referred to as Commercial Port Field 1; (4) a 16.0 a (6.5 ha) site located south of the Navy Exchange Center and Commissary, referred to as Field 3; (5) a 26.6 a (10.8 ha) site located northwest of the Commissary, between Shoreline Drive and Marine Drive, referred to as Field 4; and (6) a 27.8 a (11.3 ha) site located between Marine Drive and Sumay Drive at the PWC Compound, referred to as PWC Compound. Polaris Point Field and Field 5 are large enough to accommodate the dredged material for both construction dredging projects (Table 4). All dewatering facilities have the capacity to store material from P-433, with the exception of Field 3. Field 3 must be used in conjunction with another alternative due to limited capacity.

Table 4. Greatest Capacity Design Specifics for Dewatering Facility Alternatives

	Field 3	Field 4	Field 5	PWC	Commercial Port 1		Polaris Point
					East	West	
Site Area (a)	16.0	26.6	53.2	27.8	22.7	14.2	44.3
Dike Center Line Perimeter (ft)	2,965	5,600	7,000	5,000	4,600	4,750	5,900
Dike Width (ft)	8	8	12	12	12	12	12
Dike Elevation (ft)	18.5	16.00	26.00	19.00	15.00	6.25	31.00
Dredged Material Lift Height (ft)	16.50	14.00	24.00	17.00	13.00	4.25	29.00
Dike Volume (cy)	129,005	185,837	606,667	242,778	145,667	33,811	711,278
Internal Volume (cy)	296,915	414,968	1,453,237	519,684	330,428	63,554	1,361,372
Total Capacity (cy)	425,920	600,805	2,059,904	762,461	476,095	97,365	2,072,649
					573,459		
Sufficient Capacity for each individual project?	No	P-433	P-433 and CVN	P-433	P-433		P-433 and CVN
Sufficient Capacity for both projects?	No	No	Yes	No	No		Yes

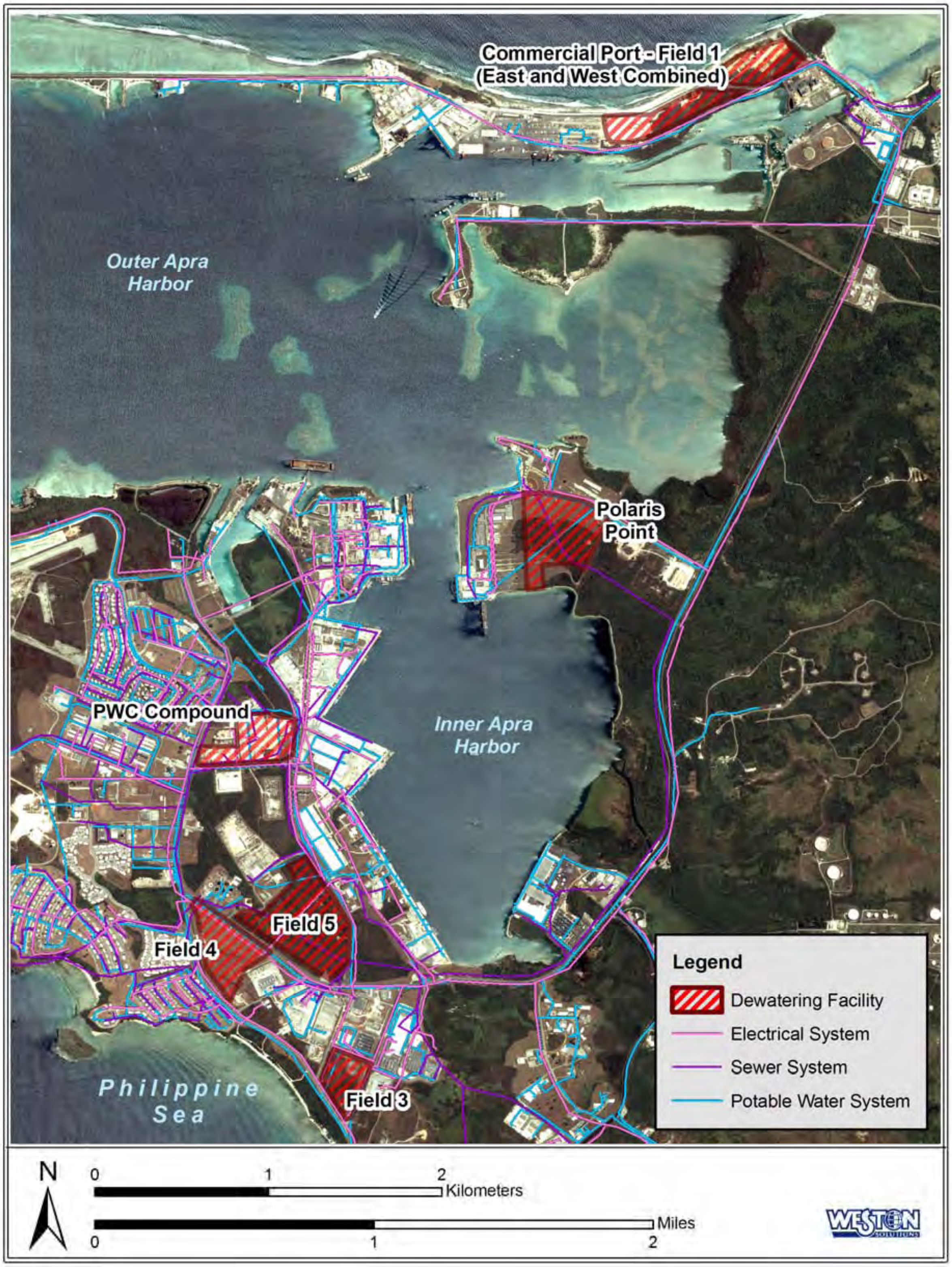


Figure 7. Location Map of Feasible Dewatering Sites.

A comparison of dredging and dewatering facility construction costs for each alternative are presented in Table 5. Costs ranged from $88.10/cy (Field 5) to $119.05/cy (Commercial Port). Unit costs are for comparative use only and assume facilities are used to their maximum capacity. Cost assumptions are provided in Section 3.1.1.

Table 5. Cost Comparison Based on Design Specifics for Dewatering Facility Alternatives

	Field 3	Field 4	Field 5	PWC	Commercial Port 1		Polaris Point
					East	West	
Greatest Capacity at Each Site (cy)	425,920	600,805	2,059,904	762,461	476,095	97,365	2,072,649
A. Dredging							
Mob/Demob Costs	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320	$ 9,208,320
Dredging Costs @$20.26/cy	$ 8,629,139	$ 12,172,316	$ 41,733,655	$ 15,447,467	$ 9,645,678	$ 1,972,608	$ 41,991,875
Munition Screening	$ 4,259,200	$ 6,008,053	$ 20,599,040	$ 7,624,613	$ 4,760,947	$ 973,647	$ 20,726,493
Subtotal A	**$ 22,096,659**	**$ 27,388,689**	**$ 71,541,015**	**$ 32,280,400**	**$ 23,614,945**	**$ 12,154,575**	**$ 71,926,689**
B. Dewatering Facility Construction Costs							
Dredge Placement - Upland ($40.52/cy)	$ 17,258,278	$ 24,344,632	$ 83,467,310	$ 30,894,933	$ 19,291,356	$ 3,945,216	$ 83,983,751
Site Prep $5000/a	$ 80,000	$ 133,000	$ 266,000	$ 139,000	$ 113,500	$ 71,000	$ 221,500
Rehandling to construct perimeter berm @ $16.50/cy	$ 2,064,079	$ 2,973,393	$ 9,706,667	$ 3,884,444	$ 2,330,667	$ 540,972	$ 11,380,444
Subtotal B	**$ 19,402,358**	**$ 27,451,025**	**$ 93,439,977**	**$ 34,918,378**	**$ 21,735,523**	**$ 4,557,189**	**$ 95,585,695**
Subtotal (A+B)	**$ 41,499,017**	**$ 54,839,714**	**$ 164,980,992**	**$ 67,198,778**	**$ 45,350,467**	**$ 16,711,763**	**$ 167,512,384**
Contingency (10%)	$ 4,149,902	$ 5,483,971	$ 16,498,099	$ 6,719,878	$ 4,535,047	$ 1,671,176	$ 16,751,238
TOTAL	**$ 45,648,919**	**$ 60,323,685**	**$ 181,479,091**	**$ 73,918,655**	**$ 49,885,514**	**$ 18,382,940**	**$ 184,263,623**
UNIT COST ($/cy)[1]	**$ 107.18**	**$ 100.40**	**$ 88.10**	**$ 96.95**	**$ 104.78**	**$ 188.81**	**$ 88.90**
					$ 119.05		

[1] Unit costs assume facilities are used to their maximum capacity.

3.2.1 Polaris Point Field Confined Upland Dewatering Site

3.2.1.1 Description

The Polaris Point Field Confined Upland Dewatering Site is situated on the undeveloped lands occupying the central and southeastern portions of Polaris Point. The site is bounded by Inner Apra Harbor to the south, a fence line to the east, and Polaris Point Road to the north and west. A site map showing the location of the dewatering facility is shown in Figure 8. A dewatering site with a footprint size of 44.3 a (17.9 ha) is large enough to accommodate the dredged material for both construction dredging projects. The maximum capacity that could be stored at this site is approximately 2,072,649 cy (1,584,654 m^3). This assumes a dike height of 31 ft (9.4 m) and would require 711,278 cy (543,811 m^3) of dike material. The footprint size was considered the maximum size that could be constructed on the vacant lands south of Polaris Point Road and east of existing and planned facilities. Earthen dikes will form the exterior walls of the dewatering site.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Alpha Wharf. Material will be offloaded at or adjacent to Alpha Wharf using a 30-ton crane equipped with a 15-cy clamshell. Then material will be loaded into 20-ton sealed-end dump trucks. The transportation route to the dewatering site extends approximately 0.25 mi (0.4 km) along Polaris Point Road to an unimproved dirt access road. Material will be dumped at the dewatering site and will be spread evenly to keep dike height to a minimum and increase drying time. Dried dredged material will be used to increase dike height as facility fills.

3.2.1.2 Capacity

As previously discussed, the Polaris Point dewatering site can be designed to contain up to an estimated 2,072,649 cy (1,584,654 m^3) of dredged material from the proposed construction dredging projects. This is sufficient capacity for both P-433 and CVN projects. The 44.3 a (17.9 ha) dewatering site will be constructed with an earthen dike with side slopes of one vertical on three horizontal. The perimeter along the centerline of the dike is approximately 5,900 ft (1,798 m). The conceptual design for the dewatering site associated with Polaris Point is summarized in Table 4.

3.2.1.3 Costs

The cost estimates for the placement of P-433 and CVN at Polaris Point are summarized in Table 5. Estimated costs are based on dredging, placement, and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $45,239,000. The total project costs for CVN are estimated to range between $42,574,000 and $67,386,000. Cost to hold P-433 and CVN are estimated to range between $87,813,000 and $112,625,000. Cost assumptions are provided in Section 3.1.1. Costs related to relocation of water and sewer lines needs to be considered.

Figure 8. Polaris Point Field Confined Upland Dewatering Site.

3.2.1.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed. The Polaris Point dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected. Impacts to marine water quality during transport of scows to the offloading site at Alpha Wharf could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site. Approximately 50 a of disturbed open woods will be cleared. Should the site present an attractive nuisance for migratory birds (e.g., standing water, scavenging of food from placed material), reflective flagging and/or other management practices may be used to discourage bird use.

No impacts to cultural resources are expected from the construction of the dewatering site. The following sections describe the potential impacts a dewatering facility at Field 5 may have on the environmental resources.

<u>Noise</u>
Noise levels should be within acceptable criteria for industrial lands located on Polaris Point during construction of most of the dike, but may temporarily exceed ANSI criteria while the southwestern portion of the dike is under construction. Noise levels at the recreational fields, beach, and day use areas located on the northern portion of Polaris Point would be exceeded during dike construction.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and inhalable particulate matter of 10 microns or less in size (PM_{10}). These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

<u>Odor</u>
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.1.5 Feasibility Evaluation

In summary, review of all available information suggests that this alternative is feasible and meets the purpose and need. Polaris Point is large enough to accommodate the dredged material for both construction dredging projects (Section 3.2). Assuming existing water and sewer lines are relocated; this alternative is technically, logistically, and economically feasible. All environmental and social impacts are determined to be minimal and temporary.

3.2.2 Field 5 Confined Upland Dewatering Site

3.2.2.1 Description

The Field 5 Confined Upland Dewatering Site is situated between Marina Drive and Sumay Drive. The Field 5 site is large enough to accommodate the dredged material for both construction dredging projects. A site map showing the location of the dewatering facility and transportation routes from Uniform Wharf are shown Figure 9. A dewatering site with a footprint size of 53.2 a (21.5 ha) will be constructed. The maximum capacity that could be stored at this site is approximately 2,059,904 cy (1,574,910 m^3). This assumes a dike height of 26 ft (7.9 m) and would require 606,667 cy (463,830 m^3) of dike material. The dewatering facility for Field 5 was designed to the maximum size that could be located on vacant lands between Marina Drive, Sumay Drive, and existing facilities. Earthen dikes will form the exterior walls of the dewatering site.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Then material will be offloaded into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 1.2 mi (1.9 km) along Sumay Drive to an access road. Material will be offloaded and spread evenly to keep dike height and drying time to a minimum at the dewatering site. Dried dredged material will be used to increase dike height as facility fills.

3.2.2.2 Capacity

As previously discussed, the Field 5 dewatering site can be designed to contain up to an estimated 2,059,904 cy (1,574,910 m^3) of dredged material from the proposed construction dredging projects. This is sufficient capacity for both P-433 and CVN projects. The 53.2 a (21.5 ha) dewatering site will be constructed with an earthen dike with side slopes of one vertical on three horizontal. The perimeter along the centerline of the dike is approximately 7,000 ft (2,134 m). The conceptual design for the dewatering site associated with Field 5 is summarized in Table 4.

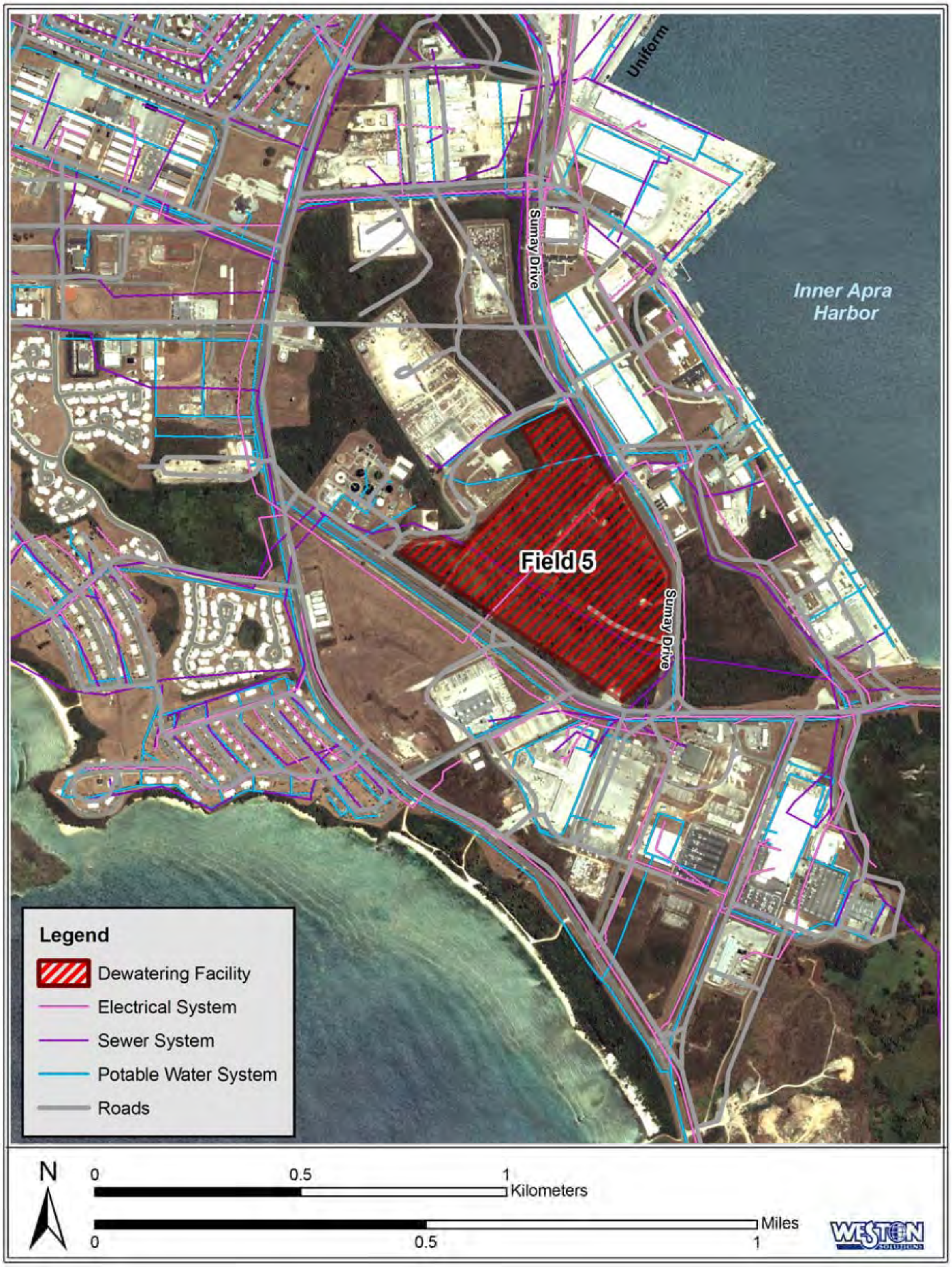


Figure 9. Field 5 Confined Upland Dewatering Site.

3.2.2.3 Costs

The cost estimates for the placement of P-433 and CVN at Field 5 are summarized in Table 5. Estimated costs are based on dredging, placement and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $44,832,000. The total project costs for CVN are estimated to range between $42,191,000 and $66,780,000. Cost to hold P-433 and CVN are estimated to range between $87,023,000 and $111,612,000. Additional costs for rerouting of electric lines will need to be considered. Cost assumptions are provided in Section 3.1.1.

3.2.2.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed with one exception: a portion of the site was disturbed for the placement of a CDF (Figure 10 and Figure 11). Dredged material from MCON P-431 was placed in this facility to dewater. The Field 5 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected. Impacts to marine water quality during transport of scows to the offloading site at Uniform Wharf could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport.

No impacts to sensitive habitats or sensitive species would occur from the construction of the dewatering site. Approximately 75% of the site was previously cleared of tangantangan forest for placement of dredged material from MCON P-431. Construction of the dewatering site would result in the conversion of the remaining 25% of tangantangan forest to unvegetated sediment. Should the site present an attractive nuisance for migratory birds (e.g., standing water, scavenging of food from placed material) reflective flagging and/or other management practices may be used to discourage bird use.

No impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 5 may have on the environmental resources.

<u>Noise</u>
Outdoor noise levels near workplace buildings located within 200 ft (61m) of the proposed dewatering facility will be near 80 dBA when the northeast and south edges of the dike are constructed. This level exceeds the recommended levels by the FAA, but is within the DoD acceptable range. Noise levels inside the building will be approximately 60 dBA during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but would temporarily exceed criteria while the northeast portion of the dike is under construction.

Figure 10. Existing Conditions in 2007 at Field 5 Dewatering Facility, Cell 1, between Sumay and Marina Drives, Apra Harbor, Guam

Figure 11. Existing conditions in 2007 at Field 5 Dewatering Facility, Cell 2, between Sumay and Marina Drives, Apra Harbor, Guam.

Air Quality

Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include CO, NO_x, SO_x, and PM_{10}. These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor

Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.2.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. Field 5 is large enough to accommodate the dredged material for both construction dredging projects (Section 3.2). This alternative is currently being used and is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. While social impacts from noise and traffic are potentially problematic due to the location and duration of activities at this facility, they do not render this alternative infeasible, providing appropriate management plans are developed.

3.2.3 Commercial Port Field 1 Confined Upland Dewatering Site

3.2.3.1 Description

The Commercial Port Field 1 site is located on Cabras Island on Commercial Port property. The proposed dewatering site is predominately open space with a mixture of concrete and alien grassland. The dewatering facility for Commercial Port Field 1 was designed to the maximum size that could be located on vacant lands west of the Piti power plant and east of the Commercial Port container storage area. Approximately 36.9 a (14.9 ha) of undeveloped land located between Cabras Road (Route 11) and Coral Road, and east of the container yard can accommodate approximately 573,459 cy (438,441 m^3) of dredged material. The Commercial Port Field 1 site is large enough to accommodate the dredged material from P-433 assuming improvements to the site are made. The preparation of the site for placement will involve removal of a 50-ft (15.2 m) limestone escarpment that is located in the eastern cell; all material greater than 30 ft (9.1 m) in elevation will need to be removed in order to achieve the capacity requirements. In addition, the northern edge of dike in the eastern cell extends along the coastline and will require armament to prevent erosion of dike during high energy storms. A site map showing the location of the dewatering facility is shown Figure 12.

Figure 12. Commercial Port Field 1 Confined Upland Dewatering Site.

The creation of a dewatering site within Commercial Port will facilitate the use of dried dredged material for the port expansion project. In order to help Guam meet its responsibilities as a transshipment hub, the Port Authority of Guam has developed a master plan that will expand the current port footprint to include new deepwater cargo piers, upgraded fisheries facilities, expanded container lay-down areas, an industrial park, and cruise-ship facilities. A substantial volume of fill material will be required for these capital improvement projects. The Navy and the Government of Guam have signed a memorandum of understanding (MOU) regarding the use of any dredged material deemed appropriate for fill material and to establish procedures for the determination of the use of the dredged material as fill material for use by the Port Authority of Guam (MOU April 2001; in Appendix D of Phase I DMMP [MEC-Weston 2005]).

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Delta or Echo Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Then material will be loaded into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 2.5 mi (4 km), along Causeway Road, north on Marina Road and to Route 11 (Figure 12). At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Dried dredged material will be used to increase dike height as facility fills.

3.2.3.2 Capacity

As previously discussed, the Commercial Port Field 1 dewatering site can be designed to contain up to an estimated 573,459 cy (438,441 m^3) of dredged material from the proposed construction projects. This is sufficient capacity for the entire P-433 project. The dewatering site is bisected by Route 11 to form two dewatering cells. The eastern cell (22.7 a [9.2 ha]) can be designed to contain approximately 476,095 cy (364,001 m^3) and the western cell (14.2 a [5.7 ha]) can be designed to contain up to an estimated 97,365 cy (74,441 m^3). The dewatering site will be constructed with an earthen dike with side slopes of 1 vertical on 3 horizontal. The perimeter along the centerline of the dike is approximately 4,750 ft (1,448 m) in the western cell and 4,600 ft (1,402 m) in the eastern cell. The conceptual design for the dewatering site associated with Commercial Port Field 1 is summarized in Table 4.

3.2.3.3 Costs

The cost estimate for the placement of P-433 at Commercial Port is summarized in Table 5. The estimated cost is based on dredging, placement and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $60,582,000. Cost assumptions are provided in Section 3.1.1.

3.2.3.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed. The Commercial Port Field 1 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected. Impacts to marine water quality during transport of scows to the offloading site (either Delta/Echo Wharves) could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport. Marine waters adjacent to the eastern cell are classified as good (M2). Design specifications will need to include BMPs to prevent drainage into the ocean.

There would be a conversion of 36.9 a (15.0 ha) of partly vegetated, urban land to unvegetated sediment with the construction of the dewatering site. Should the site present an attractive nuisance for migratory birds (e.g., standing water, scavenging of food from placed material) reflective flagging and/or other management practices may be used to discourage bird use.

No impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 5 may have on the environmental resources.

<u>Noise</u>
Outdoor noise levels near workplace buildings located within 250 ft (76 m) will be near 80 dBA when the eastern edge of the dike is constructed, exceeding the recommended levels by the FAA, but within the DoD acceptable range. Noise levels inside buildings will be approximately 60 dBA during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but may temporarily exceed criteria while the western portion of the dike is under construction.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and inhalable particulate matter of 10 microns or less in size (PM_{10}). These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

<u>Odor</u>
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility.

3.2.3.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. This alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. While social impacts from noise and traffic are potentially problematic due to the location and duration of this facility they due not render this alternative infeasible, providing appropriate management plans are developed.

3.2.4 PWC Compound Confined Upland Dewatering Site

3.2.4.1 Description

The PWC Compound Confined Upland Dewatering Site is bounded by Harbor Drive to the south, Marine Drive to the west, Sumay Drive to the east and NOB Hill Bowl Theater to the north. A dewatering site with a footprint size of 27.8 a (11.3 ha) will be constructed to provide capacity for dewatering of material from P-433 construction dredging project. The maximum capacity that could be stored at this site is approximately 762,461 cy (582,943 m^3). This assumes a dike height of 19 ft (5.8 m) and would require 242,778 cy (185,617 m^3) of dike material. A site map showing the location of the dewatering facility is shown in Figure 13.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Then material will be loaded into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 0.25 miles (0.4 km), along Sumay Drive to an access road on Harbor Drive. At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Dried dredged material will be used to increase dike height as facility fills.

3.2.4.2 Capacity

As previously discussed, the PWC Compound dewatering site can be designed to contain up to an estimated 762,461 cy (582,943 m^3) of dredged material from the proposed construction projects. This is sufficient capacity for the entire P-433 project. The 27.8 a (11.3 ha) dewatering site will be constructed with an earthen dike with side slopes of 1 vertical on 3 horizontal. The perimeter along the centerline of the dike is approximately 5,000 ft (1,524 m). The conceptual design for the dewatering site associated with PWC Compound is summarized in Table 4.

3.2.4.3 Costs

The cost estimates for the placement of P-433 at PWC Compound are summarized in Table 5. Estimated costs are based on dredging, placement and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $49,336,000. Additional site preparation costs including the removal of abandoned buildings needs to be considered. Cost assumptions are provided in Section 3.1.1.

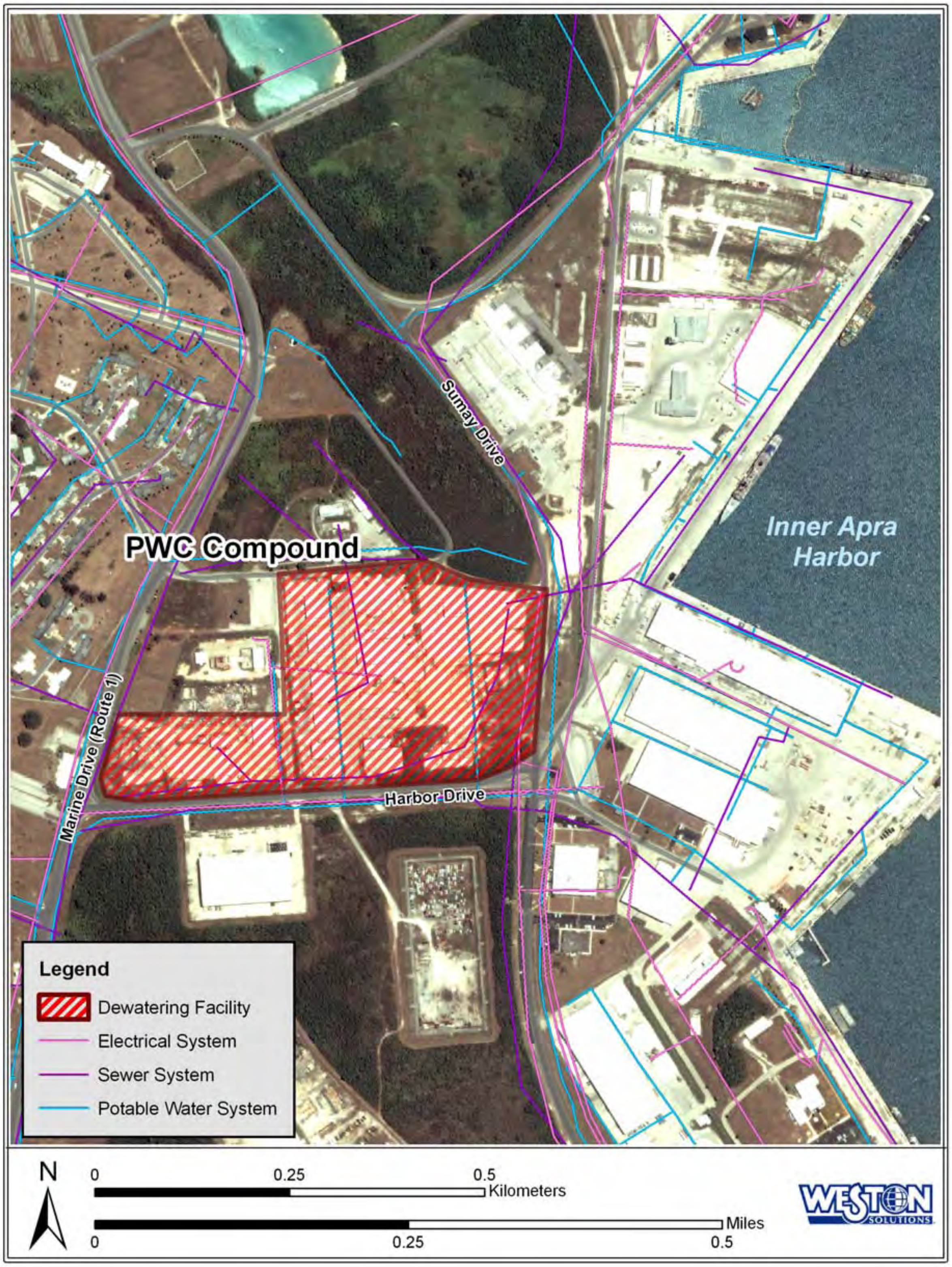


Figure 13. PWC Compound Confined Upland Dewatering Site.

3.2.4.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. PWC Compound dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected; there are no surface waters or wetlands on this site.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site.

No impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at the PWC Compound may have on the environmental resources.

<u>Noise</u>
The Lockwood Terrace residential area is located approximately 200 ft (61 m) from the western edge of the PWC Compound; in addition, the closest industrial buildings are located approximately 200 ft (61 m) form the eastern edge of the PWC Compound. Outdoor noise levels may exceed 80 dBA when the work is being conducted in the portion of the PWC Compound that is adjacent to these homes and buildings. These levels exceed the FAA recommended levels of 75 dBA. Exterior noise levels associated with this alternative will exceed the HUD guideline for residential areas. Noise levels inside adjacent buildings will be approximately 60 dBA (20 dBA less) during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but may temporarily exceed criteria while the dike is under construction.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulfur (SO_x), and inhalable particulate matter of 10 microns or less in size (PM_{10}). These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.4.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. Assuming the removal of approximately 20 buildings, this alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise may be potentially problematic due to the location and duration of this facility; however they due not render this alternative infeasible, providing appropriate management plans are developed. Destruction or movement of structures identified as cultural resources may need to be evaluated prior to construction.

Purpose and Need
In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. This alternative is technically, logistically and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise may be problematic due to the location and duration of activities proposed for this facility.

3.2.5 Field 3 Dewatering Site

3.2.5.1 Description

The Field 3 Dewatering Site is situated on undeveloped lands south of the Commissary. The site is bounded on the east by Route 2B (Exchange Road), on the south by Shoreline Drive and on the west by an unmarked north-south arterial connecting Shoreline Drive with Marine Drive, passing to the west of the Commissary. The Field 3 site, with a footprint size of 16.0 a (6.5 ha), will be constructed to provide capacity for dewatering of material from P-433 construction dredging project. The maximum capacity that could be stored at this site would be approximately 425,920 cy (325,639 m^3). This assumes a dike height of 18.5 ft (5.6 m) and a lift height of 16.5 ft (5.0 m). A site map showing the location of the dewatering facility is shown in Figure 14.

Mechanically dredged material will be excavated using a clam shell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Material will be offloaded directly into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 1.75 miles (2.8 km). At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Earthen dikes will form the exterior walls of the dewatering site. Dried dredged material will be used to increase dike height as facility fills.

Figure 14. Field 3 Confined Upland Dewatering Site.

3.2.5.2 Capacity

As previously discussed, the Field 3 dewatering site can be designed to contain up to an estimated 425,920 cy (325,639 m^3). This is not sufficient capacity for the entire P-433 project; however it could be used in conjunction with other sites. The 16.0 a (6.5 ha) dewatering site will be constructed with an earthen dike with side slopes of 1 vertical on 3 horizontal. The perimeter along the centerline of the dike is approximately 2,965 ft (904 m). The conceptual design for the dewatering site associated with Field 3 is summarized in Table 4.

3.2.5.3 Costs

The cost estimate for the placement of P-433 at Field 3 is summarized in Table 5. The estimated cost is based on dredging, placement, and rehandling in the dewatering facility. The total project costs for 425,920 cy (325,639 m^3) of P-433 material is estimated to be $45,650,000. Consideration for removal of a water line needs to be considered. Cost assumptions are provided in Section 3.1.1.

3.2.5.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources, and cultural resources, are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Field 3 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water and exposure of sensitive organisms are not expected; there are no surface waters or wetlands on this site. Impacts to marine water quality during transport of scows to the offloading site at Uniform Wharf could be minimized by BMPs (if necessary) such as restricting load volumes to avoid over-flow during transport.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site.

Field 3 is located in an area thought to be part of the historical Orote Village; however, artifacts related to the village have not been found within the proposed dewatering site (Lauter-Reinmann 1998). While two concrete pads (TN-8) are located in the northeastern portion of Field 3, they are not eligible to be listed on the National Register. Therefore, no impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 3 may have on the environmental resources.

<u>Noise</u>
The Autoport Facility, Commissary, and Naval Exchange are the closest facilities to the proposed dewatering site. The distance will vary depending on the location of construction activities. The distances between the proposed facility and the Autoport will range from

approximately 250 to 1,000 ft (76 to 304 m). The distances between the proposed facility and Commissary will range from approximately 400 to 1,500 ft (122 to 457 m). The distances between the proposed facility and the Naval Exchange will range from approximately 600 to 2,100 ft (183 to 640 m). Construction noise levels will range from 55 to 83 dBA outside the Autoport Facility, 50 to 79 dBA outside the Commissary, and from 47 to 75 dBA outside the Naval Exchange. Therefore, average exterior noise levels during construction will be expected to meet FAA (average of 75 dBA or less) and DoD (up to 84 dB outdoors with indoor noise reduction) guidance levels for industrial lands.

Distances between the proposed facility and Dadi Beach, south of Shoreline Drive, range from approximately 400 to 1,400 ft (122 to 427 m). Noise levels will range between 53 and 77 dBA at the beach during construction of the dikes. Therefore, noise levels at the beach will be elevated relative to the ANSI noise guideline of 55 dBA for neighborhood parks when construction activities occur along the south end of the dewatering site.

Distances between the proposed dike and the South Tipaloa housing development range from approximately 2000 to 4000 ft (610 to 1220 km). Construction noise levels will attenuate to approximately 49 to 65 dBA outside the residences, and will be approximately 20 dBA less indoors with doors and windows closed. Therefore, average noise levels during construction of the dewatering site would be expected to be within the HUD guidance level of 65 dB for residential exterior noise levels.

<u>Air Quality</u>
Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include CO, NO_x, SO_x, and PM_{10}. These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

<u>Odor</u>
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.5.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate a portion of the dredged material associated with P-433. Assuming the relocation of a water line, this alternative is technically, logistically, and economically feasible. All environmental and social impacts are determined to be minimal and temporary.

<u>Purpose and Need</u>
In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate a portion of the volume of P-433 assuming that an existing water line is relocated. This alternative is technically, logistically,

and economically feasible. All environmental and social impacts are determined to be minimal and temporary.

3.2.6 Field 4 Dewatering Site

3.2.6.1 Description

The Field 4 Dewatering Site is situated on the undeveloped lands near the Tipaloa housing complex. The site is bounded by Shoreline Drive to the west and Marine Drive to the east. The Field 4 site, with a footprint size of 26.6 a (10.8 ha), will be constructed to provide capacity for dewatering of material from P-433 construction dredging project. The maximum capacity that could be stored at this site would be approximately 600,805 cy (459,348 m^3). This assumes a dike height of 16 ft (4.9 m) and a lift height of 14 ft (4.3 m). A site map showing the location of the dewatering facility is shown in Figure 15.

Mechanically dredged material will be excavated using a clamshell dredge and placed in an adjacent dump scow. Tugs will transport the scow approximately 0.5 mi (0.8 km) to Uniform Wharf. Material will be offloaded at the wharf using a 30-ton crane equipped with a 15-cy clamshell bucket. Material will be offloaded directly into sealed-end dump trucks for transportation to the dewatering facility. The transportation route to the dewatering site extends approximately 1.2 mi (0.9 km), along Sumay Drive to an access road. At the dewatering site material will be offloaded and spread evenly to keep dike height and drying time to a minimum. Earthen dikes will form the exterior walls of the dewatering site. Dried dredged material will be used to increase dike height as facility fills.

3.2.6.2 Capacity

As previously discussed, the Field 4 dewatering site can be designed to contain up to an estimated 600,805 cy (459,348 m^3). This is sufficient capacity for the entire P-433 project. The 26.6 a (10.8 ha) dewatering site will be constructed with an earthen dike with side slopes of one vertical on three horizontal. The perimeter along the centerline of the dike is approximately 5,600 ft (1,707 m). The conceptual design for the dewatering site associated with Field 4 is summarized in Table 4.

3.2.6.3 Costs

The cost estimate for the placement of P-433 at Field 4 is summarized in Table 5. The estimated cost is based on dredging, placement, and rehandling in the dewatering facility. The total project cost for P-433 is estimated to be $51,091,000. Consideration for removal of power lines needs to be considered. Cost assumptions are provided in Section 3.1.1.

Figure 15. Field 4 Confined Upland Dewatering Site.

3.2.6.4 Existing Conditions

Existing conditions, including land use, air quality, geology, water quality, biological resources and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Field 4 dewatering facility site was determined to be a feasible management alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Long-term environmental impacts caused by migration of chemical contaminants to water, and exposure of sensitive organisms are not expected; there are no surface waters or wetlands on this site.

No impacts to sensitive habitats or sensitive species will occur from the construction of the dewatering site. There will be a conversion of urban/alien grassland to unvegetated sediment with the construction of the dewatering site.

While two Quonset huts are located on the edge of Field 4, they are not eligible to be listed on the National Register. Therefore, no impacts to cultural resources are expected from the construction of the dewatering site.

The following sections describe the potential impacts a dewatering facility at Field 4 may have on the environmental resources.

Noise

The Tipaloa residential area is located 200 ft (61 m) from the southeastern edge of Field 4; in addition, industrial buildings are located 200 ft (61 m) from the southern edge of Field 4. Outdoor noise levels may exceed 80 dBA during work in the portion of Field 4 that is adjacent to these homes and buildings. These levels exceed the FAA recommended levels of 75 dBA. The HUD guideline for an acceptable exterior noise level is 65 dBA, which also applies to DoD housing. Thus, exterior noise levels associated with this alternative will exceed the HUD guideline. Noise levels inside adjacent buildings will be approximately 60 dBA (20 dBA less) during construction. Noise levels should be within acceptable criteria for industrial lands during construction of most of the dike, but may temporarily exceed criteria while the southern portion of the dike is under construction.

Air Quality

Air emissions and fugitive dust will be generated by heavy equipment and trucks during construction of the containment dikes. Emissions will include those typical of fossil-fuel combustion sources and include CO, NO_x, SO_x, and PM_{10}. These emissions represent temporary construction impacts. Depending upon the phase of construction and the number and types of equipment in operation, control measures may be required to reduce SO_2 emissions within the nonattainment area. BMPs such as water spray could be used to minimize fugitive dust impacts.

Odor
Odors associated with dredged material drying may be expected at distances up to 0.2 mi (0.3 km) from the proposed dewatering facility. However, volatilization rates were considered to be too small to pose a public health or safety hazard (Olin-Estes et al. 2002).

3.2.6.5 Feasibility Evaluation

In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate dredged material associated with P-433. Assuming the relocation of overhead power lines, sewer lines, and water lines, this alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise and traffic may be potentially problematic due to the location and duration of this facility; however, they do not render this alternative infeasible, providing appropriate management plans are developed.

Purpose and Need
In summary, a review of all available information suggests that this alternative is feasible and meets the purpose and need. The dewatering site can accommodate the volume of P-433 assuming power lines are relocated. This alternative is technically, logistically, and economically feasible. All environmental impacts are determined to be minimal and temporary. Social impacts from noise and traffic may be problematic due to the location and duration of activities proposed for this facility.

3.3 Existing Dewatering Facility Alternatives

SRF and Orote Airfield are existing dewatering sites that are currently, or projected to be, at capacity with maintenance dredged material and P-502 construction dredged material. These alternatives assume that the dredged material currently placed at these CDFs could be removed for beneficial use prior to the dredging of the proposed construction projects.

The SRF is located to the west of the Inner Apra Harbor entrance channel and is bounded to the north by Outer Apra Harbor, Sumay Cove to the west, and general purpose wharves to the south. The SRF site is located on fill land in a highly developed, urban area, although many of the buildings are no longer in use. The primary function of property within the SRF is for industrial or maintenance purposes. The SRF property is currently under lease to the GEDA. The Guam Shipyard, Inc. is responsible for support, maintenance, and repair of naval vessels (HHFP 2003b). There are two wetlands located approximately 600 ft (183 m) southwest of the site.

The existing CDF was constructed for management of dredged material from the Phase I maintenance dredging project at Victor and X-Ray Wharves, Inner Apra Harbor, Guam. The acreage of the existing CDF at the SRF is approximately 2 a (0.8 ha). Utilizing the same dike configuration and lift heights, the maximum capacity of the site is 16,000 cy (12, 233 m^3).

The Orote Airfield CDF is located on Orote Point, bounded by Orote Point Road to the north, and Orote Airfield runways to the south. The airstrip is still active and is designated as a historic site, thus the required 16.5 ft (5 m) setbacks from the runway limit the area available for disposal (Schroeder et al. 2001). The Orote Airfield is located on the Orote Peninsula, a limestone plateau that slopes from 80 ft (24 m) in the east to 200 ft (61 m) in the west. It is populated by a mixture of urban and alien grasslands and tangantangan forest (DON 2001a). Limestone forest occurs along the cliffs immediately to the north of the Orote Airfield dewatering site and along the southern cliffs of the peninsula. Limestone forest is a preferred habitat for several endangered birds of Guam.

The existing CDF was constructed for management of dredged material from the Phase I maintenance dredging project at Victor and X-Ray Wharves, Inner Apra Harbor, Guam. The acreage of the existing site at Orote Airfield is approximately 16.8 a (6.8 ha). Utilizing the same property and potentially the same berm structures, the maximum capacity of this site is 71,900 cy (54,975 m^3).

The capacity of the existing CDFs at SRF and Orote Airfield is insufficient to accommodate the volume of dredged material for the proposed dredging projects in this DMMP. However, they are designated CDFs containing dewatered dredged material and may be considered resources for the management of material.

3.4 Beneficial Use Alternatives

Beneficial use includes a wide variety of options that utilize dredged material for a productive purpose. Beneficial uses of dredged material may make traditional placement of dredged material unnecessary, or reduce the level of disposal. The broad categories of beneficial uses, based on the functional use of the dredged material or site, defined by the USACE (1987) are as follows:

- Habitat restoration/enhancement (wetland, upland, island, and aquatic);
- Beach nourishment;
- Aquaculture;
- Parks and recreation (commercial and non-commercial);
- Agriculture/horticulture/forestry;
- Mine and quarry reclamation;
- Landfill cover for solid waste management;
- Shoreline stabilization;
- Industrial and commercial use;
- Material transfer (fill, dikes, roads, etc.); and
- Construction material.

Many of the designated beneficial use alternatives are not appropriate for dredged material from Apra Harbor and are discussed below:

- **Habitat restoration/enhancement (wetland, upland, island, and aquatic)**: No projects are identified, therefore an evaluation cannot be conducted to determine if the dewatered dredged material is suitable for use.
- **Beach nourishment**: Guam does not have a policy regarding beach nourishment. Coastal erosion is not a major issue for Guam because of soil types and because of barrier/fringe/patch reef system of protection. Assuming requirements would be similar

to the State of Hawaii, dredged material from Apra Harbor for use in beach nourishment does not meet the engineering requirements (HDLNR 2005). Dewatered dredged material from in and outer Apra Harbor does not meet the majority of the guidelines, which include less than 6% fines, no more than 50% of fill material with a grain diameter less than 0.125 millimeter (mm), dominantly composed of naturally occurring carbonate beach or dune sand, and free of contaminants of any kind such as excessive silt, organic matter, clay, or any other pollutant that would produce an undesirable condition to the beach or water quality.

- **Aquaculture**: This beneficial use alternative consists of the construction of a facility with a primary function of dredged material containment and a secondary function for aquaculture operations. Creating an aquaculture facility in the Apra Harbor Complex does not meet the Navy's purpose and need.
- **Parks and recreation (commercial and non- commercial)**: The parks and recreation beneficial use alternative consists of the construction of a park or recreational facility following closure of the CDF. Conversion of the CDF to a parks and recreation facility requires the closure and capping of the dewatering facility. Currently, the Navy's purpose and need is to continue to use the CDF for the management of the dredging projects previously discussed. An eventual closure and creation of a recreation facility may be suitable in the future, but has not been identified in Navy planning documents.
- **Agriculture/horticulture/forestry**: The feasibility of beneficially using dredged material as topsoil is primarily dependent on two site related factors: the location of the end use site relative to the dredge material source; and the top soil demand relative to quantities of dredged material available. Secondary logistical factors are process related and include the demand rate of the final topsoil product in quantity per year, the production rates of dredged material, dewatering and other processing rates. The factors affecting feasibility are highly dependent on the specific project. At a minimum, the project location and quantity demand must be selected prior to conducting a detailed logistical feasibility analysis. Dredged material from a marine environment requires treatment to wash or reduce salinity concentrations in order to make the material suitable for flora and fauna. A study conducted for the Island of Oahu in Hawaii determined the market for topsoil is declining and may not sustain the development of a topsoil treatment facility (Belt Collins 2002). Creating topsoil treatment facility in the Apra Harbor Complex does not meet the Navy's purpose and need.
- **Mine and quarry reclamation**: Dredged material from P-433 and CVN is likely suitable for mine and quarry reclamation. However, no reclamation projects are identified.
- **Shoreline Stabilization**: Shore erosion is a major problem along many ocean, bay, and estuary shorelines due to wave action, sea level rise, and/or subsidence. Shoreline restoration is the process of restoring and/or mitigating a shoreline to its original or desired position following any natural or man-made disturbance. The use of clean dredged material in shoreline restoration projects provides environmental and economic benefits. Shoreline restoration has the potential to create habitat and improve water quality while reducing the loss of valuable waterfront property. Stabilization and enhancement of eroding shorelines with dredged materials may also help reduce the volume and frequency of future maintenance dredging. While, no shoreline restoration projects are identified in this document, material from Inner Apra Harbor that is compatible with receiver site in terms of grain size, and that is relatively free of contaminants, would be suitable for shoreline restoration.

- **Construction Products**: Use of dewatered dredged material as an aggregate in concrete or asphalt would require the material to be transported to a processing facility and separated into specific size fractions (by pretreatment washing and possible size fractionation using hydrocyclones). The appropriate granular fractions recovered can then be sold for direct use as an aggregate in concrete or in asphalt pavement that utilize solidification technologies. Sand could be used by the construction industry as an addition in Portland cement. An alternative beneficial use option would need to be identified for the remaining fine-grained material. Based on a previous evaluation for Pearl Harbor (Belt Collins 2002), only 25% of dredged material would be useable as aggregate. Separation of the coarse grained material for use as an aggregate would require the development of a dredged material processing facility (DMPF). Currently, a DMPF has not been constructed in Guam. A DMPF would need to be developed to physically separate the grain size fractions of the dredged material.

  Belt Collins (2002) concluded that basaltic and limestone sand, as well as gravels, generated from a DMPF in Hawaii could be used as aggregates in asphalt and concrete. In Hawaii, the estimated costs for construction of a pilot facility to demonstrate the effectiveness of treating dredged material for specific beneficial use options would be comprised of an initial capital of $16-$20 million for construction of the facility, $1 million for design, and an annual operating cost of the DMPF of approximately $1.5 million. Additional operation costs include the transport of material from the CDF to the DMPF. Revenue would be generated from the sale of the aggregate materials. Sand produced from the DMPF could potentially be sold at a rate of $37.50/cy and gravel could be sold at a rate of $22.50/cy (Belt Collins 2002). It is assumed the costs for Hawaii would be similar as Guam; however, the demand may be less on Guam.

  Using dried dredged material from CDFs in the production of construction blocks and bricks has successfully been demonstrated, mostly in pilot studies, to be a viable beneficial use option. However, this technology is not readily available. Manufacturing of blocks, bricks, and tiles from dredged material would require the development of a DMPF in Guam. Belt Collins (2002) determined that although the development of a DMPF to produce construction materials (blocks, bricks) was technically feasible, market demands dictate that construction blocks and bricks need to be consistent in color and composition. Due to the inherent variability of dredged material, construction blocks made from dredged material would not be of consistent color and composition. Further, the production of construction blocks would likely require the use of Portland cement as a binder that would result in a low-strength block that does not meet industry standards. Due to lack of a strong market for the products and the low-quality product that is produced from dredged material, this technology is not a feasible alternative for the Navy nor does it meet their purpose and need.

3.4.1 Economic Benefits

The productive use of dredged material provides tangible and intangible benefits that enhance the environment, the local community, and society. Economic benefits can be seen in cost savings from more effective port and channel maintenance dredging, and using dredged material in other beneficial applications, such as construction. Long-range planning for dredged material management should consider future needs of the public and private sectors and what applications would provide the greatest economic benefit. Beneficial uses may be incorporated in planning for public recreation applications, environmental enhancement, and beach and shore protection.

3.4.2 Social Benefits

Social benefits are generally a direct consequence of the particular beneficial use adopted. The most tangible direct benefit enjoyed by the local community is financial. This may be in the form of reduced community costs for a construction project, or increased community income through improved agriculture, fisheries, tourism, product manufacturing, or job creation. Improved beaches may also boost tourism.

Another important social benefit is improvements to the environment, and recreational and sporting opportunities. The local landscape may be enhanced through changes in topography and introduction of new plant and wildlife species. Enhancements to sporting activities, such as fishing, swimming, surfing, sailing, water skiing, and wildlife observation, will usually result in a better quality of life.

Beneficial reuse reduces the need for new CDFs. Valuable land would available for alternative uses, including those uses that produce revenue.

The following sections present descriptions of potential beneficial use alternatives of dredged material identified by USACE (1987) that may be applicable to use in the Apra Harbor Complex.

3.4.3 Material Transfer

Dewatered dredged material is commonly used for commercial/industrial sites, including port facilities. The applicability of dredged material to a particular construction project depends on the physical and engineering properties of the material and the specific requirements of the project. However, if the material has poor foundation qualities, a suitable additive such as cement may be added to increase shear strength and bearing capacity. Material dredged from Inner Apra Harbor may be used in the construction of magazines. Magazines are areas designated for the storage of explosives and ammunition, and are designed according to the type and amount of ordnance to be stowed. Dewatered dredged material can be used in the actual magazine construction or as earthen berms between two adjacent magazines or in the construction storage pads. The use of dredged material for the construction of magazines may decrease project costs by eliminating or reducing the amount of off-site material normally used in their construction. Specific examples of this beneficial use are described below.

3.4.3.1 Market Demand

Due to concerns over potential liability, the Navy's preferred beneficial use of dredged material is to remain on DoD lands. Therefore, a consumer based market demand assessment is not relevant to this evaluation. The total estimated cost for excavation of material from the dewatering site ($3/cy, $3.92/m^3), transportation ($2/cy, $2.62/m^3), and rehandling of the material to the Ordnance Annex for beneficial use ($2/cy, $2.62/m^3) is $7/cy ($9.16/m^3).

3.4.3.2 Construction of Magazines: Ordnance Annex Magazines

The Ordnance Annex for the Apra Harbor Naval Complex is approximately 6 mi (9.6 km) southeast of Inner Apra Harbor in south central Guam (Figure 16). Ammunition storage at naval installations consists of various types of open storage and magazines, depending upon the nature of the material to be stowed.

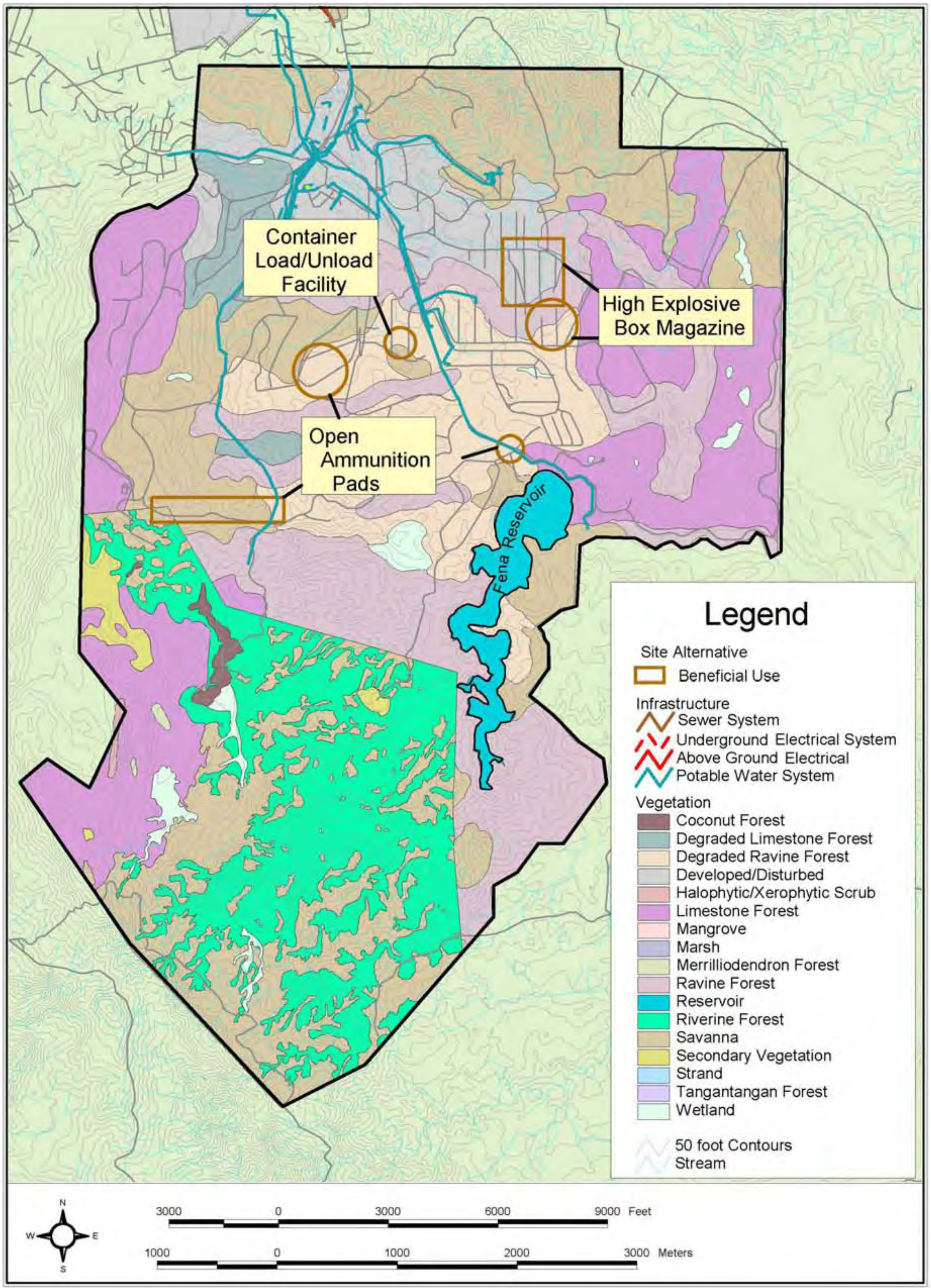


Figure 16. Potential Beneficial Use Alternative within the Ordnance Annex.

The Ordnance Function Plan (HHFP 2003a) proposes several construction projects to increase ordnance handling capacities and to provide for operational improvements at the Ordnance Annex. The proposed timeline indicates that these projects will be initiated in 2008. Several of these projects include the construction of earthen berms in the designs. Dredged material could be used for these projects in the construction of barricades or cover, or as effective strategies for reducing risks associated with the storage of hazardous ordnance materials. The alternative would include the beneficial use of dredged material dewatered at one or more dewatering sites. After dewatering and consolidation, the dredged material would be removed from the dewatering site, and transported and offloaded at the Ordnance Annex site(s) (MEC-Weston 2005). Ordnance magazine construction includes a container holding yard, open ammunition storage, and high explosive storage.

Capacity: Conceptual design specifications for barricades and earth cover requirements were obtained from the Navy publication "NAVSEA OP 5" (DON 2001b). Construction of container holding yards, open ammunition storage, and high explosive magazines are planned. The total capacity for these three Ordnance Annex construction projects for beneficial use alternatives discussed below would be 47,350 cy (36,204 m^3). This includes the construction of three container holding yards, planned for FY 2008, with 40,000 square feet (sf) (3,716 square meters [m^2]) concrete pads in each holding yard and a barricade surrounding the north and east sides of the holding yard consisting of 5,250 cy (4,014 m^3) of material, based on the dimensions described in the Phase I DMMP (MEC- Weston 2005). Another project includes the construction of nine 9,350 sf (868 m^2) open ammunition storage pads with earthen berms to provide intraline distance protection between any two potential explosive sites. The construction of nine 9,350 sf (868 m^2) open ammunition storage pads requires 30,000 cy (22,938 m^3) of material for barricade construction. In addition, the construction of the high explosive magazines includes two 8,000 sf (743 m^2) magazines, with a capacity of material required for earth cover of 12,100 cy (9,251 m^3). The details of these capacity estimates are discussed in detail in the Phase I DMMP (MEC-Weston 2005).

Cost: This alternative would provide capacity for 47,350 cy (36,202 m^3). Estimated total cost to remove dredged material from a dewatering site, and transportation and offloading at the beneficial use sites is $331,450, which represents $7/cy ($9.16/m^3). These costs are within the expected cost for relocation of material, and therefore are feasible. Costs for construction of the magazines beneficial use projects are not included in this estimate.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Ordnance Annex Magazine Construction was determined to be a feasible beneficial use alternative during the initial Phase I DMMP study (MEC-Weston 2005).

Temporary impacts from noise and air emissions may result due to the use of dewatered dredged material for the Ordnance Annex beneficial use projects. Excavation, removal, and transportation of dewatered dredged material to project sites will take one to two months. Dewatered dredged material would be trucked from one or more of the on base dewatering site alternatives considered in this report and/or from the existing SRP CDF and Orote Airfield CDF. At distances beyond 400 ft (122 m) from the road, noise levels will be less than 75 dBA, which is generally compatible with industrial activities. However, the truck route will pass within 300 to 3,200 ft (91 to 975 m) of the Apra Heights housing development. Exterior noise levels will range from 44 to 77 dBA at those distances, which may exceed the HUD guideline level of 65 dBA for residences closest to the transportation route.

Air emissions will result from truck trips from the dewatering site to the Ordnance Annex, and from the operation of equipment during excavation of the dewatering site and offloading of material at the Ordnance Annex project sites. Operation of stationary equipment such as crane engines will require approval from GEPA, which will ensure that the emissions do not exceed National Ambient Air Quality Standards (NAAQS) or prevention of achievement of plans developed under the Clean Air Act (CAA).

3.4.3.3 Construction of Magazines: Orote Peninsula Magazines

The Orote Peninsula magazine site is approximately one mi (1.6 km) from the western tip of Orote Peninsula. The Orote Peninsula is a limestone plateau with elevations of approximately 120 ft (36.6 m) at the proposed magazine site . The area is populated with urban or alien grasslands and tangantangan forests (DON 2001 a). Limestone forests occur along the limestone cliffs to the north and south of the site and are a preferred habitat for several endangered bird species of Guam.

This alternative would beneficially use dredged material from the proposed construction projects in barricades and box magazine earth cover at the Orote Peninsula magazine site. Ammunition storage at naval installations consists of various types of open storage and magazines, depending upon the nature of the material to be stowed. Barricades and earth cover are effective strategies for reducing the damaging effects of explosions , fire, and fragments. The Ordnance Function Plan (HHFP 2003a) sites two ammunition storage construction projects at the Orote Peninsula magazine site for 2008, including Open Ammunition Storage and Non-Propagation Wall/Earth Covered Magazines.

Capacity: The total volume of material for the two Orote Peninsula magazine construction projects would be 102,400 cy (78,295 m^3), which assumes 20,400 cy (15,598 m^3) would be used for barricades in the construction of six 9.350 sf (869 m^2) open ammunition storage pads and 82,000 cy (62,697 m^3) would be used for earth cover in the construction of 17
4,800-sf (446 m^2) box magazines.

Cost: This alternative would provide capacity for 102,400 cy (78,295 m^3). Estimated total cost to remove dredged material from a dewatering site, and transportation and offloading at the beneficial use sites is $716,800, which represents $7/cy ($9.16/m^3). These costs are within the expected cost for relocation of material and therefore are feasible. Costs for construction of the magazines beneficial use projects are not included in this estimate.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed. The Construction of Magazines at Orote Peninsula were initially determined to be infeasible in the Phase I DMMP study because the construction at the Orote Peninsula magazine site was slated for FY 2006 (MEC-Weston 2005). However, because construction at this site has not yet occurred, beneficial use at this site is now possible.

Temporary environmental impacts to the native avifauna in the limestone forests would occur. Noise levels during construction and/or transportation of dredged material to the construction sites could exceed 60 dBA in the limestone forests adjacent to the project site. Excavation, removal, and transportation of dewatered dredged material to project sites will take one to two months.

Temporary environmental impacts are possible due to beneficial use of material at this site. Limestone forests occur along the limestone cliffs to the north and south of the site and are a preferred habitat for several endangered bird species of Guam.

3.4.3.4 Construction of Magazines: Other Magazines

Additional magazine sites may be required depending on the relocation of military troupes. The capacity would potentially be in the same range as that described for the Ordnance Annex and Orote Peninsula Magazines. Costs would be similar to that of the Ordnance Annex with modifications based on transportation to the site of construction.

3.4.4 Industrial and Commercial Development

Industrial and commercial development near waterways can be aided by the availability of fill material from nearby dewatering sites. The use of dredged material as fill to expand or enhance port-related facilities may be a viable beneficial use alternative because dredged material is typically in surplus from local dredging activities. This may also be a viable option for contaminated dredged material since dredged material used in such construction projects may be amended, stabilized, or isolated as part of the project. Amendments include crushed glass, lime, cement, and fly ash that can be used for this purpose. The type, combination, and amount of amendment material depends on the moisture content, the amount of fines (clays and silts), and organic content of the dredged material. Greater amounts of amendments are typically required if the dredged material has a high clay and/or organic content. The amount and type of amendment will also be dictated by the required physical properties of the finished product. Such amendments can also be used to stabilize contaminants, making this a potential use for contaminated dredged material. Proven methods have been developed for land improvement by filling the site with sand or fine sediments, such as consolidated clay and silt/clay, produced by maintenance dredging. Specific drying techniques may increase the suitability of material for use as fill. The use of fine sediments often requires various dewatering techniques, most commonly subdividing the placement area into cells and filling individual cells to a limited depth on a rotational basis to allow adequate time for dewatering of the material while filling another cell. As each cell dries, low ground-pressure agricultural or earth-moving equipment is used to rework the filled area mixing coarse-grained material or admixtures with the fine-grained material.

3.4.4.1 Market Demand

Due to concerns over potential liability, the Navy's preferred beneficial use of dredged material is to remain on DoD lands. Therefore, a consumer based market demand assessment is not relevant to this evaluation. The total estimated cost for excavation of material from the dewatering site ($3/cy, $3.92/$m^3$), transportation ($2/cy, $2.62/$m^3$), and rehandling of the material at the commercial port expansion site ($2/cy, $2.62/$m^3$) is $7/cy ($9.16/m^3). The cost will vary depending upon transportation distance and the volume of material actually used for this alternative.

3.4.4.2 Commercial Port Expansion

The Port Authority of Guam operates the largest U.S. deepwater port in the Western Pacific. Located in the northeast corner of Outer Apra Harbor (Figure 17), the Commercial Port currently handles about two million tons of cargo a year. In order to help Guam meet its responsibilities as a transshipment hub, the Port Authority of Guam has developed a master plan that will expand the current port footprint to include new deepwater cargo piers, upgraded fisheries facilities, expanded container lay-down areas, an industrial park, and cruise-ship facilities. A substantial volume of fill material will be required for these capital improvement projects. The Navy and the Government of Guam have signed a MOU regarding the use of any dredged material deemed appropriate for fill material and to establish procedures for the determination of the use of the dredged material as fill material for use by the Port Authority of Guam (MOU April 2001; in Appendix D of Phase I DMMP [MEC-Weston 2005]). Conceptual plans indicate that there may be a need for 1.5 million cy for terminal expansion, and 600,000 sf (55,742 m^2) for a proposed new deep wharf in Outer Apra Harbor (Weston 2005). Making dredged material available to the Port for their use in planned port expansion construction projects represents a potential beneficial use alternative.

This alternative includes the removal of dewatered dredged material from the dewatering site(s) and transporting it to the Commercial Port for the Port of Authority of Guam's use in their development of the Commercial Port. The engineering properties of the dewatered dredged material would need to be tested to provide information for planning purposes regarding the appropriate application of dredged material for Commercial Port development projects.

Capacity: Designs have not been finalized; however, a "concept sketch" was provided by the Port Authority of Guam during the December 2003 site visit. The sketch shows that approximately 1.5 million cy of dewatered dredged material fill may be required for the development of Commercial Port (Figure 17). Plans include the construction of a deep-water wharf and the reclamation of 600,000 sf (55,742 m^2) of land at the Glass Breakwater between Hotel Wharf and the Shell fuel pier.

Cost: The cost to excavate, transport, and offload construction dredged material from the on-base dewatering sites to the port will be approximately $7/cy ($9.16/m^3). Cost estimates are within the standard range for moving of material, therefore economically feasible. Transportation costs will be reduced for the Government of Guam and security issues will be eliminated for the Navy if Commercial Port Field 1 is used.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed and are discussed in further detail in this initial study. The Commercial Port Expansion was determined to be a feasible beneficial use alternative during the initial Phase I DMMP study (MEC-Weston 2005).

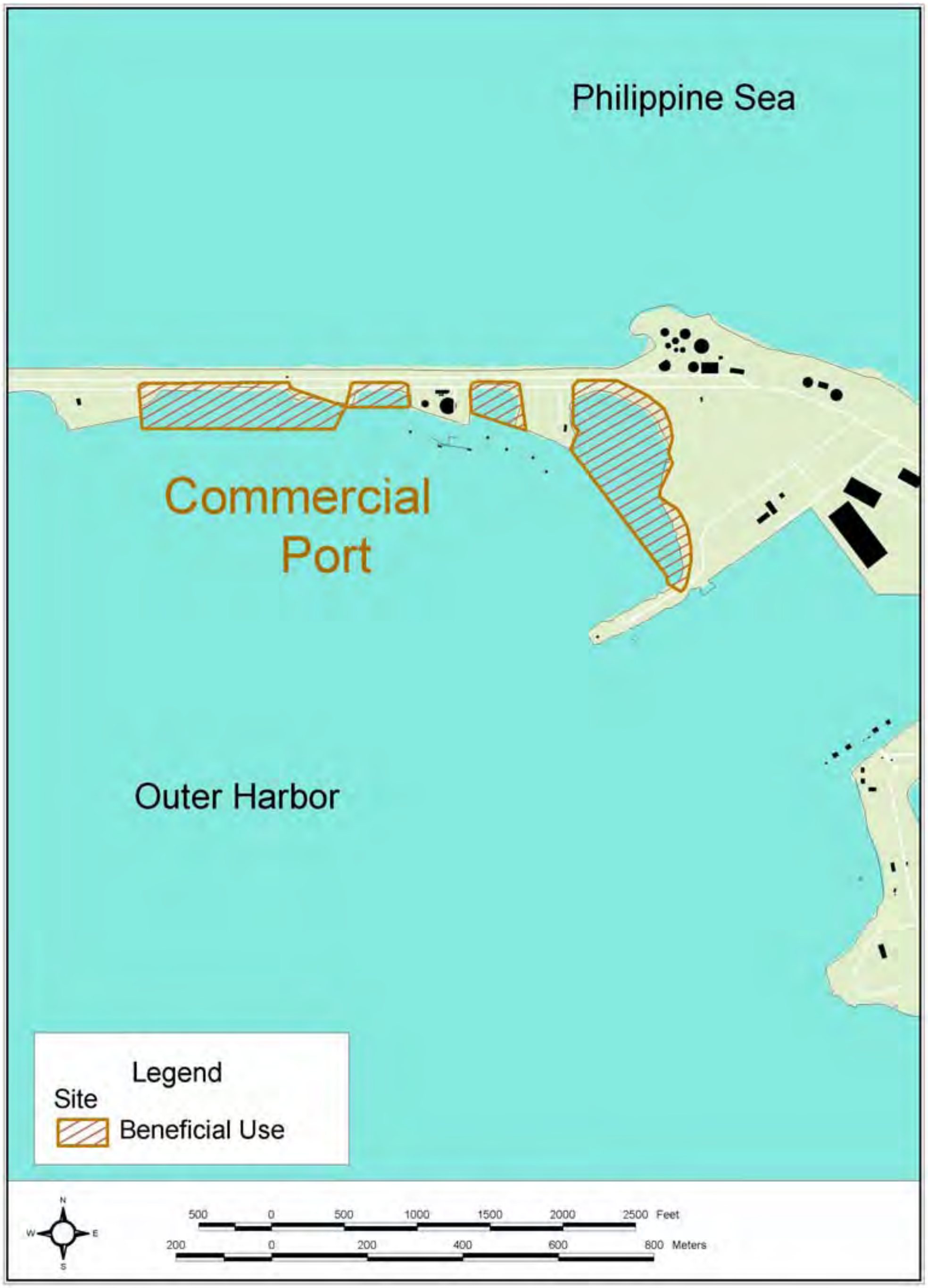


Figure 17. Commercial Port Expansion Beneficial Use Site.

No impacts to existing conditions are expected from noise levels associated with truck hauling of dewatered dredged material from one or more of the dewatering site alternatives considered in this report. At distances beyond 400 ft (122 m) from the road, noise levels are less than 75 dBA, which is generally compatible with industrial activities. Noise impacts would be minimized if material was dewatered at Commercial Port Field 1.

No impacts to existing conditions are expected from air emissions associated with the operation of equipment during excavation at the dewatering site, truck trips from the dewatering site(s) to the port, and from offloading material to stockpile areas at the port. Operation of stationary equipment such as crane engines will require approval from GEPA, which will ensure that the emissions do not exceed NAAQS, or prevention of achievement of plans developed under the CAA. Air quality impacts would be minimized if material was dewatered at Commercial Port Field 1.

Impacts to waters, biological resources, and cultural resources as a result of port expansion construction projects will need to be addressed as part of the Commercial Port project, and are outside the scope of this Upland Placement Study.

3.4.5 Landfill Cover for Solid Waste Management

Dried dredged material may be used as daily landfill cover. The solid waste in a sanitary landfill is covered daily with clean material. The location of a sanitary landfill is often constrained by the availability of cover material. Dredged material typically possesses important cover material characteristics such as workability, moderate cohesion, and low permeability. In addition, all forms of dredged material from silts to gravel make excellent cover, with the exception of peat and highly organic material. In order for dredged material to be economically feasible for daily cover, the landfill should be located less than 50 mi (80 km) from the dredged material supply. Sealed end dump truck hauling should be used as the transportation mode to the landfill. Dredged material from Inner Apra Harbor that passes a paint filter test and is RCRA compliant is a potential beneficial resource that can be used as landfill cover, such as in the specific landfill described below.

3.4.5.1 Market Demand

Due to concerns over potential liability, the Navy's preferred beneficial use of dredged material is to remain on DoD lands. Therefore, a consumer based market demand assessment is not relevant to this evaluation. The total cost associated with the beneficial use of dredged material for daily landfill cover includes the removal of material from the on base dewatering site, transporting to and off loading at the landfill. Minor incidental costs also will be incurred to periodically test the material to ensure its suitability for daily cover. The total estimated cost for excavation of material from the dewatering site (\$3/cy; \$3.92/m^3), transportation to the landfill (\$2 to \$3/cy [\$2.62 to \$3.92/m^3] depending upon distance), and rehandling of the material at the beneficial use sites (\$2/cy; \$2.62/m^3).

3.4.5.2 PWC Landfill

The PWC Landfill is located south of Inner Apra Harbor, comprising lands east of the Autoport Facility and Field 2 (refer to Subsection 3.2.4) (Figure 13). It is bounded to the west by Perimeter Road "B" and by Shoreline Drive and wetlands to the east. The landfill is approximately 40 a (16 ha) in size and serves as the primary landfill site for the Apra Harbor Naval Complex. The PWC landfill is currently in use with an estimated 15 to 20 years of continued service; however, the total remaining capacity is not known (Pers. Comm. Cruz 2004). Currently, material from various construction projects is used for daily cover. There is an ongoing and constant need for clean daily cover material at the PWC Landfill (Pers. Comm. Cruz 2004).

Capacity: The solid waste in the PWC landfill is covered daily with a minimum of six inches of clean material. Daily landfill cover requirements range between 18,200 and 22,620 cy/year (13,916 and 17,292 m^3/year; Pers. Comm. Cruz 2004). Beneficial use of construction dredged material at the PWC landfill may begin as early as FY 2008.

Cost: The annual cost to excavate, transport, and rework the material at the PWC landfill will range from $127,400 to $204,400, representing an average cost of $7 cy ($9.16 m^3). The use of dewatered dredged material for beneficial use is economically feasible. The cost to deliver (22,620 cy/yr) dewatered material to the landfill from a dewatering facility for 15 years (the estimated life of the landfill after 2008) is $2,375,100.

Existing Conditions: Land use, air quality, geology, water quality, biological resources, and cultural resources are described in detail in the Phase I DMMP. Since the development of the Phase I DMMP in 2005, existing environmental resources at this site have not significantly changed, and are discussed in further detail in this initial study. The PWC Landfill was determined to be a feasible beneficial use alternative during the initial Phase I DMMP study (MEC-Weston 2005).

No major impacts of transportation of dewatered dredged material to residential areas are expected, due to truck hauling of dredged material from one or more of the on-base dewatering site alternatives. At distances beyond 400 ft (122 m) from the road, noise levels are less than 75 dBA, which is generally compatible with industrial activities. Noise levels from earth moving equipment at the landfill would represent no change to existing noise levels at the landfill.

No impacts associated with air emissions are expected due to operation of equipment during excavation of material from the dewatering site and from truck trips from the dewatering site to the landfill. Operation of stationary equipment such as crane engines will require approval from GEPA, which will ensure that the emissions do not exceed NAAQS or prevention of achievement of plans developed under the CAA. There would be no change in air emissions of equipment used at the landfill with this alternative.

No change in land use will occur as a result of this alternative. No impacts to waters, including groundwater, would occur with this alternative. No impacts to wetlands located 300 ft (91 m) to the east of the landfill would occur. No impacts to sensitive species would occur from the excavation of construction dredged material from dewatering sites or its transport and use at the PWC Landfill. No impacts to cultural resources would occur from the use of dewatered dredged material at the landfill.

3.4.5.3 Other Landfills

When the PWC Landfill is full, other landfill options will be implemented. As a consequence, these landfills are also possible beneficial use sites because they will also have a need for clean daily cover material. Costs would be similar to that described above for the PWC site with differences associated with transportation, specific to the location of any other landfill option.

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FINAL REPORT

CVN-CAPABLE BERTHING STUDY

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Territory of Guam

July 2008

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FINAL REPORT
CVN Capable Berthing Study

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ACRONYMS AND ABBREVIATIONS

AHWWTP	Apra Harbor Wastewater Treatment Plan
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
ATFP	Anti-Terrorism/Force Protection
AWWA	American Water Works Association
BMP	Best Management Practice
BOW	Bilge Oily Waste
BOWCA	Bilge Oily Waste Collection Ashore
BOWTS	Bilge Oily Waste Treatment System
CATV	Cable Television
CHT	Collection-Holding-Transfer
CVN	Carrier Vessel Nuclear
CY	Cubic Yard
DHI	Danish Hydraulic Institute
DoD	Department of Defence
EHSS	Electronic Harbor Security System
EL	Elevation
ELW	Extreme Low Water
EPR	ethylene propylene rubber
ESS	Explosive Safety Submittal
FPC	Facilities Planning Criteria
FWTP	Fena Water Treatment Plant
FY	Fiscal Year
GEDCA	Guam Economic Development and Commerce Authority
gpd	Gallons per Day
gpm	Gallons per Minute
h:v	Horizontal to Vertical
I/I	Infiltration/Inflow
ITG	Interim Technical Guidance
ITN	Information Transfer Node
kV	kilovolt
LOA	Length Overall
$ M	Million US Dollars
m	meter
m^2	square meters
MEC	Munitions and Explosives of Concern
MG	Million Gallons
MGD	Million Gallons per Day
MLLW	Mean Lower Low Water
Mph	miles per hour
MVA	Megavolt Asynchronous Current
MWR	Morale, Welfare and Recreation
NAVFAC	Naval Facilities Engineering Command
NCTS	Navy Computer and Telecommunications Systems
NOSSA	Naval Ordnance Safety and Security Activity
NPS	National Pipe Straight Thread
PCC	Portland Cement Concrete
PEO Carriers	Program Executive Officer for Aircraft Carriers
PSB	port security barriers
psi	Pounds per Square Inch
psig	Pounds per Square Inch Gauge
RPZ	Reduced Pressure Backflow-Prevention Assembly
SCDB	Ship's Characteristic DataBase
SCFM	Standard Cubic Feet per Minute
SPS	Sewage Pump Station
SRF	Ship Repair Facility
SWOB	Ship Waste Offloading Barge
SWWCA	Ship Waterwaste Collection Ashore
UFC	Unified Facilities Criteria
YON	Yard Oiler Navy Barge

Executive Summary

Commander Pacific Fleet requires dedicated nuclear aircraft carrier (CVN) berthing capability on Guam to support current and projected future Fleet warfighting readiness and presence requirements in the PACOM WESTPAC AOR. The focus of this study is the conceptual design of the dredging, waterfront structures, utilities, and security improvements necessary to provide a dedicated wharf facility at Naval Base Guam to support approximately three CVN visits per year, nominally up to 21 days per visit. Wharf infrastructure requirements for these visits are more robust than current design criteria for traditional transient berths but less than that of homeport berths. Therefore, this study breaks new ground in developing the appropriate design criteria.

Description of Alternatives

Previous studies identified three possible site locations and multiple configurations at each site. Further refinement led to the two sites and three alignments selected for this study. The initial portion of this study reviewed the alignments and optimized them to the greatest extent possible, given the data provided[1]. These sites/alignments are identified as follows:

- Alternative 1 - Former Ship Repair Facility (SRF)
- Alternative 2 - Polaris Point Parallel to Shore
- Alternative 3 - Polaris Point Diagonal Offshore

Alternative 1 - Former SRF. This site is located at the northern shore of the former Ship Repair Facility, currently under leasehold to the Guam Economic Development and Commerce Authority (GEDCA) and operated by the Guam Shipyard. Figure G-1 shows the overall layout for this alternative.

The selected alignment follows the current shore line as it extends from the end of the finger pier at Lima Wharf in a northwesterly direction toward the current location of the floating dry dock AFDB-8. For purposes of this study, the berth face runs approximately along the EL –50 feet Mean Lower Low Water (MLLW) contour. This alignment results in a temporary access impediment to AFDB-8 only when the CVN is at berth. The wharf structure clears the channel allowing ships to navigate safely along the dry dock entrance channel when the CVN is not berthed.

Alternative 1 is the lowest cost alternative, estimated at roughly $317 million. This site offers the least amount of dredging and related coral mitigation costs.

Alternative 2 - Polaris Point Parallel to Shore. This site is located at the northern shore of Polaris Point at the location of former Charlie wharf. The location (east and west) is set to minimize the impact to navigation along the channel leading into the inner harbor. The berth is located (north and south) to run approximately along the EL –50 feet MLLW contour to minimize dredging. Alternative 2 is shown on Figure G-2.

[1] Further refinement may be needed during final engineering design.

Figure G-1 CVN Berth at Former SRF

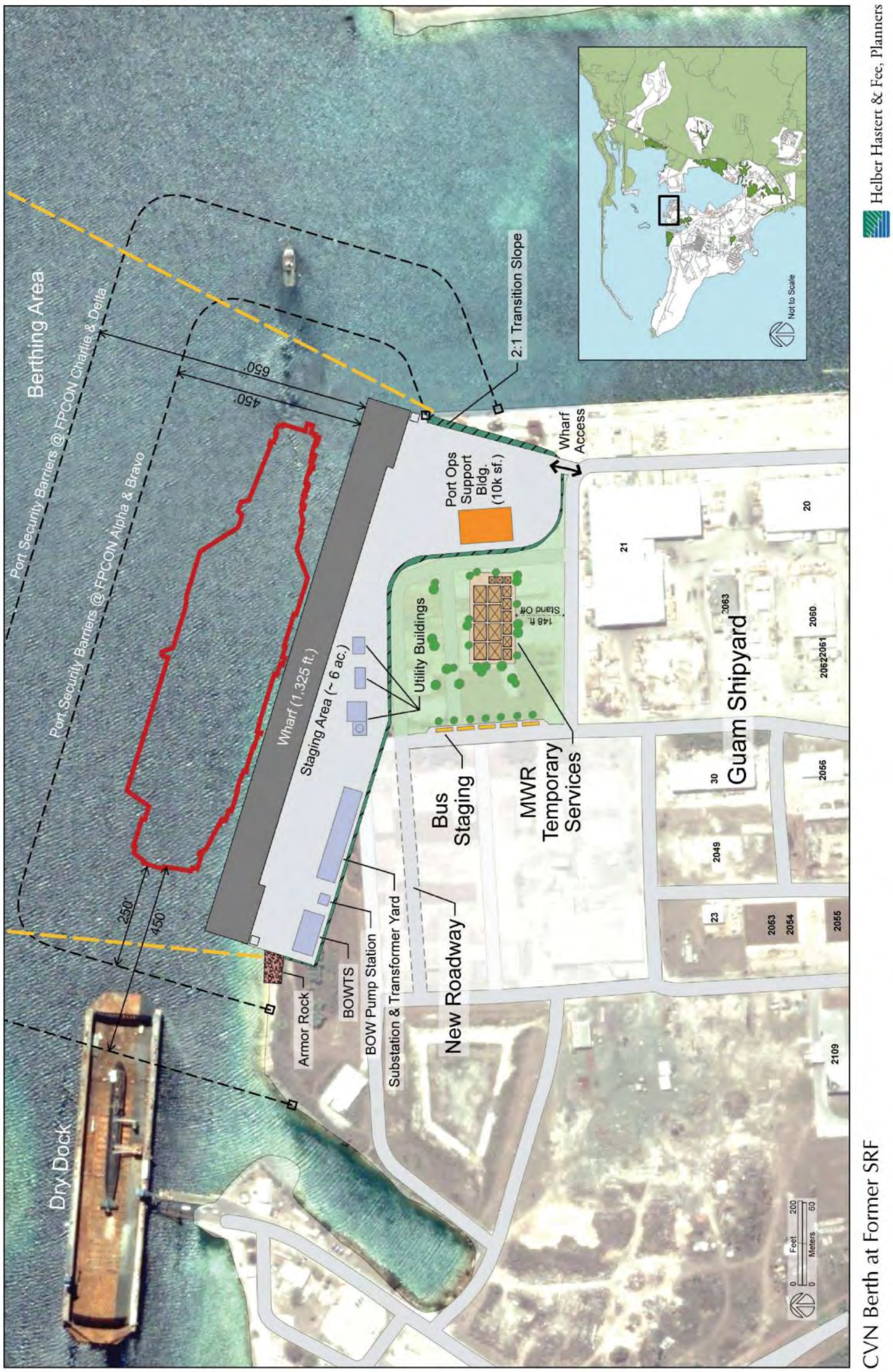
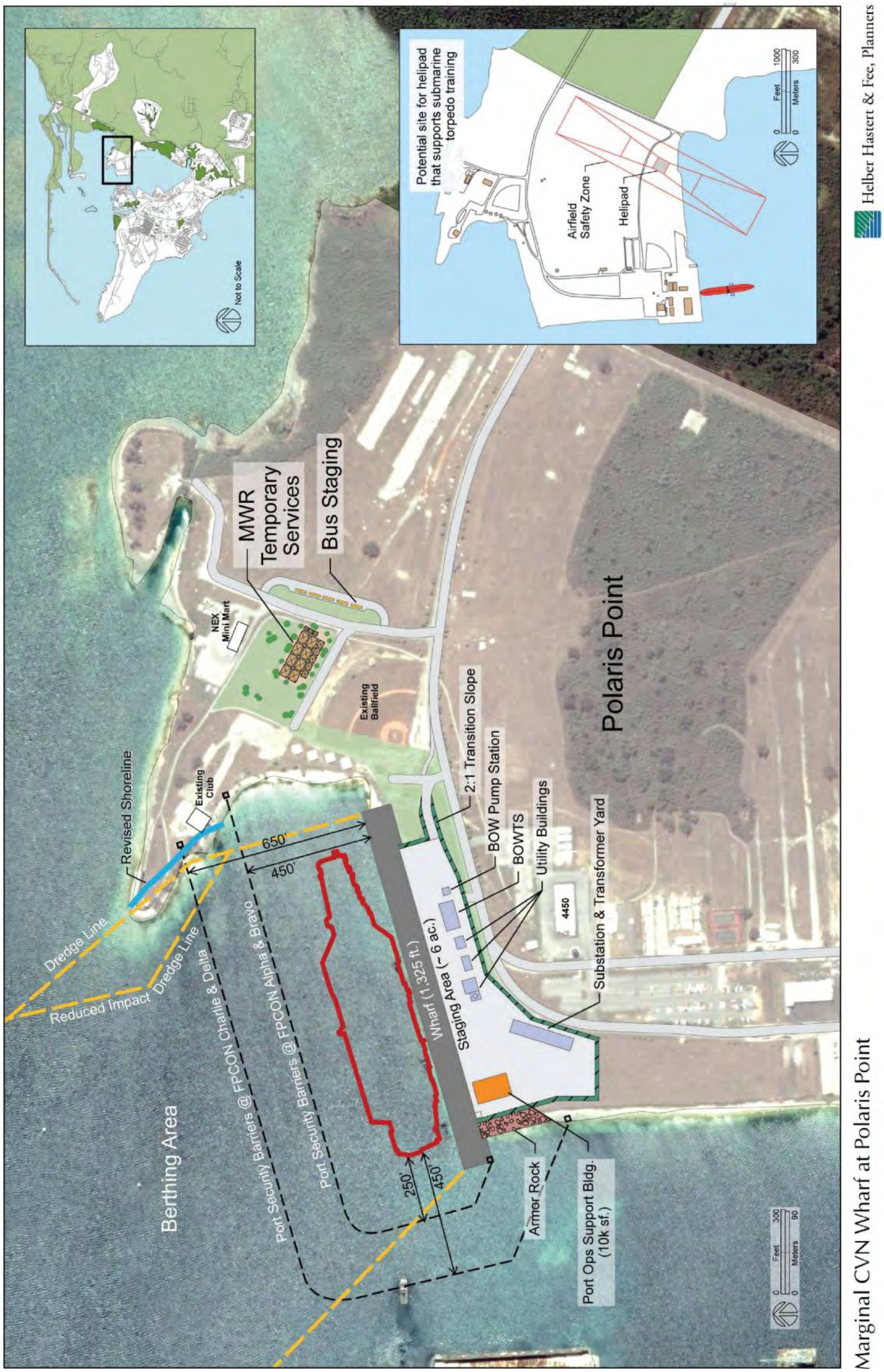


Figure G-2 Marginal CVN Wharf at Polaris Point



There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. The first alignment (Alt. 2) sets the berth width at 600 feet as interpreted from the defined “slip width” in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.* The north point must be removed in this alternative, as shown in the figures. A “reduced impact” Alternative (Alt. 2A) is proposed whereby the berth width is slightly less than 600 feet inside the bay, near the bow of the CVN, and the dredged area follows the existing contours of the northern point. The alternative dredge plans are shown in Figures N-2 and N-7 for Alternatives 2 and 2A, respectively.

Alternative 2 is the mid-range cost alternative with a total estimated cost of roughly $339 million. The primary reason for the high cost is the additional dredging and coral mitigation costs. The reduced impact, Alternative 2A, reduces the cost to $324 million, bringing it closer to Alternative 1, but still higher overall. The reason for the higher cost is the additional dredging required between the berth and the turning basin when compared to Alternative 1.

<u>Alternative 3: Polaris Point Diagonal Offshore.</u> This site is also located at the northern shore of Polaris Point. The pier spans across the existing bay, and is located so the abutments are on shore at each end. Alternative 3 is shown on Figure G-3.

Alternative 3 is the highest cost alternative with a total estimated cost of roughly $368 million. This alternative has the highest cost structural element, but offers some reduced dredging over Alternative 2, and reduced marine revetment costs over the other two marginal wharf alternatives.

CVN Capable Berth Criteria

CVN class 68 and 78 vessels have been evaluated in this assessment based on guidance provided by Naval Facilities Engineering Command (NAVFAC) Pacific and applicable Unified Facilities Criteria (UFC) documents. Site specific information was obtained through a field visit conducted from 01 October 2007 through 05 October 2007 and discussions with personnel from NAVFAC Marianas, NAVFAC Pacific, Base personnel, and various contractors with experience in Guam. This information forms the basis of engineering analysis and cost estimates presented in this preliminary report.

Table ES-1 provides a summary of project criteria used for preliminary design and cost estimating the critical elements for the CVN capable berth.

Figure G-3 Diagonal CVN Wharf at Polaris Point

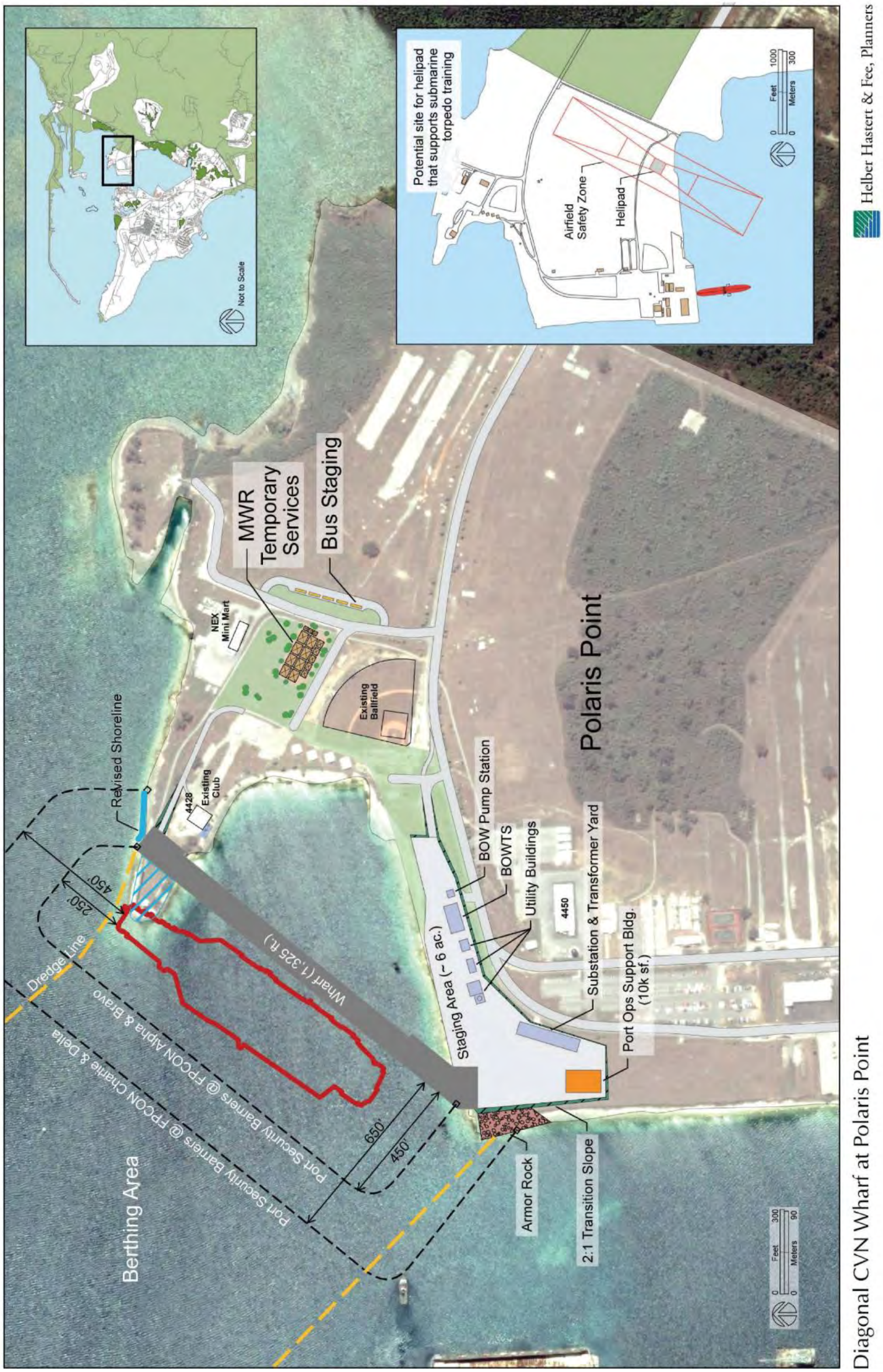


Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Navigation / Dredging	Channel / Fairway Width	600 ft.	600 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.g.	
	Channel Bend	2,000 ft. - 10,920 ft. radius	2,000 ft. - 10,920 ft. radius	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.2.2.	The UFC stipulates a minimum radius of bend of 1,200 ft-2,000 ft with tug assistance, but based on the vessel size and the angle of deflection (54 degrees) the recommended radius is 10 times LOA of the vessel, for 10,920 ft for the CVN class.
	Turning Basin	minimum radius .75 times Length Overall (LOA), optimal radius 2 times LOA	minimum radius .75 times LOA, optimal radius 2 times LOA	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.4.2. Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.f. Unified Facilities Criteria (UFC 4-159-02) Engineering and Design of Military Ports section 3-6.c.	
	Berthing Area Width and Length	Width:600 ft * Length:1,325 ft	None provided Assume same as for CVN 68	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.a.	* 600 ft width applies to 'slip width'. 800 ft slip width with CVN on opp. berth. (240 ft clearance between). Actual 'berth width' not defined.
	Dredge Depth	-49.5 ft. at MLLW	-49.5 ft. at MLLW	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.b. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007) Section 3.2.1. Interim Technical Guidance (ITG) CVN Dredge Depth Criteria (06 MAR 07)	
Structural	Wharf Width	90 ft.	90 ft.	Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-1.a.	The wharf is not used for maintenance which would requre a wider wharf. Vessels are not berthed on both sides.

Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement CVN 68	Requirement CVN 78	Source	Notes
Structural (con't)	Wharf Length	1,325 ft.	1,292 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.c. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007)	Total wharf length for Alternative 3 is 1545 ft; required by site topography and the need to provide on-shore abutments to resist seismic and berthing loads. The length would be the same for the CVN 68 or CVN 78.
	Wharf Deck Height	Elev +12 ft.	Elev +12 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-2.b.	The significant wave height and final deck elevation need to be confirmed.
	Pier Strength	Live Load = 800 psf min.		As above, Section 4-3.a.	
	Mobile Crane Load	2 - 140 ton mobile cranes		As above, Section 4-3.b.	
	Bollards	100 ton, 100 ft spacing	100 ton, 100 ft spacing	As above, Section 4-3.d.	
	Storm Bollards	4 - 200 ton bollards at each end of wharf	4 - 200 ton bollards at each end of wharf	As above, Section 4-3.d.	Location must be back from the face of wharf beyond 90 ft. Since lateral soil strength is not yet determined, wharf deck is extended to support these bollards. Final design may allow these to be on shore for Alternatives 1 and 2 only.
Supporting Facilities	Security Measures	Electronic Harbor Surveillance System		OPNAVINST 5530.14D, Appendix VIII - Waterside and Waterfront Security Draft UFC 4-025-01 Security Engineering: Waterfront Security UFC 4-021-02NF Security Engineering: Electronic Security Systems	Minimum requirements include electronic water/waterside security system (CCTV, associated alarms, surface craft or swimmer detection, and underwater detection). Local components of EHSS require integration into the base-wide ESS
		Perimenter Fencing		UFC 4-025-01 DRAFT Waterfront Security Design (24 July 05)	Concrete barriers with fencing on top of barriers
	Laydown Area	5 Acres (+/-)		IITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-4.c.	Laydown area for temporary visits not defined; however, area is fully utilized for buildings, transit shed, equipment, etc.
	Port Operations Building	10,000 sf Storage Shed		COMNAVMAR	Provide bathroom only - office not required in buildiing.

Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
MWR Services	Open Pad Area	8500 sf - 12,000 sf		Interviews with NAVBASE Guam MWR personnel and guidance from NAVFAC	
	Road/Parking Improvements	Bus staging, parking, etc.		As above	
	Electrical Service	208V 3-Phase Recept. Bank		As above	
Bilge Oily Waste	Peak Quantity	80,000 gpd	82,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Average Quantity	35,000 gpd	38,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Design Rate	90 gpm	90 - 180 gpm*	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77, FPC for the CVN 78 Class (Review Draft, REV 1, July 2007 & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	* Clarification provided from the Program Executive Officer for Aircraft Carriers (PEO CARRIERS) per email dated 24Sept07. The CONOPS for the CVN 78 is to use only one pump, limiting the output to 90 gpm.
Wastewater	Average Daily Flow	550,000 gpd	550,000 gpd	Per UFC 3-240-2N, using 100 gpcd and 5,000 personnel for both CVN 68 and 78 plus additional 10% for escort ships accompanying the CVN during the 21-day visit.	Based on information provided in Setiadi/Belt Collins report 28Sept2006, rev 21Jan2007.
	Design Rate	4 pumps at 400 gpm each*	Fwd, stbd side: 250 gpm Aft, stbd side: 500 gpm**	*Per Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, assume 3 CHT pumps operating at 400 gpm each (design for 1,200 gpm).	**Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing CHT requirements for CVN 68, which has a larger output of 1,200 gpm.
Potable Water	Average Demand	185,000 gpd	235,000 gpd	Per Table C-4 in UFC 4-150-02 for CVN 68 (with Air Wing or Troops Aboard) & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing water demands for CVN 78.
		18,500 gpd*	23,500 gpd*	*Assuming 10% for escort ships accompanying the CVN during the 21-day visit.	*CVN escort ships' water demand.

Table ES-1
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Potable Water (con't)	Design Rate	1,000 gpm	1,000 gpm	Based on UFC 4-150-02 for Active Berthing for all berth lengths up to 2,000 feet, plus 500 gpm for each additional 2,000 ft.	
	Minimum Pressure	40 psi	40 psi	Based on UFC 4-150-02 for Active Berthing. Minimum pressure required at the most remote outlet on the pier, downstream of a backflow preventer.	
Steam	Constant	7500 lb/h*	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	*Includes 50% for Air Wing on board
	Intermittent	7200 lb/h	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	Use 70F outside design temperature.
Compressed Air	Design Rate	2400 scfm	Not req'd	Table B-2 UFC 2150-02; Table 5, MIL-HDBK 1025/2, CVN -78 FPC July, 2007	
Pure Water	Peak Rate	150 gpm	100 gpm	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
	Design Rate	20,000gal/day	20,000gal/day	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
Shore Power	Peak Demand	21 MW @ 4,160V	30 MW @ 13,800V*	Per Table C-7 in UFC 4-150-02 for Aircraft Carriers & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	*25 MW without Air Wing
Information Systems	Capacity	200 pr copper; 48-strand fiber optic cable; provision for CATV connection	*	Per Table C-8 in UFC 4-150-02 for CVN 68, Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, and based on NCTS discussions.	* None provided in UFC documents. Assume same as CVN 68.

Engineering Analysis

The pertinent aspects of the CVN Capable Berthing Study are:

- Wave Conditions (coastal engineering)
- Dredging & Navigation (dredging)
- Waterfront Structures (structural)
- Backlands, Drainage, Security & Support (civil)
- Steam, Compressed Air & De-ionized Water (mechanical)
- Bilge Oily Waste (BOW), Wastewater, Potable Water (sanitary engineering)
- Electrical Power Distribution, Communications System (electrical engineering)

Wave Conditions

The Alternative 3 - Polaris Point Diagonal site was found to be the most exposed to extreme waves with the highest wave crest elevation. This was due to the alignment to incoming waves. Alternative 1 - Former SRF was the least exposed, as the waves approach in the alongshore direction and has a slightly lower wave crest elevation. Wave height calculations were approximated using available studies and will require greater refinement and calibration through additional modeling before a reliable design wave crest height and associated wave forces can be used for final design. The difference between the wave crest elevation and the underside of the deck will determine the wave pressure (uplift) for which the deck and piling must be designed.

Dredging & Navigation

Dredging will be required for all alternatives to improve navigation. Dredging is required to: (1) widen the channel approach to the turning basin to a minimum of 600 feet; (2) create a turning basin with a minimum radius of 1,200 feet; and (3) provide a berth in front of the wharf structure of at least 1,325 feet long x 600 feet wide. Minimum depth for all is -49.5 feet MLLW. Realignment of the channels leading to the turning basin and berth will require relocation of the current aids to navigation, including channel buoys and range lights. The volume of dredging is the least with Alternative 1 - former SRF and greatest with Alternative 2 - Polaris Point Parallel to Shore (full-width berth).

Dredging will have direct impacts on coral. The impact on coral was avoided where practical while still meeting operational requirements. For example, three channel fairways were assessed. The fairway that would have the least direct impact on coral was selected although it would be the most challenging from a CVN navigation perspective.

The analysis of potential indirect impacts, which are related to sediment plumes possibly travelling from the dredging location to remote locations during construction, has not been fully assessed. Potential indirect impacts could be impacts to coral and/or turbidity in the water column. It is anticipated that silt curtains and other Best Management Practices (BMPs) plans implemented during construction can effectively mitigate indirect impacts. However, to be conservative in the cost estimating of this CVN study, the assumption is the entire eastern edge of Big Blue Reef would be indirectly impacted by all alternatives, because of its proximity to the turning basin dredging activities in all alternatives.

Alternative 2, Polaris Point, if constructed to meet the guidance criteria of a 600-foot wide berth, would result in the removal of the point of land (and associated coral) located north of the proposed wharf (Figure N-2). Alternative 2A was developed specifically to avoid this loss and minimize the amount of dredging by reducing the berth width to 440 feet at the bow of the vessel (Figure N-7). This alternative was reviewed and approved by the harbor pilots and Navy Base personnel, and CPF/NAVSEA provided verbal concurrence with the Alternative 2A configuration.

The disposal of dredge material is dependent upon available disposal options, each with different associated cost factors. Possible options include: 1) ocean disposal (an ocean disposal site has not been designated, but is proposed by USEPA); 2) uplands placement (current method in Apra Harbor; potential upland dewatering sites have been identified); and 3) beneficial use (fill material for the staging areas for example, up to 62,000 cubic yards). An assessment of disposal options based on laboratory data will be required to support the Army Corps of Engineers permit application. For cost estimating purposes, it is assumed dredging shall be accomplished using a closed bucket clamshell dredge and dredged material would be placed upland. This is the most conservative cost assumption.

Naval Ordnance Safety and Security Activity (NOSSA) Instruction (NOSSAINST) 2080.15A states that an Explosive Safety Submittal (ESS) may be required for construction dredging in areas known, or suspected, to contain Munitions of Explosive Concern (MEC). Based on current information and knowledge of site history, it is NOSSA's opinion that an ESS would not be required at this time. Therefore, costs for ordnance screening of dredge materials are not included in the project cost estimate. A draft "Request for a NOSSA ESS Determination" is included as part of the DD1391 documentation and must be updated and submitted, during project design.

Historically, contaminated soils have been found adjacent to shipyard activities. However, results from initial sampling and analysis of potential dredged material near the former SRF site showed low site sediment contamination. Therefore, costs for hazardous waste handling and disposal, associated with highly contaminated dredged material, are not included in the cost estimates for dredging. Additional dredged material characterization may be done if the SRF site alternative is selected as the final wharf site.

Waterfront Structures

Three alternative types of waterfront structures were considered for general site compatibility, constructability, costs, and seismic performance. These were: (1) pile-supported wharf deck, (2) sheet pile bulkhead wharf, and (3) a concrete caisson wharf. While both the sheet pile bulkhead wharf and the concrete caisson wharf are used in Apra Harbor, it was determined that the pile supported wharf deck was the best alternative due to its documented superior seismic performance and relative costs. Steel piles were chosen over prestressed concrete piles due to the anticipated variable bearing depth (i.e., the length of steel piles can be field adjusted more easily than concrete piles). Costs were developed for the pile-supported wharf for all three alternatives. The caisson wharf would be much more costly than the pile supported wharf; and although the initial cost of the sheet pile bulkhead maybe slightly less, the life-cycle costs and the seismic risks make this option less desirable than the pile supported deck option.

The wharf structure for Alternatives 1 and 2 are identical, and are of typical construction. Alternative 3 is in deeper water without the benefit of an under-deck embankment, and thus requires a unique structural system. The bridge-like configuration of Alternative 3 lends itself to having two abutments (one at each end) where the structure comes onshore. These abutments are needed to carry the seismic loads of the entire wharf, as the long length of the in-water piles is not suitable for this task. The abutments provide the only access to the structure. The longer in-water pile lengths with their larger diameter, as well as the addition of the two abutments, makes this structural alternative considerably more expensive that the structure of the other two alternatives.

The proposed deck elevation for all three alternatives is currently set at +12 feet MLLW at the berth face to comply with wave overtopping requirements.

Backlands, Drainage, Security & Support

A staging area of approximately 6 acres is provided for each alternative, based upon reported needs of various users and *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998*, which calls for a minimum 5 acre staging area. The staging area is contiguous with the wharf in Alternatives 1 and 2, and immediately adjacent to the wharf in Alternative 3. Staging areas for all alternatives can be constructed with a minimal amount of disturbance to existing structures, roads, and utilities. In Alternatives 1 and 2, the staging area matches grade with the backside of the wharf and is sloped to a maximum of 1 percent (%) for drainage. The elevation of the staging area requires fill to raise grade to the level indicated. At the former SRF site, trenching for utilities and drainage system into potentially contaminated soil is avoided because the staging area site is elevated. The elevation at Alternative 3 is set lower than the others as there is no need to match grade along the backside of the wharf; only a ramp up to the abutment is needed. This reduces the amount of fill material. By using dredge material as fill, disposal costs are reduced and the costs for imported borrow is avoided. The raised staging areas also provide additional site security and protection against flooding during typhoons. Finally, it is beneficial to port operations to have the staging areas close to the berth face. Utility buildings are sited within the area reducing the length of utility runs to the berth face.

Drainage for all alternatives includes collecting the sheet flow off of the pavement via perimeter swales and catch basins into an underground pipe system. Storm water collected can be cleaned to local water quality standard using BMPs and a cyclonic separator before being discharge through a new harbor outfall. The drainage system for the Polaris Point Diagonal alternative was somewhat more expensive that the other two alternatives, because the overall flow distances dictated two systems, each requiring a separator and outfall.

Landside and waterside Antiterrorism Force Protection (ATFP) security requirements were established from the *Draft Unified Facilities Criteria (UFC) 4-025-01 – Waterfront Security Design (24-4-05)*. Landside security is provided by hardened perimeter fencing and controlled access. Waterside security is provided by floating port security barriers that are deployed when the CVN is at berth. Security is enhanced by hardened watch towers and patrol by the Harbor Patrol. Security may be a greater concern at the former SRF site due to its proximity to the commercial ship repair facility. Polaris Point; however, is isolated and has no commercial activity within its perimeter. The Polaris Point Parallel to Shore alternative offers better security than the Polaris Point Diagonal Offshore alternative because the former has only one point of entry to the secure perimeter, while the latter has a potential of intrusion from the opposite shoreline. All alternatives will have the same security measures (i.e. hardened fencing, two watch towers, controlled access point, and floating port security barriers). The Polaris Point Diagonal Offshore alternative will require the longest line of floating barriers, and it is expected there will be a somewhat longer time to deploy and retrieve this system. This is due to the longer length of the wharf and the need to wrap the barriers around the bow and stern of the CVN as shown on Figures C-1, C-2 and C-3.

All alternatives include electronic surveillance (Closed Circuit Television), associated alarms, surface craft or swimmer detection, and underwater detection) defined as Electronic Security Systems on the landside and Electronic Harbor Security Systems (EHSS) on the waterside. Local components of both systems require integration into the base-wide security system. Included are both infrastructure and equipment costs. Infrastructure cast are included in this study while the procurement and installation of equipment is funded outside of MCON.

The following support buildings are required to support CVN operations (building sizes are approximate):

- Port Operations Support Building (10,000 square feet storage shed with bathroom)
- Air Compressor Building (1,162 square feet)
- Water Treatment Building (1,216 square feet)
- Boiler House (2,010 square feet)
- Fuel Tank (13,210 gallon), surrounded by a containment berm (968 square feet)
- Electrical Substation (10,125 square feet)
- BOW Pump Station (625 square feet)
- Bilge Oily Waste Treatment System (BOWTS) – (5,000 square feet)

All buildings will be designed to the current Guam building code, modified by applicable UFC criteria. Buildings will be designed to criteria for typhoon winds, seismic events, ATFP, sustainability, and other issues in accordance with UFC 1-200-01. It should be noted that none of the proposed buildings are considered occupied structures, and thus will not require radon mitigation measures. If future plans include occupied buildings to support the CVN Berth, such as constructing an office in the Port Operations Building, a passive radon mitigation system shall be incorporated into the building design.

Steam, Compressed Air & Pure Water

Saturated steam (150 pounds per square inch gauge [psig]) is used by CVN 68 class vessels to supply shipboard laundry and galley facilities, in addition to any supplementary heating requirements. The steam demand is what is required by the berthed vessel crew complement with an embarked air wing. The actual requirements remain a subject of debate, and at this writing criteria based upon the tropical climate conditions in Guam was used, in lieu of criteria for colder CONUS regions. Steam is not required for CVN 78.

A compressed air system is required for CVN 68 at all active berths. Under emergency conditions, the vessel compressed air system will be used to “top off” any compressed air demand. Typically, the vessel requirement for 125 psig compressed air should be at a minimum commercial quality. However, it is presumed that the air may also be used for breathing and thus shall meet the requirements of Class D breathing air as described by American National Standards Institute (ANSI) G-7.1-1989. Both the steam and compressed air requirements and conditions are defined by MIL-HDBK 1025/2, and UFC manual 2150-02.

The Grade A pure water is being provided to meet the ship’s needs for active berthing.

The possibility of using temporary portable equipment was evaluated and determined not feasible due to procurement costs, maintenance, storage when not in use; and labor for set-up, tearing down, and certification.

Bilge Oily Waste (BOW)

The existing BOW systems at Apra Harbor Naval Complex are inadequate to handle the CVN BOW requirements of either CVN 68 or CVN 78 for a 21-day duration. Therefore, it is recommended that a permanent BOW collection and treatment system be constructed near the location of the proposed berth. The BOW collection and treatment system will consist of a combined gravity and force main collection system, a BOW pump station, and a Bilge Oily Waste Treatment System (BOWTS) as indicated on Figure M-2 for the former SRF location and on Figure M-6 for the Polaris Point location.

Wastewater

The existing wastewater collection system at Apra Harbor Naval Complex is inadequate to handle the CVN wastewater requirements of either CVN 68 or CVN 78 for a duration of 21 days. Depending on the selected berthing location, upgrades will be required for various portions of the landside wastewater collection system.

Proposed improvements to the wastewater system at Apra Harbor Naval Complex are programmed under upcoming projects P-262 and P-534. The scopes of these projects are to correct existing structural and capacity deficiencies in the system. Neither of these projects will upgrade the system to accommodate the additional capacity required to support the CVN berthing. Therefore, the recommended wastewater system improvements to support the CVN berthing will be independent of those proposed in P-262 and P-534.

For the proposed berthing at the former SRF site location, a separate and dedicated wastewater collection system sized to handle only the CVN loadings is recommend. This dedicated system will include the construction of three new submersible type sewage pump stations and 6,700 linear feet of associated force mains as indicated on Figures M-3 and M-4. In addition to the pressurized systems, approximately 4,420 linear feet of new gravity sewers are recommended, of which 2,720 linear feet of 15-, 18-, and 24-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline "A" for the CVN berthing.

For the proposed berthing at the Polaris Point site location, upgrades to the existing SPS No. 9, associated force main, and trunkline "B" are necessary to accommodate the additional flows from a CVN. Unlike the former SRF facility option, a separate and dedicated system for the CVN may not be feasible due to the limited corridor space available along Marine Drive resulting from project P-494. Therefore, the proposed improvements to the wastewater collection system will include the construction of a new submersible type sewage pump station, a new dry pit – wet well type pump station to replace the aging SPS No. 9, and 14,800 linear feet of associated force mains as indicated on Figures M-7 and M-8. In addition to the pressurized systems, approximately 4,940 linear feet of new gravity sewer lines are recommended, of which 4,420 linear feet of 8-, 12-, 15-, and 21-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline "B" for the CVN berthing.

Potable Water

The existing potable water system at Apra Harbor Naval Complex was found to be adequate to handle the larger potable water requirements of a CVN 78. Therefore, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets as shown on Figure M-5 for the former SRF site and on Figure M-9 for the Polaris Point location.

Electrical Power Distribution and Communications System

The existing power and communications infrastructure is not adequate to support either the CVN 68 or CVN 78 berthing. Upgrades to provide required system capacity include a new GPA 34.5 kV feeder from Piti Power Plant, construction of a new shore power substation including four step-down transformers with 34.5, 13.8, and 4.16 kilovolt (kV) switchgear, new communications ductbanks, and various electrical distribution system enhancements as required.

Summary of Projects and Costs

The project costs are summarized in Table ES-2. Referring to the table, there are many line items required to develop a fully functional support berth for CVN visits. When comparing the proposed sites, there are two types of line items to evaluate: those that are mutual to both sites, such as fairway dredging, and those that are site-specific, such as berth dredging and construction, and certain utilities costs. The site-specific line items provide the information necessary to determine the more favorable site and berth alignment.

Estimated costs for each line item are included in the table, and the total estimated cost for each Alternative is provided. Costs are presented in Fiscal Year (FY) 2011 Guam Costs. An escalation factor of 1.0867; October 2007 to October 2011, was used for time escalation, and estimates were developed using either actual Guam costs, or an Area Cost Factor of 2.64 was used to escalate baseline cost taken from the Unified Facilities Criteria (UFC).

Table ES-2 Summary of Project Descriptions and Costs ($,000's, FY 2011, Guam)

Project Item	Alternative 1 Former SRF Facility	Alternative 2 Polaris Point Parallel to Shore[1]	Alternative 3 Polaris Point Diagonal Offshore
Project General Conditions	**$16,381**	**$17,839**	**$21,030**
Mob/Demob and Housing	**$9,308**	**$10,136**	**$11,949**
Dredge Fairway, Turning Basin and Berth; Mob/Demob	478,900 CY **$ 38,313**	993,200 CY (ALT. 2) **$ 69,570** 758,000 CY (ALT. 2A) **$ 55,276**	672,400 CY **$ 50,073**
Munition Screening (N/A – NAVFAC Guidance)	**$ 0**	**$ 0** (ALT. 2) **$ 0** (ALT. 2A)	**$ 0**
Coral Mitigation ($430/m2 – Agency Recommendation)	**$ 19,566**	**$ 23,068** (ALT. 2) **$ 22,495** (ALT. 2A)	**$ 21,466**
Adjust Navigation Markers	**$2,026**	Same as Alternative 1 **$ 2,026**	Same as Alternative 1 **$ 2,026**
Wharf / Pier Construction incl. Camels	90'x1325' Pile Supported Concrete Deck Structure **$ 92,868**	90'x1325' Pile Supported Concrete Deck Structure **$ 92,868**	90'x1545' Pile Supported Concrete Deck w/ conc. abutments each end **$ 148,328**
Marine Revetment	Quarry Stone & Riprap **$ 10,205**	Quarry Stone & Riprap **$ 10,205**	Quarry Stone & Riprap **$ 2,230**
Site Work and Floating Barriers	Demo, fill, pavements, drainage, security **$ 24,004**	Demo, fill, pavements, drainage, security **$ 24,909**	Demo, fill, pavements, drainage, security **$ 22,288**
Buildings	Misc. Buildings **$ 9,547**	Misc. Buildings **$ 9,547**	Misc. Buildings **$ 9,835**
Steam / Air / Pure Water	Construct new systems **$ 10,081**	Same as Alternative 1 **$ 10,259**	Same as Alternative 1 **$ 10,259**
Electrical and Communications	34.5 kV feeder, upgrades at GPA,comm.,lighting **$ 59,616**	34.5 kV feeder, upgrades at GPA,comm.,lighting **$ 38,300**	Same as Alternative 2 **$ 38,300**
Bilge Oily Waste	90gpm BOW System **$ 4,580**	90gpm BOW System **$ 4,580**	Same as Alternative 2 **$ 4,580**
Wastewater	SWWCA & Dedicated Collection to Trunk „A' **$ 19,500**	SWWCA; Upgrade SPS No.9, Main&Sewer Lines **$ 24,660**	Same as Alternative 2 **$ 24,660**
Potable Water + Electrical for BOW, WW, Water systems	Pierside Work & Connect to Exist. Water System **$ 560**+**$330** Misc.Elect	Pierside Work & Connect to Exist. Water System **$ 610**+**$280** Misc.Elect	Same as Alternative 2 **$ 610**+**$280** Misc Elect
SUB-TOTALS	**$ 316,885**	**$ 338,857** (Alt. 2) **$ 323,990** (Alt. 2A)	**$ 367,914**
Estimated 1391 Cost[2]	**$ 388 Million (M).**	**$ 416 M** (Alt. 2) **$ 397 M** (Alt. 2A)	**$ 453 M**

1. There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. ALT. 2 requires the removal of the north point, and ALT. 2A is a reduced impact alternative which preserves the point.

2. Estimated 1391 costs include contingency (10%), Post Construction Award Services (PCAS) (1%), Guam Gross Receipts Tax (4%), Design-Build Services (4%) and Supervision, Inspection and Overhead (SIOH – 6.2%) to provide a better approximation of programming costs..

Construction Phasing for Incremental Funding

A construction schedule for design-build was assumed at 48 months for Alternative 1 - Former SRF and Alternative 2 - Polaris Point Parallel to Shore options and 54 months for Alternative 3 - Polaris Point Diagonal option. The starting point for each was assumed at mid-fiscal year, thus the schedule covers 5 fiscal years. An additional 6 months is required for the construction of the wharf in Alternative 3 due to its increase length, deep water piling, and abutments at each end.

The various major elements of work for Alternatives 1 and 2 were scheduled over the duration indicated as described below. Work for Alternative 3 is similar except that the wharf construction continues into the 5th year.

Table ES-3 Construction Phasing for Incremental Funding

Year 1 (6 mos.)	Activity
Dredging	Design
Wharf Construction	Design (75%)
Site Work	
Buildings	
Steam, Air, Pure Water	
Bilge Oily Waste Systems	
Wastewater Systems	Design
Potable Water System	
Electrical Utilities	
Year 2 (12 mos.)	
Dredging	Mobilize dredge; dredge berth, turning basin, and fairway (25%); place quarry run on berth slope
Wharf Construction	Complete design; order piling; mobilize; place armor stone (42%); drive pipe piling (29%); construct deck (8%)
Site Work	Design
Buildings	Design (50%)
Steam, Air, Pure Water	Design (33%)
Bilge Oily Waste Systems	Design
Wastewater Systems	PS Equipment and Material Ordering; Construct Pump Stations (33%)
Potable Water System	
Electrical Utilities	Design; Construct Duct System (17%)
Year 3 (12 mos.)	
Dredging	Complete dredging of fairway; navaids; closeout
Wharf Construction	Complete placing armor stone; complete driving pipe piling; construct deck (58%)
Site Work	Mobilization; demolition; earthwork; storm drain; substructures
Buildings	Complete design; mobilization & material procurement; construct air, water, & steam buildings (75%)
Steam, Air, Pure Water	Complete design; mobilization & material procurement; install mechanical systems (13%)
Bilge Oily Waste Systems	BOWTS Equipment & Material Ordering; Construct BOWCA and BOW

Table ES-3 Construction Phasing for Incremental Funding

Wastewater Systems	Complete pump stations; construct FM & sewers (50%); construct SWWCA
Potable Water System	Construct pier-side water lines & outlets; supply lateral to pier; commissioning & closeout
Electrical Utilities	Complete duct system; cable procurement; substation and wharf equipment procurement
Year 4 (12 mos.)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 1 & 2)
Site Work	Paving; security & fencing (67%)
Buildings	Complete air, water, & steam buildings; construct transit shed; construct misc. bldgs (33%)
Steam, Air, Pure Water	Install mechanical (93%)
Bilge Oily Waste Systems	Construct BOWTS; commissioning & closeout
Wastewater Systems	Complete FM & sewers; commissioning & closeout
Potable Water System	
Electrical Utilities	Construct electrical; commissioning & closeout
Year 5 (6 mos., 12 mos. Alt 3)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 3 only)
Site Work	Complete all remaining work & close out
Buildings	Complete other buildings & close out
Steam, Air, Pure Water	Complete mechanical installation; start up and commissioning; close out
Bilge Oily Waste Systems	
Wastewater Systems	
Potable Water System	
Electrical Utilities	

To complete the work according to the schedule, the following funding requirements are necessary (Table ES-4), expressed as percentage of total funds.

Table ES-4 Incremental Funding Over Construction Period

Year	Alt 1	Alt 2	Alt 3
1	6%	6%	6%
2	34%	34%	29%
3	38%	38%	33%
4	20%	20%	25%
5	2%	2%	7%
Total	100%	100%	100%

Phasing of CVN 68 and CVN 78 Requirements

Structural, dredging, and civil requirements are essentially the same for both the CVN 68 and CVN 78, thus there is no opportunity to phase-in the construction for these items. Utility demands for steam, compressed air, and pure water are expected to remain the same, decrease, or be eliminated for the CVN 78 class. Thus, the need for these facilities at the commissioning of the berth remains unchanged.

The demands for BOW, wastewater and potable water systems are also the same for CVN 68 and CVN 78 vessels, and thus no project phasing is possible.

The electrical and communications base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated 15 kV feeder cables and power receptacles. The cost of a future project to provide two additional 13.8 kV switchgear sections, associated 15 kV feeder cables, and power receptacles is approximately $500,000.

Site Selection Pros and Cons

Various pros and cons for each site alternative have been developed and these are detailed in Chapter 7. The pros and cons focus primarily on the engineering aspects of the projects, and no attempt was made to judge one site as superior to another based on non-quantifiable or subjective data. The pros and cons developed in this study are summarized in Table ES-5.

Table ES-5 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF Facility		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
GENERAL NOTES					
Lowest overall project cost			Higher overall project cost than Alt. 1		Highest overall project cost
	Demolition required and possible contaminated soils	"Greenfield" site Minimal contamination expected		"Greenfield" site Minimal contamination expected	
	Requires renegotiation of leasehold to reduce Guam Shipyard footprint	Land not encumbered		Land not encumbered	
Contiguous with backlands – allows more efficient operations		Contiguous with backlands – allows more efficient operations			Non-contiguous with backlands – less efficient operations
NAVIGATION, DREDGING and CORAL IMPACTS					
	Port pilots least preferred alignment	Alignment preferred by port pilots	Alt 2A berth has reduced with (440 feet vs 600 feet) at CVN bow		
	Restricts access to drydock AFDB-8 when CVN at berth				
Least dredging overall	Contaminated dredged material, if encountered, may require special handling		Alt. 2 most dredging. Alt 2A reduces dredging by 24% of Alt. 2.	Less dredging than Alt. 2	More dredging than Alt 1
Least direct impact to coral (least mitigation cost)	Closest to Big Blue coral reef	Alt 2A reduces coral impact (lower mitigation cost) vs. Alt 2 and Alt.3.	Alt 2: Highest estimated coral area impacted (mitigation costs). Alt 2A: Saves North Point and reduces estimated mitigation costs vs. Alt 2	Less coral impact (mitigation costs) than Alt 2 or Alt 2A	Higher estimated coral mitigation costs than Alt 1. Dredging removes end of North Point and associated coral

Table ES-5 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF Facility		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
STRUCTURAL and COASTAL CONSIDERATIONS					
Typical pile supported wharf construction		Typical pile supported wharf construction			Unique and more costly structural system
Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & caisson	Steel sheet piles bulkhead not advised
Slightly less exposed than the Polaris Pt. sites to extreme waves			Slightly more exposed than the SRF site to extreme waves		More exposed than the other sites to extreme waves
UTILITIES					
Existing Steam Plant is under the control of Base Operation Support Contractor (BOSC) for the Government. Possible use of existing steam system.	Existing air system is under control of Guam Shipyard. Assume new system is required. Existing steam system requires repairs and capacity expansion.		Requires construction of new plant for steam & air		Same as Alt. 2
Lower project cost for wastewater systems.	More pump stations than other Alt.s will result in higher life cycle costs and additional operational requirements.	Proposed wastewater system improvements will increase the capacity and improve the reliability of the existing infrastructure which will benefit other facilities in Polaris Point and neighboring areas.	Part of force main route outside Navy property. Uncertain how this might impact project	Same as Alt. 2	Same as Alt. 2
			Higher project costs for wastewater system due to length of forced mains required		Same as Alt. 2
	Higher project cost for electrical power service	Lower project cost for electrical power service		Same as Alt. 2	
	Higher project cost for communications	Lower project cost for communications		Same as Alt. 2	

Conclusions and Recommendations

There are advantages and disadvantages to locating the CVN berth at the former SRF site or at the Polaris Point site. One common conclusion is the pile supported marginal wharf (Alternatives 1 and 2) is the preferred structural system. The diagonal pier at Polaris Point is the least preferred alternative because of seismic considerations, inconvenient berth access, high structural costs, exposure to extreme wave events, and direct dredging impact to the northern tip of Polaris Point.

Alternative 2 is not a preferred alternative because of the greater direct impacts to coral compared to Alternative 2a. Alternative 2A and Alternative 1 can be viewed as comparable. The primary differences, from the engineering perspective, are:

- Electrical Power Costs, which are higher at the former SRF site
- Dredging Costs, which are higher at the Polaris Point site
- Wastewater Costs, which are higher at the Polaris Point site

The results of this engineering investigation indicate that Alternative 1 - Former SRF, is the lowest cost alternative. This is primarily due to the differences in dredging volumes and the estimated coral mitigation costs.

A sediment sampling and analysis plan will be completed as a requirement to obtain a dredging permit. Soil contamination, if present, will be discovered during this process. If the soils are found to be contaminated, project costs may have to be adjusted.

Ultimately, final site selection will be influenced by multiple factors, many of which are outside the scope of this study. Examples are: CVN repair/maintenance. on and off-base traffic, sailor “Quality of Life,” AT/FP, safety and drydock access.

Recommendations:

Because impact to coral is a factor in site selection, the coral reef stakeholders (agencies) were asked to review the project footprints and propose a rough estimate of monetary cost per square foot of direct impact to coral. The coral mitigation costs presented reflect stakeholder “worst case scenario” input of $430 per square meter of impact. It is recommended that agencies and the Navy continue to work together to reduce the worst case cost scenario.

Recommendation for Additional Studies:

Additional studies and investigations are required to complete the final design. Other studies could be conducted to provide alternatives to the proposed concepts of this study. The studies are described below:

- A site specific CVN Dredge Depth Study will be required to be performed by NAVFAC LANT CIENG/NSWCCD and coordinated with NAVSEA 08, AIRPAC, and Program Executive Officer for Aircraft Carriers.
- Complete a localized geotechnical investigation at the selected site for purposes of finalizing pile lengths and determining subsurface conditions in preparation for final design.

- Prepare a dredge material disposal study to compare various options for beneficial reuse of the materials (including that already identified in this project), identifying possible users or uses on other projects, in order to minimize ocean disposal. Study should also consider methods of uplands disposal of contaminated but non-hazardous materials, possibly by incorporating such materials into the project.
- Complete additional detailed and calibrated coastal engineering studies, including: a) deployment of instrument at the site to monitor actual conditions for calibrating numerical models; b) dynamic berthing analysis for operating conditions; c) final determination of wave heights, run-up, and impact for pile-supported structures.
- For Alternative 1, complete a site-specific hazardous materials subsurface investigation immediately on and off-shore in the vicinity of the proposed wharf. This may be combined with the sediment sampling plan required to obtain dredging permits.
- For Alternative 1, as may be required, complete an evaluation of the benefits and costs of rotating the AFDB-8 one hundred eighty degrees so that access to the dock is from the west. This will mitigate any concerns that this site negatively impacts the operator of the dry dock or has security concerns.
- Prepare a report detailing the criteria, requirements, and configuration of the Electronic Harbor Security Systems (EHSS) for the selected site, including integration of such system into current and future port-wide security systems.
- During final design stages, complete periodic reports that 1) refine and update the project schedule, 2) identify logistic concerns, and 3) identify critical resource usage of this project against the background of all other projects expected to proceed forward.

Other studies that could be of benefit include:

- Additional evaluation of innovative structural concepts, like floating piers.
- Performance-based interpretation of CVN berthing requirements.

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1.0 INTRODUCTION

1.1 Background

Apra Harbor currently supports an average of 1-2 Carrier Strike Group (CSG) port visits per year. Carrier Vessel Nuclear (CVN) vessels have historically berthed at Kilo Wharf because it is the only wharf that meets CVN draft requirements of -50 feet Mean Lower Low Water (MLLW).

There are four major drawbacks to continued use of Kilo Wharf for future CVN visits to Guam. First, Kilo Wharf presently lacks full “hotel” utilities services necessary to support a CVN vessel if the onboard engineering plant is not fully operating. Second, Kilo Wharf does not have the required length to properly berth the CVN. Third, wind and wave conditions at Kilo Wharf during various times of the year (particularly October) limit the operations at the berth. In a study for the expansion of Kilo Wharf, HPA concluded that wind and short and long period waves control the overall berth availability. The total estimated downtime was determined to be 15.2% annually and 28.6% in October. Fourth, and most importantly, Kilo Wharf is the only dedicated ordnance wharf in the Western Pacific Region. The wharf ordnance operations demand are projected to increase, resulting from programmed Navy and Air Force buildup and Marines’ relocation. Current demand for ordnance operations at Kilo Wharf is 55 ordnance ship visits of 4-5 day duration per year. For as many as 90 days of the year, Kilo Wharf is not available due to weather or maintenance activities. Kilo Wharf is operating at capacity and past CVN visits were disruptive to ordnance operations. Therefore, a new CVN capable wharf at Apra Harbor is essential to ensure uninterrupted Department of Defense ordnance operations and to minimize other logistic impacts that result from CVN visits.

Commander Pacific Fleet wishes to conduct operations that will bring a CVN 68, and later CVN 78, to Guam. The planning scenario is three 21-day CVN visits per year. The mission and thus the design criteria are unique, as neither the CVN Homeport configuration nor the Port of Call configuration exactly matches the needs of the 21-day visit, as described in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998*. This study therefore breaks new ground in developing criteria for the project.

1.2 Purpose and Objectives

The Purpose of the CVN Capable Berthing Study is to define and estimate costs for the infrastructure required to permit the berthing of CVN class vessels at Apra Harbor, Guam. The study evaluated the requirements for dredging, wharf/pier construction, full utilities requirements to support the CVN 68 and CVN 78 class vessels, and additional support infrastructure for backlands operations and security.

Previous studies had identified three possible site locations and multiple configurations at each site. Further refinement led to the two sites and three alignments selected for this study. These sites/alignments are identified as follows:

- Alternative 1 - Former Ship Repair Facility (SRF)
- Alternative 2 - Polaris Point Parallel to Shore
- Alternative 3 - Polaris Point Diagonal Offshore

This report provides preliminary engineering analyses, project descriptions, descriptions of pros and cons for each site, and cost estimates that may help facilitate a decision regarding a preferred site for the CVN berth.

Figure 1-1 provides an overview of the three alternatives and the proposed 600 foot wide entrance fairway and turning basin.

1.3 Description of Alternatives

Drawings, images from three-dimensional (3D) models, and 3D animations of the facilities for the alternatives are included at the end of this report.

Alternative 1 - Former SRF. This site is located at the northern shore of the former Ship Repair Facility, currently under leasehold to the Guam Economic Development and Commerce Authority (GEDCA) and operated by the Guam Shipyard.

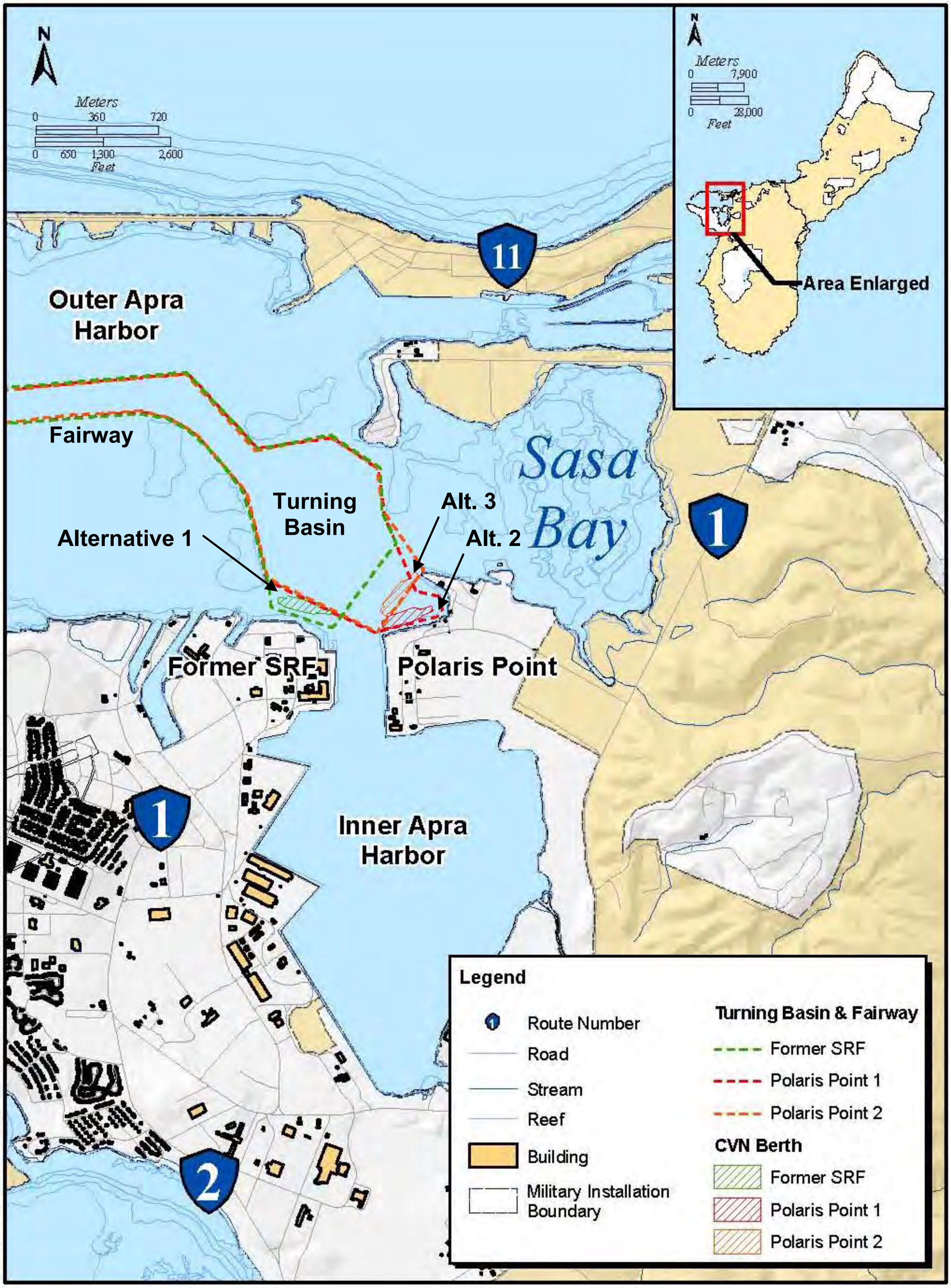
The selected alignment follows the current shore line as it extends from the end of the finger pier at Lima Wharf in a northwesterly direction toward the current location of the floating dry dock AFDB-8. For purposes of this study, the berth face runs approximately along the EL –50 feet MLLW contour. This alignment results in a temporary access impediment to AFDB-8 only when the CVN is at berth. The wharf structure clears the channel allowing ships to navigate safely along the dry dock entrance channel when the CVN is not berthed.

Alternative 2 - Polaris Point Parallel to Shore. This site is located at the northern shore of Polaris Point. The location (east and west) is set to minimize the impact to navigation along the channel leading into the inner harbor. The berth is located (north and south) to run approximately along the EL –50 feet MLLW contour to minimize the dredging at Polaris Point.

There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. The first alignment, Alternative 2 sets the berth width at 600 feet as interpreted from the defined "slip width" in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.* The north point must be removed in this alternative, as shown in the figures. A "reduced impact", Alternative 2A, is proposed whereby the berth width is slightly less than 600 feet inside the bay, near the bow of the CVN, and the dredged area follows the existing contours of the northern point.

Alternative 3 - Polaris Point Diagonal Offshore. This site is also located at the northern shore of Polaris Point. The pier spans across the existing bay, and is located so the abutments are onshore at each end.

Figure 1-1 Location Map



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2.0 GENERAL CONSIDERATIONS AND CRITERIA

2.1 CVN Capable Berth Criteria Summary

CVN class 68 and 78 vessels have been evaluated in this assessment based on guidance provided by NAVFAC Pacific and applicable Unified Facilities Criteria (UFC) documents. Vessel characteristics are summarized in Table 2.1-1. Site specific information was obtained through a field visit conducted from 01 October 2007 through 05 October 2007 and discussions with personnel from NAVFAC Marianas, NAVFAC Pacific, Base personnel, and various contractors with experience in Guam. This information forms the basis of engineering analysis and cost estimates presented in this preliminary report.

Table 2.1-1 Vessel Characteristics

Vessel Characteristic	CVN 68	CVN 78
LOA	1,123 ft	1,092 ft
Length at waterline	1,040 ft	1,040 ft
Beam, with removable appurtenances	280 ft	280 ft
Beam, without appurtenances	256 ft	256 ft
Beam at waterline	134 ft	134 ft
Draft, max	40.8 ft	40.8 ft
Displacement	104,200 LT	104,400 LT
Height at light load (air draft)	215 ft	215 ft

Table 2.1-2 provides a summary of project criteria used for preliminary design and cost estimating the critical elements for the CVN Capable berth. Additionally, a full list of reference documents used to produce this study is provided in Chapter 10, References. This chapter provides detailed information regarding the general considerations and describes the application of CVN Berth criteria used for this study.

2.2 Navigation Channel and Turning Basin Geometry

The navigation analysis effort looked at three alternative channel alignments and their impact to navigation and existing coral. Two alignments (Option 2 and Option 3, Figures N-5 and N-6) set out to improve the navigation by eliminating the tight angle bend around Western Shoals. Option 1 (Figure N-4) follows the current fairway alignment, widening it to the required 600 ft. Options 2 and 3 provide operational benefits by allowing for unassisted CVN transiting to and from the turning basin. These options, however, required dredging through the coral shoals, significantly increasing the dredging volume and direct impact (removal) on the coral. These options have therefore have been discarded from further analysis. All of the turning basin and berthing options are thus based upon channel alignment Option 1. Both the CVN 68 and CVN 78 require a constant minimum depth of -49.5 feet MLLW throughout the channel and the turning basins. Minimum channel width was determined to be 600 feet while the minimum turning basin radius is 1,200 feet.

Tug assistance at all times is assumed. No provisions are available for emergency exiting of the harbor without tug assistance.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Navigation / Dredging	Channel / Fairway Width	600 ft.	600 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.g.	
	Channel Bend	2,000 ft. - 10,920 ft. radius	2,000 ft. - 10,920 ft. radius	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.2.2.	The UFC stipulates a minimum radius of bend of 1,200 ft-2,000 ft with tug assistance, but based on the vessel size and the angle of deflection (54 degrees) the recommended radius is 10 times LOA of the vessel, for 10,920 ft for the CVN class.
	Turning Basin	minimum radius .75 times Length Overall (LOA), optimal radius 2 times LOA	minimum radius .75 times LOA, optimal radius 2 times LOA	Unified Facilities Criteria (UFC 4-150-06) Military Harbors and Coastal Facilities, section 5-6.2.4.2. Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-2.f. Unified Facilities Criteria (UFC 4-159-02) Engineering and Design of Military Ports section 3-6.c.	
	Berthing Area Width and Length	Width:600 ft * Length:1,325 ft	None provided Assume same as for CVN 68	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.a.	* 600 ft width applies to 'slip width'. 800 ft slip width with CVN on opp. berth. (240 ft clearance between). Actual 'berth width' not defined.
	Dredge Depth	-49.5 ft. at MLLW	-49.5 ft. at MLLW	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.b. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007) Section 3.2.1. Interim Technical Guidance (ITG) CVN Dredge Depth Criteria (06 MAR 07)	
Structural	Wharf Width	90 ft.	90 ft.	Interim Technical Guidance (ITG) - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-1.a.	The wharf is not used for maintenance which would requre a wider wharf. Vessels are not berthed on both sides.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Structural (con't)	Wharf Length	1,325 ft.	1,292 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 2-3.c. Facilities Planning Criteria for the CVN 78 Class (PMS 378 Rev July 2007)	Total wharf length for Alternative 3 is 1545 ft; required by site topography and the need to provide on-shore abutments to resist seismic and berthing loads. The length would be the same for the CVN 68 or CVN 78.
	Wharf Deck Height	Elev +12 ft.	Elev +12 ft.	ITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-2.b.	The significant wave height and final deck elevation need to be confirmed.
	Pier Strength	Live Load = 800 psf min.		As above, Section 4-3.a.	
	Mobile Crane Load	2 - 140 ton mobile cranes		As above, Section 4-3.b.	
	Bollards	100 ton, 100 ft spacing	100 ton, 100 ft spacing	As above, Section 4-3.d.	
	Storm Bollards	4 - 200 ton bollards at each end of wharf	4 - 200 ton bollards at each end of wharf	As above, Section 4-3.d.	Location must be back from the face of wharf beyond 90 ft. Since lateral soil strength is not yet determined, wharf deck is extended to support these bollards. Final design may allow these to be on shore for Alternatives 1 and 2 only.
Supporting Facilities	Security Measures	Electronic Harbor Surveillance System		OPNAVINST 5530.14D, Appendix VIII - Waterside and Waterfront Security Draft UFC 4-025-01 Security Engineering: Waterfront Security UFC 4-021-02NF Security Engineering: Electronic Security Systems	Minimum requirements include electronic water/waterside security system (CCTV, associated alarms, surface craft or swimmer detection, and underwater detection). Local components of EHSS require integration into the base-wide ESS
		Perimenter Fencing		UFC 4-025-01 DRAFT Waterfront Security Design (24 July 05)	Concrete barriers with fencing on top of barriers
	Laydown Area	5 Acres (+/-)		IITG - Facilities Homeporting Criteria for Nimitz Class Aricraft Carriers (3 NOV 98), Section 4-4.c.	Laydown area for temporary visits not defined; however, area is fully utilized for buildings, transit shed, equipment, etc.
	Port Operations Building	10,000 sf Storage Shed		COMNAVMAR	Provide bathroom only - office not required in buildiing.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement CVN 68	Requirement CVN 78	Source	Notes
MWR Services	Open Pad Area	8500 sf - 12,000 sf		Interviews with NAVBASE Guam MWR personnel and guidance from NAVFAC	
	Road/Parking Improvements	Bus staging, parking, etc.		As above	
	Electrical Service	208V 3-Phase Recept. Bank		As above	
Bilge Oily Waste	Peak Quantity	80,000 gpd	82,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Average Quantity	35,000 gpd	38,000 gpd	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77 and FPC for the CVN 78 Class (Review Draft, REV 1, July 2007).	
	Design Rate	90 gpm	90 - 180 gpm*	Per Table C-5 in UFC 4-150-02 for CVN 68 to 77, FPC for the CVN 78 Class (Review Draft, REV 1, July 2007 & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	* Clarification provided from the Program Executive Officer for Aircraft Carriers (PEO CARRIERS) per email dated 24Sept07. The CONOPS for the CVN 78 is to use only one pump, limiting the output to 90 gpm.
Wastewater	Average Daily Flow	550,000 gpd	550,000 gpd	Per UFC 3-240-2N, using 100 gpcd and 5,000 personnel for both CVN 68 and 78 plus additional 10% for escort ships accompanying the CVN during the 21-day visit.	Based on information provided in Setiadi/Belt Collins report 28Sept2006, rev 21Jan2007.
	Design Rate	4 pumps at 400 gpm each*	Fwd, stbd side: 250 gpm Aft, stbd side: 500 gpm**	*Per Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, assume 3 CHT pumps operating at 400 gpm each (design for 1,200 gpm).	**Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing CHT requirements for CVN 68, which has a larger output of 1,200 gpm.
Potable Water	Average Demand	185,000 gpd	235,000 gpd	Per Table C-4 in UFC 4-150-02 for CVN 68 (with Air Wing or Troops Aboard) & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	Per notes provided on "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document - Recommend providing water demands for CVN 78.
		18,500 gpd*	23,500 gpd*	*Assuming 10% for escort ships accompanying the CVN during the 21-day visit.	*CVN escort ships' water demand.

Table 2.1-2
Summary of Project Criteria for CVN-Capable Berth

System	Criteria	Requirement		Source	Notes
		CVN 68	CVN 78		
Potable Water (con't)	Design Rate	1,000 gpm	1,000 gpm	Based on UFC 4-150-02 for Active Berthing for all berth lengths up to 2,000 feet, plus 500 gpm for each additional 2,000 ft.	
	Minimum Pressure	40 psi	40 psi	Based on UFC 4-150-02 for Active Berthing. Minimum pressure required at the most remote outlet on the pier, downstream of a backflow preventer.	
Steam	Constant	7500 lb/h*	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	*Includes 50% for Air Wing on board
	Intermittent	7200 lb/h	Not req'd	Table 1 MIL-HDBK 1025/2; Table B-1 UFC 2150-02, CVN -78 FPC July, 2007	Use 70F outside design temperature.
Compressed Air	Design Rate	2400 scfm	Not req'd	Table B-2 UFC 2150-02; Table 5, MIL-HDBK 1025/2, CVN -78 FPC July, 2007	
Pure Water	Peak Rate	150 gpm	100 gpm	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
	Design Rate	20,000gal/day	20,000gal/day	"CVN 68 Utility Requirements with CVN 78 notes for Guam 21 August, 2007 document.	
Shore Power	Peak Demand	21 MW @ 4,160V	30 MW @ 13,800V*	Per Table C-7 in UFC 4-150-02 for Aircraft Carriers & Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.	*25 MW without Air Wing
Information Systems	Capacity	200 pr copper; 48-strand fiber optic cable; provision for CATV connection	*	Per Table C-8 in UFC 4-150-02 for CVN 68, Guidance provided in "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document, and based on NCTS discussions.	* None provided in UFC documents. Assume same as CVN 68.

The determination of the channel and turning basin geometry needed to support berthing of CVN 68 or CVN 78 class vessels at either the SRF or Polaris Point sites is based on guidance provided by various Navy criteria, input from the pilots operating in Apra Harbor, and physical constraints imposed in the Harbor (e.g., coral beds that must be protected). Table 2.1-2 summarizes the key guidance criteria used by the Navy in the design of military harbors, the recommendations provided in the feasibility study for CVN berthing at Apra Harbor, and recommendations for turning basin sizes for the four berthing options currently under consideration:

- *Interim Technical Guidance (ITG) – Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers (12-12-01)*

  This ITG specifies the optimal turning basin to provide a 2,200 foot radius. A basin which provides a radius of 1,650 feet is identified as the absolute minimum, provided tug assistance is available.

- *Unified Facilities Criteria – Engineering and Design of Military Ports (1-18-04)*

  This UFC indicates that a vessel can normally be turned comfortably in a radius twice its length, which for a CVN 68/78 would correspond with a turning basin which provides a 2,148 foot radius. Where maneuverability is not important the basin may be reduced to a radius equal to the length of the vessel (1,092 feet). This may be further reduced, but the vessel must be turned around some fixed point, must utilize the ship's anchor and/or require tug assistance.

- *NAVFAC–Site Specific Report SSR-2983-SHR CVN Berthing Feasibility Study for Apra Harbor, Guam (2-05)*

  This report repeats the criteria from the 12-01 ITG for an optimal turning basin with a diameter of 4,400 feet (2,200 foot radius). It does however indicate that a minimum size of 1,648 feet is adequate (which is very close to the 1,650 foot minimum identified in the ITG) and the figures included in the report seems to illustrate this size turning basin. No discussion is provided; however, regarding operational assumptions or limitations associated with the less-than optimal turning basin.

2.2.1 Channel and Turning Basin Criteria

All three documents referenced above are consistent in the requirements for channel and berth widths; identifying the required inner channel width of 600 feet and a berth/slip width of 600 feet. The minimum berth length identified by the UFC is 1,325 feet.

The primary constraints on determining viable channel and turning basin geometry are the coral reefs and the existing shoreline. In developing the proposed navigation geometry, therefore, the minimum channel and berth/slip width was used and aligned to the extent possible with existing deep water (deeper than EL -50 feet MLLW) in the Harbor for each of the three proposed berth options. Alternative turning basins were then prepared utilizing three guidance criteria (2,200 foot radius optimal, 1,650 foot radius minimal and 1,092 foot radius minimal) to identify the potential impacts of each. Refer to Figures N-1 to N-3 to see these illustrated for each of the berthing alternatives being considered. The optimal 2,200 foot radius and the minimal 1,650 foot radius were both rejected for all options as these would involve significant upland excavation and demolition of landside facilities or complete removal of the sensitive coral reefs. The criteria of providing a basin with a radius equal to the ship's length will however fit within the harbor without significant loss of coral habitat, and in fact will completely avoid the four sensitive reefs. The recommended basin for each of the berthing options, however is somewhat larger based on an approximate best fit within the confines of the harbor, avoiding the coral reefs and expanding upon the 1,092 feet up to existing EL -50 feet MLLW bathymetric contours. This approach increases the size of the basin without incurring additional dredging. This size turning basin will require tug assistance, although the criticality of this is mitigated by the relatively small angle of rotation that the CVN will have to make in order to berth (starboard to) at the various berthing options being considered.

The recommended basins are as follows:

- Berthing Alternative 1 – 1,230 feet radius
- Berthing Alternative 2/2A – 1,230 feet radius
- Berthing Alternative 3 – 1,200 feet radius

2.2.2 Channel Bend Geometry Criteria

A channel bend will be required to transition from the first reach of the Inner Channel to the Turning Basin and then lead to the Berth. In order to avoid the four sensitive coral reefs and make best use of existing deep water in the harbor, the channel must make a bend of 54 degrees. This is a relatively large bend requiring a widening of the channel through the bend. The criteria used for designing channel bends depend upon:

- the angle of channel deflection,
- the speed and properties of he vessel using the channel,
- the characteristics of the channel,
- the visibility, obstructions, and aids to navigation in the vicinity of the bend, and
- human elements.

The general rules governing the determination of the radius of curvature for a channel bend are:

- minimum radius equal to 3,000 feet (914.4 meter [m]) for a ship under its own power, and
- radius equal to 1,200 feet to 2,000 feet (365.8 m to 609.6 m) for vessels with tug assistance.

The criteria for larger vessels and a channel bend of this degree would indicate a radius of 10,920 feet (3,328.4 m) for a CVN 68/78 Class vessel under its own power. Complying with these criteria would require complete removal of the Western Shoals and the adjacent reef bed, resulting in a complete loss of the sensitive coral habitat (Figure N-5). This alternative was therefore not carried forward.

Figure N-6 illustrates an alternative to the optimal radius bend; which will provide a straight channel leading directly into the turning basin. This alternative reduces the impact to the coral reefs, when compared to the optimal channel bend geometry shown in Figure N-5, and will allow CVN class vessels to transit the Inner Channel under their own power with no tug assistance outside of the turning basin and berthing areas. The potential loss of coral was significant and this alternative was dismissed from further investigation.

Using the less stringent criteria of a 2,000 foot radius bend (assuming tug assistance) would avoid the coral. This alternative is shown on Figure N-4. The usability of this relatively tight bend can be improved by the Pilot's use of the existing deep water north of the proposed channel as a turning flare that requires no dredging to construct. If it is determined this flare is needed, additional navigation aids may be required to designate this area.

2.2.3 Channel Depth Criteria

In March 1997 the Navy prepared an *ITG – CVN Dredge Depth Criteria (ITG 97)* which was intended to define depth criteria for Nimitz Class Aircraft Carriers. The ITG was a summary of the quantitative analysis that was performed in San Diego for determining dredge depths for several Military Construction Projects relating to CVN Homeporting. In November 1998 an *ITG – Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers (ITG 98)* was prepared to further refine dredge depth requirements as well as to provide guidance for the planning and design of homeport facilities, including minimum channel, berth and turning basin width and depth requirements.

ITG 97 discussed 11 factors affecting water depth requirements and required dredge depths for Nimitz Class Aircraft Carriers transiting to and moored at homeports, ports of call, and shipyards. The ITG also provided specific criteria guidance for all but three of these factors that would be associated with operations at Apra Harbor. Specific criteria were provided for static draft (including mean static draft, trim and list), depth requirements to accommodate appendages, and the draft effect of salinity and temperature. Specific criteria were also provided for dynamic draft conditions created by squat and heel, but indicated the need for specific analysis of ship's motion in the Outer Channel resulting from wind and wave action. Standards were also promulgated for underkeel clearances.

Not addressed were the additional dredging depths that are a result of advance maintenance dredging and typical overdredge tolerances. Advance maintenance dredging is typically performed in areas that experience ongoing sedimentation and is intended to defer maintenance dredging for some predicted period of time. A review of past maintenance dredging frequency and periodic condition surveys indicates that sedimentation is not a serious concern in Apra Harbor. Therefore, advance maintenance dredging does not appear to be warranted. Overdredge tolerance can be affected by the choice of dredging equipment, but as a standard practice 2 feet is typically used for contracting.

Table 2.2-1 illustrates the analysis of water depth requirements as described in ITG 97 for Apra Harbor under either shipyard or homeport operations of a CVN class vessel.

Table 2.2-1 Summary of Dredge Depth Criteria

	Homeport Depths (feet)				Shipyard Depths (feet)			
	Berth	Turning Basin	Inner Channel	Outer Channel	Berth	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	40.8	37.9	37.9	37.9	37.9
Trim	0.8	0.8	0.8	2.1	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-	1.4	1.4	-	-
Appendages	-	-	-	-	-	-	-	-
Salinity & Temp.	-	-	-	-	-	-	-	-

Table 2.2-1 Summary of Dredge Depth Criteria

	Homeport Depths (feet)				Shipyard Depths (feet)			
	Berth	**Turning Basin**	**Inner Channel**	**Outer Channel**	**Berth**	**Turning Basin**	**Inner Channel**	**Outer Channel**
Motions / Component[2]	-	-	-	a	-	-	-	a
Squat	-	-	1.0	1.3	-	-	1.0	1.3
Heel	-	-	0.8	-	-	-	0.8	-
Clearance	6.0	6.0	6.0	2.0	6.0	6.0	6.0	2.0
Nominal Depth	49.0	49.0	49.4	46.2 + a	46.1	46.1	46.5	43.3 + a
Advanced Maintenance	0	0	0	0	0	0	0	0
Contract Depth	49.0	49.0	49.4	46.2 + a	46.1	46.1	46.5	43.3 + a
Overdredge	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Permitted Depth	51.0	51.0	51.4	48.2 + a	48.1	48.1	48.5	45.3 + a

All elevations indicated are provided relative to MLLW. The depths shown include Design Depth (also called nominal or project depth), Contract Depth (which includes advance maintenance but not overdredge tolerance), and Permitted Depth (which includes overdredge tolerance).

ITG 97, however defines minimum water depth requirements of 50.0 feet of water for Entrance Channels, -49.5 feet at MLLW, or -45.5 Extreme Low Water (ELW) (whichever is deeper) for Inner Channels, Turning Basins and Berths. ELW at Apra Harbor is equal to -1.6 feet MLLW, so that -45.5 feet ELW equals -47.1 feet MLLW. The minimum required depth for the channel, turning basin and berth area for this project is therefore -49.5 feet MLLW.

2.2.4 Berth Width Criteria

The criteria cited discusses the required berth width for CVN, defined as that distance perpendicular to the wharf face which is free from obstacles above the required dredged depth. The berth width and the berth length form a rectangle ("the dredge box"). In some cases the dredge box may be a lowered area in front of the berth face surrounded by higher sea bottom (typically called a "bathtub") to which there may be only one entrance. Other times the berth width may be determined by an adjacent berthing structure, in which case the berth width may be included in or defined by the slip width (physical distance between the two berth faces).

The berth/slip width for a CVN berth is set at 600 feet. An obstacle above the required dredged depth within the dredge box makes the berth non-compliant. Depending upon the extent and the location of the encroachment, safe berthing may or may not be possible. This issue is further discussed for Alternative 2, Polaris Point Parallel to Shore.

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[2] Variable derived from coastal analysis but not germane to this study.

2.2.5 Recommendations

The -49.5 foot MLLW requirement presents the minimum depth requirement for the Inner Channel, Turning Basin, and Berths at Apra Harbor for CVN vessel calls. The existing water at the Entrance Channel is well in excess of -50 feet MLLW and no dredging is required there. An additional 2 feet for overdredge tolerance will be added for the evaluation of dredge quantities for regulatory (permit) purposes and for contracting flexibility. The estimated dredge volumes for each alternative with channel options are provided in Table 2.2-2.

Table 2.2-2 Estimated Dredge Volumes

	Dredge Volume (to EL -49.5 feet MLLW (CY)	2-Foot Overdredge Tolerance (CY)	Total (CY)
Former SRF (with Channel Option 1)	342,200	136,700	478,900
Former SRF (with Channel Option 2)	1,838,400	208,200	2,046,600
Former SRF (with Channel Option 3)	751,200	158,400	909,600
Polaris Point Parallel to Shore (with Channel Option 1)	803,700	189,500	993,200
Polaris Point Parallel to Shore - Reduced Impact (with Channel Option 1)	587,700	170,300	758,000
Polaris Point Diagonal Offshore (with Channel Option 1)	503,700	168,700	672,400

2.3 Aids To Navigation

In order to accommodate the widened channel, turning basin, and approaches to the three berthing alternatives, the existing aids to navigation will require modification. The primary Inner Harbor Channel (also termed the Fairway) for the Apra Outer Harbor is marked at the entrance with two lighted buoys designated as: “Fl G 4s” and “Fl R 4s.” The centerline of this channel is defined for navigation by the Entrance Range lights designated “QY” and “Iso Y 6s.” Because the proposed realignment and widening of this channel is not symmetrical with the current centerline, relocation of the Entrance Lighted Buoy “Fl R 4s” and both range lights “QY” and “Iso Y 6s” will be required.

The Approach Channel to the Inner Harbor is also proposed to be realigned and widened to transit CVNs from the Entrance to the proposed Turning Basin. The alignment of this channel is currently designated by range lights “Q R” and “Iso R 6s.” Additionally, the channel limits are marked with lighted buoys to warn pilots of the shoals that the channel passes between. To minimize the direct impact of dredging on these shoals, which have been identified as having significant coral resources, the Approach Channel is proposed to be realigned. This will require relocation of both range lights “Q R” and “Iso R 6s” to redefine the channel centerline. For the berthing alternatives at Polaris Point, the range lights will have to be raised to be seen above the deck of the berthed CVN (for other ships transiting the channel). The lighted buoys don’t appear to conflict with the proposed channel.

The proposed enlargement of the turning basin will also require relocation or removal of two other buoys. One is a mooring buoy located at the eastern edge of the proposed basin and the other is Lighted Buoy “9” just north of the mooring buoy.

Although the two Inner Harbor Channel realignment options have been discarded from further study, theoretically these options would also require changes be made to the navigation aids. These alternatives would require relocation or removal of the Dry Dock Point West Entrance Day Beacon “2”. Both options would also necessitate installation of lighted buoys to designate the remaining shoals following construction of the channel through the existing shoals.

Figure N-8 illustrates the buoys and range lights that will have to be relocated or removed. This figure uses Alternative 1 – Former SRF to illustrate the impact, but the aids to navigation that are affected are the same for each of the three alternatives being considered.

2.4 Dredging

Regardless of which alternative site and berth alignment is selected, dredging will be required in order to meet CVN capable berthing criteria.

Dredging in Apra Harbor is complicated by a number of factors, including but not limited to: (1) the current lack of an ocean disposal site; (2) the need to protect coral assets; (3) possible need to provide munitions and UXO screening prior to disposal; (4) possible sediment contamination; (5) long distance from the U.S.-based dredging fleet and the cost to mobilize a U.S.-hull dredge (Jones Act); and (6) possible use of dredged materials as fill on the project in lieu of imported barrow materials trucked-in from other areas on Guam. These factors are further discussed below.

Tradition methods of dredging in Apra Harbor include drag buckets, clam-shell buckets, and barge-mounted excavators. This equipment can be obtained locally in Guam. For larger projects, hydraulic suction dredging is more economical due to its greater productivity, providing there is sufficient quantity of dredging to cover the costs of mobilizing the equipment. The Jones Act requires all U.S. dredging (including Guam) to utilize U.S. hulls (top-side equipment can be foreign made). The closest available fleet is on the U.S. West Coast. Depending upon business conditions on the West Coast at the time of the project, this fleet may or may not be economically available.

For cost estimating purposes it is assumed dredging shall be accomplished using a closed bucket clamshell dredge, and upland disposal. This provides a suitable cost cushion in the event that ocean disposal is not available or permitted, and that due to economic conditions on the West Coast, mobilization to Guam is not cost effective. When estimating dredge quantities, an overdredge tolerance of 2 feet was assumed above required dredge depths, and advance maintenance dredging was assumed not to be necessary.

Advance maintenance dredging is typically performed in areas that experience ongoing sedimentation and is intended to defer maintenance dredging for some predicted period of time. A review of past maintenance dredging frequency and periodic condition surveys indicates that sedimentation is not a serious concern in Outer Apra Harbor. Therefore, advance maintenance dredging does not appear to be warranted. Overdredge tolerance can be affected by the choice of dredging equipment, but as a standard practice 2 feet is typically used for contracting.

2.4.1 Dredge Material Disposal

U.S. Environmental Protection Agency (USEPA) is proposing to designate an ocean disposal site for dredged materials that meet USEPA and Army Corps of Engineers testing criteria. The candidate locations are approximately 10 to 12 nautical miles west of Apra Harbor. While it is possible that the site will be designated in time for this project, the assumption for cost estimating purposes is upland placement, which represents a worst case cost scenario. In other U.S. locations, ocean disposal of dredged material a short distance off-shore is less expensive than upland placement. Beneficial use is another option and the cost would vary with proposed use.

Previous sediment testing in Apra Harbor has shown that the vast majority of the sediment would be suitable for ocean disposal (Sediment Characterization for Construction Dredging at Charlie, Sierra and SRF Wharves, Apra Harbor, Guam. Weston Solutions. August 2006). Limited testing was previously conducted in the vicinities of the wharf locations proposed by this study. No additional testing was done as part of this study. Laboratory analysis of the sediment will be completed to determine the disposal options in support of the Army Corps of Engineers permit application.

Historically, contaminated soils have been found adjacent to shipyard activities. However, results from initial sampling and analysis of potential dredged material near the former SRF site showed low site sediment contamination. Therefore, costs for hazardous waste handling and disposal, associated with highly contaminated dredged material, are not included in the cost estimates for dredging. Additional dredged material characterization may be done if the SRF site alternative is selected as the final wharf site.

2.4.2 Coral Impacts and Mitigation Costs

Every attempt was made to reduce potential dredging impacts to coral while still complying with published design criteria for CVN navigation. The selection of the “sharp bend” fairway option and proposing Alternative 2A, a reduced impact version of Alternative 2, are examples of proposing reducing coral loss. Where there was a choice, high quality coral (high in biodiversity and percent cover) was protected over low quality coral (low in biodiversity and percent coverage).

Dredging activities may adversely impact coral reefs in two ways: direct and indirect impacts. The direct impact of dredging is the physical removal of coral by dredging activities. Indirect impacts could occur from the resuspension of and deposition of marine sediments on coral during dredging activities. During the preparation of the CVN Environmental Impact Statement (EIS), wave and sediment transport analysis will be conducted to assess potential indirect impacts to coral.

BMPs, including deployment of silt curtains during construction, are proposed to avoid indirect coral impacts. This feasibility study relied primarily on the August 2007 marine survey: Ecological Assessment of Stony Corals and Associated Organisms, prepared for Naval Facilities Engineering Command Pacific (NAVFAC 2007). Quantitative estimates of coral cover, utilizing the Point Centered Quarter method were utilized to assess the area of potential dredging activities. After project footprints were proposed, it became apparent that an area outside of the August 2007 survey area in the vicinity of the fairway sharp bend would also be dredged. In this CVN capable berthing study, the shoal location is referred to as the fairway “elbow”. Towed video was used to qualitatively assess this site in (NAVFAC, November 2007, unpublished). Based upon the video coverage, the shoal is believed to support dense coral, with over 90% cover to a depth of -70 ft MLLW. With the assistance of the authors of the 2007 marine surveys, a conceptual qualitative map of coral coverage and biodiversity was prepared. The project dredging footprints were overlaid on this map.

The methodology used in this study for approximating the area of coral impacted and coral mitigation costs in this CVN study was as follows:

1. overlay the dredging footprint over the conceptual coral mapping;

2. calculate the area (square meters [m^2]) of coral removed by construction in four project areas: elbow, fairway, turning basin, and wharf construction area for each alternative.

   Conservative cost assumption for all alternatives: That the eastern edge of Big Blue Reef is lost due to indirect impacts. This is believed to be improbable if BMPs are properly employed. However, in the absence of more definitive information, it is one way to allow for the possibility of some indirect impacts. For this assumption, it was logical to choose the eastern edge of Big Blue Reef, since it is closest to the actual dredging footprint.

3. Estimate the amount of coral present. Multiply area impacted (m^2) by a percent of coral coverage, as recommended by author of the 2007 coral study:

   a. elbow: 90% coverage

   b. fairway: 16% coverage

   c. turning basin: 21% coverage

   d. wharf areas:

      i. Polaris Point = 13%

      ii. Former SRF = negligible (this area was described as having less than 0.25% coverage in the biological survey)

   e. east side of Big Blue Reef (indirect impact) = 21% coverage

4. Calculate the mitigation costs

On March 25, 2008, regulatory agencies were provided draft copies of this report, the coral maps with project footprints and the August 2007 marine survey. The Navy requested assistance in developing a unit mitigation cost per area of coral lost for budget programming purposes. This cost estimate was acknowledged to be a best guess based on available information. It would be proposed in advance of planned sediment analysis, marine surveys and final design drawings.

On April 18, 2008 the agencies (U.S. Fish and Wildlife Service, National Marine Fisheries Service, USEPA, and Guam Department of Agriculture) collectively responded and the emailed response is attached to this report as Appendix C. Based on recent Kilo Wharf Extension (P-502) negotiations, the agencies calculated a mitigation cost of $1,740,000 per acre of coral loss ($430 per m^2). The Kilo Wharf coral mitigation unit cost is variable, based on assumptions, and lower unit costs can be derived. For cost conservatism, the CVN cost estimates proposed in this report assume the $430 per m^2 unit cost.

The agency letter provides total cost estimates for Alternative 2 and 2A based on the assumption that the entire dredged area is covered in coral. These cost estimates were $108.36 million and $102.5 million for Alternatives 2 and 2A, respectively. The agencies acknowledged these are worst case scenarios that could be amended based on review of information that will be available in the future. The Navy's proposed mitigation costs for the four alternatives range from $19,566,075 to $23,068,000, which are considerably less than the worst case scenario. The Navy figures are based upon quantitative estimates of the actual percentage of the sea floor covered by coral. It should be noted, that most of the proposed project area is soft unconsolidated sediment which is not suitable for coral growth or recruitment (refer to *Ecological Assessment of Stony Corals and Associated Organisms, prepared for Naval Facilities Engineering Command Pacific* [NAVFAC 2007] for additional details on the coral surveys).

2.4.3 Ordnance Safety

Naval Ordnance Safety and Security Activity (NOSSA) Instruction (NOSSAINST) 2080.15A states that an Explosive Safety Submittal (ESS) may be required for construction dredging in areas known, or suspected, to contain Munitions of Explosive Concern (MEC). Based on current information and knowledge of site history, it is NOSSA's opinion that an ESS would not be required, at this time. Therefore, costs for ordnance screening of dredge materials are not included in the project cost estimate. A draft "Request for a NOSSA ESS Determination" is included as part of the DD1391 documentation and must be updated and submitted, during project design.

Summary of site history research findings:

- The Apra Harbor area did experience hostile activity during WWII.
- Inner Apra Harbor was dredged, 1944-1946. Historical ordnance disposal records contain no reports of ordnance found during dredging operations.
- Modern Explosive Ordnance Disposal records contain no reports of ordnance discovered in the project dredging areas.
- Current and historical ammunition wharves are Kilo and Hotel wharves, and neither is close to the project dredging areas.
- Extensive coral surveys have been conducted, and no ordnance has been sighted in the project dredging areas.
- Archaeological surveys have researched, visually identified, and inventoried sunken planes and ships in Apra Harbor. There are no known sunken ships or planes in the project dredging areas.

2.5 Staging Area, Buildings and Security

For staging area needs, the *ITG–Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers (12-12-01)* suggests a minimum area for a CVN homeport location of 5 acres. No minimum requirements have been defined for a CVN 21-day port of call visit. Thus, the areas developed in this study are based upon reported needs by various users.

The following support buildings are required to support CVN operations (building sizes are approximate):

1. Port Operations Support Building (10,000 square feet storage shed with bathroom)
2. Air Compressor Building (1,162 square feet)
3. Water Treatment Building (1,216 square feet)
4. Boiler House (2,010 square feet)
5. 13,210 Gallon Fuel Tank [surrounded by berm] (968 square feet)
6. Electrical Substation (10,125 square feet)
7. BOW Pump Station (625 square feet)
8. Bilge Oily Waste Treatment System (BOWTS) – (5,000 square feet)

Buildings are essentially the same for all alternatives, only the specific location of each relative to the wharf varies. All buildings will be designed to the current Guam building code, modified by applicable UFC criteria. Buildings will be designed to criteria for typhoon winds, seismic event, ATFP, sustainability, and other issues in accordance with UFC 1-200-01. Foundations can be shallow if soil improvement methods are utilized to consolidate the fill materials and native soils beneath to preclude liquefaction. Otherwise, deep foundations will be required. Buildings will be all-concrete construction, with doors, windows, and other openings designed and detailed for high winds. Buildings have appropriate ATFP set-backs from the secured perimeter to resist attack.

It should be noted that none of the proposed buildings are considered occupied structures, and thus will not require radon mitigation measures. If future plans include occupied buildings to support the CVN Berth, such as constructing an office in the Port Operations Building, a passive radon mitigation system shall be incorporated into the building design.

Landside and waterside security requirements were established from *UFC 4-025-01 – (Draft) Waterfront Security Design (24-4-05).* The perimeters of staging areas are designed against vehicle intrusion with hardened security fencing (security fencing supported on concrete vehicle barriers). In areas inaccessible to vehicles such as rock revetments and beach shorelines, only security fencing is used to prevent pedestrian intrusion. The wharf access control point, via the staging area or directly from an approach ramp, will be at a guard booth controlling active vehicle barriers (hydraulic bollards and traffic spikes) for the inspection of vehicles.

Watch towers are required for the berth. Criteria require that they be at least 30 to 50 feet above the wharf, positioned to monitor the waterfront, spaced at approximately 1,000-foot intervals, and that they be hardened and secured by fencing. The towers will be sized to support 2 personnel with HVAC, water, sewage, telephone, fire alarm, security power circuits, etc, but designed to be operated by single person.

Floating port security barriers (PSB) are required to surround the CVN while it is at berth. The recommended minimum barrier standoff requirement is 250 feet from the CVN hull, comprised of 200 feet standoff for FPCONs ALPHA and BRAVO plus a boat penetration distance of 50 feet. In the event that FPCON CHARLIE and DELTA are declared, the PSB's will need to be relocated to the greater standoff distance, 200 feet beyond that of Alpha/Bravo. The locations are shown in Figures G-1, G-2, and G-3. This may cause significant interference with operations in adjacent areas. However, FPCON CHARLIE and DELTA are not expected to last an extensive length of time.

It is understood that Navy security boats will be positioned in Apra Harbor in a readied state less than two nautical miles from any of the alternative site locations for security response.

Observations and General Recommendations

The following observations and recommendations are applicable to both the SRF and Polaris Point sites.

The staging area for the CVN services are configured and sized to provide unimpeded access to the wharf, and a reasonable amount of area for operations, staging, and support. In addition, adequate areas to accommodate the various buildings listed in the previous section and associated parking are provided. The alternatives are laid out to reduce demolition of nearby buildings and roadways to a minimum.

As there is ample suitable fill material available from dredging, it is reasonable to save upland disposal costs by using the nearshore dredged material to construct the entire staging area to relatively the same elevation as the wharf. For Alternatives 1 & 2, the staging area will be sloped landward at 1%, the same as the wharf deck, providing for a consistent surface for forklifts or other moving equipment on and off the new asphalt concrete pavement. This eliminates the need to have ramp(s) up to the back edge of the wharf. For Alternative 3, the staging area is not contiguous with the wharf, thus ramps to the wharf deck are provided.

Another benefit to elevating the staging area pad is to protect the area from possible typhoon inundation and damage. For this reason each alternative layout shows varying amounts of armor rock protection at vulnerable locations to prevent erosion of the fill and damage to the pavement. Also the concrete cut-off wall at the back of the wharf has been extended and/or angled to retain some of the nearby fill material for the staging area.

Elevating the pad above the surrounding grade enhances security. The wharf and the staging area will have a level line of sight. The elevated pad will be surrounded by a 2:1 h:v slope with a hardened fence along the top. This will make incursions through the fence much more difficult. When possible, the watch towers are shown constructed on the pad near the back of the wharf. Per Draft UFC 4-025-01, two towers are warranted for the size of the facility. This increases their observation level while keeping them in a secure area. The locations shown on the figures are subject to final determination.

In each alternative, security is enhanced by a combined single entrance and exit ramp to the surrounding grade. Access to the facility is controlled by a guard building at the entrance and protected by hydraulic bollards and traffic spikes. Traffic queuing is afforded to various degrees in each alternative layout. Each layout is designed so that rejected vehicles can turn around without being boxed in from behind. This eliminates the possibility that a vehicle would have to drive past the check point and make a U-turn and leave. For additional protection, the entrance ramps are also situated a reasonable distance from the asset.

An enclave gate and concrete sidewalk along the entrance side of the ramp is also provided for pedestrians. Pedestrian access is controlled by the same guard booth as the vehicles.

OPNAVINST 5530.14D, Appendix VIII - Waterside and Waterfront Security, “Security of Waterfront Assets Matrix in U.S. Navy Controlled Ports” provides criteria for security for various classes of facilities including CVN. Minimum requirements include electronic water/waterside security system (Closed Circuit Television [CCTV], associated alarms, surface craft or swimmer detection, and underwater detection) along with the other physical security elements addressed above. Draft UFC 4-025-01 Security Engineering: Waterfront Security delineates electronic surveillance as Electronic Security Systems on the landside and Electronic Harbor Security

Systems (EHSS) on the waterside. An Electronic Security System is defined in Draft UFC 4-025-01 as the integrated electronic system that encompasses interior and exterior Intrusion Detection Systems, CCTV systems for assessment of alarm conditions, Automated Access Control Systems, Data Transmission Media, and alarm reporting systems for monitoring, control, and display. Criteria for Electronic Secutity Systems are found in UFC 4-021-02NF Security Engineering: Electronic Security Systems. EHSS is not similarly defined in Draft UFC 4-025-01, but can be reasonably assumed to include all of the above plus systems for detection of in-water and underwater threats. A specific UFC for EHSS is not known to exist. Current development of state-of-the-art systems is underway at SPAWARSYSCEN, San Diego. Local components of both systems require integration into the base-wide electronic security system. Included are both infrastructure and equipment costs. Infrastructure costs are included in this study while the procurement and installation of equipment should be funded by separate centrally-managed funding outside of MCON appropriation.

2.6 Steam, Compressed Air & Pure Water

Criteria

Saturated steam (150 psig) is used by CVN 68 class vessels to supply shipboard laundry and galley facilities, in addition to any supplementary heating requirements. The demand is that required by the berthed vessel crew complement with an embarked air wing. Criteria for tropical climate conditions were applied, in lieu of criteria for colder CONUS regions. Steam is not required for CVN 78.

A compressed air system is required for CVN 68 at all active berths. Under emergency conditions, the vessel compressed air system will be used to “top off” any compressed air demand. Typically, the vessel requirement for 125 psig compressed air should be at a minimum commercial quality. However, it is presumed that the air may also be used for breathing and thus shall meet the requirements of Class D breathing air as described by ANSI G-7.1-1989. Both the steam and compressed air requirements and conditions are defined by MIL-HDBK 1025/2, and UFC manual 2150-02.

The Grade A pure water is being provided to meet the ship’s needs for active berthing.

The CVN 78 class carriers will require neither steam nor compressed air. The Grade A pure water requirements are as defined by ITG Facilities Planning Criteria Document for the CVN 78 Class (PMS 378, revision 1 dated July 2007).

Observations and General Recommendations

The mechanical utility systems include high pressure steam, medium pressure compressed air and Grade A pure water. These pipelines will be routed in a dedicated utility gallery parallel to the face of the wharf.

Facilities for steam and compressed air are currently located at dock-side Lima Wharves, which could be extended to a new CVN berth located at the former SRF site (Alternative 1). However, compressed air is currently under the control of the commercial contractor, Guam Ship Yard, and may or may not be available for Navy use. The steam utility is managed by the Base Operation Support Contractor, but is not in use (i.e., in dry layup). Correspondence with NAVFAC Marianas personnel indicates that there are a number of projects required to bring the facility back on line. These include: relocation of the boiler plant equipment from Kilo Wharf to replace one of the two existing boilers; repairs to the other remaining boiler system; and replacement of the current temporary metal building with a permanent concrete/masonry building meeting current typhoon and seismic resistance criteria. Even with the proposed projects the final capacity of the steam plant will be insufficient to meet both current demands and future CVN demand. In order to ensure availability, the costs for independent new system for SRF are included in this study. It may be possible to combine the two systems and provide a highly redundant configuration, or it may be possible to expand the current plant to provide additional capacity in conjunction with the proposed improvements. In either case, the costs for the combination of capacity increases along with repairs/modifications of the existing plant to meet current demand are considered to be essentially the same as the construction of a new facility at the CVN wharf site.

Steam, compressed air, and pure water utilities do not exist at Polaris Point. Thus, the systems must be constructed in their entirety.

The steam and compressed air will be generated locally at the wharf. The pure water will take potable water from the existing infrastructure and further treat it to Grade A quality at the wharf in a dedicated treatment facility. The supplied quantities are based on the berthing of either CVN 68 or CVN 78 class vessels with the greater requirements of the two classes determining the utility sizing.

The potential for providing steam, compressed air, and pure water using temporary, portable, generation systems was considered. This option was deemed impractical for the following reasons.

- Lack of locally available temporary equipment implies the Navy must purchase and store the portable versions of the permanent plants. No savings in capital costs is envisioned between portable and permanent, unless the portable equipment can be put to use elsewhere in the harbor when the CVN is not a berth. Portable equipment must be stored between use, thus requiring similar building areas to that of the permanent plant.
- In lieu of this, portable equipment could be leased and shipped to Guam for each visit. However, this increases costs and adds to the lead time for arranging for shipment to the facility. The availability and reliability of supply would be questionable and would require significant planning in anticipation of each visit which may not be practical based on the notification lead time for each visit.
- The operational costs would be more than permanent systems as there are additional costs in mobilizing the portable equipment to the site, setting up and tearing down, and maintenance costs for each visit. The level of operational personnel would be equivalent thus there is no savings in terms of labor.
- Extensive testing and commissioning would be required for the systems for each visit.

For these reasons this report is based on providing permanent systems.

2.7 Bilge Oily Waste (BOW) Systems

Criteria

The bilge is a storage compartment located at the bottom of the hull of a ship where water from various parts of the vessel is collected. Bilge water typically contains about 1% of oil and grease and some heavy metals and organic contaminants. Therefore, this waste water must be treated prior to discharge. Due to its composition, pre-treatment of bilge waste is necessary prior to discharge into a domestic wastewater treatment system.

Criteria for the quantity and design rate of BOW for various types of ships are provided in *UFC 4-150-02, Dockside Utilities for Ship Service*. Detailed design criteria regarding the collection, transport, and treatment of the bilge oily waste is provided in *UFC 4-832-01N, Design: Industrial and Oily Wastewater Control.* According to Table C-5 provided in Appendix C of UFC 4-150-02, the following shore service requirements for various classes of CVNs are required, as summarized in Table 2.7-1.

Table 2.7-1 Shore Services for Aircraft Carriers – Oily Waste/Waste Oil Discharge

Ship Symbol	Pump Station	Pump	Pump Rating (gpm)	Qpeak (gpd)	Qave (gpd)	Discharge Connection Location	Discharge Connection Size
CVN 65	1	1A	200	35,000	35,000	2 Connections @ Main Deck: Frame 146 Starboard; Frame 149 Port	2.5 inches
		1B	200				
CVN 68 to 71	1	1A	90	80,000	35,000	2 Connections @ Main Deck: Frame 128 (512 foot aft of FP) Port, Frame 170 (680 foot aft of FP) Starboard	2.5 inches
CVN 72 to 77	1	1A	90	80,000	35,000	3 Connections @ Main Deck: Frame 128 (512 foot aft of FP) Port, 2 each @ Frame 170 (680 foot aft of FP) Starboard	2.5 inches
		1B	90				

**Note: Shaded row presents criteria applicable to a CVN 68.*

For a CVN 68, the design bilge oily waste flow quantities for peak and average day are 80,000 gallons per day (gpd) and 35,000 gpd, respectively. The pumping rate is 90 gallons per minute (gpm).

No criteria are provided in the UFC documents for a CVN 78. Based on information provided in the review draft document of the Facilities Planning Criteria (FPC) for the CVN 78 Class, REV 1, July 2007, BOW generated from the CVN 78 will be comprised of a steady quantity of 8,000 gpd of oily water with an initial discharge of 52,000 gallons. Waste oil generated from the CVN 78 will total 30,000 gallons per offload occurrence. No discharge quantity of aircraft waste fuel or average and peak discharge rates were provided in the review draft FPC. Based on the available information in the FPC, the average discharge rate used for this analysis was calculated using the combined output of the steady discharge rate of 8,000 gpd plus one 30,000 gallon offload occurrence of waste oil per day; totaling 38,000 gpd. Similarly, the peak discharge rate used for this analysis was calculated using the combined output of the initial discharge of 52,000 gallons plus one 30,000 gallon offload occurrence of waste oil per day; totaling 82,000 gpd.

The review draft FPC for the CVN 78 indicated that the BOW pumping rate will range from 90 to 180 gpm. Clarification provided from the Program Executive Officer for Aircraft Carriers (PEO Carriers) indicated that the concept of operations for the CVN 78 is to operate only one pump at a time. Therefore, although this vessel is equipped with two 90 gpm pumps, the BOW output from the vessel will be limited to 90 gpm.

The design criteria for the BOW system for the CVN 68 and 78 are similar, with slightly higher average and peak discharge rates estimated for the CVN 78 of 38,000 gpd and 82,000 gpd, respectively. Since the pumping rate for both carrier types are the same and there is less than a 10% difference between their respective average and peak flow rates, construction phasing for the BOW system for the CVN 68 and the CVN 78 will not result in a significant economic benefit. For this reason, the analysis performed in the subsequent chapters will be based on providing the facilities required to accommodate the ultimate BOW requirements of the CVN 78.

Observations and General Recommendations

The following observations and recommendations are applicable to the SRF and Polaris Point sites.

There are two existing BOWTS located in the Apra Harbor Naval Complex. The first BOWTS was constructed in 1997 and is located at Victor Wharf. The design capacity of this system is 150 gpm and is equipped with a load equalization tank of 50,000 gallons. The second BOWTS was constructed at Polaris Point under MCON Project P-250 in 2005. This system was designed primarily to handle the BOW generated by submarines and the tender docked at Polaris Point. This system has a design capacity of 40 gpm and is equipped with a load equalization tank of 20,000 gallons.

Based on discussions with Port Operations, the BOWTS at Polaris Point has yet to be placed in operation. This facility has been idle for approximately 2 years due to construction deficiencies. Currently, the BOWTS at Victor Wharf is used to process all BOW generated by the ships berthed at Apra Harbor. A mobile BOWTS unit is available; however, this unit has an extremely low processing capacity and will not be able to handle the BOW requirements of a CVN.

There is currently no BOW collection system available to convey BOW to the BOWTS at Victor Wharf. BOW is collected from each ship using ship waste offloading barges (SWOB). Port Operations currently operates three SWOBs. The largest is a yard oiler Navy barge (YON) which was converted to a SWOB. The capacity of the YON is 350,000 gallons, while the two other SWOBs have a capacity of 70,000 gallons each.

Based on previous experience with carriers being berthed at Apra Harbor, extreme stress was placed on both the existing BOWTS at Victor Wharf and the SWOBs. Personnel at Port Operations highly recommend a new BOWTS and BOW collection system to be constructed for the CVN near the proximity of the berthing location.

2.8 Wastewater Systems

Criteria

Wastewater generated onboard a ship is collected in the ship's Collection-Holding-Transfer (CHT) system. This wastewater is primarily domestic in nature, but is typically more concentrated than typical domestic wastewater. When docked, waste collected in the CHT system must be discharged to a landside sanitary sewer system for treatment and disposal.

Criteria for the design discharge rate of the CHT systems for various types of ships are provided in *UFC 4-150-02, Dockside Utilities for Ship Service*. According to Table C-6 provided in Appendix C of UFC 4-150-02, the following shore service requirements for various classes of CVNs are required, as summarized in Table 2.8-1.

Table 2.8-1 Shore Services for Aircraft Carriers – Sanitary (CHT) Discharge

Ship Symbol	Pump Station	Pump	Pump Rating (gpm)	Discharge Connection Location	Discharge Connection Size
CVN 65	1	1A	400	6 Connections; 5 @ Main Deck; 1 @ 02 Level as follows: 67P (320 feet aft); 02-80S (348 feet aft); 97P (428 feet aft); 103S (452 feet aft); 162S (688 feet aft); 197P (828 feet aft)	4 inches
		1B	400		
	2	2A	400		
		2B	400		
	3	3A	400		
		3B	400		
	4	4A	400		
		4B	400		
	5	5A	400		
		5B	400		
	6	6A	400		
		6B	400		
	7	7A	400		
		7B	400		
CVN 68 to 71	1	1A	400	4 Connections @ Main Deck; located as follows: Frame 113-114 Port, Frame 126-127 Starboard, Frame 178-179 Port, Frame 183-184 Starboard	4 inches
		1B	400		
	2	2A	400		
		2B	400		
CVN 72 to 77	1	1A	400	4 Connections @ Main Deck; located as follows: Frame 113-114 Port, Frame 68-69 Starboard, Frame 183-184 Port, Frame 194-195 Starboard	4 inches
		1B	400		
	2	2A	400		
		2B	400		

**Note: Shaded row presents criteria applicable to a CVN 68.*

A CVN 68 is equipped with a total of four pumps, each with a capacity of 400 gpm. Clarification provided by NAVFAC Pacific, indicate that three CHT pumps may operate concurrently, resulting in a combined flow rate of 1,200 gpm.

No criteria are provided in the UFC documents for a CVN 78. Based on information provided in the review draft document of the Facilities Planning Criteria (FPC) for the CVN 78 Class, REV 1, July 2007, the forward starboard side of the CVN 78 is equipped with 250 gpm pumps and the aft starboard side is equipped with 500 gpm pumps. Since the pumping requirements for a CVN 68 are greater than the CVN 78, the flow rate of 1,200 gpm will be used for planning purposes per guidance provided by NAVFAC Pacific.

A significant increase in wastewater flows to the Apra Harbor Wastewater Treatment Plant (AHWWTP) is anticipated during the 21-day CVN visit. Criteria for the average daily flow quantities are provided in UFC 3-240-2N, Wastewater Treatment Systems, Augmenting Handbook. This report utilizes a CVN 68's complement of approximately 5,000, plus an additional 10% for the CVN's escort ships, for the analysis of the wastewater treatment system. The resulting estimated average daily flow to the plant will increase by 550,000 gpd. The CVN 78's complement and escort ships will be similar to that of the CVN 68.

Observations and General Recommendations

Based on the location selected for the CVN berthing, various gravity sewers, pump stations, and force mains will be impacted. A schematic of the existing wastewater system is shown on

Figure M-1. The following is a description of the portion of the wastewater collection system that will be impacted as a result of the CVN berthing location.

Former SRF Site Conditions

Wastewater generated at the former SRF site enters Sewage Pump Station (SPS) No. 18. SPS No. 18 pumps waste flows through a 6-inch force main to Trunkline "D" located along Sumay Drive. Trunkline "D" discharges into SPS No. 16. SPS No. 16 is a major pump station in the wastewater collection system, receiving flows from a majority of the Apra Harbor wharves and associated facilities. SPS No. 16 pumps waste flows through a 12-inch force main to Trunkline "A" located along Marine Drive. Trunkline "A" is the primary collection sewer which receives flow from almost all of the main base facilities prior to entering the AHWWTP.

Polaris Point Site Conditions

Wastewater generated at Polaris Point enters SPS No. 9. SPS No. 9 conveys this flow through approximately 13,500 linear feet of 8-inch force main to Trunkline "B", near the intersection of Marine Drive and Bright Road. Trunkline "B" is the primary collection sewer which receives flow from the outlying areas and a small portion of the main base prior to entering the AHWWTP.

Previous Wastewater System Assessments

Previous studies performed by Setiadi/Belt Collins in 28 September 2006 (rev. 31 January 2007) and Parsons in April 2007 evaluated the condition and capacity of the existing wastewater system serving the Apra Harbor Naval Complex. Analyses performed in these studies assumed full wharf occupancy, restored housing assets, and the completion of future bachelor housing facilities. These previous wastewater system assessments also applied the loadings of a CVN carrier docked at Kilo Wharf and Delta/Echo wharves. Based on the existing wastewater system schematic illustrated on Figure M-1, a CVN carrier docked at Kilo Wharf will impact SPS No. 32, gravity sewers in the Lockwood Terrace and Sumay Housing area, and a portion of trunkline "A". A CVN carrier docked at Delta/Echo wharves will impact the SPS at Delta/Echo wharves, SPS No. 9 at Polaris Point, the associated force mains, and trunkline "B" as indicated on Figure M-1. The results of these studies identified current deficiencies associated with various portions of the wastewater collection and treatment systems, initiating the development of projects P-262 and P-534.

Project P-262 is scheduled for Fiscal Year (FY) 2008 – 2009 and is currently undergoing a 60% design review process for the "Request-For-Proposal" document. The scope of P-262 includes increasing the capacity of SPS No. 16 from 0.54 MGD (375 gpm) to 1.0 MGD (695 gpm) to meet current flow conditions. The pump station will be designed such that it can be upgraded to accommodate a defined future flow. As flow increases due to future development, the capacity of SPS No. 16 and associated force main will be increased to 3.0 MGD (2,080 gpm). The future loading used to develop the ultimate design capacity of SPS No. 16 does not include the loading of a CVN vessel. Project P-262 also includes restoring the design average daily flow capacity of the AHWWTP to its original design capacity of 4.3 MGD.

Project P-534 is scheduled for FY 2009. The scope of P-534 includes various wastewater system improvements throughout the Apra Harbor Naval Complex. This project has undergone several scope changes. The most current rendition of the scope for this project includes the following improvements:

- Pump Station Replacement/Repair:
  - ***SPS No. 18***
  - SPS No. 22
  - SPS No. 10
  - SPS No. 7
- Force Main Replacement:
  - ***From SPS No. 18***
  - From SPS at Delta/Echo
- Gravity Sewer Replacement/Relief Sewers:
  - ***Trunkline "D" (between SPS No. 18 and 16, approximately 2,100 linear feet)***
  - From SPS No. 32 to AHWWTP, including ***portion of Trunkline "A"*** (approximately 7,600 linear feet)
  - ***Replace sewers in Guam Shipyard***
  - ***Portions of Trunkline "B"***
- Miscellaneous:
  - Victor Wharf Coast Guard CHT risers and force mains
  - SCADA work at AHWWTP

Although, some of the improvements proposed in P-534 include portions of the wastewater system that will be impacted by the CVN berthing (highlighted in bold italicized font in the list above), none of these improvements will be designed to provide additional capacity for the CVN berthing. Based on discussions with the design consultants for P-534, the intent of that project is to correct only the existing deficiencies in the wastewater system.

Based on the current schedules for P-262 and P-534, both projects should commence prior to the proposed CVN berthing. Neither scope of projects P-262 or P-534 includes additional capacity for the CVN berthing. Both are limited to correcting the existing deficiencies in the wastewater system. Therefore, the improvements proposed in this study are based on accommodating only the loadings of the CVN. All other deficiencies will be corrected under P-262 and P-534. Detailed descriptions of the proposed wastewater system improvements for the CVN berth at the former SRF site and the Polaris Point site are provided in Chapters 4 and 5, respectively.

Apra Harbor Wastewater Treatment Plant (AHWWTP)

All wastewater generated in the Apra Harbor Naval Complex and neighboring outlying naval areas are processed at the AHWWTP. Therefore, regardless of the location selected for the proposed CVN berthing, the total wastewater generated by the CVN will be processed at the AHWWTP. Project P-262 proposes to restore the design average daily flow capacity of the plant to 4.3 MGD. This project is scheduled for FY 2008 – 2009.

An infiltration/inflow (I/I) survey report prepared in February 2007 indicated high infiltration rates due to structural defects in the wastewater collection system. This results in increased loadings, especially during the wet weather season. Based on influent data collected at the AHWWTP between January 2001 and August 2007, flows ranged between 0.81 MGD to 8.78 MGD. A program to replace sewer lines recommended in the February 2007 I/I report will mitigate the infiltration problem, thus reducing the extraneous loadings to the AHWWTP. According to AHWWTP personnel, the current influent flow to the plant is typically 2.9 MGD during dry weather conditions.

Based on the improvements proposed in the I/I study and P-262, the average daily flow of 0.55 MGD from the CVN and its escort ships can be processed at the AHWWTP.

2.9 Potable Water

Criteria

According to *UFC 4-150-02, Dockside Utilities for Ship Service*, potable water should be provided for all berthing spaces. Regardless of the type of ship berthed, potable water must be supplied at a rate of 1,000 gpm for all berth lengths up to 2,000 feet, with a minimum residual pressure of 40 pounds per square inch (psi) downstream of a backflow preventer located at the most remote outlet on the pier. The wharf length for a CVN 68 is 1,325 feet and for a CVN 78 is 1,292 feet. Since both wharf lengths are less than 2,000 feet, a minimum flow rate of 1,000 gpm is necessary for both CVN 68 and CVN 78, as prescribed in UFC 4-150-02.

The flow rate requirement of 1,000 gpm at the berthing location will have a localized impact on the potable water distribution system, but will not likely have an effect on the treatment and storage facilities. However, the increase in the total daily water demand required for the CVN during the 21-day visit will impose a stress to the existing treatment and storage facilities. Criteria for the daily potable water demand for various types of ships are provided in UFC 4-150-02. According to Table C-4 provided in Appendix C of UFC 4-150-02, the following shore service requirements for various classes of CVNs are summarized in Table 2.9-1.

Table 2.9-1 Shore Services for Aircraft Carriers – Potable Water

Ship Symbol	Normal Requirement with Ships Complement (gpd)	Requirement with Air Wing or Troops Aboard (gpd)	Station Location (feet)	Station Height (feet)
CVN 65	100,000	140,000	105S, 148 PS, 220P	MAIN DECK
CVN 68	100,000	185,000	300S, 540S	36

**Note: Shaded row presents criteria applicable to a CVN 68.*

The potable water demand for a CVN 68 is 185,000 gpd. No criteria are provided in the UFC documents for a CVN 78. The potable water demand for a CVN 78 is 235,000, based on information provided in the review draft document of the Facilities Planning Criteria (FPC) for the CVN 78 Class, Rev. 1, July 2007. With an additional water demand of 10% required for the CVN's escort ships, the total potable water demand for a CVN 68 and CVN 78 are 203,500 gpd and 258,500 gpd, respectively.

Observations and General Recommendations

Potable water for the naval facilities located at the Apra Harbor Naval Complex, neighboring outlying areas, Naval Hospital, Nimitz Hill, and NCTAMS WESTPAC Barrigada is supplied by the Fena Water Treatment Plant (FWTP). Upgrades to the facility under P-256 have been completed, restoring the capacity of the plant to 13.5 MGD. Based on future navy water demands established in a utility system assessment of the potable water system dated January 2005, plus current water usage by the government of Guam areas, the average daily water demand is estimated as 11.3 MGD. The daily potable water requirements for a CVN 68 and

CVN 78 are 0.204 MGD and 0.256 MGD, respectively. Therefore, no improvements are necessary at the FWTP to accommodate the CVN water demands.

There are two main storage tanks supplying water the Apra Harbor Naval Complex and neighboring outlying areas. The Apra Heights Tank has a storage capacity of 5.0 million gallons (MG) and serves a majority of the Apra Harbor Naval Complex. The Tupo Tank also has a storage capacity of 5.0 MG and serves the outlying areas, including Polaris Point. Based on the location of the proposed CVN berthing, the storage capacity of one of these tanks will be impacted. This is discussed further in later chapters.

The adequacy of the transmission and distribution system piping network was determined using a computer water modeling program. The existing hydraulic model was developed by Engineering Concepts, Inc. in 2005. This model was updated to include recently completed and proposed improvements to the water system. The water system was evaluated based on its ability to supply 1,000 gpm at the berthing location with a minimum pressure of 40 psi. The results of the water model for each alternative site are presented in later chapters.

2.10 Power and Communications

Descriptions of the existing electrical power and communications systems serving the Apra Harbor Naval Complex were based on information presented in the various utility system studies conducted for the installation, information provided by NAVFAC Marianas utility system and NCTS (Navy Computer and Telecommunications Systems) Guam personnel. Key information on the electrical distribution system that will be in place by the time this project is slated for execution was obtained from RFP documents for FY08 MCON Project P-494*,* Harden Electrical System Main Base Distribution/Substation, U.S. Navy PWC/COMNAVMAR, Guam, M.I. Per guidance provided by NAVFAC Pacific Planning, projects programmed for and before the FY 2009 will be assumed to be completed and “existing” for this analysis. Projects programmed for FY 2010 and beyond will not be considered in this analysis. A discussion of each system follows.

2.10.1 Power Distribution System Background

The GIMDP Electrical Engineering Assessment Guam briefly covered supply of electrical power requirements for a CVN 68, but not a CVN 78. The assessment did not involve a full electrical system capacity analysis, particularly in consideration of the improvements planned to be implemented under FY08 MCON Project P-494. It made gross assumptions and addressed concepts for utilizing standby generation available at Orote Power Plant and at the GPA Piti Power Generating Station. There was no dialog with GPA to obtain costs for improvements that GPA would have to implement to accommodate the CVN berth. Rough Order of Magnitude estimates were given as follows:

- CVN at SRF: $78 million with backup generation from Piti, $82 million with backup generation from Orote
- CVN at Polaris: $59 million with backup generation from Piti, $65 million with backup generation from Orote

The Orote Power Plant contains three 6.6 Megawatt (MW) diesel engine generators totaling 19.8MW. It is not capable of supporting a single CVN 68 at full load. Additionally, its capacity is needed to support critical Main Base Loads during an extended outage such as the Apra Harbor Wastewater Treatment Plant, the NEX, Cold Storage Facilities and other critical base facilities.

The aforementioned GIMDP Study did not provide details on how electrical system improvements would be made to support the CVN. While it mentions backup generation, it does not address redundancy to maintain power to the CVN if there should be a feeder or transformer failure. The GIMDP study report appears to imply that the new GPA 34.5 kV feeder to either berth site would be dedicated to the berth and not integrated into the base electrical system.

During the team's data gathering visit to the island, there appeared to be strong interest in obtaining a power supply scheme to either berthing site that would provide for redundancy. Base personnel also indicated that it would be better if the new 34.5 kV feeder proposed to supply the CVN berth could be used to enhance the Main Base electrical system, particularly if the CVN berth is not in use for most of the year. Subsequent direction received indicates that it is not necessary to have redundant power feeds to the berth substation, but redundant transformers should be provided at the berth substation to maintain shore power service if a transformer fails.

Following receipt of the RFP documents for FY 2008 MCON Project P-494, the project team exchanged information with MK Engineers (the Prime Consultant for P-494), to develop a scheme that would meet the desired objectives. The objectives included power to the CVN berths with non-redundant feeders and redundant transformer capacity, and utilization of the new 34.5 kV GPA feeder to enhance the reliability of the Main Base distribution system.

The scheme developed for the former SRF berthing option includes a non-redundant feeder from SRF Substation to the SRF Berth Substation, redundant transformers, upgrade of two existing 34.5 kV feeders between Orote Substation and former SRF Substation, upgrade of the 34.5 kV X20 feeder from Piti 34.5 kV Switching Station to Orote Substation, and addition of a new 34.5 kV feeder from Piti 34.5 kV Switching Station to Orote Substation. The latter two tasks are necessary to maintain single contingency redundancy to the Main Base electrical system with the addition of the CVN loads.

The scheme developed for the Polaris Point berthing options include a new non-redundant 34.5 kV feeder from the Piti 34.5 kV Switching Station to the Polaris Point Berth Substation and redundant transformers. Since this feeder does not interconnect into the Main Base distribution system, it neither degrades, nor enhances the Main Base distribution system. In this scheme, while it is ultimately desirable to upgrade the 34.5 kV X20 feeder to achieve single contingency redundancy for the main base distribution system as other projects increase the Main Base power demand, it is not within the scope of this project to do so.

The resultant schemes are described in the electrical power system descriptions that follow.

2.10.2 Electrical Distribution System

Criteria

CVN 68 requires 21MW at 4,160V and the anticipated load for CVN 78 is 30MW at 13,800V.

The electrical base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated 15 kV feeder cables and power receptacles.

Observations and General Recommendations

The electrical distribution system on the Main Base will be undergoing major upgrades under FY 2008 MCON Project P-494. Three new substations will be constructed (Cold Storage Substation, Orote Substation and SRF Substation), and on-base 13.8 kV overhead lines will be converted to underground distribution systems to improve reliability and minimize susceptibility to typhoon damage. In addition, new 34.5 kV underground express feeder circuits will be constructed between the Orote Substation and the SRF Substation.

There are planned follow-on projects to P-494 which are presently identified as P-495 and P-496. P-495 is presently in the scope validation and DD1391 preparation phase. P-496 has yet to be programmed and scoped.

None of the three projects include the capacity to support a CVN berth at either site.

An inquiry made to GPA via NAVFAC Marianas confirmed that there is space for just one additional 34.5 kV feeder circuit breaker at their Piti 34.5 kV Switching Station that can be used to enhance the capacity of the Main Base electrical system or provide power for a CVN berth.

This evaluation is built upon the electrical distribution system and substations that will be in place following completion of *FY08 MCON Project P-494, Harden Electrical System Main Base Distribution/Substation.* There are three 34.5 kV overhead feeders supplying power to the Main Base electrical system. GPA Circuits X20 and X21 originate in the Piti 34.5 kV Switching Station and GPA Circuit X36 originates in the GPA Apra Substation. At present Circuits X21 and X36 consist of 927.2 kcmil AAAC conductors with a capacity of roughly 50 MVA. Circuit X20 utilizes #4/0 copper conductors and should be reconductored by GPA to 927.2 kcmil AAAC conductors to increase its capacity to match Circuits X21 and X36.

Details regarding the electrical distribution system for a CVN berth at the former SRF site are in Chapter 4, and Chapter 5 provides details for the Polaris Point site.

2.10.3 Communications System

Criteria

CVN 68 and CVN 78 require the same communications system interface, and the communications system base infrastructure required to support both the CVN 68 and CVN 78 is identical.

Observations and General Recommendations

Base communications system infrastructure consists of Central Office Building 3012 with Information Transfer Node (ITN) buildings located throughout the Base for area connectivity. In addition to the Base communications system needs, the existing communications system primary backbone infrastructure has capacity for 24 concurrent shipboard locations, including necessary fiber optic, telephony, and CATV requirements.

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3.0 STRUCTURAL CONSIDERATIONS

3.1 Coastal Environment and Operational Limitations

A brief coastal engineering study was performed to determine coastal conditions at the two sites (SRF and Polaris Point) during extreme weather events (typhoons). The purpose of the study was to determine survivability of particular conceptual designs, design parameters, and to a lesser extent define the operational environment. Danish Hydraulic Institute (DHI) MIKE-21 Spectral Wave module was used to model Apra Harbor. The model includes a new generation spectral wind-wave module based on unstructured meshes, and simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. This study relies upon and extends the work of two previous Apra Harbor studies (References):

- *Moffatt & Nichol (2007), Coastal Engineering Design Basis and Dynamic Ship Mooring Analysis, Final Report, FY08 MCON Project P-502, Kilo Wharf Extension, COMNAVMARIANAS, Main Base, Guam.*

- *Thompson, E. F. and Scheffner, N. W. (2002), Typhoon-induced Stage-Frequency and Overtopping Relationships for the Commercial Port Road, Territory of Guam. U.S. Army Corps of Engineers, Engineer Research and Development Center, Coastal and Hydraulics Laboratory Report, ERDC/CHL TR-02-01.*

Wave agitation in Apra Harbor under normal operational conditions does not appear to be a typical problem. The configuration of Apra Harbor further prevents large wind-waves from being generated within the confines of the Harbor during operational conditions.

Potentially hazardous wave conditions within Apra Harbor occur mainly during periods of strong westerly winds when swell passes through the west-facing Harbor Entrance.

Historically, the extreme winds on Guam have come from a single source - typhoons. The strongest wind gust experienced in recent history on the island is estimated to be about 200 mph during Typhoon Karen (November, 1962) and 170 mph during Typhoon Paka (December, 1997). Most storms are seen to move in from the east-southeast but exhibit wide dispersion after moving west of Guam. Storms that pass to the south of Guam typically bring higher winds than storms passing the same distance to the north.

3.1.1 Bathymetry

Three separate sources of bathymetry were used to construct a composite numerical model bathymetry used in the numerical simulations. Inside the harbor, detailed bathymetric soundings were available from a 2001 LIDAR survey as well as an updated multi-beam survey performed in 2005. For areas immediately offshore of the harbor, the bathymetry was supplemented by information from C-MAP and digitized NOAA nautical chart 81054.

The dry dock facility AFDB-8 to the west of the former SRF site was not included in the existing bathymetry. The potential relocation/re-orientation of the dry dock facility is under consideration and its current position can not be guaranteed. Simulations without the dry dock are considered to be conservative, as the presence of the dry dock will shelter the project sites to wave exposure from the westerly directions.

Due to the known effects of deep-draft navigation channels on wave propagation, the proposed channel and turning basin options were analyzed to look at any potential effects that could be felt at the project sites. Test simulations were conducted with these layout alternatives, and results indicate negligible changes at either project site, and therefore all simulations were conducted with the existing bathymetry.

3.1.2 Wave Analysis - General

Waves at the project site are from two sources. The first and primary source of wave energy is the typhoon-induced deep water waves that are transmitted through the harbor entrance. The second source of wave energy is locally generated wind-waves created inside the harbor by typhoon winds. For the typhoon-induced wave propagation simulations, each of the thirty events listed in Reference (a) were propagated through the harbor entrance, at the corresponding still water level (including surge and tide). No winds were included in the propagation simulations.

As a check, the results of the model were compared to those obtained in the two earlier studies (References a and b). The comparison was performed at a point south of Cabras Island, as that was the location of the USACE results (Ref b). There are some differences between the three sets of results, but the comparison is reasonable and provides confidence in the present model's ability in simulating the propagation of wave energy into the harbor[3].

3.1.3 Wave Analysis at the Sites, Immediately Off-shore

Results for both propagated and wind-generated waves, for all thirty typhoon events, were extracted at two locations representative of conditions and water depths immediately off-shore of the project sites. The SRF location was at water depth -73 feet MLLW and the Polaris Point location was at water depth -62 feet MLLW. There is little difference between the two locations for the larger wave heights. For the smaller wave heights, the SRF location in general shows slightly greater wave exposure. For all the events, the shallow shoal and reef areas immediately west of the site locations affords sheltering due to increased dissipation in incident wave energy as a result of bottom friction and wave breaking.

Extreme value analyses were performed for the total significant wave height series at both site locations. The return levels associated with return periods of 2, 5, 10, 25, 50 and 100 years are shown in Table 3.1-1 and Table 3.1-2.

Table 3.1-1 Extreme Values of Significant Wave Height at Former SRF Site

Return Period (Years)	**2**	**5**	**10**	**25**	**50**	**100**
Significant Wave Height (feet)	1.1	2.9	3.9	5.2	6.2	7.1

Table 3.1-2 Extreme Values of Significant Wave Height at Polaris Point Site

Return Period (Years)	**2**	**5**	**10**	**25**	**50**	**100**
Significant Wave Height (feet)	0.9	2.8	4.0	5.5	6.7	7.7

[3] The present model (as well as those used in the previous studies) is completely un-calibrated, and only default recommended parameters have been used in the model setups. Calibration of the model is beyond the scope of this report.

3.1.4 Storm Surge Water Elevations

Storm surge is caused by wind stress on the water surface and the effects of atmospheric pressure reduction. Apra Harbor's location on the west side of Guam protects it from the worst effects of storm surge from storms moving from east to west, the most common movement. A tropical cyclone passing north of the Harbor would pose the greatest threat to Apra Harbor of storm surge due to wind stress.

An extreme value analyses was performed on the total water levels (of tide and storm surge offshore of the Harbor, as shown in Table 3.1-3). These levels only provide a rough indication of the extreme levels to be expected at the sites, and for a more accurate determination of site-specific water levels, regional and local hydrodynamic modeling (with tidal and meteorological forcing) is recommended.

Table 3.1-3 Extreme Value Analysis of Total Water Level (offshore of Apra Harbor)

Return Period (Years)	**2**	**5**	**10**	**25**	**50**	**100**
Total Water Level (feet MLLW)	2.4	3.1	3.6	4.2	4.6	4.9

3.1.5 Wave Crest Elevations at the Sites

In order to evaluate the survivability of the pile-supported deck structure for extreme events, the wave crest elevation of the maximum sized wave must be determined and compared with the proposed deck elevation. Both the significant wave height and the total water level contribute to the calculation. However, the extreme 100 year event for both need not occur at the same time. Indeed, given the relatively sheltered west-side location of the Harbor, the two happening together is extremely unlikely. For purposes of this analysis, the 100 year significant wave height and the 25 year total water level event were used. To find the wave-crest height, the crest elevation of the maximum wave above still water must be found, where still water elevation is the 25 year total water level elevation.

It should be noted that these calculations are only approximate and additional studies and calibration of the model needs to be completed prior to final design of the structures. The preliminary wave crest elevation analysis suggests 15.3 feet MLLW at the Polaris Point site and 14.4 feet MLLW at the former SRF site.

Using slightly relaxed criteria of 50 year wave and 50 year water level, the preliminary wave crest elevation analysis suggests 14.1 feet MLLW at the Polaris Point site and 13.5 feet MLLW at the former SRF site.

3.2 Structural Design Criteria

The following Military Publications, Design Manuals, and Instructions are used for design:

- *Interim Technical Guidance (ITG) – Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.*
- *Unified Facilities Criteria (UFC), UFC 1-200-01 Design: General Building Requirements, July 2002*
- *UFC 4-150-06, Military Harbors and Coastal Facilities, 12 December 2001 (formerly Design Manuals DM 26.1, 26.2, and 26.3)*

- *UFC 3-440-05N, Tropical Engineering*
- *UFC 4-152-01, Piers and Wharves*
- *UFC 4-159-03, Mooring Design*
- *UFC 1-200-01, General Building Requirements (formerly Structural Engineering Concrete Structures, DM 2.04)*
- *UFC 4-150-06, Military Harbors and Coastal Facilities*
- *Technical Report TR-2069-SHR, Design Criteria for Earthquake Hazard Mitigation of Navy Piers and Wharves, March 1997*

Additional documents

- 2006 International Building Code (for seismic design)
- Geotechnical Letter Report by Diaz Yourman & Associates for CVN Berthing Study, Apra Harbor, Guam, October 9, 2007

The facility will be designed for a minimum 25 year service life as required by UFC 4-151-10, General Criteria for Waterfront Construction, Section 5-1, Service Life with a preference to increase service life to 50 or 75 years using concrete service life modeling techniques not yet codified in UCF criteria. The vertical steel pipe piles will be protected by a marine coating system and a cathodic protection system according to MIL 1004.10, Electrical Engineering Cathodic Protection

The following ship characteristics were used for the conceptual fender design and for determining the berthing loads that the wharf must resist.

- Draft (feet) 40.8
- Displacement – Maximum (LTons) 104,200
- Length (feet) 1123
- Breadth at waterline (feet) 134
- Breadth at flight deck (feet) 280
- Height at light load (feet) 215

Bollards with a rating of at least 100 tons will be spaced at 100 feet centers along the berth. Storm bollards with a rating of at least 200 tons will be provided at each end of the berth, 100 feet behind the face of wharf.

Two floating “barge” type structures approximately 50-feet wide x 60-feet long will be installed as camels for berthing (see Figure S-2). Yokahama or Seaward fenders will be installed outboard of the camels. This will provide approximately a 60-foot standoff between the pierhead line and the ship’s hull to allow clearance for the ship’s elevators. An additional spare camel will be provided.

<u>Design Loads</u>

Seismic design will generally conform to *UFC 4-152-01, Design Piers and Wharves.*

Live Loads:

- Uniform Deck LL = 800 psf
- Crane Load = 140-ton mobile crane
- Truck Load = HS20-44
- Fork Lift = 20 ton capacity
- Gantry crane – none
- Loads from extreme wave impact – to be determined during final engineering design

Mooring Loads: Standard bollards as discussed above are used for the cost estimate. For this study, it is assumed that the mooring forces will not govern the structural design of the wharf. Seismic loads are greater than the mooring loads.

Berthing Loads: A conceptual fender design includes determining the berthing energy to be absorbed by the fender system and selecting the size and types of fenders. The design will assume the entire energy is absorbed at one camel and the berthing angle is 6 degrees. The approach velocity is 0.20 feet per second. The maximum berthing force transmitted to the wharf will be determined from the force/deflection properties of the fender selected assuming the fender is compressed to its maximum rated capacity.

3.3 Alternative Wharf Structures

In order to accommodate the proposed sites' topographical and environmental conditions in the most economical manner, a brief study was undertaken to review various structure-type options available for the wharf. Based upon previous studies conducted in the mid-90s to determine the optimal retaining structures for the Pier 400 Landfill project in the Port of Los Angeles, the all-vertical pile supported wharf on armored sloped embankment is selected as the preferred alternative, based upon historically excellent seismic performance and economical costs, for berths approximately 50-feet in depth. It should be noted that virtually all new berth construction along the seismically active continental U.S. West Coast is of this type.

However, Apra Harbor is also subjected to typhoon induced storm waves, which can damage the pile supported wharf if special precautions and designs are not implemented. These precautions are not usually required for the other two structure types. Thus, while the all-vertical pile supported deck is preferred for seismic reasons, the caisson and sheet pile bulkhead concepts are more inherently resistive to wave impact, and thus preferred in locations exposed to extreme wave events.

In addition to the all-vertical pile supported deck concept, two other structure types common to Guam were reviewed. The options are:

- Tied-back steel sheet pile bulkhead, which represents the majority of wharf construction in the Inner Harbor and is also being used in MCON P-431 Alpha-Bravo Wharf Improvements.

- Concrete caisson, similar to that used in the construction of the Kilo Wharf, and the Kilo Wharf Extension (MCON P-502).

Any of the three options is possible for the three alternatives, although there are practical limitations as indicated. For the remainder of this study, it is presumed that the all-vertical pile supported deck wharf is the preferred alternative, based upon perceived benefits, risks, and costs. Final design, using refined data, analyses, and costs, may indicate one of the other alternatives, especially the sheet pile bulkhead wall, is better suited.

3.3.1 Pile Supported Wharf Deck

The berthing structure is a concrete deck superstructure 90 feet wide by 1,325 feet long, supported by all-vertical piling. When all piles are installed vertically, the deck and piles resist lateral loads as a ductile moment-resisting frame. This allows the wharf to flex slightly during an earthquake without serious damage. Piling is driven through the surficial shoreline materials to underlying rock below. Batter-piling are not used due to the high seismic activity of the Island and the documented poor seismic performance of batter piles in wharf construction.

Both prestressed concrete piling and steel piling were considered for the structure. Generally, prestressed concrete piles are preferred in a marine environment due to their inherent corrosion resistance capacity. These can be installed at sites with sands and bay mud, and even very dense sands with the aid of jetting. However, at sites with limestone, rock, or similar materials, concrete piles require difficult and expensive pre-drilling to penetrate the rock. Steel piles were selected due to the highly variable soil strata expected at the site. Given that either type of pile would be imported into Guam, steel lends itself better to on-site lengthening/shortening to match the variability in the bearing depth and embedment. During final design after additional site subsurface investigations have determined the actual bearing elevations, the steel vs. concrete issue can be revisited. Concrete could then be selected if a cost savings to do so was apparent. With modern coatings and suitably maintained cathodic protection systems, steel piles can easily obtain a 50-year life or more.

A flat plate (i.e., beam-less) concrete deck structure was selected. In addition to excellent seismic performance, the concrete flat slab is very durable in the marine environment and can support a variety of loads. The concrete flat plate is of uniform thickness. No beams protrude below the soffit of the deck. This arrangement offers additional clearance to extreme wave conditions. This type of construction is common in ports along the Pacific Rim and has the following advantages:

- Simplified forming over beam and slab.
- Improved corrosion resistance (fewer corners than in beam & slab construction; corners allow chloride ion ingress from two directions, thus accelerating the time to corrosion).
- Forgiving of misplaced piles. Piles that have been driven such that the pile butt is up to one foot out of alignment can be accepted with additional deck reinforcing only. Forming can be easily accommodated vice having to meet tighter location criteria for beams.

The underlying embankment slopes upward from EL -50 MLLW to EL +7 MLLW[4]. Some dressing of the existing slope will be required to prepare the slope for the rock. The slope is

[4] Final elevation still to be determined based upon final coastal engineering evaluation.

protected with large armor rock over a filter course of quarry run. For cost purposes, a slope 3 to 1 h:v was selected for the temporary dredge slope and 1.5 to 1 feet h:v for the quarry run and final armor rock placement[5].

The sloped embankment and armor rock also provide lateral support for the piling against seismic, mooring, and berthing forces. The rock and sloped embankment are an integral part of the entire structure. A similar structure was constructed for the two CVN berths at North Island, San Diego. Since the seismic conditions for San Diego and Guam are very similar, and the structure meets current CVN requirements, this structure has been used for planning purposes at this site with modifications to reflect the needs of this project and advances in seismic engineering since the construction of the San Diego wharves.

3.3.2 Sheet Piles Bulkhead Wharf

Sheet pile bulkhead construction is has long been considered economical in many ports and military harbors due to its simplicity, ease and speed of construction, available U.S. suppliers, and costs, when considered for non-seismic berths to 30 or 35 foot depth. Unfortunately, many times these systems were installed without adequate protection (coatings and/or cathodic protection) and thus earned a bad reputation for durability. However, with proper modern coatings and periodically maintained cathodic protection systems, the expected life is 50 years or more.

For berths greater than 30 feet water depth and in seismic areas, such as this project, the advantages of sheet pile bulkheads quickly disappear. Sheet pile bulkheads have performed badly in severe seismic events, such as the 1993 7.7M Guam earthquake. Most of the wharves experienced some degree of structural damage, ground cracking and settlement, liquefaction, and lateral spreading. Underground utility lines and structures located within the affected areas were damaged, and significant settlement of trench backfill occurred. The worst damage occurred along portions of the Victor, Uniform, Sierra, and X-Ray Wharves, with Sierra experiencing lateral displacements of 4 to 6 feet. The primary cause was liquefaction of loose material placed behind the bulkhead during construction and the subsequent failure of the tie back system.

While the bulkheads and backfill can be designed for these seismic events, the need to use very large and heavy sheet pile sections negates the cost effectiveness they once enjoyed. They also tend to fail in a non-yielding manner, which cause abrupt and not-easily-repaired failures. The deeper berths require more retained fill and hence larger soil retaining stresses. Furthermore, these heavy sections are only produced by one or two foreign mills[6] and require long lead times for large quantities. To resist the lateral forces caused by the seismic event, tie-back system should be pile supported, which introduces more cost-inefficiencies. Liquefaction of the backlands still remains a problem unless soil improvement techniques (surcharging, stone columns, and dynamic deep compaction being the most common) are incorporated.

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[5] Final slope to be determined during final design and based upon geotechnical parameters selected after a site-specific subsurface investigation.

[6] American produced Pipe piles are sometimes used in-lieu of the heavier H-Sections as the primary load carrying member in a king-pile system. The need to specially fabricate pipe piles with the interlocks to connect to the adjacent infill sheets raises the cost typically over that of supplying the proprietary foreign H-shapes. Thus if the “Buy-American” clause is maintained for the sheet pile procurement, there is this option albeit a more expensive option.

Nonetheless, a new steel sheet bulkhead system was proposed by the design-build contractor for the extension of the Bravo wharf, in-lieu of the pile-supported deck system originally proposed on the contract drawings[7].

3.3.3 Concrete Caisson Wharf

Concrete caissons are commonly used in Asia and ports in the Canadian Northwest (Vancouver B.C, in particular). They are particularly useful in areas of large tidal fluctuations. A caisson structure was used in the construction of the Kilo Wharf. This type of construction is also employed where extreme waves are known to occur that could uplift and destroy a pile supported wharf. This is the primary reason that caissons were utilized in both the original construction and the planned extension (MCON P-502).

The caisson is constructed in the dry (typically in a graving yard or dry dock), floated into place and sunk, and founded on a dredged and prepared gravel foundation. The cells of the caisson are then filled with soil and Portland Cement Concrete (PCC) paving is placed on top to provide the working surface. Because caissons are stand-alone units, they can be used in off-shore installations by themselves (as is the case in a portion of the Kilo Wharf facility) or backfilled to provide a contiguous area with the backlands.

Similar to the sheet pile bulkhead, the caisson has a history of poor seismic performance, the primary example being Kobe Port during the Hyogoken Nanbu 6.8 M event of 1995. In this case, the primary mode of failure was lateral movement (up to 25 feet) and rotation of the top of the caissons (tipping) due to foundation failure. Both were due to liquefaction of the retained and supporting materials.

Due to the need to have a level foundation for the full width of the caisson, additional dredging/excavation is necessary to cut out and level the area behind the selected berth face. Alternatively, the caisson can be placed further offshore in deeper water, which could require placing a gravel pad to raise the elevation of the foundation to an appropriate level. In addition to the cost for concrete, dry construction and launching, and towage to the site, the added costs of foundation preparation and dredging/excavation makes caissons the most expensive option of the three.

Caisson fabrication in Guam is problematic. There is essentially only one facility capable of fabricating and launching the caissons in a timely manner: AFDB-8. This floating dry dock is currently the property of the Guam Shipyard, and may not be available for use in construction of the caissons. MCON P-502 Kilo Wharf Extension, when bid, will provide additional insight into the construction opportunity for caissons in Guam. Other foreign fabricators may be able to provide caissons in cost effective manner, even though transportation costs may be high. There may be other options such as partial construction on land, launching into nearby shallow waterway, and finishing construction in deeper water. None of these options have been evaluated in any detail for this study.

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[7] It is assumed that the primary reason for the use of the sheet pile wall system was that it was already being used to upgrade the majority of the Alpha-Bravo project, and switching to a completely new system of construction did not justify the additional mobilization and project initiation costs.

4.0 ALTERNATIVE 1 – FORMER SRF

This site is located at the northern shore of the former SRF, currently under leasehold to the Guam Economic Development and Commerce Authority (GEDCA) and operated by the Guam Shipyard.

4.1 Dredging

The guidance criteria define the required berth for a CVN 68 or CVN 78 as 1,325 feet long x 600 feet wide at minimum dredged depth or below. Figure N-1 illustrates the required berthing for this alternative, which shows the 1,325 foot long berth tying directly to the turning basin 600 feet away from the face of wharf (consistent with the 600 foot wide berthing criteria). The existing shoreline is dressed to slopes of 3:1 h:v to prepare the embankment for quarry run placement and armor rock.

4.1.1 Berth Alignment

Three potential berth alignments were studied evaluate the impact of the new wharf on the access to the adjacent AFDB-8 drydock. Two alignments were discarded, and one final alignment was developed for this site. The selected Minimal Impact alignment follows the current shore line as it extends from the end of the finger pier at Lima Wharf in a north-westerly direction toward the current location of the floating dry dock AFDB-8. The precise final location in the onshore-offshore direction is subject to refinement and minor adjustment during final engineering design. The exact location is a function of the specific geotechnical requirements of the site, and the possible need to use the existing finger piers as confined disposal sites for any contaminated dredge materials found during the course of final design and/or construction. For purposes of this study, the berth face runs approximately along the EL -50 feet MLLW contour.

The alignment study mentioned above was undertaken to review the impacts of various alignments had on access to AFDB-8 by ships entering and exiting the dry dock. The bearing (SE to NW) is the same for all three, only the proximity to land and the resulting amount of dredging needed to construct the wharf varied. A security concern was identified in having a possible foreign ship at the commercial ship repair facility pass close by the berthed CVN on its way to the AFDB-8. Each of the sub alternatives addressed this concern. The three alignments reviewed are:

Significant impact: The location of the berth permanently blocked access to AFDB-8 as it is currently configured. The wharf structure extended farthest into the channel and, with the coral reef on the opposite side, effectively precludes any ship from navigating around the obstruction. A possible mitigation would be to turn AFDB-8 180 degrees so that access would be from the opposite end. The port pilot estimated that this would add no more than 30 minutes to the commute time. The security concern is eliminated.

Minimal impact: Selected Alignment. This alignment temporarily blocks access to AFDB-8 as it is currently configured only when the CVN is at berth. The wharf structure is placed further back towards land, requiring some additional dredging but clears the channel allowing ships to navigate safely along the dry dock entrance channel when the CVN is not berthed. A possible mitigation would be to turn AFDB-8 180 degrees so that access would be from the opposite end. The port pilot estimated that this would add no more than 30 minutes to the commute time. The security concern is eliminated, as the foreign vessel could physically not use the channel while the CVN is at berth

No impact: This alignment clears the channel and provides continuous access to AFDB-8 at all times, even with the CVN berthed and the floating security barriers in-place. To achieve this, the wharf is constructed in a recess created along the shoreline that consumes significant amounts of existing land area and generates considerable soil excavation/dredging quantities to obtain the desired offset from the channel. Given the location, such excavated soil materials would be assumed to be contaminated, requiring special handling. The security concern would have to be addressed by other means.

4.1.2 Potential Impact to Coral & Mitigation Costs

It is believed there will be minimal direct impact to coral related to dredging the turning basin, approach to the berth, of the berthing area itself. The former SRF site itself does not contain any appreciable quantities of coral directly in front of the proposed berth area. Alternatively, there may be indirect impact due to sediment transport over the adjacent Big Blue Reef.

Using the methodology described in Section 2.4-2, the estimated area of coral impact is 45,500 m^2 (Drawing A-1). Using the unit cost of \$430/m^2, the coral impact mitigation cost is estimated at \$19,566,000. The impact area includes the eastern edge of Big Blue Reef, in a preliminary attempt to capture potential indirect impacts, as described in Section 2.4-2.

4.2 Coastal Engineering Considerations

Results from the initial investigation (see Section 3.1.5) suggest that the extreme wave event just off-shore of the berth face will have a 14.4 foot maximum crest elevation. This will not affect the stability of either the caisson or the sheet pile bulkhead wall, but will require special design of the pile supported wharf, as the wave crest elevation is approximately 2.4 feet higher than the deck elevation. At the former SRF site, the primary wave energy is directed along shore rather than perpendicular to shore. This suggests that rock dike wave protection could be installed at the northeast end to mitigate wave impact under the deck.

Final design may require special mitigations, such as the installation of better wave-energy absorbing armor protection, heavier armor, higher deck elevation, deck designed for uplift, lowered crest elevation of the embankment below the deck, and a run-up/over-topping catch basin behind the embankment crest to relieve wave pressures. The extent of these mitigation measures can only be determined during final design and after the wave analysis, begun in this study, is calibrated and confirmed and the relative costs for abatement vs. strengthening are evaluated. In the extreme, costs for abatement/strengthening may tip the benefit-cost balance towards the sheet pile bulkhead option.

4.3 Berthing Structure Alternatives

Either the pile supported wharf or the sheet pile bulkhead wharf is suitable for the former SRF location. While the caisson option could be constructed, additional costs will be incurred for temporary shoring to retain the earth while a pocket is dredged for the caissons. The option to move the caissons off-shore into deeper water is not available due to the proximity of the AFDB-8 entrance channel.

The area behind is vacant for the construction of pile supported anchor system for the tie-backs of the sheet pile bulkhead wall. For economy, the location of the wall is set so that the amount dredging required in front of the wall to reach EL -50 feet MLLW can be used to fill the space behind the wall.

The deck elevation is currently set at +12 feet MLLW. This elevation was chosen to conform to surrounding land elevations (for access and visibility) while still providing a deck elevation that minimizes overtopping (for the bulkhead and caisson options) and potential deck uplift (for the pile-supported deck option).

The wharf plan for Alternative 1 is shown in Figure S-1. The face of wharf is located near the existing -50 ft water depth to minimize dredging and landside demolition. The structure is located 100 feet away from the approach channel leading into the floating dry dock. The concrete deck is 90 feet wide by 1325 feet long. It is 115 feet wide where the storm bollards are installed.

The typical wharf section is shown in Figure S-2. After the berth and embankment are dredged, the embankment is covered with “quarry run” rock and larger armor stone. Then steel pipe piles are installed. If large armor stones (i.e., greater than 500#) are needed due to shore protection requirements, the piling can be driven first and the armor stones placed second, although care must be utilized in the placement so that the piles are not damaged or dislocated. The piles support temporary formwork to construct the cast-in-place reinforced concrete deck. A concrete plug is cast inside the top 15 to 20 feet of the steel pipe pile with reinforcing that extends into the concrete deck. This serves as the pile-to-deck seismic moment connection. Fenders and bollards are attached to the deck with special embedded anchor bolts. Ladders and other miscellaneous metals complete the structure. The utilities are installed in the trench extending the full length of the wharf. These are connected to shore by installing sleeves and duct banks inside the concrete slab.

4.4 Demolition and Site Preparation

Site preparation will require the grubbing and removal of all ground cover for construction of the staging area. This will include the demolition and removal of a minor building (approximately 700 square feet – assumed to be removed by the Guam Shipyard per direction from COMNAVMAR personnel) and the removal of about 3,400 square feet of the end of inner finger pier. The remaining portions of this finger pier and the other finger pier closest to the channel, both of which are bulkhead supported, will remain and will be built into the embankment/dike under the wharf. There will be some minor roadway removal around the demolished building and re-alignment of some utility lines along E-Street near the demolished building location. The pavement over the finger piers will be pulverized and left in place. The soil in the other areas will be scarified and re-compacted to prevent differential settlement before the fill material is placed. The water areas between the slips will be filled and the entire site will be raised to grade indicated using reclaimed dredged materials. Soil improvement methods may need to be utilized to consolidate the various soil fills to prevent liquefaction.

4.5 Shoreside Improvements

4.5.1 Staging Area

The former SRF location provides for an approximate 6.0 acre staging area immediately along side the back of the wharf (Figure C-1). The staging area will be sloped landward at 1%, the same as the wharf deck. The entire area will be paved with asphalt concrete over crushed base. All underground utilities and storm drains, building and light standard foundations will be installed prior to paving.

4.5.2 New Buildings

Building requirements are common for all Alternatives and they are described in Section 2.5. The building locations for Alternative 1 – Former SRF are shown on Figure C-1.

4.5.3 Improvements for Morale, Welfare and Recreation (MWR) Services

The Navy MWR area for supporting CVN activities will be situated on a 4 acre lot to the west of the access control point for the staging area (Figures G-1 and C-1). There are nine existing structures totaling about 36,500 square feet that will need to be razed (assume buildings will be removed by the Guam Shipyard) and about 43,900 square feet of roadway servicing the buildings to be removed. Subsequently, the area will be graded and landscaped for lawn and trees. It is assumed that lawn will be supported by a permanent irrigation system. A 3-inch thick asphalt lot about ½ acre in size will be constructed for locating the following temporary facilities:

- Food and beverage booths
- 500 seating area
- 40 phone bank seats
- Parking for visitor and rental cars (100 stalls)
- Portable restrooms
- Laundry facilities
- Temporary lighting
- Trash dumpsters

The MWR area will need electrical, water, telephone, and sewer connections. The area will be enclosed by a 900-foot long chain link fence and will have multiple locking swing gate entry points. One of the gates will have a permanent turnstile and guard shack. Additional parking for five buses will be provided in a 10 foot wide by 300-foot long turnout on the east side of Main Street.

4.5.4 Security

Both watch towers are located just behind and at either end of the wharf. The transfer shed is located on the east side of the staging area just west of the facility entrance. The entrance is accessed from the frontage road along the channel between the Outer and Inner Harbors. One small building, approximately 720 square feet, at the corner of E Street and Main Street will need to be demolished with a portion of the roadway around it. Armor rock is located west of the wharf and configured to protect the elevated pad

4.5.5 Stormwater Drainage Systems

A concrete swale, to collect surface flow, will run east to west along the perimeter of the pad on the east side and will subdivide the pad on the west side. Flow captured in catch basins will be conveyed through two separate concrete storm drains pipe systems. Following the last catch basin and before discharge, the storm water will be treated in each system by inline cyclonic separators to remove oil, grease, and trash. The separators will collect and retain the undesirable material for the first ½ inch of rainfall that occurs. Greater flows will bypass the separator. Discharge from the separators will be to an outfall to the Outer Harbor and at the channel connecting the Outer and Inner Harbors.

4.6 Waterside Security

Criteria for placement of floating PSB are provided in Section 2.5. The type of barrier will be selected during final engineering design. PSBs will be stored when not deployed for the CVN in the Inner Harbor to reduce exposure to wave action and reduce congestion in the Outer Harbor. The clump anchors for the barriers will be kept on station and a small marker buoy will be attached to the buoy as well as being tethered to the submerged anchor chain. Navy response boats for security deployment will be stationed elsewhere in Apra Harbor. An Electronic Security System on the landside and an Electronic Harbor Security System on the waterside will be provided as described in Section 2.5 above.

4.7 Collateral Equipment

Collateral equipment such as power cables, ship-to shore conveyor, mooring lines, and material handling (forklifts) will be stored in the Port Operations Support Building when not needed. Fenders will be permanent installations on the wharf and the camels will be moved to the Inner Harbor to reduce exposure to wave action when not deployed for the CVN. Costs for collateral equipment are included in this study.

4.8 Utilities

4.8.1 Steam System

The steam system will be designed in accordance with *UFC 4-150-02 Design: Dockside Utilities for Ship Service and UFC 4-213-10 Design: Graving Drydocks.* UFC 4-150-02 requires that the steam service supplied to the ships be 150 psig saturated steam (Tsat = 365°F). Since the Berth is to be constructed in a tropical region, freeze protection measures will not be required. The saturated steam properties should be in accordance with Table 4.8-1.

Table 4.8-1 Steam Properties

Property	Vapor	Liquid
Enthalpy (BTU/lb)	1,195	338
Specific Volume (cubic feet/lb)	2.74	0.01819

Wharf steam capacity requirements will be in accordance with steam loads stated in *UFC-4150-02 and the Ship's Characteristic Data Base (SCDB)*. If the capacities are different for similar vessels, the larger of the two demands will be used, unless otherwise instructed by NAVSEA or NAVFAC. The vessel types anticipated to berth at the Wharf will include: CVN 68, and CVN 78 class vessels. Steam capacity requirements for the different vessel classes per *UFC 4-150-02* and/or SCDB are listed in Table 4.8-2.

Table 4.8-2 Design Vessel Steam Demands

Vessel	Vessel Class	Intermittent Load (lb/hr)	Constant Load (lb/hr)
CVN	CVN 68	7,200	7,500
CVN	CVN 78	Not Required	Not Required

The maximum steam consumption based on the single largest steam-consuming ship at the wharf will be that of the CVN 68. UFC 4-150-02 (Revised 12 May, 2003) lists the constant load demand for the CVN 68 class vessels at 7,500 lb/hr. The intermittent load is based on winter severity region. The proposed site of the berth is outside the five zones described in UFC 4-150-02, and UFC 2150-02. UFC 4-150-02 does not indicate a value for the intermittent load. MIL-HDBK 1025/2 however, does indicate that for an outside design temperature of 70°F, the intermittent steam demand for a Nimitz class carrier is an additional 7,200 lb/h. The total steam supply will be 14,700 lb/hr comprising:

- Constant (Laundry/Galley) -7,500 lb/hr
- Intermittent (Max. Heating) -7,200 lb/hr

The latent heat of vaporization at the design conditions is approximately 857 BTU/lb. The corresponding heat flow is 10,455,400 BTU/hr.

Steam piping will be designed in accordance with *UFC-3-430-09N Design: Exterior Distribution of Steam, High Pressure Water, Chilled Water, Natural Gas, and Compressed Air*.

System redundancy and capacity is defined in UFC 3-430-08N, paragraph 3.2.1. Two fire tube scotch marine oil fired boilers (312 HP, 12,200 lbs/hr capacity), together providing 166% capacity[8], will be installed in a boiler house complete with condensate collection systems, deaeration and feedwater forwarding systems. The boilers will be manifolded into an 8-inch, insulated carbon steel pipe. Two welded 6-inch steam wharf supply pipes will run underground/under deck from the boiler house to the wharf utility gallery, wherein a 6-inch steam main will be installed to supply three steam shore tie riser locations. The two supplies will supply steam to either end of the utility gallery main to create a loop. The 8-inch boiler header will provide taps for high pressure, intermediate and low pressure steam to supply boiler burner fuel atomization, deaerator scrubbing steam and any other miscellaneous process steam requirements.

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[8] Current and proposed future capacity of the existing steam plant at SRF is limited to 2 boilers at 8,625 lbs/hr each. Allowing for 5,000 lbs/hr for current usage, which is expected to continue, only 12,250 lbs/hr is available for CVN (2 x 8,625 – 5,000 = 12,500). With a demand of 12,200 lbs/hr without the air wing and 14,700 lbs/hr with the air wing, the SRF plant provides only 100% and 83% capacity, respectively. This does not conform to UFC 3-430-08N criteria.

Wharf high pressure steam branches will each be isolated from the manifold via new 6-inch, manually operated, 150 Class welded end gate valves. Steam piping will be pitched down 0.2% (2½ inch per 100 feet) in the direction of flow. All low points will have trapped drip pockets in accordance with *MIL-HDBK 1003/8A.* Steam piping will be anchored between expansion joints and at riser locations. The length of piping sections between anchors will be limited to keep the thermal expansion of each section to no more than 4 inch.

Shore-ties branching from the wharf main will terminate above deck of the wharf. Three shore-tie stations will be provided on the wharf itself. The location of the risers will accommodate the locations of the utility brows for the moored design vessels. Steam shore-ties will be served by a minimum 4-inch riser complete with riser isolation valve. The shore-tie positions will be protected by a pipe rail guard. The manual riser valves will be above the top of the wharf deck.

The welded manifolds will be of the same piping as the riser and will consist of six 2-inch threaded hose connections complete with welded isolation valves suitable for steam service. Two of the six connections will be spare connections. Each 2 inch hose connection will have a socket welded, ½ inch diameter hose bleed valve between the hose connection isolation valve and the ship-side end of the hose connection.

All steam piping will be welded pre-engineered, pre-insulated, and in accordance with MIL-HDBK 1003/8A and ASME B31.1 (No flanged connections will be used except at equipment nozzles). Where permitted, flanges will be of the weld neck type for piping 2½ inch or larger, and socket weld type for 2 inch and smaller. All flanges will conform to ANSI B16.5 150 Class. Pipe material will be American Society for Testing and Materials (ASTM) A-53 Gr. B ERW for 2½ inch or larger piping, and ASTM A-106 seamless carbon steel for 2 inch or smaller piping. For pipe diameters 2½ inch or larger pipe wall thickness will be standard wall. For piping 2 inch and smaller, minimum nominal wall thickness will be Schedule 80 for welded ends and “Extra Strong” for threaded end piping.

The condensate from the vessels will not be collected. Only condensate formed in the distribution pipeline will be collected and sent back to the boiler house. The condensate collection system will consist of piping main drip/trap stations along the steam line spaced approximately 200 feet apart. The drip/trap stations will consist of a welded 6 inch condensate pocket, steam trap, complete with inline strainer, insulated piping and trap isolation and bypass valves. The pocket will have a 2 inch cleanout line welded at its end with a ball or gate valve to permit drainage of condensate during warm up and emptying of pocket prior to an extended wharf steam main outage. The sloped condensate will be piped to condensate collection vessel with integral pump in the utility trench. There will be drip/trap stations at every shore-tie riser. All steam traps will be of the float and thermostatic type. Condensate piping will be either ASTM A-106 seamless, schedule 80 for socket welded piping or “Extra Strong” for threaded piping.

Pipes will typically be supported by slide or roller supports mounted on wall brackets in the utility gallery. The steam pipe will be located such that there is ample clearance for the sloping of the piping and access to the drip/trap stations. The lateral motion of the pipes due to thermal expansion will be restrained with pipe guides. Due to the space constraints in the trench, pipe stresses due to thermal expansion will be accommodated by weld-end bellows type expansion joints. The riser connections will be positioned at anchor locations. This will preclude the lateral motion of risers due to axial expansion of the Wharf main.

The minimum insulation thickness for steam piping NPS 2 inch to NPS 6 inch is 3 inches.

4.8.2 Pure Water System

The pure water system for the wharf will be designed in accordance with the draft of CVN 78 FPC. The pure water requirements for the wharf will be based on the requirements of the vessel with the largest pure water consumption, as shown in Table 4.8-3.

Table 4.8-3 Design Vessel Pure Water Demands

Vessel	Class	Normal Requirement for ship's complement (gpd) @ (gpm)	Normal requirement including troops/air wing (gpd) @ (gpm)
CVN	CVN 68	20,000 @ 150	20,000 @ 150
CVN	CVN 78	20,000 @ 150	20,000 @ 150

Piping will be sized in accordance with *UFC 4-150-02* for a peak rate of flow of 150 gpm having a residual pressure of 40 psi at the most remote outlet. Pipe and fittings will comply with MIL-HDBK-1005/7A Water Supply Systems.

The source of the pure water will be from the existing potable water infrastructure. This potable water will be treated to Grade A quality. A dedicated, structure will house the treatment equipment. Two 6 inch wharf supply pipes will run underground/under deck from the treatment building to the wharf utility gallery. The two supplies will supply pure water to either end of the utility gallery main to create a loop. The utility gallery piping will consist of a NPS 6 inch main run in the wharf utility gallery to supply three water shore tie riser locations. The two legs of the wharf main will be isolated from the treatment building mains by new 6 inch, manually operated, 125/150 Class flanged end gate valves.

Three, 4 inch branch connections will be provided to shore-ties at the wharf. The risers will be located to accommodate the utility brows of the moored design vessels. The risers will each have a 4 inch RPZ backflow preventer in accordance with AWWA Manual M14, Recommended Practice for Backflow Prevention and Cross-Connection Control. The ship's hose connections will be 2 ½ inches.

The pure water piping in the gallery will be flanged ductile iron in accordance with AWWA C151 and AWWA C115. The flange rating will be ANSI 125/150 Class in accordance with ANSI B16.5. Buried potable water piping will have restrained mechanical joints and thrust blocking at changes in direction greater than 45 degrees. The piping will have an epoxy external coating. The piping will be cement-mortar lined in accordance with AWWA C104.

4.8.3 Compressed Air

Compressed air system will be designed in accordance with *UFC 3-150-02 Design: Dockside Utilities for Ship Service, UFC 4-213-10 Design: Graving Drydocks, UFC 3-430-09N Design: Exterior Distribution of Steam, High Pressure Water, Chilled Water, Natural Gas, and Compressed Air and DM-3.5 Design Manual Compressed Air and Vacuum Systems*.

Compressed air system will be sized by the largest vessel requirement, shown in Table 4.8-4.

Table 4.8-4 Design Vessel Low Pressure Compressed Air Flow Rates

Vessel	Class	Quantity SCFM	Minimum Branch Pipe Size NPS (inches)	Minimum Risers per Berth
CVN	CVN 68	2,400	4	5
CVN	CVN 78	Not Required	N/A	N/A

The largest consumer of compressed is the CVN 68 class which requires 2,400 Standard Cubic Feet per Minute (SCFM) compressed air at a terminal pressure of 125 psig.

Compressed air piping will be designed as per *UFC 2150-02 Dockside Utilities for Ship Service and UFC 3-430-09N Design: Exterior Distribution of Steam, High Pressure Water, Chilled Water, Natural Gas, and Compressed Air*. The piping will be sized based on a maximum pressure drop of 5 psi from the tie in point to the furthest hose connection.

The new wharf main will be a NPS 6 inch run in the utility gallery between five NPS 4 inch branch lines and same sized risers will tie into the new wharf main. Each riser will consist of an isolation valve located above the wharf deck, and a welded-pipe manifold. Each manifold will consist of three NPS ¾ inch, three NPS 1¼ inch maintenance and repair connections. One of each size of connection is a spare. In addition the manifold will have two 4 inch ship's hose connections, one active and one spare. The 4 inch connections will be ANSI 150 Class flanges with blind flange covers. Each hose connection will have an isolation valve. Each hose connection will have a ½ inch hose bleed valve downstream of the hose connection isolation valve.

The utility gallery piping will be pre-engineered welded pipe. The risers will be ASTM A53 or A105 standard wall carbon steel. The ½ inch and 1¼ inch piping will be socket welded schedule 80 and Extra Strong wall thickness where pipe will be threaded to accept threaded adaptors for the hose connections. The end connections of the maintenance hook ups will match the type used by the shipyard.

4.8.4 Bilge Oily Waste (BOW) System

As previously presented in Section 2.7, this discussion on the BOW system Will be based on providing the facilities required to accommodate the ultimate requirements of the CVN 78. According to the review draft FPC with guidance provided by PEO Carriers, the BOW system shall be adequately sized to handle a pumping rate of 90 gpm with an average daily flow rate of 38,000 gpd and a peak flow rate of 82,000 gpd, as required for a CVN 78.

The existing bilge oily waste systems at Apra Harbor Naval Complex are inadequate to handle the CVN BOW requirements of either CVN 68 or CVN 78 for a duration of 21 days. Mobile BOWTS units are available; however, these units are typically small and will not be able to process the amount of BOW generated by a carrier. Therefore, it is recommended that a BOW collection and treatment system be constructed near the location of the proposed berth. The BOW collection and treatment system will consist of a combined gravity and force main collection system, a BOW pump station, and a BOWTS as indicated on Figure M-2.

The bilge oily waste transfer and collection system will be constructed concurrently with the site work while the construction of the bilge oily waste treatment system will commence upon completion of the staging area. This portion of the improvements is anticipated to take approximately two years to complete.

4.8.5 Wastewater System

As previously presented in Section 2.8, the wastewater system requirements for a CVN 68 is greater than or equivalent to that of a CVN 78. Therefore, the wastewater infrastructure improvements proposed for the CVN 68 will be applicable to the CVN 78. According to applicable UFC documents and guidance provided by NAVFAC Pacific, the existing wastewater infrastructure was evaluated based on handling an additional flow rate of 1,200 gpm and an average daily flow of 550,000 gpd required for the CVN 68 berthing.

The existing wastewater system serving the former SRF site includes SPS Nos. 18 and 16 and Trunklines “D” and “A”. The existing capacities of these pump stations and trunklines was found to be inadequate to handle the wastewater generated from either a CVN 68 or 78. There are plans to upgrade the capacities of SPS Nos. 18 and 16 under P-262 and P-534; however, these plans do not include the flows from a carrier. Therefore, the scope of these existing projects will need to be expanded or supplementary upgrades will need to be proposed under a separate project to account for the additional flows from the CVN.

In lieu of upgrading the existing wastewater infrastructure, alternate options include transporting the wastewater from the ship’s CHT using tanker trucks to the AHWWTP and construction of a temporary holding tank at the berthing location to contain and manage the discharge to the existing wastewater system. Due to the quantity and duration of the wastewater generated from a CVN, these options are not feasible. Transporting the wastewater using 5,000-gallon capacity tanker trucks will require over 100 roundtrips from the berthing location to the AHWWTP. Constructing a storage tank to contain the wastewater will require proper and careful management of the discharges for the entire duration of the CVN visit to prevent sewage spills in the system.

P-262 and P-534 are scheduled for implementation in FY 2009. The progress and design status of these projects indicate that the CVN loadings should be handled through separate supplementary wastewater system upgrades. These upgrades will be designed to handle only the flows from the CVN and will not be sized to provide additional capacity in the system. This will require the construction of three new submersible sewage pump stations and 6,700 linear feet of associated force mains as indicated on Figures M-3 and M-4. In addition to the pressurized systems, approximately 4,420 linear feet of new gravity sewers are recommended, of which 2,720 linear feet of 15-, 18-, and 24-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline “A” for the CVN berthing.

Majority of the wastewater system improvements required to support the CVN berthing are located backlands and will not be dependent on the construction schedule of the wharf. This portion of the improvements is anticipated to take a minimum of three years to complete. Therefore, this work may be initiated during the early stages of the CVN berthing project so that all infrastructure improvements are in place for the CVN berthing. The ship wastewater collection ashore system will be located at the berthing wharf and construction of this portion of the improvements will take place concurrently with the wharf site work.

4.8.6 Potable Water System

As previously presented in Section 2.9, the potable water flow rate required for active berthing is based on the wharf length and not on the type ship berthed. According to applicable UFC documents, 1,000 gpm must be provided for all berth lengths up to 2,000 feet, with a minimum residual pressure of 40 psi downstream of a backflow preventer located at the most remote outlet on the pier. The wharf length for both a CVN 68 and CVN 78 are less than 2,000 feet. Therefore, both ships will require a minimum flow rate of 1,000 gpm with a residual pressure of 40 psi.

According to applicable UFC documents and guidance provided in the review draft FPC, the daily average potable water requirements, with air wing or troops aboard, for a CVN 68 is 185,000 gpd and for a CVN 78 is 235,000 gpd. Therefore, the existing potable water system will be evaluated based on its ability to supply a minimum flow rate at the berthing location of 1,000 gpm at 40 psi and satisfy an average daily demand of 235,000 gpd. Typically, the flow rate requirement will have a localized impact on the existing water distribution system while the average daily demand will effect the potable water treatment and storage facilities.

Potable water is supplied to the former SRF site from the Apra Heights Tank system. In addition to the former SRF site, the Apra Heights Tank supplies water to a majority of the Apra Harbor Naval Complex. Based on the water demands of the service area and the maximum fire flow requirements, the storage capacity of the tank was evaluated based on criteria provided in *UFC 3-230-19N*. The storage capacity required, including the larger water demand of a CVN 78, was calculated to be 2.6 MG. The Apra Heights Tank has a capacity of 5.0 MG. Therefore, no improvements are required for the Apra Heights Tank for the berthing of either a CVN 68 or CVN 78 at the former SRF site.

Approximately 1,200 linear feet of 10-inch water line along the entrance road to the former SRF site will be replace with a 12-inch water line under project P-494 (FY 2008). In addition to this project, approximately 2,200 linear feet of 16-inch water line along Sumay Drive is currently being replaced with an 18-inch main. These improvements were incorporated in the water system model used to evaluate the capacity of the existing potable water system. The results of the model indicates that more than 1,000 gpm can be provided at pressures exceeding 40 psi to the berthing site at the former SRF site. Therefore, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets as shown on Figure M-5.

The potable water system improvements required to support the CVN are located along and adjacent to the proposed berthing location. The pierside water lines and outlets will be constructed concurrently with the wharf site work. Construction scheduling of the supply lateral to the wharf shall be coordinated with other adjacent site improvements. This portion of the improvements is anticipated to take less than a year to complete.

4.8.7 Power

Present Situation

P-494 will construct a new SRF Substation to support planned waterfront upgrades for Sierra, Romeo, and Uniform Wharves and existing SRF loads. The SRF Substation will be fed from the new Orote Substation with two 34.5 kV circuits, each with conductors capable of roughly 25 MVA, but with duct capacity that will enable doubling the capacity of each circuit.

The scope of P-494 does not include capacity to accommodate the CVN without additional circuits and 34.5 kV switchgear additions.

Recommendations

- Provide a new 34.5 kV feeder circuit breaker in the GPA Piti 34.5 kV Switching Station (By GPA).
- Upgrade existing GPA 34.5 kV Overhead Feeder Circuit X20 between Piti 34.5 kV Switching Station and Orote Substation from #4/0 AWG copper conductors to 927.2 kcmil AAAC conductors. (By GPA)
- Provide a new underground, concrete encased, 34.5 kV feeder circuit from the GPA Piti 34.5 kV Switching Station to new Bus D in the Orote Substation. The feeder is to consist of two sets of 3-750 kcmil copper conductors with ethylene propylene rubber (EPR) insulation rated for 35 kV, 133% insulation level.
- Provide additions to the Orote Substation 34.5 kV switchgear, including a new bus tie circuit breaker and a new GPA incoming main circuit breaker to form new Bus D.
- Provide the second set of 3-750 kcmil copper conductors with EPR insulation rated for 35 kV, 133% insulation level to each of the two express feeders connecting SRF Substation to Orote Substation. Conductors will be provided in ducts installed under P-494.
- Provide a new CVN Berth Substation consisting of a switchgear building, a transformer yard, 34.5 kV indoor metal-clad switchgear, 13.8 kV indoor metal-clad switchgear, 4.16 kV indoor metal-clad switchgear, two 20/26/33 MVA transformers, two 12/16/20 MVA transformers, one zigzag grounding transformer, and miscellaneous substation electrical systems.
- Provide one underground, concrete-encased, 34.5 kV express feeder circuits from the SRF Substation to the CVN SRF Berth Substation. The feeder circuit will consist of two sets of 3-750 kcmil copper conductors with insulation rated for 35 kV, 133 % insulation level.
- Provide a supervisory control and data acquisition system remote terminal unit in the CVN SRF Berth Substation to integrate with the SCADA system provided under P-494.
- Provide 13.8 kV and 4.16 kV shore power mounds, feeder conductors, control wiring, and ducts for connection to the CVN Berth Substation.
- Provide 13.8 kV feeders, pad-mounted transformers, and secondary electrical systems to support BOWTS, wastewater pumping stations, and MWR facilities.
- Provide wharf operational and security lighting using high-mast steel poles with metal-halide luminaires.

4.8.8 Communications

Present Situation

Existing infrastructure at the former SRF site is not adequate to support the CVN information system requirements. The nearest ITN is Building 3169, which contains fiber optic and CATV connectivity only. Closest telephony connection is at Central Office Building 3012. Ductbanks from the former SRF site to these buildings do not exist.

Recommendations

- Provide a new concrete-encased ductbank from the CVN Berth to the nearest ITN located at Building 3169. A 48-strand fiber optic cable will be provided from ITN Building 3169 to the CVN Berth.
- Provide a new concrete-encased ductbank from ITN Building 3169 to Central Office Building 3012. A 200-pair copper cable will be provided from Building 3012 to the CVN Berth via ITN Building 3169.
- Provide three communications system interface enclosures at the CVN Berth; one enclosure will be provided at each end and one at the center. The center enclosure will have capacity for 2-T1 interfaces, 200-pair copper, and CATV. Each end enclosure will have capacity for 1-T1 interface, 100-pair copper, and CATV.
- Provide an interface enclosure for MWR facilities, including provisions for portable payphone connections.

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5.0 ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE

This site is located at the northern shore of Polaris Point. The location (east and west) is set to minimize the impact to navigation along the channel leading into the inner harbor. The berth is located (north and south) to run approximately along the EL –50 feet MLLW contour to minimize the dredging at Polaris Point.

5.1 Dredging

There are two dredging alternatives for the Polaris Point Parallel to Shore alignment. The first alignment (Alt. 2) sets the berth width at 600 feet which is consistent with the criteria for slip width found in *ITG Facilities Homeporting Criteria for Nimitz Class Aircraft Carriers, 3 November 1998.* The north point must be removed in this alternative, as shown in the figures. A reduced impact alternative (Alt. 2A) is illustrated whereby the berth width is less than 600 feet inside the bay, near the bow of the CVN, and the dredged area follows the existing contours of the northern point.

The guidance criteria define the required berth for a CVN 68 or CVN 78 as 1,325 feet long x 600 feet wide (600 feet for a "slip"). Figure N-2 illustrates the dredging footprint for this alternative. To comply with the criteria, coral and the adjacent land mass at the point would be dredged. Alternative 2A (Figure N-7) was developed to minimize the dredging and excavation at Polaris Point, but reduces the minimum berth width to 440 feet at the bow of the vessel. This alternative may require a variance from the Navy's standard criteria, albeit the "slip width" criterion does not strictly apply to this berth scenario. Port Operations personnel and the Harbor Pilots were consulted, and they indicated the concept is acceptable with regard to navigation and berthing a CVN vessel in the designated berth area. Also, CPF/NAVSEA provided verbal concurrence with the Alternative 2A configuration.

5.1.1 Potential Impact to Coral & Mitigation Costs

<u>Point Removed (Alt. 2)</u>: The Polaris Point site itself does not contain any appreciable quantities of coral directly in front of the proposed wharf; however, recent coral surveys indicated there is coral present on the north side of the northern point. Under the alternative where the northern point is completely removed, the direct coral impacts are increased.

<u>Reduced-Impact (Alt 2A)</u>: Preserving the point reduces dredging and the related direct impacts to coral.

Using the methodology described in Section 2.4-2, the estimated area of coral impact for Alternative 2 is 53,650 m^2 (Figure A-2) and Alternative 2A (Figure A-3) is 52,313 m^2. Applying a unit cost of $430/$m^2$, the coral impact mitigation cost is estimated at $23,068,000 for Alternative 2 and $22,495,000 for Alternative 2A. The impact areas include the eastern edge of Big Blue Reef, in a preliminary attempt to capture potential indirect impacts, as described in Section 2.4-2. Alternative 2A was proposed specifically to minimize the impact to coral.

5.2 Coastal Engineering Considerations

Results from the initial investigation (see Section 3.1.5) suggest that the extreme wave event just off-shore of the berth face will have a 15.3 foot maximum crest elevation. This will not affect the stability of either the caisson or the sheet pile bulkhead wall, but will require special design of the pile supported wharf, as the wave crest elevation is approximately 3.3 feet higher than the deck elevation. At the Polaris Point site the primary wave energy is directed more to perpendicular to shore rather than along shore. Thus, this site is more prone to direct attack from storm waves.

Final design may require special mitigations, such as the installation of better wave-energy absorbing armor protection, heavier armor, higher deck elevation, deck designed for uplift, lowered crest elevation of the embankment below the deck, and a run-up/over-topping catch basin behind the embankment crest to relieve wave pressures. The extent of these mitigation measures can only be determined during final design and after the wave analysis, begun in this study, is calibrated and confirmed and the relative costs for abatement vs. strengthening are evaluated. In the extreme, costs for abatement/strengthening may tip the benefit-cost balance towards the sheet pile bulkhead option.

5.3 Berthing Structure Alternatives

Either the pile supported wharf or the sheet pile bulkhead wharf is suitable for the Polaris Point Parallel to Shore location. While the caisson option could be constructed, additional costs will be incurred for temporary shoring to retain the earth while a pocket is dredged for the caissons. There is the option to move the caissons off-shore into deeper water; however this quickly approaches the 3rd alternative, Polaris Point Diagonal Offshore, and is thus not considered.

The area behind is vacant for the construction of pile supported anchor system for the tie-backs of the sheet pile bulkhead wall. For economy, the location of the wall is set so that the amount dredging required in front of the wall to reach EL -50 feet MLLW can be used to fill the space behind the wall.

The deck elevation is currently set at +12 feet MLLW. This elevation was chosen to conform to surrounding land elevations (for access and visibility) while still providing a deck elevation that minimizes overtopping (for the bulkhead and caisson options) and potential deck uplift (for the pile-supported deck option).

The wharf plan for Alternative 2 is shown in Figure S-3. The structure is identical to Alternative 1 except the west end extends over the existing slope near the entrance to the inner harbor. The location east and west is set to minimize the impact to navigation along the channel leading into the inner harbor and to minimize the dredging at Polaris Point.

The typical wharf section is the same as Figure S-2 for Alternative 1.

5.4 Demolition and Site Preparation

Site preparation will require the grubbing and removal of all ground cover for construction of the staging area. This will include the demolition and replacement in-kind of three minor buildings (totaling approximately 940 square feet). There will be some minor roadway removal and possibly re-alignment of utility lines along this portion of roadway. The soil will be scarified and re-compacted before the fill material is placed to prevent differential settlement.

5.5 Shoreside Improvements

5.5.1 Staging Area

The Polaris Point Parallel to Shore Alternative provides for approximately 5.8 acre staging area immediately along side the back on the wharf (Figure C-2). The staging area will be sloped landward at 1%, the same as the wharf. The entire area will be paved with asphalt concrete over crushed base. All underground utilities and storm drains, building and light standard foundations will be installed prior to paving.

The layout provides access from Polaris Point Road with a short one-way access lane cut through the apex of the softball field lot. This provides queuing for about 12 vehicles without obstructing Polaris Point Road or the right hand turn-off to the softball diamond. Vehicles denied entry will be have room to back up on to the turn-off road and return back down Polaris Point Road. The driveway entrance/exit is quite a bit longer than that for the former SRF site except that the slope is not as steep.

5.5.2 New Buildings

Building requirements are common for all Alternatives and they are described in Section 2.5. The building locations for the Alternative 2 at Polaris Point are shown on Figure C-2.

5.5.3 Improvements for MWR Services

The Navy MWR area for supporting CVN activities will be situated on a 2.4 acre lot north of the existing baseball field on Polaris Point (Figures G-2, and C-2). The MWR is located about 500 feet north of the access control point for the staging area. There is a 7,200 square foot building pad that will need to be razed before that area can be graded and landscaped for lawn and trees. It is assumed that lawn will be supported by a permanent irrigation system. A 3-inch thick asphalt lot about ½ acre in size will be constructed for locating the following temporary facilities:

- Food and beverage booths
- 500 seating area
- 40 phone bank seats
- Parking for visitor and rental cars (100 stalls)
- Portable restrooms
- Laundry facilities
- Temporary lighting
- Trash dumpsters

The MWR area will need electrical, water, telephone, and sewer connections. The area will be enclosed by a 1,300-foot long chain link fence and will have multiple locking swing gate entry points. One of the gates will have a permanent turnstile and guard shack. A loop road will be constructed off of the east side of the Polaris Point access road. The loop road will have a 10 foot wide by 300-foot long turnout on the west side to park five buses.

5.5.4 Security

There is only one watch tower planned for the staging area. This is located at west corner of the staging area. It is assumed that the existing tower near the end of Polaris Point is in an appropriate location to cover the CVN asset. However, it may be necessary to upgrade the facility and/or provide additional security in accordance with the *draft UFC 4-025-01*.

5.5.5 Stormwater Drainage Systems

The drainage system for the staging area will rely on a continuous straight concrete swale running from east to west to collect runoff from the pavement into a series of catch basins. The swale on the eastern side of the area borders the southerly perimeter and on the west side runs through the middle of the paved area. A cyclonic storm water separator is located beneath the last catch basin and the outfall is located on the east end of the channel between the Apra Inner and Outer Harbors. Armor rock is featured from the wharf to about 100 feet south of the outfall and protects the staging area slope on the west side.

5.6 Waterside Security

Criteria for placement of floating PSB are provided in Section 2.5. The type of barrier will be selected during final engineering design. PSBs will be stored when not deployed for the CVN in the Inner Harbor to reduce exposure to wave action and reduce congestion in the Outer Harbor. The clump anchors for the barriers will be kept on station and a small marker buoy will be attached to the buoy as well as being tethered to the submerged anchor chain. Navy response boats for security deployment will be stationed elsewhere in Apra Harbor. An Electronic Security System on the landside and an Electronic Harbor Security System on the waterside will be provided as described in Section 2.5 above.

5.7 Collateral Equipment

Collateral equipment such as power cables, ship-to shore conveyor, mooring lines, and material handling (forklifts) will be stored in the Port Operations Support Building when not needed. Fenders will be permanent installations on the wharf and the camels will be moved to the Inner Harbor to reduce exposure to wave action when not deployed for the CVN.

5.8 Utilities

5.8.1 Steam System

Except for lengths of piping from the wharf structure and water source to the steam production plant, there are no differences in terms of Steam systems between this Alternative and that described for Alternative 1, Former SRF.

5.8.2 Pure Water System

Except for lengths of piping from the wharf structure and water source to the pure water production plants, there are no differences in terms of Pure Water systems between this Alternative and that described for Alternative 1, Former SRF.

5.8.3 Compressed Air

Except for lengths of piping from the wharf structure and to the compressed air production plants, there are no differences in terms of compressed air systems between this Alternative and that described for Alternative 1, Former SRF.

5.8.4 Bilge Oily Waste (BOW) System

As previously presented in Section 2.7 this discussion on the BOW system will be based on providing the facilities required to accommodate the ultimate requirements of the CVN 78. According to the review draft FPC with guidance provided by PEO Carriers, the BOW system shall be adequately sized to handle a pumping rate of 90 gpm with an average daily flow rate of 38,000 gpd and a peak flow rate of 82,000 gpd as required for a CVN 78.

The existing bilge oily waste systems at Apra Harbor Naval Complex are inadequate to handle the CVN BOW requirements of either CVN 68 or CVN 78 for a duration of 21 days. Mobile BOWTS units are available; however, these units are typically small and will not be able to process the amount of BOW generated by a carrier. Therefore, it is recommended that a permanent BOW collection and treatment system be constructed near the location of the proposed berth. The BOW collection and treatment system will consist of a combined gravity and force main collection system, a BOW pump station, and a BOWTS as indicated on Figure M-6.

5.8.5 Wastewater System

As previously presented in Section 2.8, the wastewater system requirements for a CVN 68 is greater than or equivalent to that of a CVN 78. Therefore, the wastewater infrastructure improvements proposed for the CVN 68 will be applicable to the CVN 78. According to applicable UFC documents and guidance provided by NAVFAC Pacific, the existing wastewater infrastructure was evaluated based on handling an additional flow rate of 1,200 gpm and an average daily flow of 550,000 gpd required for the CVN 68 berthing.

The existing wastewater system serving Polaris Point includes SPS No. 9 and Trunkline "B". The existing capacities of this pump station and main sewer trunkline were found to be inadequate to handle the wastewater generated from either a CVN 68 or CVN 78. Therefore, the existing wastewater infrastructure must be upgraded to handle the additional sewer flows from the CVN berthed at Polaris Point.

In lieu of upgrading the existing wastewater infrastructure, alternate options include transporting the wastewater from the ship's CHT using tanker trucks to the AHWWTP and construction of a temporary holding tank at the berthing location to contain and manage the discharge to the existing wastewater system. Due to the quantity and duration of the wastewater generated from a CVN, these options are not feasible. Transporting the wastewater using 5,000-gallon capacity tanker trucks will require over 100 roundtrips from the berthing location to the AHWWTP. Constructing a storage tank to contain the wastewater will require proper and careful management of the discharges for the entire duration of the CVN visit to prevent sewage spills in the system.

It is recommended that a new SPS No. 9 and corresponding force main be constructed to accommodate both the current wastewater flows generated in the Polaris Point tributary area and the additional wastewater loading form the CVN. This is in contrast to two separate pump station force main system, one for the CVN and one for the existing waste loadings at Polaris Point.

The recommendation is warranted due to the deteriorated structure condition of the existing SPS No. 9, which was placed on the Tier 1 prioritization list for replacement. Concerns with safety, design and condition of the pump station was based on an inspection performed in February 2006.

Secondly, with the existing utilities in Marine Drive and plans to upgrade the existing overhead electrical distribution system to an underground system, there may not be sufficient space in the underground corridor to accommodate two force mains.

The proposed wastewater system improvements include the construction of a new submersible type sewage pump station, a new dry pit – wet well type pump station to replace the aging SPS No. 9, and 14,800 linear feet of associated force mains as indicated on Figures M-7 and M-8. In addition to the pressurized systems, approximately 4,940 linear feet of new gravity sewer lines are recommended, of which 4,420 linear feet of 8-, 12-, 15-, and 21-inch relief sewer lines are proposed along Marine Drive to increase capacity of the existing sewer trunkline "B" for the CVN berthing.

5.8.6 Potable Water System

As previously presented in Section 2.9, the potable water flow rate required for active berthing is based on the wharf length and not on the type ship berthed. According to applicable UFC documents, 1,000 gpm must be provided for all berth lengths up to 2,000 feet, with a minimum residual pressure of 40 psi downstream of a backflow preventer located at the most remote outlet on the pier. The wharf length for both a CVN 68 and CVN 78 are less than 2,000 feet. Therefore, both ships will require a minimum flow rate of 1,000 gpm with a residual pressure of 40 psi.

According to applicable UFC documents and guidance provided by in the review draft FPC, the daily average potable water requirements, with air wing or troops aboard, for a CVN 68 is 185,000 gpd and for a CVN 78 is 235,000 gpd. Therefore, the existing potable water system will be evaluated based on its ability to supply a minimum flow rate at the berthing location of 1,000 gpm at 40 psi and satisfy an average daily demand of 235,000 gpd. Typically, the flow rate requirement will have a localized impact on the existing water distribution system while the average daily demand will effect the potable water treatment and storage facilities.

Potable water is supplied to Polaris Point from the Tupo Tank system. In addition to Polaris Point, the Tupo Tank supplies water to areas outside of the Apra Harbor Naval Complex and up north to NCTAMS WESTPAC Barrigada, including GovGuam and navy areas in between. Based on the water demands of the service area and the maximum fire flow requirements, the storage capacity of the tank was evaluated based on criteria provided in *UFC 3-230-19N*. The storage capacity required, including the larger water demand of a CVN 78, was calculated to be 4.2 MG. The Tupo Tank has a capacity of 5.0 MG. Therefore, no improvements are required for the Tupo Tank for the berthing of either a CVN 68 or CVN 78 at Polaris Point.

Project P-431 is currently ongoing and proposes to improve the water distribution lines within Polaris Point. Approximately 5,000 linear feet of 8 and 12-inch water lines supplying water to Polaris Point will be replaced with a 16-inch main. The 6-inch water lines along the wharf areas will be replaced with 8-inch lines. A new fire pump house is also proposed under this project.

These improvements were incorporated in the water system model used to evaluate the capacity of the existing potable water system. The results of the model indicates that more than 1,000 gpm can be provided at pressures exceeding 40 psi to the berthing site at Polaris Point. Therefore, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets as shown on Figure M-9.

5.8.7 Power

Present Situation

The electrical infrastructure at Polaris Point is capable of support planned upgrades ongoing at Alpha and Bravo Wharves under MCON Project P-431 and new projects such as MCON Project P-465, Consolidated SLC Training & CSS-15 HQ Facility, and P-528, Construct Torpedo Exercise Support Building.

The electrical infrastructure at Polaris Point is incapable of accommodating the CVN Polaris Point Berth without major improvements and additions.

Recommendations

- Provide a new 34.5 kV feeder circuit breaker in the GPA Piti 34.5 kV Switching Station (By GPA).
- Provide a new CVN Berth Substation consisting of a switchgear building, a transformer yard, 34.5 kV indoor metal-clad switchgear, 13.8 kV indoor metal-clad switchgear, 4.16 kV indoor metal-clad switchgear, two 20/26/33 MVA transformers, two 12/16/20 MVA transformers, one zigzag grounding transformer, and miscellaneous substation electrical systems.
- Provide a new underground, concrete-encased, 34.5 kV feeder circuit from the GPA Piti 34.5 kV Switching Station to the new Polaris Point CVN Berth Substation. The feeder is to consist of two sets of 3-750 kcmil copper conductors with EPR insulation rated for 35 kV, 133% insulation level.
- Provide a supervisory control and data acquisition system remote terminal unit in the CVN Polaris Point Berth Substation to integrate with the SCADA system provided under P-494.
- Provide 13.8 kV and 4.16 kV shore power mounds, feeder conductors, control wiring, and ducts for connection to the CVN Polaris Point Berth Substation.
- Provide 13.8 kV feeders, pad-mounted transformers, and secondary electrical systems to support BOWTS, wastewater pumping stations, and MWR facilities.
- Provide wharf operational and security lighting using high-mast steel poles with metal-halide luminaires.

5.8.8 Communications

Present Situation

Existing ITN Building 4434 located at Polaris Point near the proposed Berth has capacity to support CVN information system requirements. This building contains connectivity for fiber optic, telephony, and CATV.

Recommendations

- Provide a new concrete-encased ductbank from the CVN Berth to the nearest Information Transfer Node (ITN) located at Building 4434. Connection will be via the existing manhole adjoining the ITN. One 48-strand fiber optic cable and a 200-pair copper cable will be provided from ITN Building 4434 to the CVN Berth.
- Provide a new concrete-encased ductbank from ITN Building 4434 to an existing manhole on Marine Drive and separated by a minimum of 50 feet from the existing ductbank. This ductbank will provide for critical information system redundancy at Polaris Point.
- Provide three communications system interface enclosures at the CVN Berth; one enclosure will be provided at each end and one at the center. The center enclosure will have capacity for 2-T1 interfaces, 200-pair copper, and CATV. Each end enclosure will have capacity for 1-T1 interface, 100-pair copper, and CATV.
- Provide an interface enclosure for MWR facilities, including provisions for portable payphone connections.

6.0 ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE

This site is located at the northern shore of Polaris Point. The pier spans across the existing bay, and is located so the abutments are on solid ground on either end.

6.1 Dredging

The guidance criteria define the required berth for a CVN 68 or CVN 78 as 1,325 feet long x 600 feet wide. Figure N-3 illustrates this for the berthing alternative considered.

6.1.1 Potential Impact to Coral & Mitigation Costs

There will be direct impact to coral related to dredging the turning basin and approach to the berth. Recent coral surveys indicated there is coral present on the north side of the northern point, which is removed under this alternative.

Using the methodology described in Section 2.4-2, the estimated area of coral impact for Alternative 3 is 49,920 m^2 (Figure A-4). Applying a unit cost of $430/$m^2$, the coral impact mitigation cost is estimated at $21,466,000 for Alternative 3. The impact area includes the eastern edge of Big Blue Reef, in a preliminary attempt to capture potential indirect impacts, as described in Section 2.4-2.

6.2 Coastal Engineering Considerations

Results from the initial investigation (see Section 3.1.5) suggest that the extreme wave event just off-shore of the berth face will have a 15.3 foot maximum crest elevation. At this berth alignment at the Polaris Point site the primary wave energy is directed almost perpendicular to the structure rather than along shore. Thus of the three alternatives, this site is the most prone to direct attack from storm waves.

Final design for the piles supported deck may require special mitigations, such as higher deck elevation and/or a deck designed for uplift, as the wave crest elevation is approximately 3.3 feet higher than the deck elevation. For the caisson, the stability of the structure will need to be checked to resist the wave forces crashing against the face. The extent of these mitigation measures can only be determined during final design and after the wave analysis, begun in this study, is calibrated and confirmed and the relative costs for abatement vs. strengthening are evaluated.

6.3 Berthing Structure Alternatives

Either the pile supported wharf or the caisson bulkhead wharf is suitable for the Polaris Point Diagonal Offshore Shore location. While the caisson option could be constructed, additional costs will be incurred to raise the foundation elevations from near -70 feet MLLW to approximately -50 feet MLLW by filling the low spots with gravel. The primary disadvantage here is the total blocking off of the beach from the bay waters. This would create a small tidal pool behind the caissons and an artificial means to ensure flushing of the pool would need to be created. This could be done by proving and alternative connection to the bay.

The sheet pile bulkhead is not considered for this alternative since the 90 foot wide wharf width does not provide adequate stability in a double-wall configuration and the need for a double wall adds significantly to the costs. Traditionally off-shore sheet pile bulkheads were constructed using a series of circular interconnected cellular cofferdams. These have a poor history of seismic performance (due to their reliance on the interlock joints between sheets for resistance against bursting forces) and thus were not considered.

The deck elevation is currently set at +12 feet MLLW. This elevation was chosen to conform to surrounding land elevations (for access and visibility) while still providing a deck elevation that minimizes overtopping (for the caisson options) and potential deck uplift (for the pile-supported deck option). For the pile supported deck option, a higher deck elevation could be selected during final design as an option to reduce (or eliminate) the need for strengthening the deck for wave impact and uplift.

The wharf plan for Alternative 3 is shown in Figure S-4. It is located so the abutments are on solid ground at each end. The deck incorporates all the features of the other alternatives but is longer in order to extend onto the shore.

The typical wharf section is shown in Figure S-5. The deck structure is similar to the marginal wharf alternatives, as described in Section 4.3 above. The piles are larger than the other alternatives in order to provide better lateral capacity and to prevent buckling in the deep water when subjected to wave forces.

The abutment plan and sections are shown in Figure S-6. As discussed above, the wharf is anchored to shore at each abutment. The group of 48-inch pipe piles at each abutment provides the primary lateral resistance. The plan view shows the pile layout and the utility trench extending to shore. All utilities connect to shore at the south abutment. Section A shows the seismic moment frame transverse to the shoreline. This includes three rows of piles and a 4 foot thick concrete slab. Section B shows how the utility trench is incorporated into the deck. Three sides of the abutment have a vertical wall to contain the landside soils as shown in Sections A and B. The north abutment is not shown but is similar to the south abutment.

6.4 Demolition and Site Preparation

Site preparation will require the grubbing and removal of all ground cover for construction of the staging area. This work will also be done for the ramp leading up to the east end of the wharf. This will include the demolition and removal of three minor buildings (totaling approximately 940 square feet) and a watch tower on Polaris Point. There will be some minor roadway removal and possibly re-alignment of utility lines along this portion of roadway. The soil will be scarified and recompacted before the fill material is placed to prevent differential settlement.

6.5 Shoreside Improvements

6.5.1 Staging Area

The Polaris Point Diagonal Offshore Alternative provides for approximately 6.0 acre staging area connected to the side the west side of the back of the wharf for 125 feet (Figure C-3). An additional 25 feet of access can be made available if the watch tower is relocated away from the back of the wharf. From the back of the wharf, the staging area will be sloped landward at 1/2%, but will have a cross slope to the southeast of 1%. The entire area will be paved with asphalt concrete over crushed base. All underground utilities and storm drains, building and light standard foundations will be installed prior to paving.

The layout provides access from Polaris Point Road with a short one-way access lane cut through the apex of the softball field lot. This provides queuing for about 12 vehicles without obstructing Polaris Point Road or the right hand turn-off to the softball diamond. Vehicle denied entry will be have room to back up on to the turn-off road and return back down Polaris Point Road. The driveway entrance/exit is quite a bit longer than that for the former SRF site except that the slope is not as steep.

Therefore, the layout is essentially the same as the Polaris Point Parallel to Shore Alternative. The exception to this is the wharf cut-off wall will be extended along the north side of the staging area to provide access for beach goers to Griffin Beach up to the +2.8 MLLW water line. To provide for a staging area comparable in size to the Polaris Point Parallel to Shore Alternative it is necessary to extend it further to the south. This results in a slightly different drainage plan with the outfall some what further to the south in Inner Apra Harbor.

6.5.2 New Buildings

Building requirements are common for all Alternatives and they are described in Section 2.5. The building locations for the Alternative 3 at Polaris Point are shown on Figure C-3.

6.5.3 Improvements for MWR Services

The Navy MWR area for supporting CVN activities will be situated on a 2.4 acre lot north of the existing baseball field on Polaris Point (Figures G-3 and C-3). The MWR is located about 500 feet north of the access control point for the staging area. There is a 7,200 square foot building pad that will need to be razed before that area can be graded and landscaped for lawn and trees. It is assumed that lawn will be supported by a permanent irrigation system. A 3-inch thick asphalt lot about ½ acre in size will be constructed for locating the following temporary facilities:

- Food and beverage booths
- 500 seating area
- 40 phone bank seats
- Parking for visitor and rental cars (100 stalls)
- Portable restrooms
- Laundry facilities
- Temporary lighting
- Trash dumpsters

The MWR area will need electrical, water, telephone, and sewer connections. The area will be enclosed by a 1,300-foot long chain link fence and will have multiple locking swing gate entry points. ne of the gates will have a permanent turnstile and guard shack. A loop road will be constructed off of the east side of the Polaris Point access road. The loop road will have a 10 foot wide by 300-foot long turnout on the west side to park five buses.

6.5.4 Security

Due to the orientation of the wharf and the dredging required at the end of the point, the existing guard tower will need to be demolished. A replacement tower is shown at the back side of the east end of the wharf. It is planned that access to the tower will be from the wharf.

To provide direct access to this tower, and additional access to the wharf and especially to the storm bollards on the east end of the wharf, an auxiliary access road is shown at Polaris Point. The spacing between the storm bollards is 20 feet. Therefore, there will be room for vehicle access. The main entrance has a sidewalk and pedestrian gate for enclave control, but this auxiliary roadway could also serve this purpose. There will be the same security features (gates, traffic spikes, retractable bollards, and guard booth) installed at this location as at the main entrance to the staging area. In addition, the layout provides for easy turn around for vehicle denied access.

6.5.5 Stormwater Drainage Systems

Surface flow is directed toward the west and south perimeters of the staging area and is intercepted by a concrete swale. The layout of the staging area intercepts surface flow from the southeast. Therefore, a catch basin is also featured to intercept this flow. (However, more refined topographical and planimetric information may demonstrate that this catch basin may be eliminated and the total design flow reduced accordingly.) The storm drain path is the same alignment as the swale, southward and then westward. The cyclonic separator is located in the southwest corner of the staging area and the outfall is located on the east end of the channel between the Apra Inner and Outer Harbors. Armor rock is featured from the back of the wharf to about 250 feet southward along the channel. The rock configuration is the same as for the Polaris Point Parallel to Shore Alternative. However, additional rock is planned on the east side of the staging area at the west end of Griffin Beach, to protect the concrete cut-off wall return from undercutting action by waves.

6.6 Waterside Security

Criteria for placement of floating PSB are provided in Section 2.5. The type of barrier will be selected during final engineering design. PSBs will be stored when not deployed for the CVN in the Inner Harbor to reduce exposure to wave action and reduce congestion in the Outer Harbor. The clump anchors for the barriers will be kept on station and a small marker buoy will be attached to the buoy as well as being tethered to the submerged anchor chain. Navy response boats for security deployment will be stationed elsewhere in Apra Harbor. An Electronic Security System on the landside and an Electronic Harbor Security System on the waterside will be provided as described in Section 2.5 above.

6.7 Collateral Equipment

Collateral equipment such as power cables, ship-to shore conveyor, mooring lines, and material handling (forklifts) will be stored in the Port Operations Support Building, when not needed. Fenders will be permanent installations on the wharf and the camels will be moved to the Inner Harbor to reduce exposure to wave action when not deployed for the CVN.

6.8 Utilities

6.8.1 Steam System

Except for lengths of piping from the wharf structure and water source to the steam production plant, there are no differences in terms of Steam systems between this Alternative and that described for Alternative 1, Former SRF.

6.8.2 Pure Water System

Except for lengths of piping from the wharf structure and water source to the pure water production plants, there are no differences in terms of Pure Water systems between this Alternative and that described for Alternative 1, Former SRF.

6.8.3 Compressed Air

Except for lengths of piping from the wharf structure and to the compressed air production plants, there are no differences in terms of compressed air systems between this Alternative and that described for Alternative 1, Former SRF.

6.8.4 Bilge Oily Waste (BOW) System

Similar to the parallel berthing alignment (refer to discussion in Section 5.8.4), a permanent BOW collection and treatment system will also be required for the diagonal alignment. The configuration of the BOW system within the staging and wharf areas will be similar to that shown for the parallel alignment on Figure M-6.

6.8.5 Wastewater System

Improvements to the landside wastewater infrastructure will be similar for either the parallel or diagonal berthing alignments. Refer to Section 5.8.5 for the discussion on the proposed improvements. The configuration of the ship wastewater collection ashore (SWWCA) system located in the staging and wharf areas will be similar to that shown for the parallel alignment on Figure M-7.

6.8.6 Potable Water System

Similar to the parallel berthing alignment, no major water system improvements will be required for this option. Water system improvements will be limited to the construction of a new 8-inch service lateral to the berthing site and the associated pierside water outlets. The configuration of the water lines located in the staging and wharf areas will be similar to that shown for the parallel alignment on Figure M-9.

6.8.7 Power

The electrical infrastructure required for the diagonal berth alignment will be similar to the parallel to shore berth alignment at Polaris Point.

6.8.8 Communications System

The communications system infrastructure required for the diagonal berth alignment will be the same as for the parallel to shore berth alignment.

7.0 COMPARISON OF ALTERNATIVES (PROS/CONS)

The advantages and disadvantages of each project site are outlined below, and Table 7-1 at the end of this chapter summarizes the pros and cons.

7.1 Dredging

Alternative 1 – Former SRF would result in the least volume of dredging.

Estimated coral impact mitigation costs range from $19,566,000 for Alternative 1 to $23,068,000 for Alternative 2 (full impact).

There are options for the management of dredged material once it is removed from the ocean. These options may include ocean disposal (pending site designation by USEPA), upland placement and beneficial use. The dredged material will undergo rigorous testing to determine the most suitable option. Segregation of dredged materials and multiple management options may be required for the dredged material if test results vary throughout the dredge footprint. These decisions will be made during final design and documented in the Army Corps of Engineers permit application. Upland placement is the disposal assumption used for the cost estimates, and it is likely to be the most expensive option.

7.2 Demolition and Site Preparation

All three alternatives will require the demolition of existing structures, removal of some road surfaces, and minor relocation of related utilities. At Polaris Point, demolished structures will be replaced in-kind outside of the staging area sites. Based on conversations with base personnel, the metal buildings at the former SRF project site are assumed to be removed as part of the Guam Shipyard footprint reduction. These structures will not be replaced. Beyond this, Alternative 1 will require the removal of the end of one of the SRF finger piers and the obsolescence of both piers slips, as they will be filled in. Therefore, there will be a slight disadvantage in not having these slips available for future use. The slips will not be replaced. This has not been evaluated in economic terms since with the proposed reduction of the Guam Shipyard footprint; these slips have no foreseeable purpose. Alternatives 2 and 3 will require the removal of the watchtower on Polaris Point. This will be of minor consequence, since pairs of new watch towers are indicated for all Polaris Point Alternatives to protect the asset.

After demolition all sites will be prepared in the same manner and selected material from the project dredging will be used to construct the elevated grades for the staging areas. The size of the staging area to be paved for all the alternatives is relatively the same at approximately 6 acres. Although the layouts for Alternatives 2 and 3 are almost identical, Alternative 3 requires about half as much fill because the top of pavement elevations away from wharf are set lower. This is done in part to reduce the surcharge behind the proposed seawall along the length of Griffin Beach and because the staging area extends further south.

From the standpoint of meeting the criteria for staging area size, proximity to the wharf, and security, all three sites are comparable. However, Alternatives 1 and 2 are preferable because they afford a longer access area that is directly alongside the back of the wharf. Alternative 3 access is limited to the far ends of the wharf. Thus more congestion of equipment and personnel in these locations during times of high activity would be expected.

Alternative 1 relies on a longer drainage system, which has two outfalls, while the other alternatives each have only one outfall. Therefore, from a water quality discharge permitting standpoint, the Alternatives 2 and 3 are more preferable.

The costs for the civil improvements differ for a variety of reasons. Alternative 2 has the overall highest cost due to more earthwork. Alternative 1 has a higher cost than Alternative 3 because of additional storm drainage needs and somewhat more earthwork.

7.3 Structural Design

The marginal wharf alternatives at the former SRF and Polaris Point Parallel to Shore sites are very similar, but the Polaris Point site is more exposed to storm waves, as noted below. This may result in higher costs at the Polaris Point alternatives for special mitigation measures. The sites are suitable for either the pile-supported deck option or the tied-back sheet pile bulkhead option, with the former being preferred for better seismic performance while the latter may be more resistive to extreme wave event and less expensive from an initial construction point of view. The caisson option is not recommend due to extensive additional costs without any significant additional benefits over the other options.

The diagonal offshore alternative at Polaris Point is the least preferred alternative related to structural design. Construction in deeper water will result in larger diameter piles, and very large concrete abutments are required to anchor the structure to land at either end. More of the structure will be constructed using expensive water-borne equipment than with the other two alternatives. This site is suitable for either the pile supported deck option or the concrete caisson option, with the former being preferred for better seismic performance and lower costs. The sheet pile bulkhead option is not recommended due to historically poor seismic performance. All structures will have to be designed to resist the forces of wave impact.

7.4 Coastal Engineering Considerations

The former SRF site is the preferable site because the primary wave energy is directed alongshore rather than perpendicular to shore. This suggests that rock dike wave protection could be installed at the northeast end to mitigate wave impact under the deck. At the Polaris Point site the primary wave energy is directed more to perpendicular to shore rather than along shore. This site is thus more prone to direct attack form storm waves, and the diagonal alternative is the most prone to direct attack from storm waves of the three.

7.5 Shoreside Improvements

The shoreside improvements are basically equal for all alternatives with regard to construction and related costs.

There are potentially additional security concerns for the former SRF site because of the adjacent commercial ship yard, which could employ foreign workers and/or repair foreign vessels.

The Polaris Point Diagonal Offshore berth is not contiguous to land, and thus the operations will be less efficient than the marginal wharf alternatives. In addition, Polaris Point is not contiguous with Main Base, and thus visiting sailors will need to be bussed to the facilities at Main Base.

7.6 Waterside Security Improvements

Waterside security improvements are essentially the same for all alternatives. The depth of water for Alternative 3, Polaris Point Diagonal Offshore makes installation slightly more costly.

7.7 Collateral Equipment

Collateral equipment will be the same for each alternative. Access to Alternative 3, Polaris Point Diagonal Offshore from the ends only (rather from adjacent backlands for the other alternatives) makes handling the collateral equipment slightly more labor intensive.

7.8 Utilities

7.8.1 Steam, Compressed Air, and Pure Water

There is a possible opportunity to re-use the existing steam plant at SRF, provided certain repairs, improvements, and capacity-expansion projects are made. Some of these are already being programmed, while others await approval. However, for the currently planned projects, capacity expansion is not included. The existing plant is unable to accommodate both the current demand and the new CVN demand. The costs for a completely new system and the costs for upgrades/expansion of the existing system are considered essentially equivalent at this level of study. Therefore, it is assumed that new facilities will need to be constructed for all alternatives, thus there are no distinguishing pros/cons for either site.

7.8.2 Bilge Oily Waste (BOW) System

For the BOW system improvements, there are no distinct pros/cons for either site since the improvements will be localized at the berthing location (i.e. none/minimal improvements outside of the staging area) and the same improvements are required for both sites.

7.8.3 Wastewater System

For the Wastewater system improvements, the Polaris Point site may be disadvantaged because a portion of the force main route will be outside of Navy property. The impact this will have on the project is uncertain at this time. The work will need to be coordinated with GovGuam and may become a "non-issue" at the time of project design and construction.

The overall project cost is higher at Polaris Point primarily because the length of forced mains that must be constructed far exceed those required at former SRF site.

However, an advantage to the Polaris Point site is that the improvements proposed will increase the capacity and improve the reliability of the existing aging wastewater infrastructure, which will be a benefit to other facilities located in Polaris Point and neighboring areas.

The disadvantage of the former SRF site is that this option adds three new submersible pump stations to the wastewater system, compared to one new submersible pump station plus one replacement pump station at Polaris Point. The life-cycle cost for the SRF option will be higher than Polaris Point (power requirement, maintenance, etc.).

7.8.4 Potable Water System

For the Potable Water system improvements, there are no distinct pros/cons for either site since the improvements will be localized at the berthing location (i.e. none/minimal improvements outside of the "staging area") and the same improvements are required for both sites.

7.8.5 Power

The electrical power costs between the two berthing sites differ significantly, and it is the need to upgrade the GPA X20 circuit and increased primary 34.5 kV feeder circuit distance that makes the SRF Berth option more expensive from an electrical power standpoint.

7.8.6 Communication Systems

The cost to construct communication system infrastructure; fiber optic, CATV and telephony systems, is greater at the former SRF site. This is because the nearest existing buildings that contain connectivity for fiber optic, telephony and CATV are further from the berth.

Existing infrastructure at the former SRF site is not adequate to support the CVN information system requirements. The nearest Information Transfer Node (ITN) is Building 3169, which contains fiber optic and CATV connectivity only. Closest telephony connection is at Central Office Building 3012. Ductbanks from the former SRF site to these buildings do not exist.

Existing ITN Building 4434 located at Polaris Point near the proposed Berth has capacity to support CVN information system requirements. This building contains connectivity for fiber optic, telephony, and CATV.

Table 7-1 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
GENERAL NOTES					
Lowest overall project cost			Higher overall project cost than Alt. 1		Highest overall project cost
	Demolition required and possible contaminated soils	"Greenfield" site Minimal contamination expected		"Greenfield" site Minimal contamination expected	
	Requires renegotiation of leasehold to reduce Guam Shipyard footprint	Land not encumbered		Land not encumbered	
Contiguous with backlands – allows more efficient operations		Contiguous with backlands – allows more efficient operations			Non-contiguous with backlands – less efficient operations
NAVIGATION, DREDGING and CORAL IMPACTS					
	Port pilots least preferred alignment	Alignment preferred by port pilots	Alt 2A berth has reduced with (440 feet vs 600 feet) at CVN bow		
	Restricts access to drydock AFDB-8 when CVN at berth				
Least dredging overall	Contaminated dredged material, if encountered, may require special handling		Alt. 2 most dredging. Alt 2A reduces dredging by 24% of Alt. 2.	Less dredging than Alt. 2	More dredging than Alt 1
Least direct impact to coral (least mitigation cost)	Closest to Big Blue coral reef	Alt 2A reduces coral impact (lower mitigation cost) vs. Alt 2 and Alt.3.	Alt 2: Highest estimated area coral impacted (mitigation costs). Alt 2A: Saves North Point and reduces estimated mitigation costs vs. Alt 2	Less coral impact (mitigation costs) than Alt 2 or Alt 2A	Higher estimated coral mitigation costs than Alt 1. Dredging removes end of North Point and associated coral

Table 7-1 Summary of Pros & Cons for the Alternatives

Alternative 1 - Former SRF		Alternative 2 - Polaris Point Parallel to Shore Alternative 2A (Reduced Impact)		Alternative 3 - Polaris Point Diagonal Offshore	
Pros	**Cons**	**Pros**	**Cons**	**Pros**	**Cons**
STRUCTURAL and COASTAL CONSIDERATIONS					
Typical pile supported wharf construction		Typical pile supported wharf construction			Unique and more costly structural system
Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & sheet pile bulkhead	Caissons would be problematic given the extra dredging needed	Suitable for both piles supported deck & caisson	Steel sheet piles bulkhead not advised
Slightly less exposed than the Polaris Pt. sites to extreme waves			Slightly more exposed than the SRF site to extreme waves		More exposed than the other sites to extreme waves
UTILITIES					
Existing Steam Plant is under the control of Base Operation Support Contractor (BOSC) for the Government. Possible use of existing steam system	Existing air system is under control of Guam Shipyard. Assume new system is required. Existing steam system requires repairs and capacity expansion.		Requires construction of new plant for steam & air		Same as Alt. 2
Lower project cost for wastewater systems.	More pump stations than other Alt.s will result in higher life cycle costs and additional operational requirements.	Proposed wastewater system improvements will increase the capacity and improve the reliability of the existing infrastructure which will benefit other facilities in Polaris Point and neighboring areas.	Part of force main route outside Navy property. Uncertain how this might impact project	Same as Alt. 2	Same as Alt. 2
			Higher project costs for wastewater system due to length of forced mains required		Same as Alt. 2
	Higher project cost for electrical power service	Lower project cost for electrical power service		Same as Alt. 2	
	Higher project cost for communications	Lower project cost for communications		Same as Alt. 2	

8.0 PROJECT CONSIDERATIONS AND COST ESTIMATES

8.1 Project Considerations

8.1.1 Equipment and Material Staging

This project will utilize specialize heavy equipment for construction. Two of the largest pieces are both waterborne and will require mobilization from the West Coast of the U.S. mainland. These are (1) a large floating crane barge with pile driving equipment and (2) a dredger. The floating crane barge will be used to drive the seaward rows of piling. Depending upon size and reach, a land-based rig can drive the first and possibly second landward row of piles for Alternative 1 and 2 and the abutment piling for Alternative 3. The land-based crane can probably be obtained locally. The crane barge could also be used in the dredging of the wharf embankments, placing of quarry-run materials and armor stone. If suction-cutter head hydraulic dredging equipment is mobilized, the crane barge, equipped with a clam-shell or environmental bucket can be utilized to assist in the dredging, especially those areas that the hydraulic dredge can not reach. Other equipment such as smaller cranes, concrete pumps, small barges, tug boats, excavation equipment can be obtained locally.

Local equipment using smaller cranes and excavators on smaller spud-barges has been used typically in Apra Harbor on smaller projects. The Inner Harbor Channel was dredged using such equipment during the MCON P-431, Alpha & Bravo Wharf Improvements. The requirements of this project will, more than likely, preclude the use of such equipment.

This project will utilize non-indigenous materials, including: steel pipe piles and steel shapes, concrete forms, miscellaneous metals, fenders, bollards, steel reinforcing and cement for concrete, asphalt, and mechanical equipment and piping for steam, compressed air, and pure water. Some assembly of these items on Guam will be required. Local aggregates for concrete, road base, asphalt paving, and possibly armor rock may be used. All imported materials will come through either the local commercial port or be specially shipped by barge. Most materials will come from the U.S. West Coast. Special items not subject to the “Buy American” clause may come from Asian sources.

8.1.2 Phasing of CVN 78 Requirements

Structural, dredging, and civil requirements are essentially the same for both the 68 and 78 class CVN, thus there is no opportunity to phase-in the construction for these items. Utility demands for steam, compressed air, and pure water are expected to remain the same, decrease, or be eliminated for the CVN 78 class. Thus, the need for these facilities at the commissioning of the berth remains unchanged

BOW Systems – The design criteria for the CVN 78 call for slightly greater waste quantities than that of the CVN 68. The pumping rate from the vessels is the same for both carrier types. The difference in the average and peak flow rates between the CVN 78 and CVN 68 is less than 10%. Due to the relatively small increase in capacity required for the CVN 78, there is no substantial economic benefit to phase the design and construction of the BOW system.

Wastewater Systems – The design criteria for the CVN 68 are greater than or equivalent to that of a CVN 78. Therefore, improvements implemented for the CVN 68 will be applicable for that of the CVN 78.

Potable Water System – The design criteria for the CVN 78 are greater than or equivalent to that of a CVN 68. Therefore, the potable water requirements for a CVN 78 were used to evaluate the existing potable water system. The analysis indicates that the landside water system is capable of satisfying the demands of a CVN 78, thus also complying with the requirements of a CVN 68. The only improvements necessary will be localized at the berthing / staging areas. These improvements will be virtually identical for either the CVN 68 or CVN 78 vessels.

The electrical and communications base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated feeder cables and power receptacles. The 13.8 kV feeder cables for the CVN 78 will be provided in the wharf utility trench, which will be constructed during the CVN 68 project with enough capacity to support the additional cabling.

8.2 Cost Estimates

8.2.1 Cost Estimate Basis and Assumptions

Most costs were derived using average construction methods, materials, labor, and equipment as they would be applicable for construction on the mainland U.S., using actual costs plus 28% for contractor's overhead & profit. Costs thus determined were multiplied by the following factors:

Design contingency	1.1000
Area Cost Factor	2.6400
Escalation	1.0867
Total Factor	3.1650

Costs provided by the U.S. Navy were assumed to be time-independent, Guam specific costs and thus not multiplied by the factors. An example of these costs is mitigation cost for potential coral impact.

When available, unit production rates, materials, labor costs, crew sizes, material costs, and equipment costs were obtained from *RS Means Heavy Construction Cost Data, 21st edition, 2007*. When required (particularly for marine work), crew costs and production rates were built-up using industry standard rates and productivity, assuming work along the Gulf Coast (which is normally regarded as having and area cost factor = 1). In some cases, *RS Mean's* rates were modified based upon experience.

For comparison with *RS Means*, a number of key rates (e.g., concrete, reinforcing, formwork, piles) were developed using Guam labor rates and productivity, material purchase on U.S. West Coast (where applicable) and transportation/freight to Guam, additional OH and profit, and other local factors. These were compared with *RS Means* rates (average U.S. mainland) multiplied by the Area Cost Factor and Escalation. A significant difference was identified, where the factored U.S. Mainland rates were much higher than the local Guam rates. The difference was attributed to a market factor which accounts for the unmitigated increases in costs in Guam due to: disparities in supply and demand, labor shortages, shipping bottlenecks, shortage of local equipment, and expected boom in the local economy.

Estimated construction cost for dredging includes dredging (clamshell), barge transport and placement at an upland dewatering site. Dredge volumes are based on dredging to a depth of -49.5 feet plus two feet of overdepth dredging within the footprint of the channel, turning basin and berthing area. Overdepth dredging is limited to dredging below -49.5 feet only in those areas currently shallower than -49.5 feet. Methodology for assigning costs for coral mitigation is described in Section 2.2-4. The unit cost is $\$430/m^2$. Dredging includes preparation of temporary slopes for the berths and adjacent areas ready for placement of quarry-run and armor stones.

Quarry run rock materials and armor stones for all Alternatives are assumed to be locally obtainable and hauled over road by conventional trucks from a quarry on Guam.

Estimated construction costs for the wharf structures were based upon both measured and assumed quantities and the unit prices developed as described above. The average pile length was assumed since site specific subsurface information is not available. Actual lengths could be quite different. Steel piles are assumed to be shipped in convenient lengths with a factory coating and field-spliced on site. Piles are driven from a floating rig. Cost of deck construction includes falsework and forming, reinforcing, concrete placement, and finishing. For Alternative 3, additional construction costs of the two end abutments are included. The wharf structure is assumed complete with the placement of the bollards, fenders, and miscellaneous metals.

The majority of the civil site work is routine construction: grubbing, grading and drainage, base materials, paving, trenching and backfilling for underground utilities and storm water drainage systems, fencing, and traffic control. Imported fill is required for the project to raise surrounding grade to the level of the back edge of the wharf (Alternatives 1 & 2), and to provide a protected and level area for Alternative 3. Fill materials are assumed to be suitable reclaimed dredged materials. The work will also include the construction of various buildings and plants for utility service, plus guard booths, and watch towers. Work is measured using the site development drawings and the various units indicated in the cost estimate.

BOW Systems – budgetary costs developed for these improvements were based on bid tabulations and construction costs of existing BOW collection and treatment systems on Guam. The cost data were modified to reflect various differences to achieve an appropriate cost that would be consistent with the proposed improvements. Based on the source of the data, applicable escalation rates were applied to provide costs consistent with the current construction environment in Guam.

Wastewater and Potable Water Systems – budgetary costs developed for these improvements were based on bid tabulations and construction costs obtained from similar infrastructure improvement projects in Guam. The cost data were modified to reflect various differences to achieve an appropriate cost that would be consistent with the proposed improvements. Based on the source of the data, the applicable escalation rates were applied to provide costs consistent with the current construction environment in Guam.

Electrical cost estimates are based on engineering experience with similar infrastructure projects recently developed on Guam. Costs are loaded with prime and subcontractor markups and reflect actual Guam construction costs.

Construction Phasing for Incremental Funding

A construction schedule for design-build was assumed at 48 months for Alternative 1 - Former SRF and Alternative 2 - Polaris Point Parallel to Shore options and 54 months for Alternative 3 -

Polaris Point Diagonal option. The starting point for each was assumed at mid-fiscal year, thus the schedule covers five (5) fiscal years. An additional 6 months is required for the construction of the wharf in Alternative 3 due to its increase length, deep water piling, and abutments at each end.

The various major elements of work for Alternatives 1 and 2 were scheduled over the duration indicated as described below. Work for Alternative 3 is similar except that the wharf construction continues into the 5th year. The construction phasing is summarized in Table 8.2-1.

Table 8.2-1 Construction Phasing for Incremental Funding

Year 1 (6 mos.)	Activity
Dredging	Design
Wharf Construction	Design (75%)
Site Work	
Buildings	
Steam, Air, Pure Water	
Bilge Oily Waste Systems	
Wastewater Systems	Design
Potable Water System	
Electrical Utilities	
Year 2 (12 mos.)	
Dredging	Mobilize dredge; dredge berth, turning basin, and fairway (25%); place quarry run on berth slope
Wharf Construction	Complete design; order piling; mobilize; place armor stone (42%); drive pipe piling (29%); construct deck (8%)
Site Work	Design
Buildings	Design (50%)
Steam, Air, Pure Water	Design (33%)
Bilge Oily Waste Systems	Design
Wastewater Systems	PS Equipment and Material Ordering; Construct Pump Stations (33%)
Potable Water System	
Electrical Utilities	Design; Construct Duct System (17%)
Year 3 (12 mos.)	
Dredging	Complete dredging of fairway; navaids; closeout
Wharf Construction	Complete placing armor stone; complete driving pipe piling; construct deck (58%)
Site Work	Mobilization; demolition; earthwork; storm drain; substructures
Buildings	Complete design; mobilization & material procurement; construct air, water, & steam buildings (75%)
Steam, Air, Pure Water	Complete design; mobilization & material procurement; install mechanical systems (13%)
Bilge Oily Waste Systems	BOWTS Equipment & Material Ordering; Construct BOWCA and BOW
Wastewater Systems	Complete pump stations; construct FM & sewers (50%); construct SWWCA

Table 8.2-1 Construction Phasing for Incremental Funding

Potable Water System	Construct pier-side water lines & outlets; supply lateral to pier; commissioning & closeout
Electrical Utilities	Complete duct system; cable procurement; substation and wharf equipment procurement
Year 4 (12 mos.)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 1 & 2)
Site Work	Paving; security & fencing (67%)
Buildings	Complete air, water, & steam buildings; construct transit shed; construct misc. bldgs (33%)
Steam, Air, Pure Water	Install mechanical (93%)
Bilge Oily Waste Systems	Construct BOWTS; commissioning & closeout
Wastewater Systems	Complete FM & sewers; commissioning & closeout
Potable Water System	
Electrical Utilities	Construct electrical; commissioning & closeout
Year 5 (6 mos., 12 mos. Alt 3)	
Dredging	
Wharf Construction	Complete deck; install fender piles & fenders; close out (Alts 3 only)
Site Work	Complete all remaining work & close out
Buildings	Complete other buildings & close out
Steam, Air, Pure Water	Complete mechanical installation; start up and commissioning; close out
Bilge Oily Waste Systems	
Wastewater Systems	
Potable Water System	
Electrical Utilities	

To complete the work according to the schedule, the following funding requirements are necessary (Table 8.2-2), expressed as percentage of total funds.

Table 8.2-2 Incremental Funding Over Construction Period

Year	Alt 1	Alt 2	Alt 3
1	6%	6%	6%
2	34%	34%	29%
3	38%	38%	33%
4	20%	20%	25%
5	2%	2%	7%
Total	100%	100%	100%

8.2.2 Phasing of CVN 68 and CVN 78 Requirements

Structural, dredging, and civil requirements are essentially the same for both the CVN 68 and CVN 78, thus there is no opportunity to phase-in the construction for these items. Utility demands for steam, compressed air, and pure water are expected to remain the same, decrease, or be eliminated for the CVN 78 class. Thus, the need for these facilities at the commissioning of the berth remains unchanged.

The demands for BOW, wastewater and potable water systems are also the same for CVN 68 and CVN 78 vessels, and thus no project phasing is possible.

The electrical and communications base infrastructure required to support both the CVN 68 and CVN 78 is similar, with the exception that upgrading the electrical system to accommodate the CVN 78 will require two additional 13.8 kV switchgear sections with associated 15 kV feeder cables and power receptacles. The cost of a future project to provide two additional 13.8 kV switchgear sections, associated 15 kV feeder cables, and power receptacles is approximately $500,000.

9.0 CONCLUSIONS AND RECOMMENDATIONS

There are advantages and disadvantages to locating the CVN berth at the former SRF site or at the Polaris Point site. One common conclusion is the pile supported marginal wharf (Alternatives 1 and 2) is the preferred structural system. The diagonal pier at Polaris Point is the least preferred alternative because of seismic considerations, inconvenient berth access, high structural costs, exposure to extreme wave events, and direct dredging impact to the northern tip of Polaris Point.

Under Alternative 2, dredging removes of the northern tip of Polaris Point and associated coral; therefore, this alternative is less preferred than Alternative 2A, which specifically avoids this loss of coral. Alternative 2A and Alternative 1 can be viewed as comparable. The primary differences, from the engineering perspective, are:

- Electrical Power Costs, which are higher at the former SRF site
- Dredging Costs, which are higher at the Polaris Point site
- Wastewater Costs, which are higher at the Polaris Point site

The results of this engineering investigation indicate that Alternative 1, Former SRF, is the lowest cost alternative. This is primarily due to the differences in dredging volumes and the estimated coral mitigation costs.

A sediment sampling and analysis plan will be completed as a requirement to obtain a dredging permit. Soil contamination, if present, will be discovered during this process. If the soils are found to be contaminated, project costs may have to be adjusted.

Ultimately, final site selection will be influenced by multiple factors, many of which are outside the scope of this study. Examples are: CVN repair/maintenance. on and off-base traffic, sailor "Quality of Life," AT/FP, safety and drydock access.

Recommendations:

Because impact to coral is a factor in site selection, the coral reef stakeholders (agencies) were asked to review the project footprints and propose a rough estimate of monetary cost per square foot of direct impact to coral. The coral mitigation costs presented reflect stakeholder "worst case scenario" input of $430 per square meter of impact. It is recommended that agencies and the Navy continue to work together to reduce the worst case cost scenario.

Recommendation for Additional Studies:

Additional studies and investigations are required to complete the final design. Other studies could be conducted to provide alternatives to the proposed concepts of this study. The studies are described below:

- A site specific CVN Dredge Depth Study will be required to be performed by NAVFAC LANT CIENG/NSWCCD and coordinated with NAVSEA 08, AIRPAC, and PEO Carriers.
- Complete a localized geotechnical investigation at the selected site for purposes of finalizing pile lengths and determining subsurface conditions in preparation for final design.

- Prepare a dredge material disposal study to compare various options for beneficial reuse of the materials (including that already identified in this project), identifying possible users or uses on other projects, in order to minimize ocean disposal. Study should also consider methods of uplands disposal of contaminated but non-hazardous materials, possibly by incorporating such materials into the project.
- Complete additional detailed and calibrated coastal engineering studies, including: a) deployment of instrument at the site to monitor actual conditions for calibrating numerical models; b) dynamic berthing analysis for operating conditions; c) final determination of wave heights, run-up, and impact for pile-supported structures.
- For Alternative 1, complete a site-specific hazardous materials subsurface investigation immediately on and off-shore in the vicinity of the proposed wharf. This may be combined with the sediment sampling plan required to obtain dredging permits.
- For Alternative 1, as may be required, complete an evaluation of the benefits and costs of rotating the AFDB-8 one hundred eighty degrees so that access to the dock is from the west. This will mitigate any concerns that this site negatively impacts the operator of the dry dock or has security concerns.
- Prepare a report detailing the criteria, requirements, and configuration of the Electronic Harbor Security Systems (EHSS) for the selected site, including integration of such system into current and future port-wide security systems.
- During final design stages, complete periodic reports that 1) refine and update the project schedule, 2) identify logistic concerns, and 3) identify critical resource usage of this project against the background of all other projects expected to proceed forward.

Other studies that could be of benefit include:

- Additional evaluation of innovative structural concepts, like floating piers.
- Performance-based interpretation of CVN berthing requirements.

10.0 REFERENCES

American Water Works Association (AWWA) Manual M14, Recommended Practice for Backflow Prevention and Cross-Connection Control

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TECHNICAL DRAWINGS LIST

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G-2 Marginal CVN Wharf at Polaris Point
G-3 Diagonal CVN Wharf at Polaris Point

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E-1C Alternative 1 - SRF Berth Communications System Site Plan
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E-6 Berth Substation Building Electrical Equipment Plan
E-7 Berth Substation 34.5 kV Switchgear Elevation

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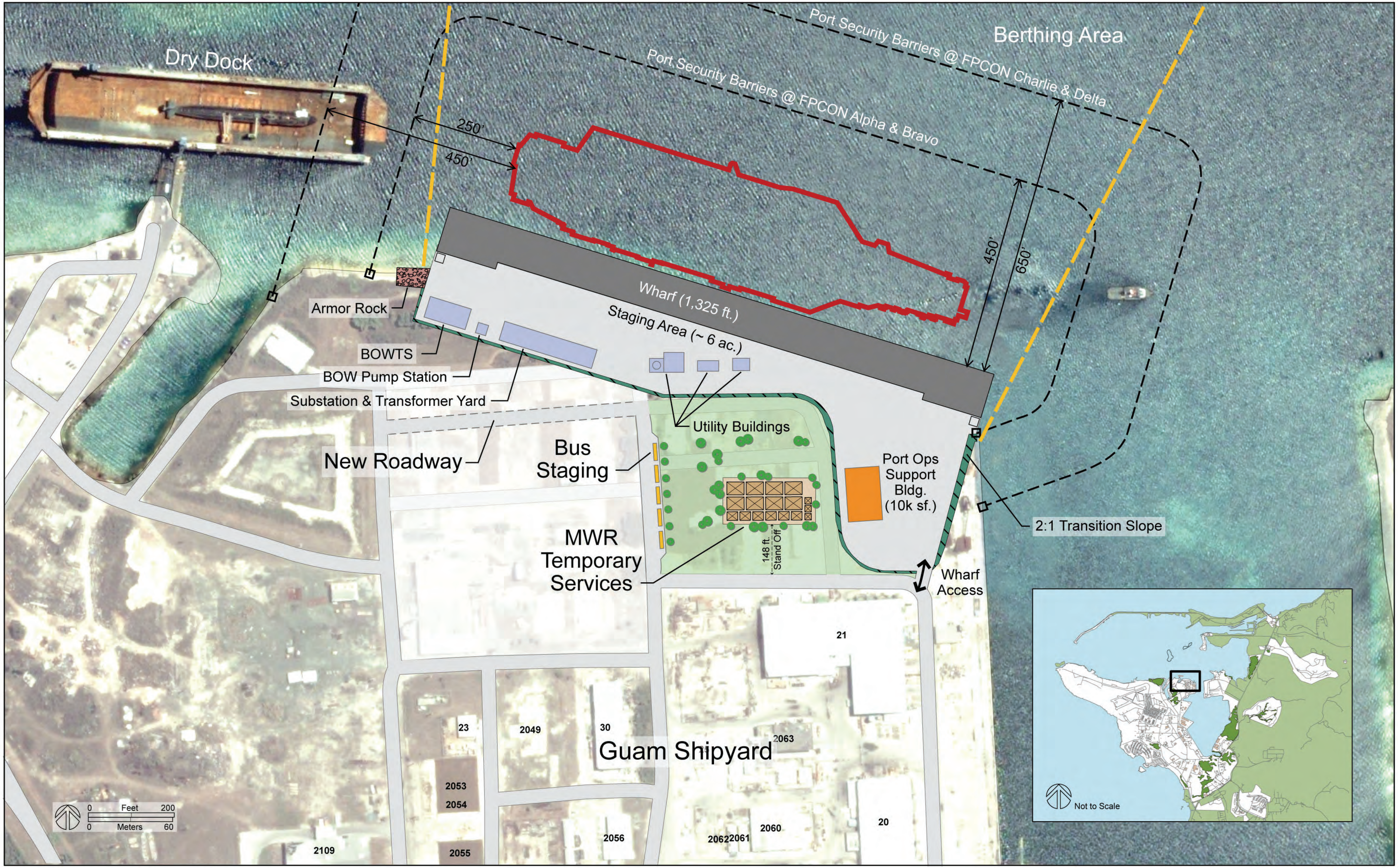
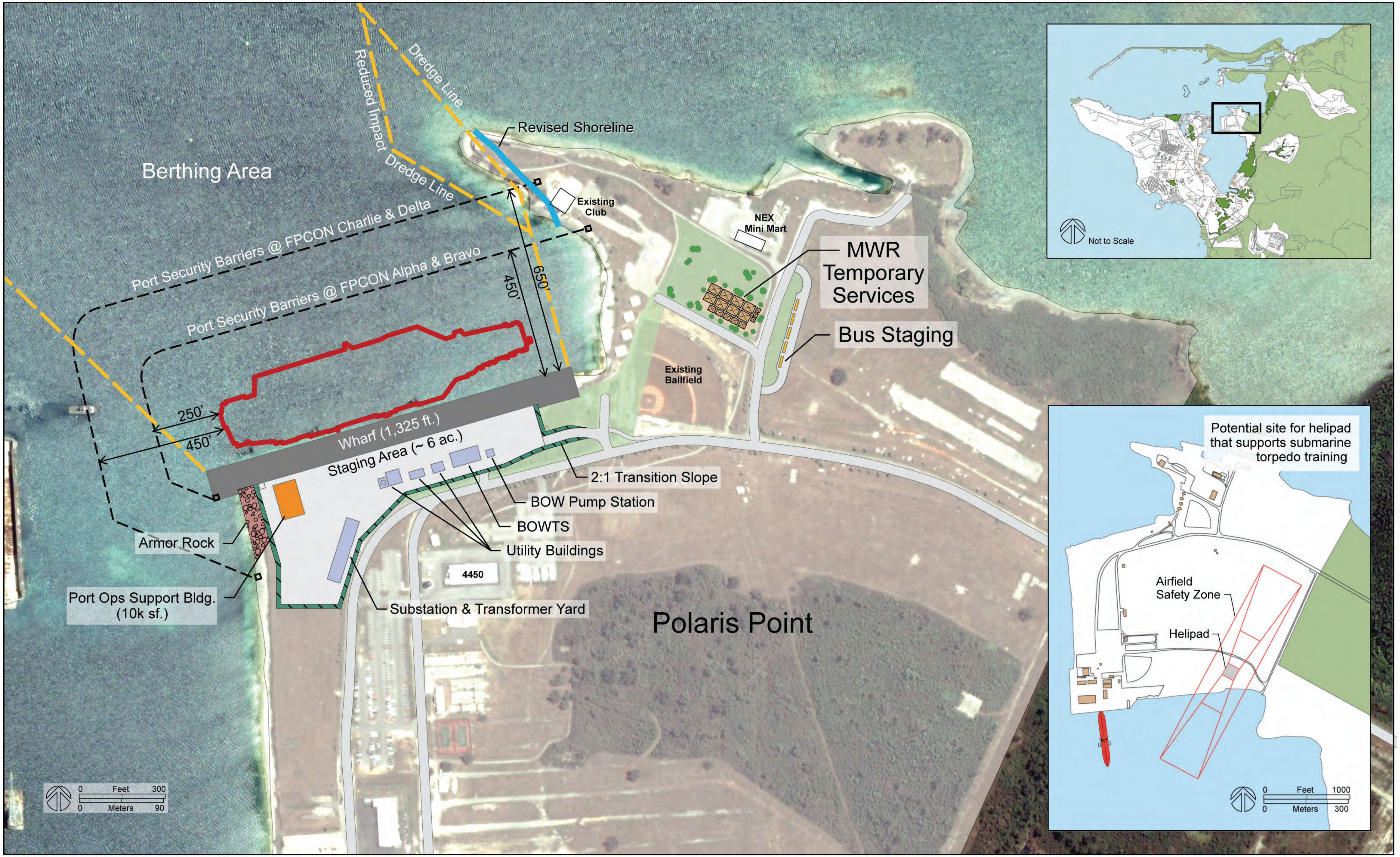


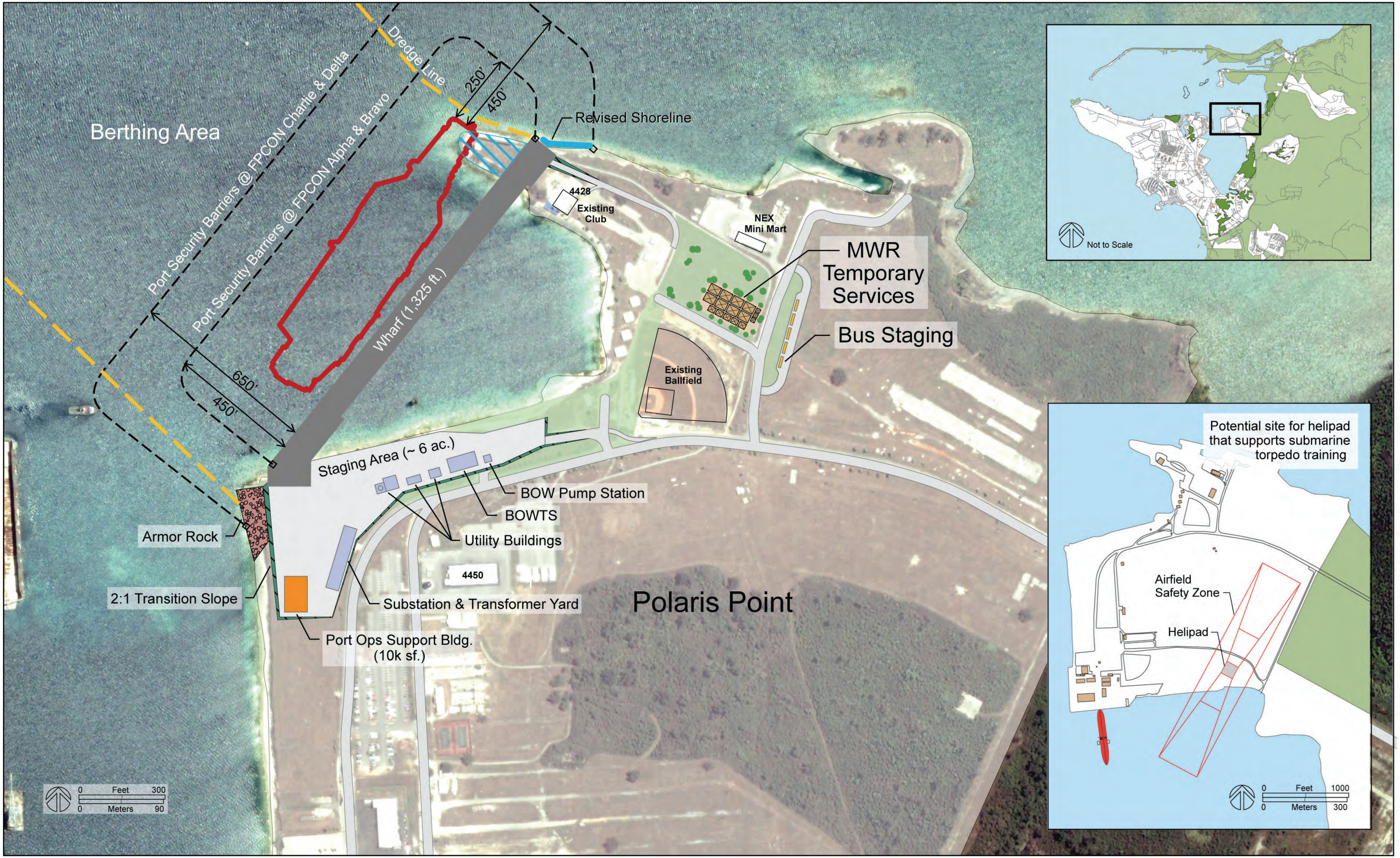
CVN Berth at Former SRF

Helber Hastert & Fee, Planners



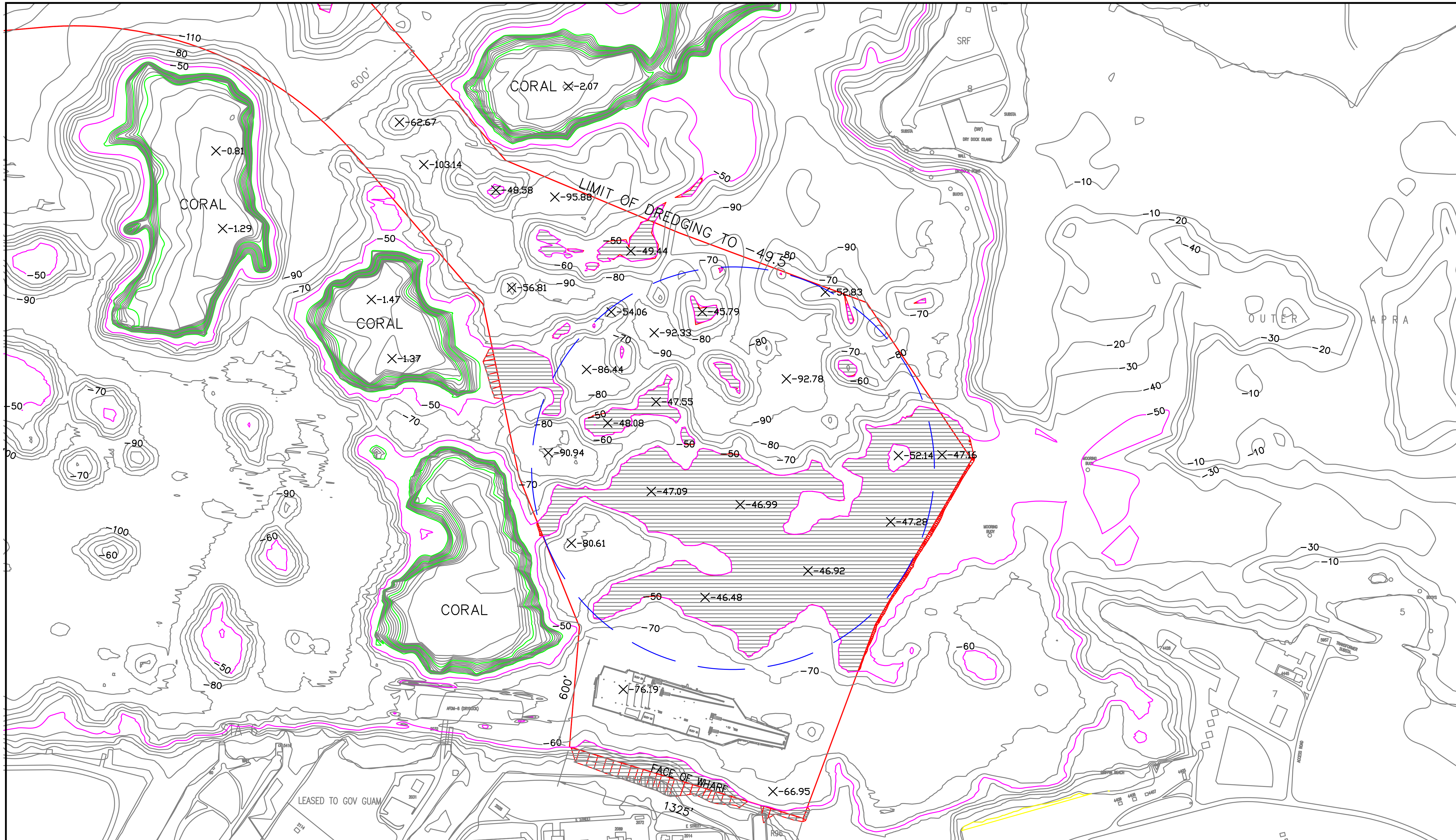
Marginal CVN Wharf at Polaris Point

Helber Hastert & Fee, Planners



Diagonal CVN Wharf at Polaris Point

Helber Hastert & Fee, Planners



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

1"=500' 0 500 1000 FT.

COMPANY LOGO

HPA

6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803

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DEPARTMENT OF THE NAVY

NAVAL FACILITIES ENGINEERING COMMAND

NAVFAC PACIFIC

PEARL HARBOR, HI

APRA HARBOR

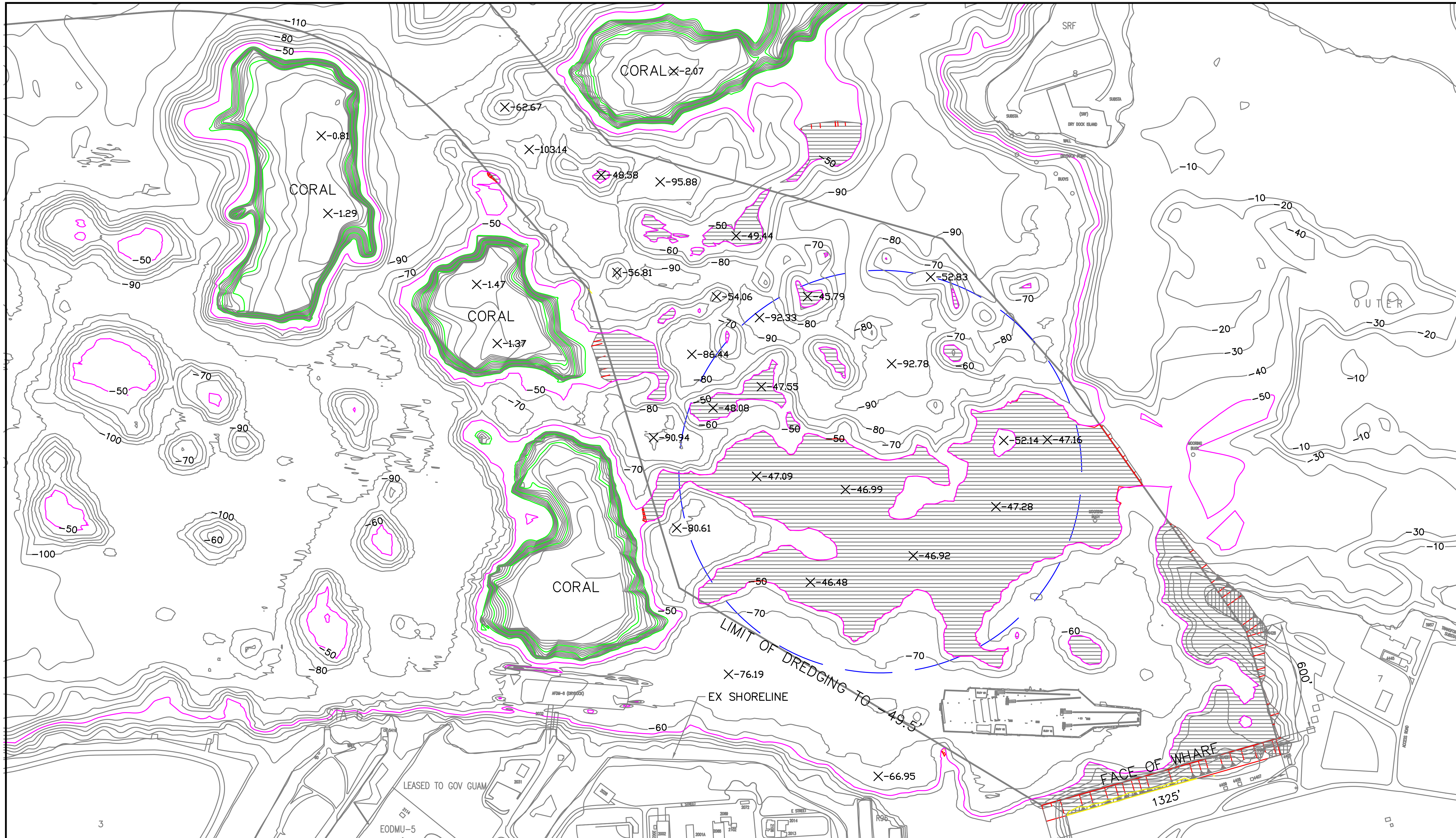
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 1
FORMER SRF FACILITY

DATE 5/29/08

FIGURE NUMBER N-1



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

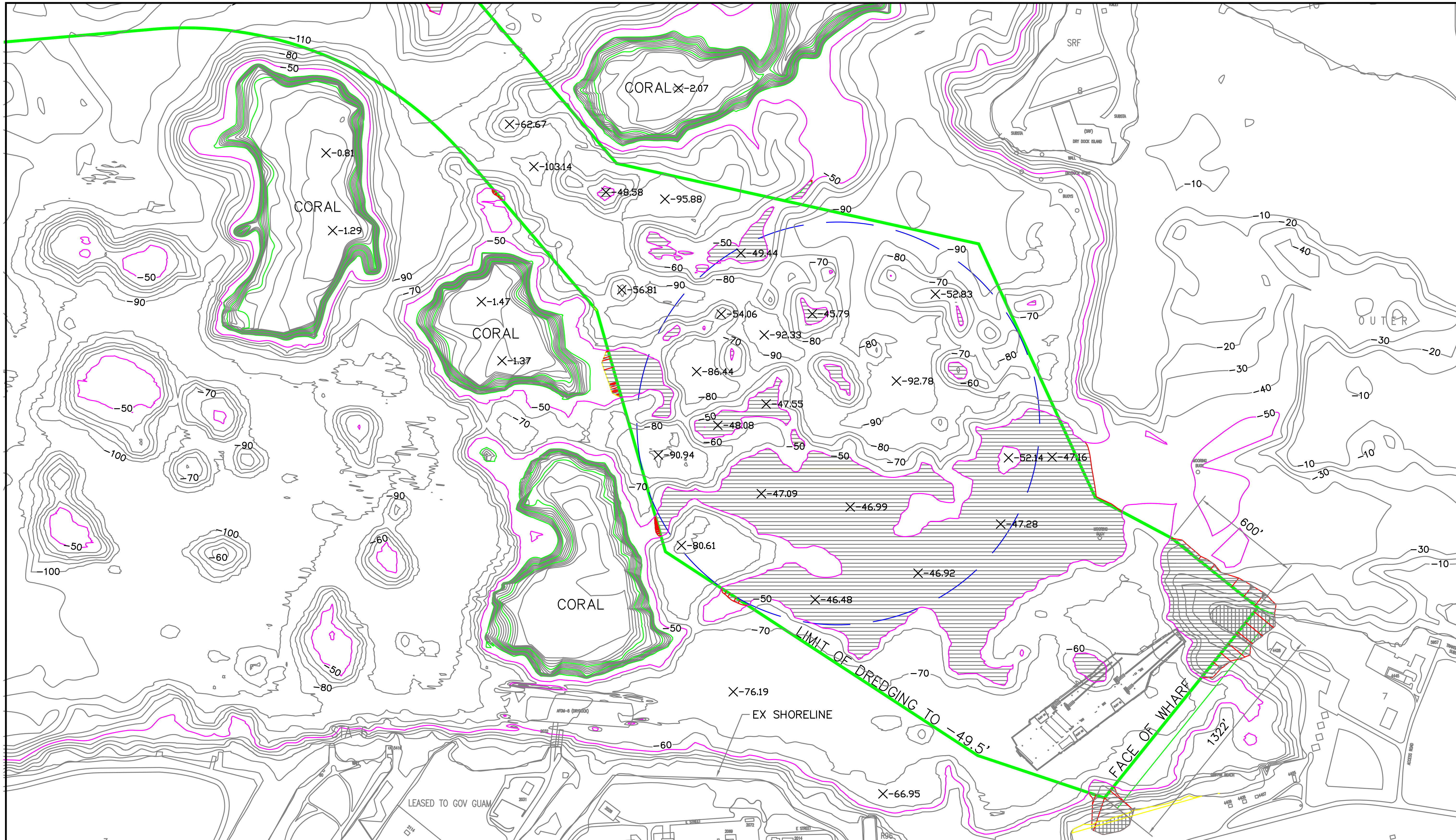
MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

EMBANKMENT DREDGING OR EXCAVATION

0 500 1000 FT.

1"=500'

COMPANY LOGO HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 3/14/08
		APRA HARBOR GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY	FIGURE NUMBER N-2
		ALTERNATIVE 2 POLARIS POINT PARALLEL TO SHORE	



LEGEND

DREDGE AREA

UPLAND EXCAVATION

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)

EMBANKMENT DREDGING OR EXCAVATION

1"=500' 0 500 1000 FT.

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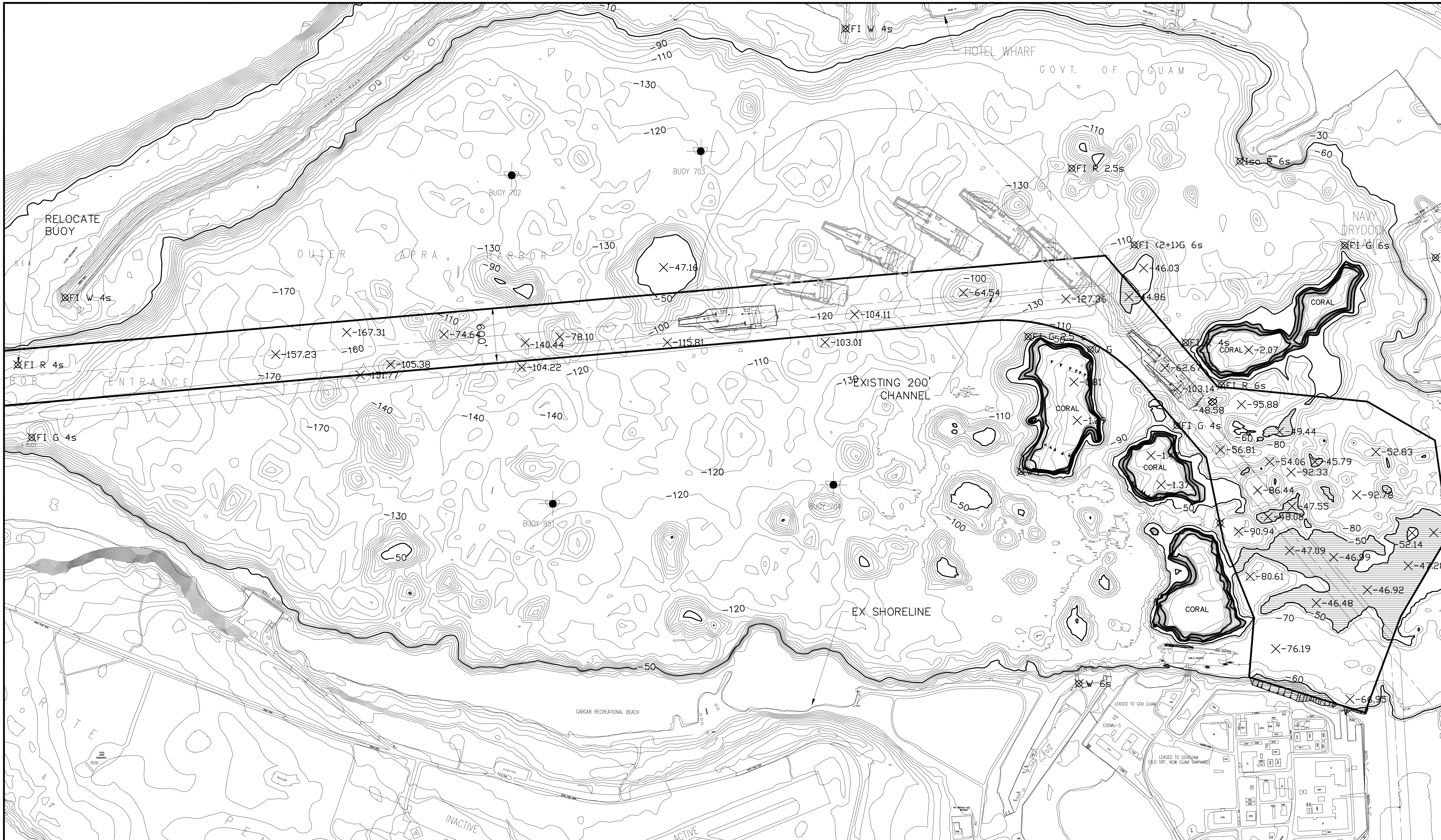
GUAM CVN-CAPABLE BERTHING STUDY

BERTHING ALTERNATIVE 3
POLARIS POINT DIAGONAL OFFSHORE

DATE
5/29/08

FIGURE NUMBER
N-3



LEGEND

- DREDGE AREA
- CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY
- EMBANKMENT DREDGING OR EXCAVATION

1"=1000'   0   1000   2000 FT.

COMPANY LOGO HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 3/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY CHANNEL ALTERNATIVE 1 MINIMUM RADIUS CHANNEL BEND	FIGURE NUMBER N-4

LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

1"=1000' 0 1000 2000 FT.

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GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

CHANNEL ALTERNATIVE 2
OPTIMAL RADIUS CHANNEL BEND

DATE
3/14/08

FIGURE NUMBER
N-5

LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

0 1000 2000 FT.

1"=1000'

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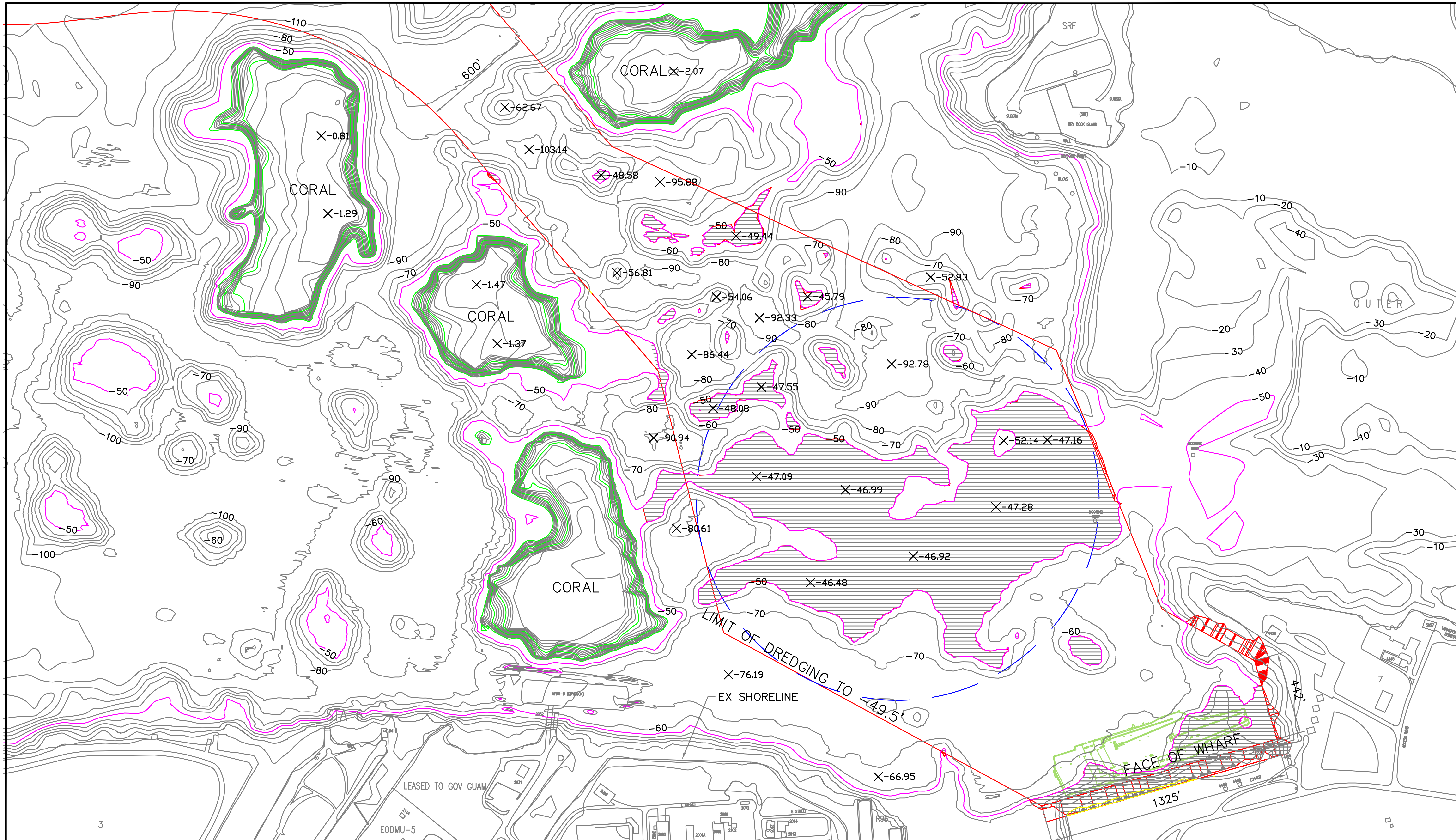
APRA HARBOR	GUAM, MARIANA ISLANDS	FIGURE NUMBER
GUAM CVN-CAPABLE BERTHING STUDY		N-6
CHANNEL ALTERNATIVE 3 NO CHANNEL BEND		



LEGEND

- DREDGE AREA
- UPLAND EXCAVATION
- CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY
- MINIMUM TURNING BASIN RADIUS = 1092' (CVN LOA)
- EMBANKMENT DREDGING OR EXCAVATION

1"=500' 0 500 1000 FT.

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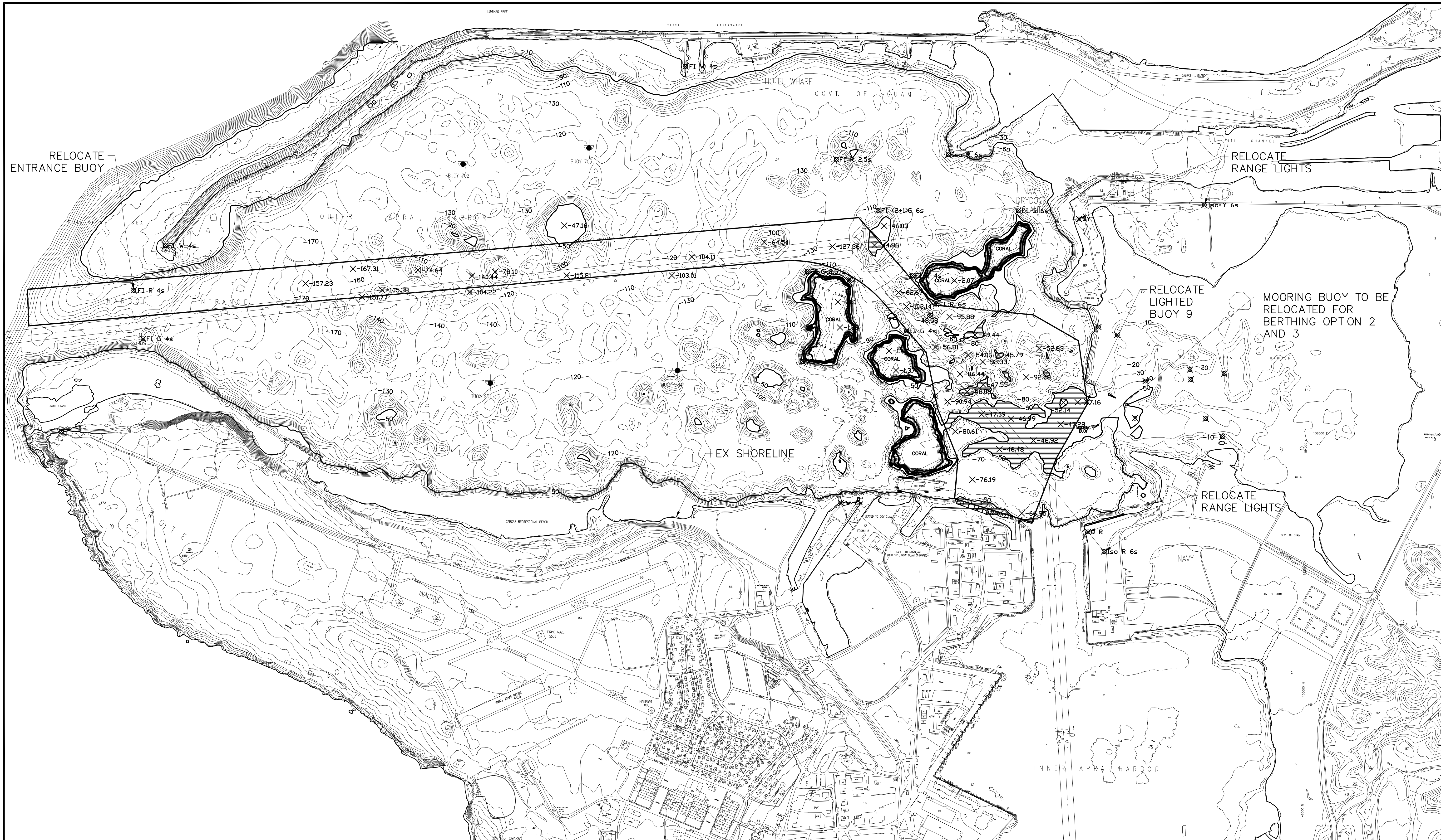
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

BERTHING ALTERNATIVE 2A
POLARIS POINT PARALLEL TO SHORE

DATE
5/29/08

FIGURE NUMBER
N-7



LEGEND

DREDGE AREA

CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY

EMBANKMENT DREDGING OR EXCAVATION

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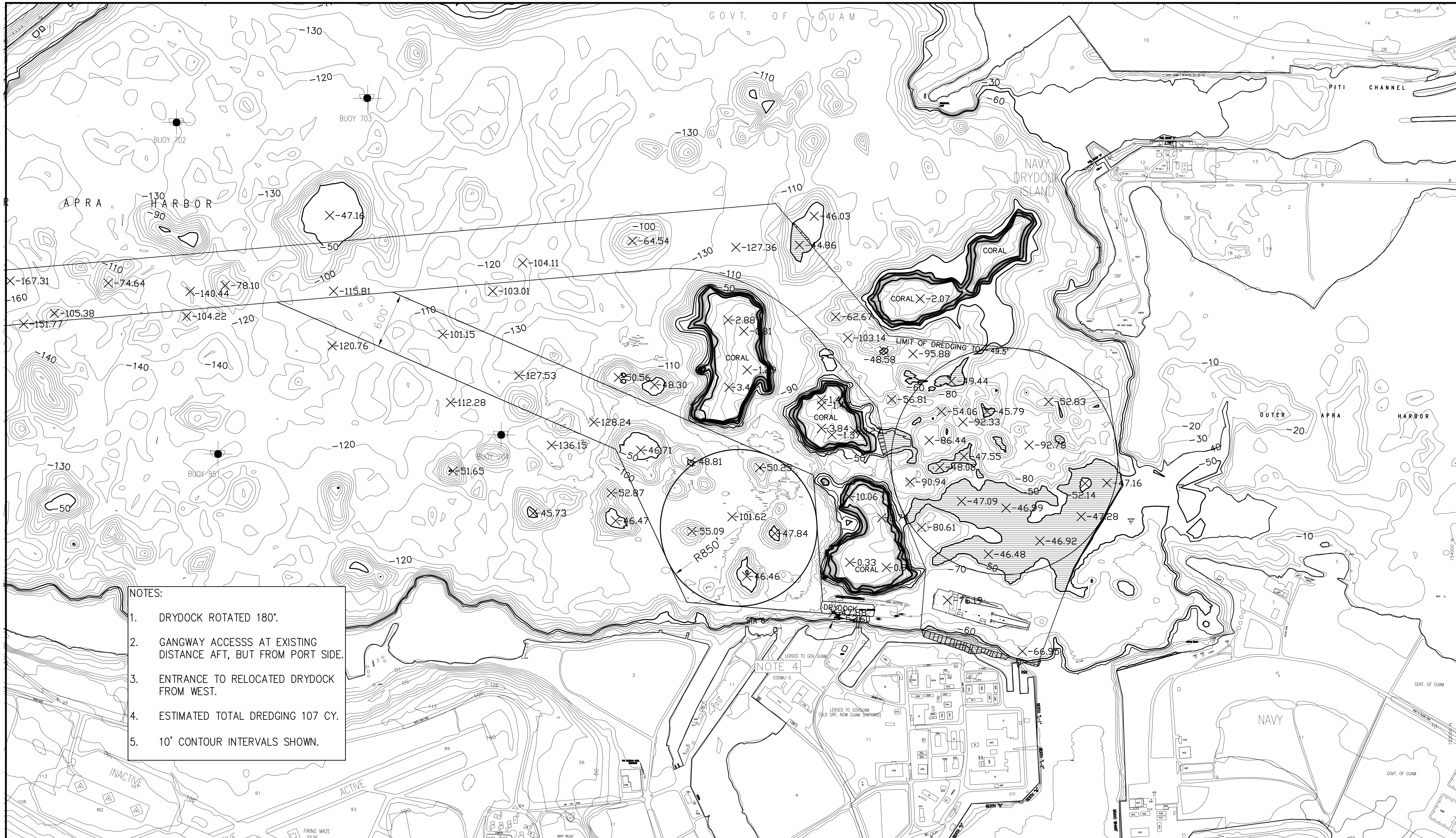
		APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY AIDS TO NAVIGATION	FIGURE NUMBER N-8



NOTES:

1. DRYDOCK ROTATED 180°.
2. GANGWAY ACCESSS AT EXISTING DISTANCE AFT, BUT FROM PORT SIDE.
3. ENTRANCE TO RELOCATED DRYDOCK FROM WEST.
4. ESTIMATED TOTAL DREDGING 107 CY.
5. 10' CONTOUR INTERVALS SHOWN.

LEGEND

- DREDGE AREA
- UPLAND EXCAVATION
- CORAL REEFS IDENTIFIED IN AUGUST 2007 CORAL STUDY
- EMBANKMENT DREDGING OR EXCAVATION

1"=1000' 0 1000 2000 FT.

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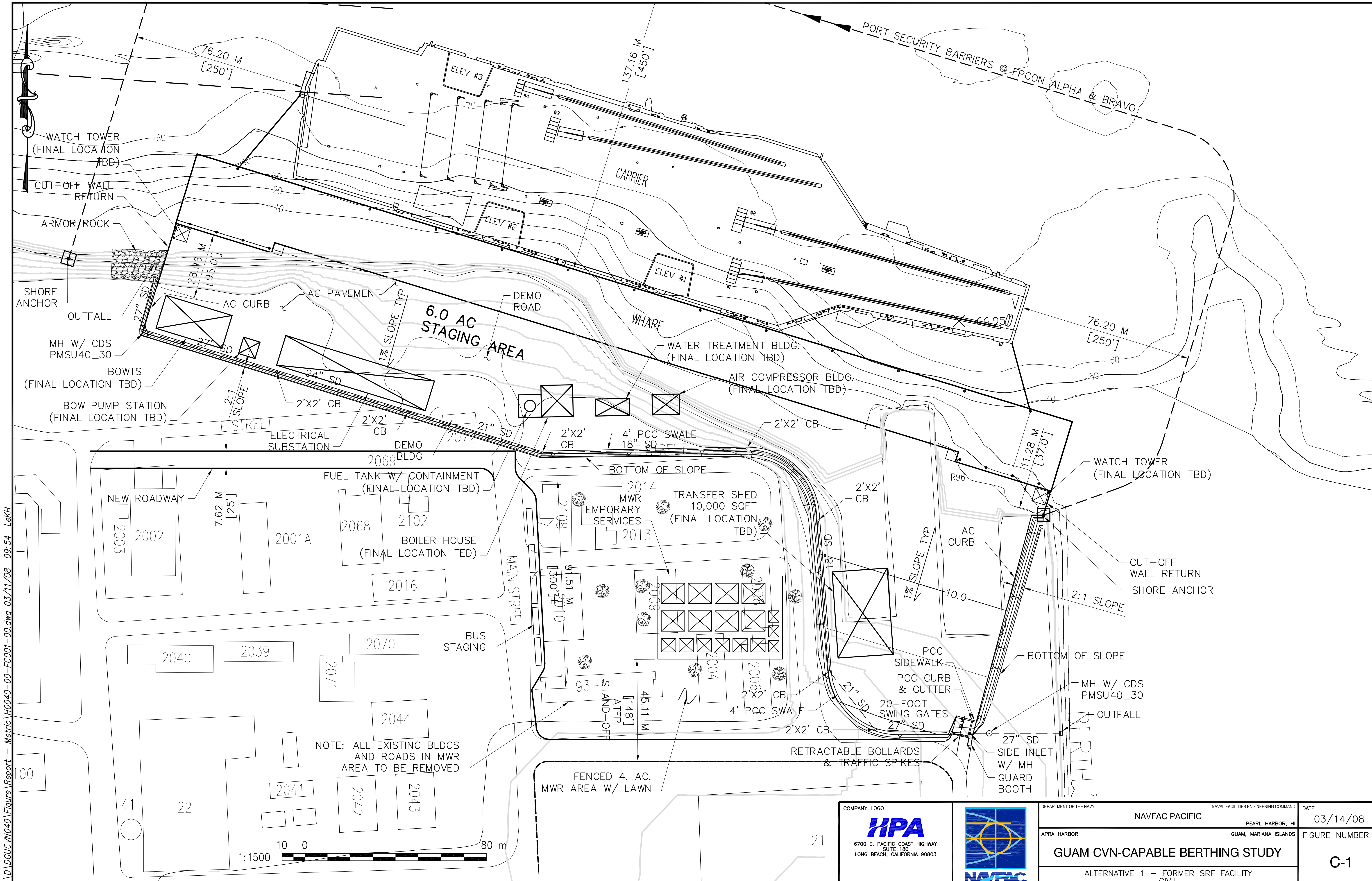
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

PROPOSED DRYDOCK RELOCATION

DATE 3/14/08

FIGURE NUMBER N-9



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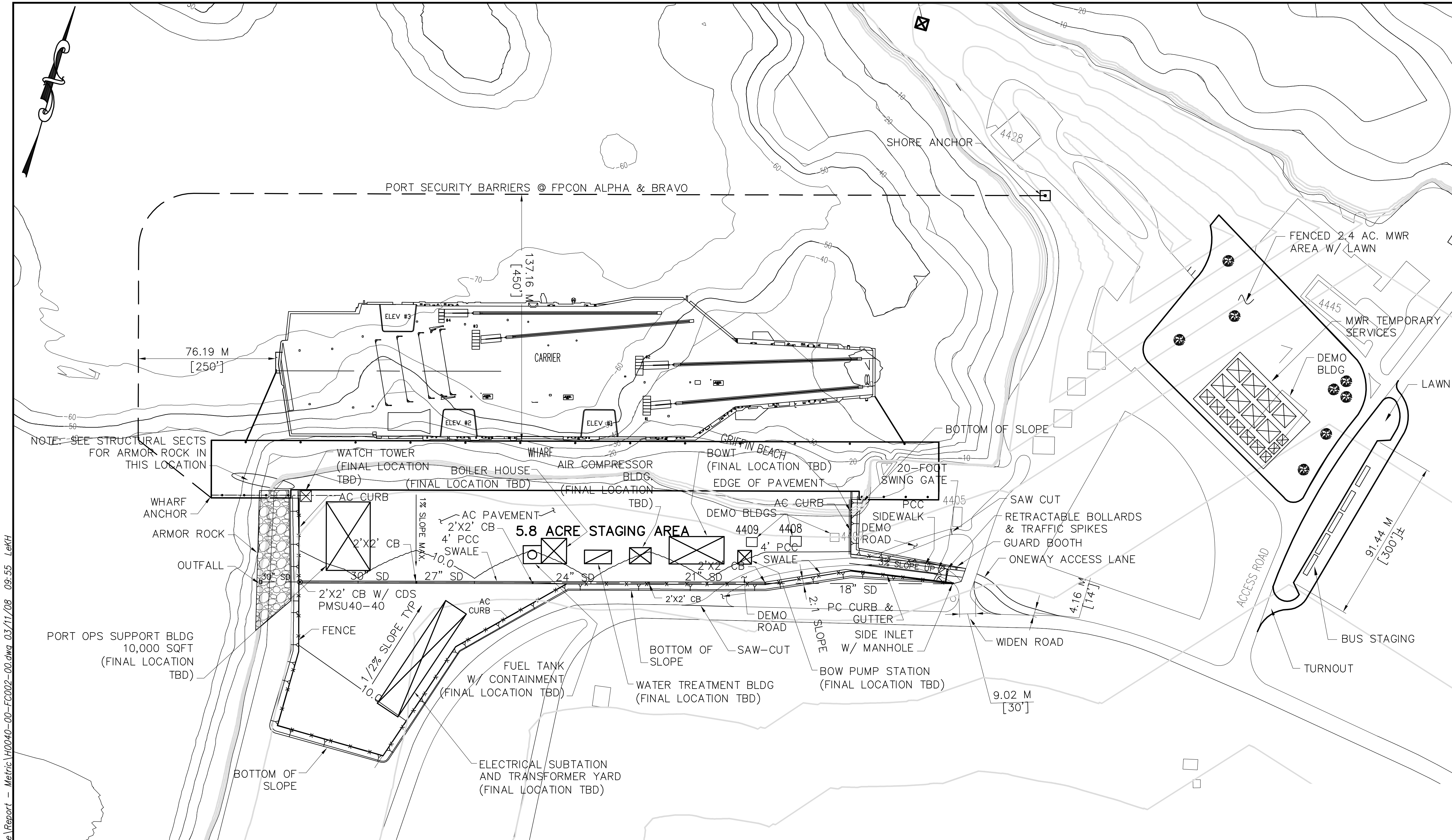
APRA HARBOR — GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 1 – FORMER SRF FACILITY
CIVIL

DATE 03/14/08

FIGURE NUMBER C-1



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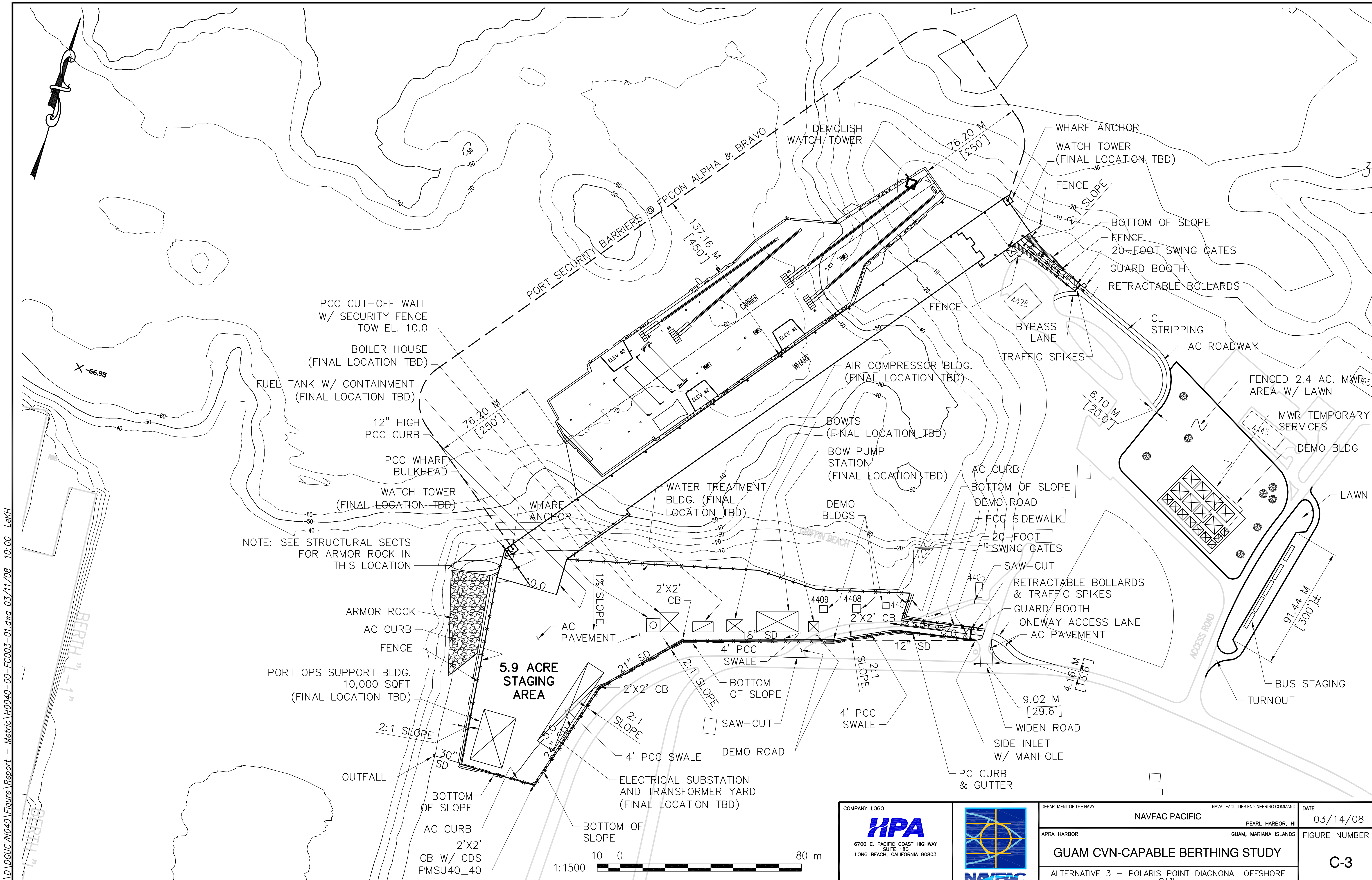
HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	NAVFAC PACIFIC, PEARL HARBOR, HI	03/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS	FIGURE NUMBER
		GUAM CVN-CAPABLE BERTHING STUDY	C-2
		ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE CIVIL	



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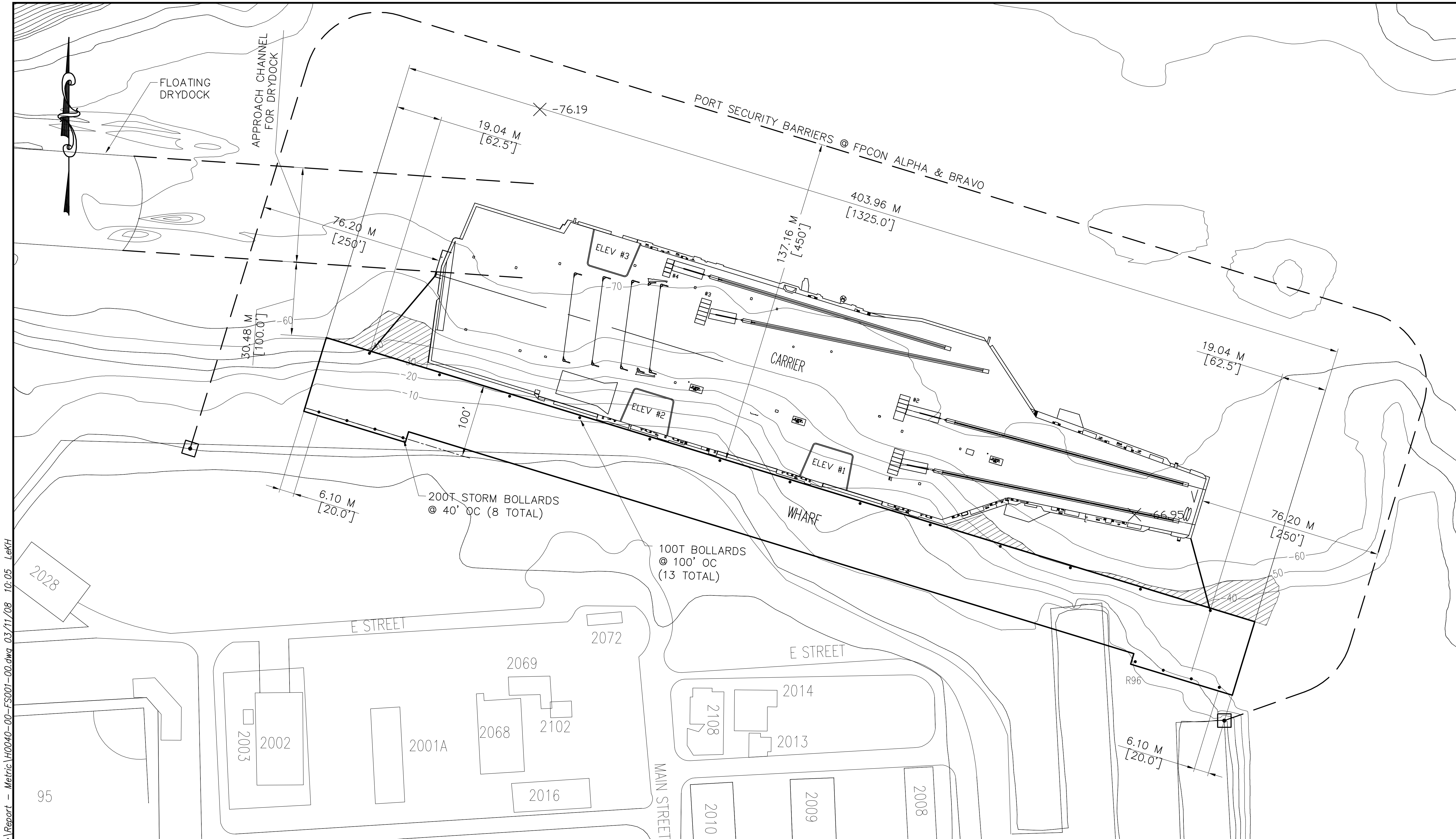
APRA HARBOR — GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE
CIVIL

DATE 03/14/08

FIGURE NUMBER C-3



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GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 1 – FORMER SRF FACILITY
WHARF PLAN

DATE 03/14/08

FIGURE NUMBER S-1

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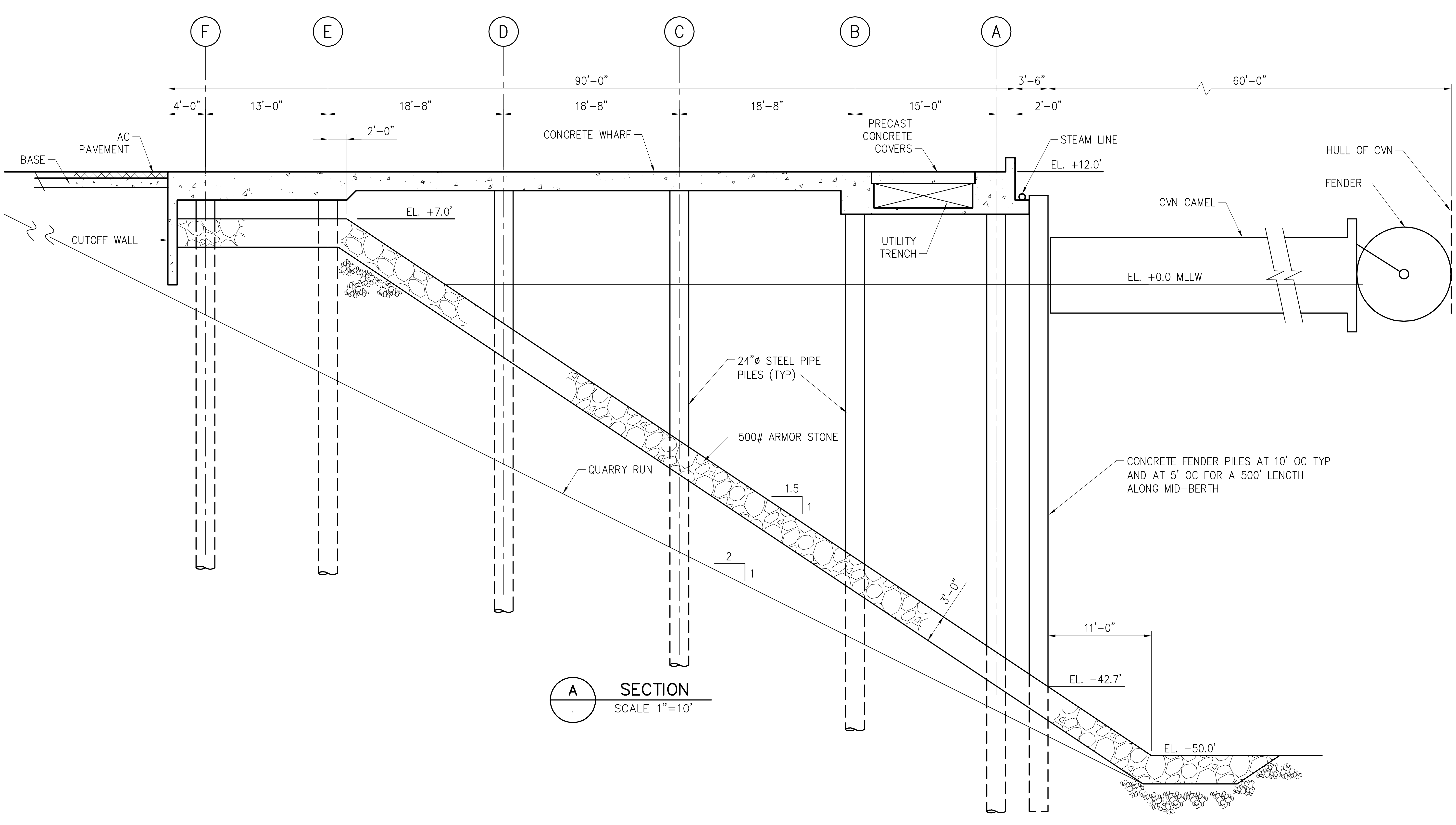

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APRA HARBOR — GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 1 & 2 – FORMER SRF FACILITY
WHARF SECTION

DATE 03/14/08

FIGURE NUMBER S-2

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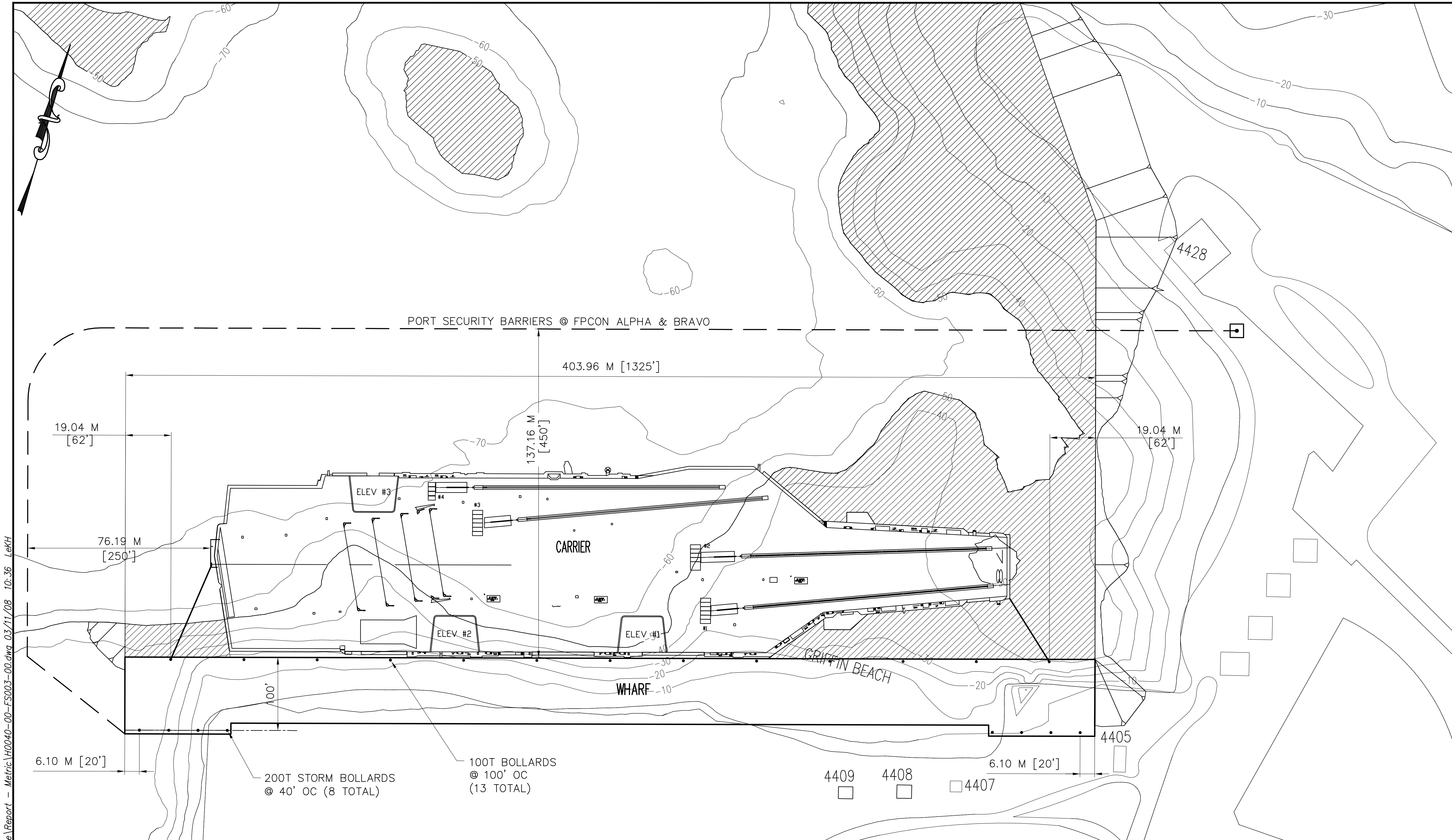

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SUITE 180
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APRA HARBOR
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY
ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE WHARF PLAN

DATE 03/14/08
FIGURE NUMBER S-3

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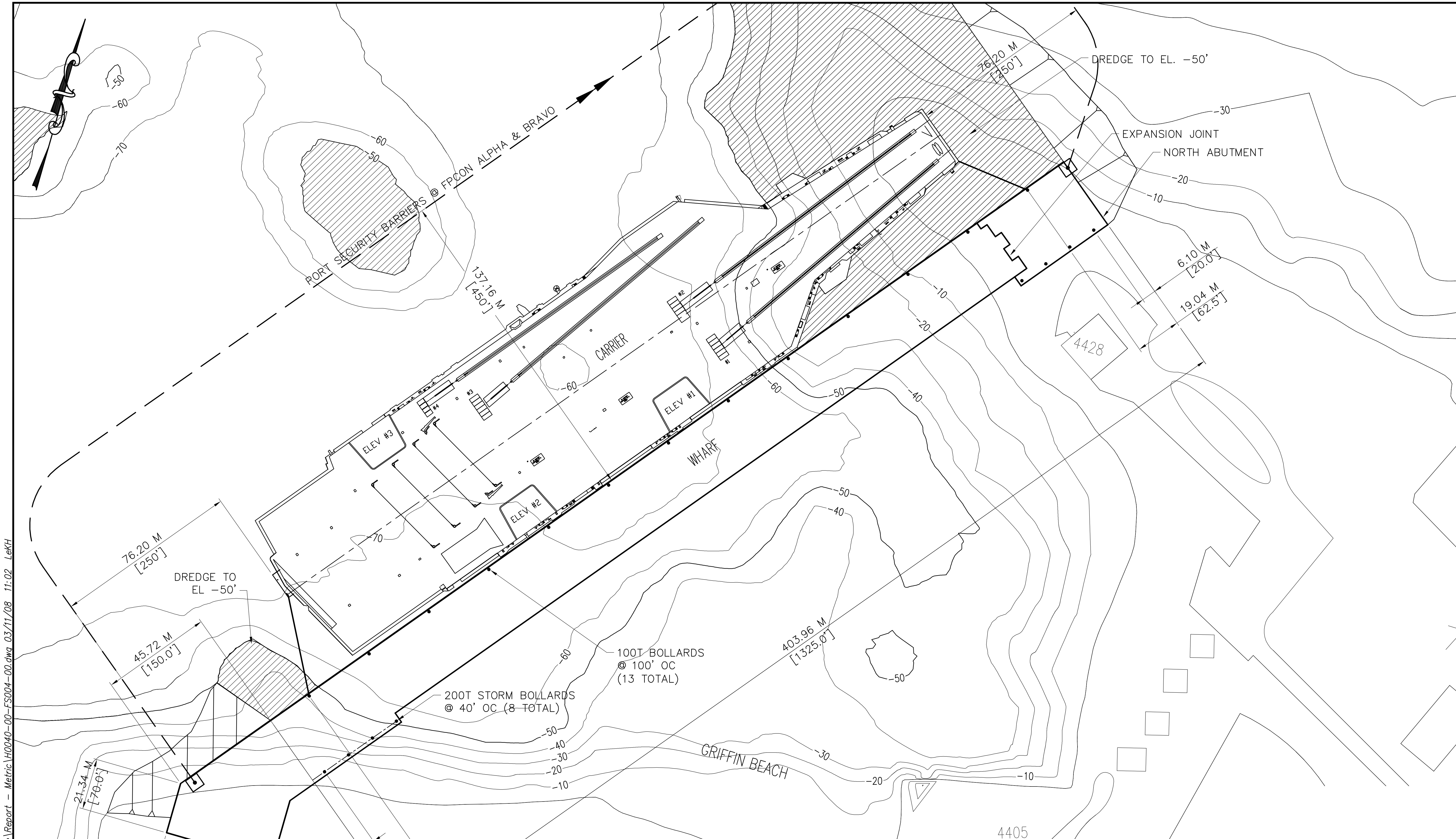

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SUITE 180
LONG BEACH, CALIFORNIA 90803

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APRA HARBOR
GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE WHARF PLAN

DATE 03/14/08

FIGURE NUMBER S-4

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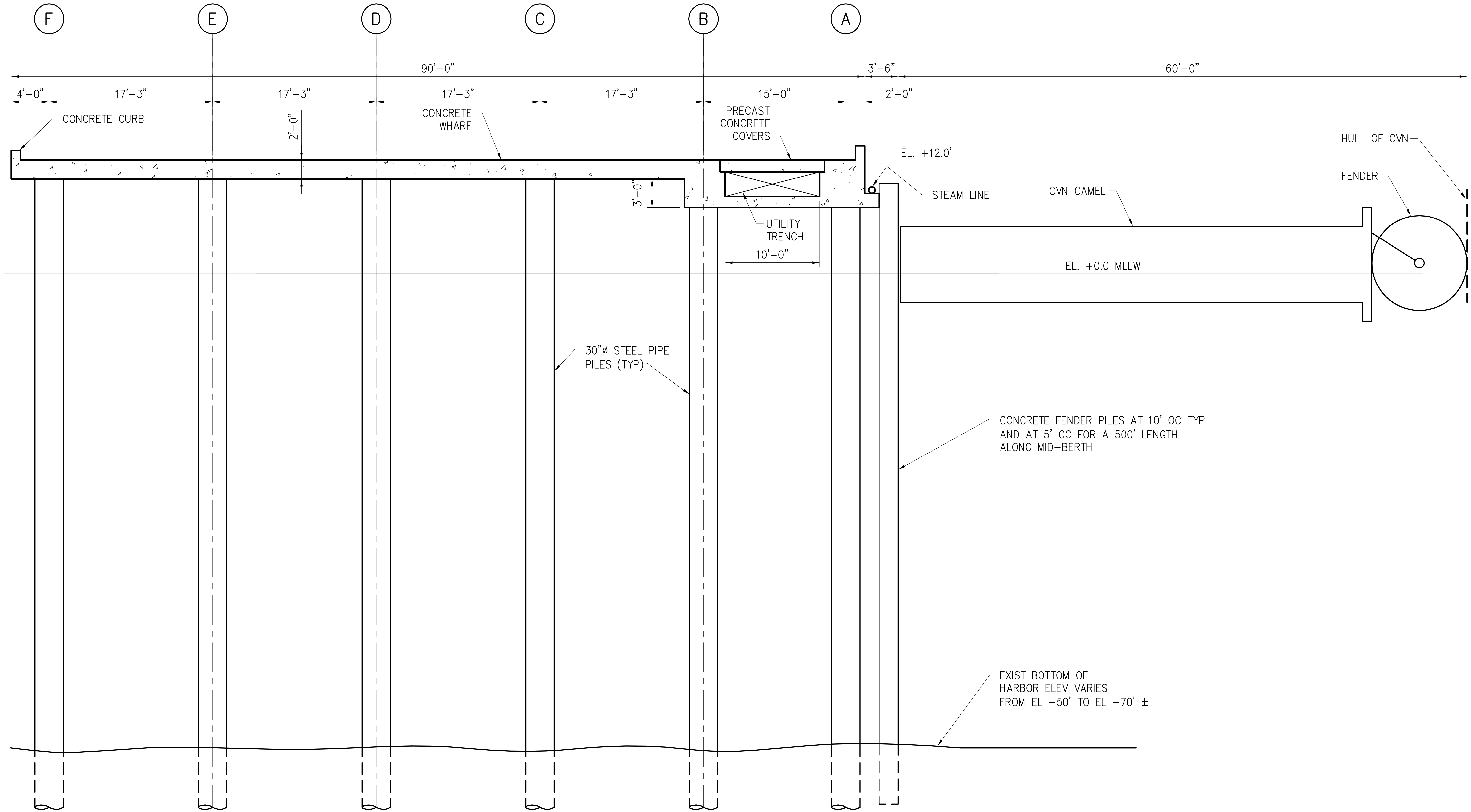

A SECTION
SCALE 1"=10'

0 10 20 FT.

COMPANY LOGO		DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND	DATE
HPA 6700 E. PACIFIC COAST HIGHWAY SUITE 180 LONG BEACH, CALIFORNIA 90803	NAVFAC	NAVFAC PACIFIC PEARL HARBOR, HI	03/14/08
		APRA HARBOR GUAM, MARIANA ISLANDS	FIGURE NUMBER
		GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE WHARF SECTION	S-5

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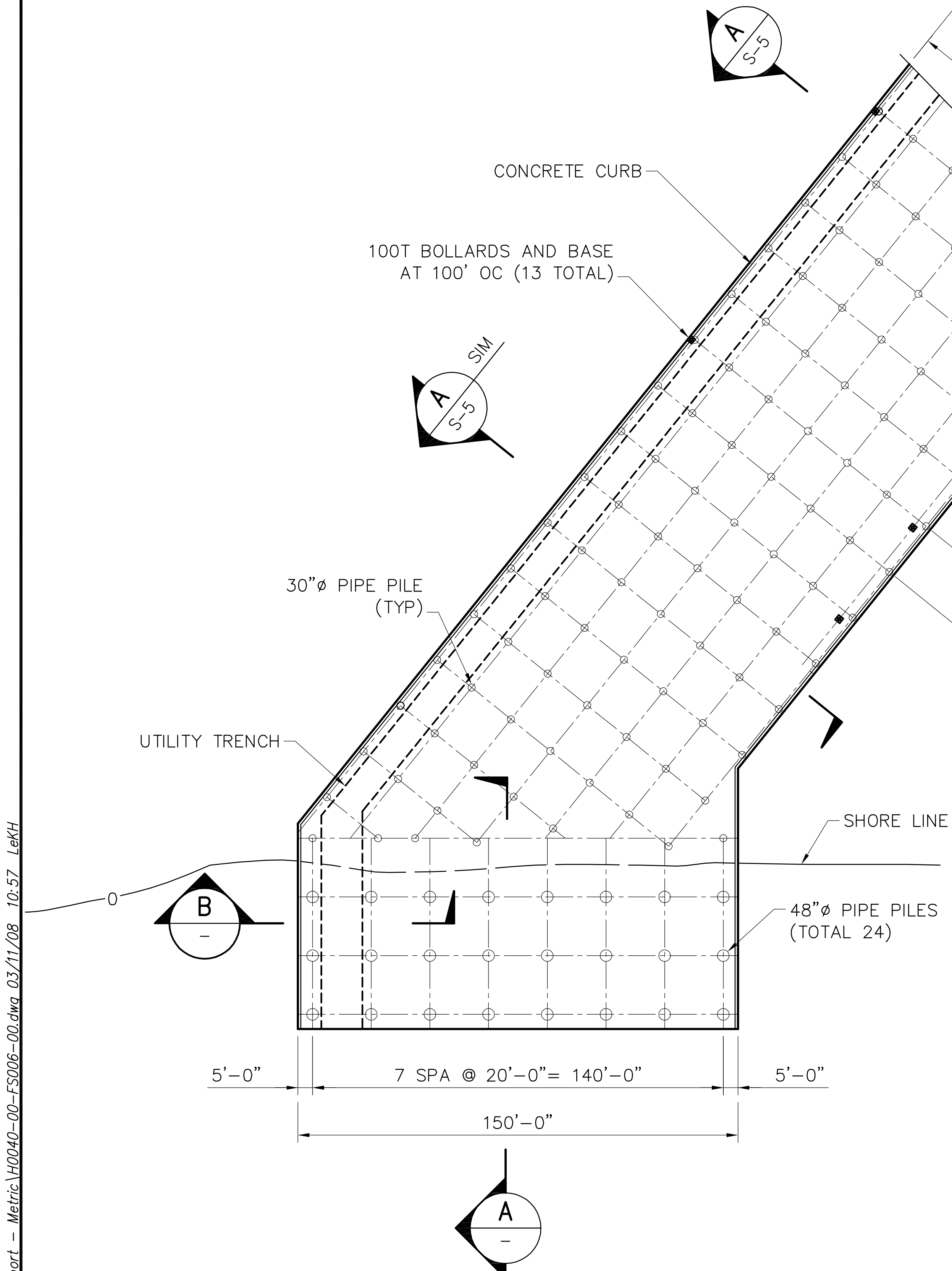
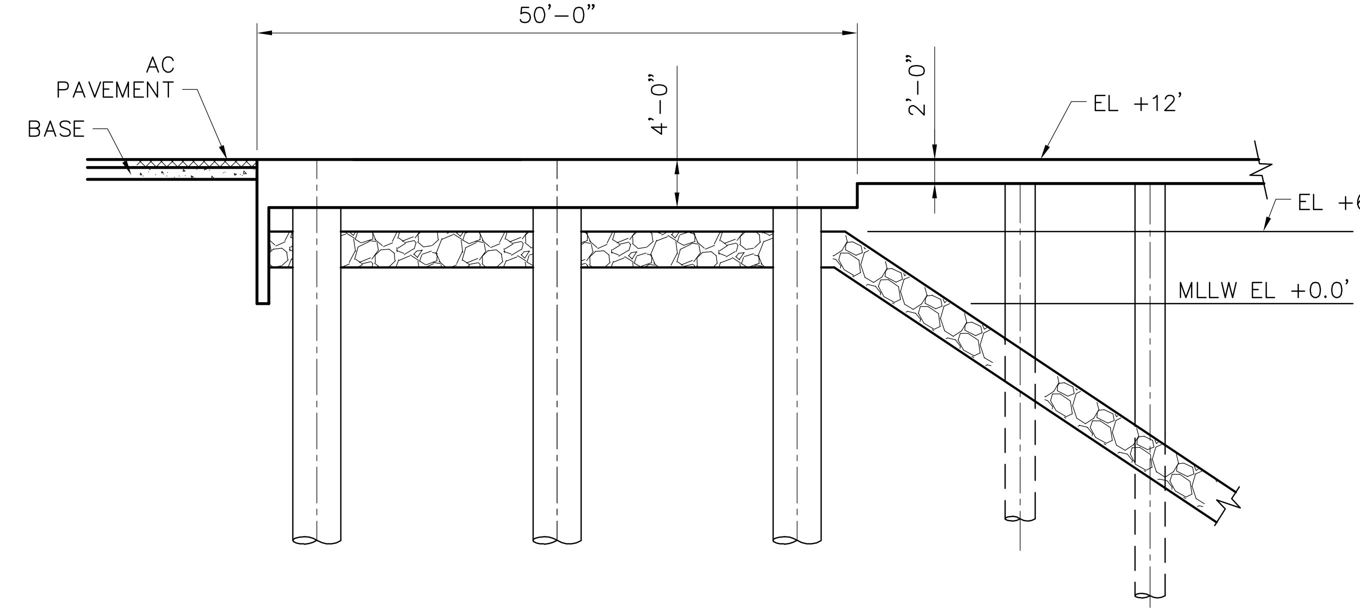
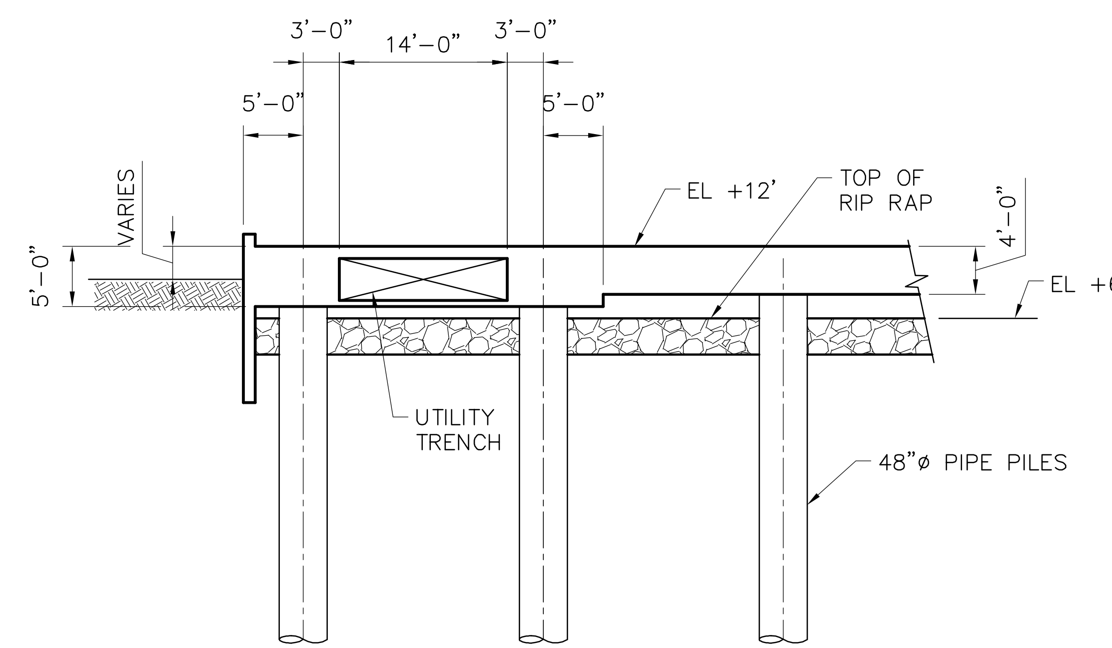


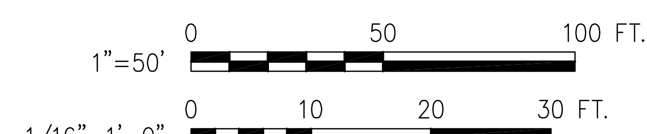
ABUTMENT PLAN
SCALE 1"=50'-0"



A
–
SECTION
SCALE 1/16"=1'-0"



B
–
SECTION
SCALE 1/16"=1'-0"



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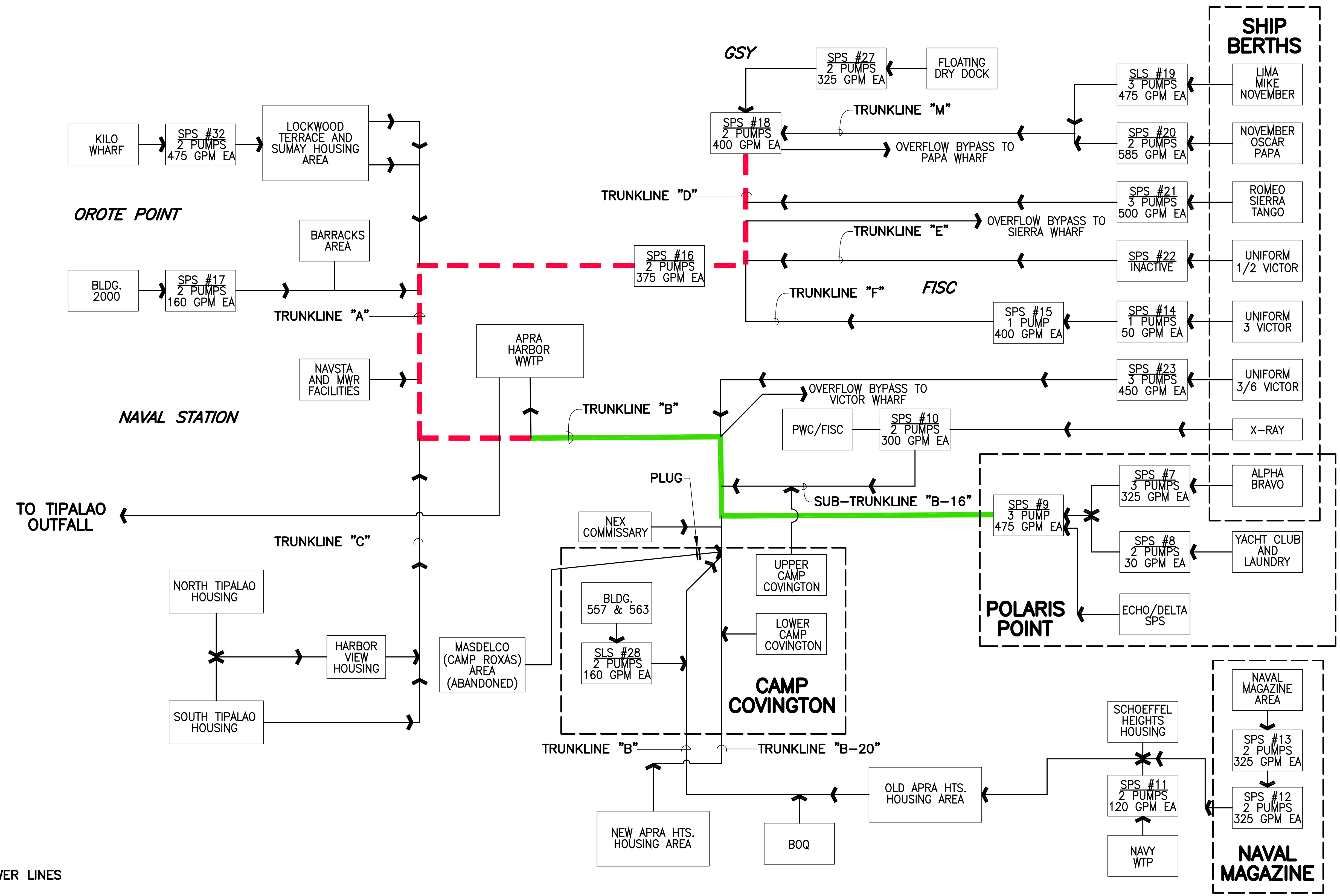
GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 3 – POLARIS POINT DIAGONAL OFFSHORE
ABUTMENT PLAN & SECTIONS

DATE
03/14/08

FIGURE NUMBER
S-6

T:\D\DGUCWN040\Figure\Report – Metric\H0040-00-FS006-00.dwg 03/11/08 10:57 LekH



LEGEND:

- SEWER LINES
- DIRECTION OF FLOW
- FLOW FROM FORMER SRF FACILITY
- FLOW FROM POLARIS POINT

SOURCE: GUAM NAVAL BASE WASTEWATER SYSTEM UTILITY TECHNICAL STUDY, APRIL 2007

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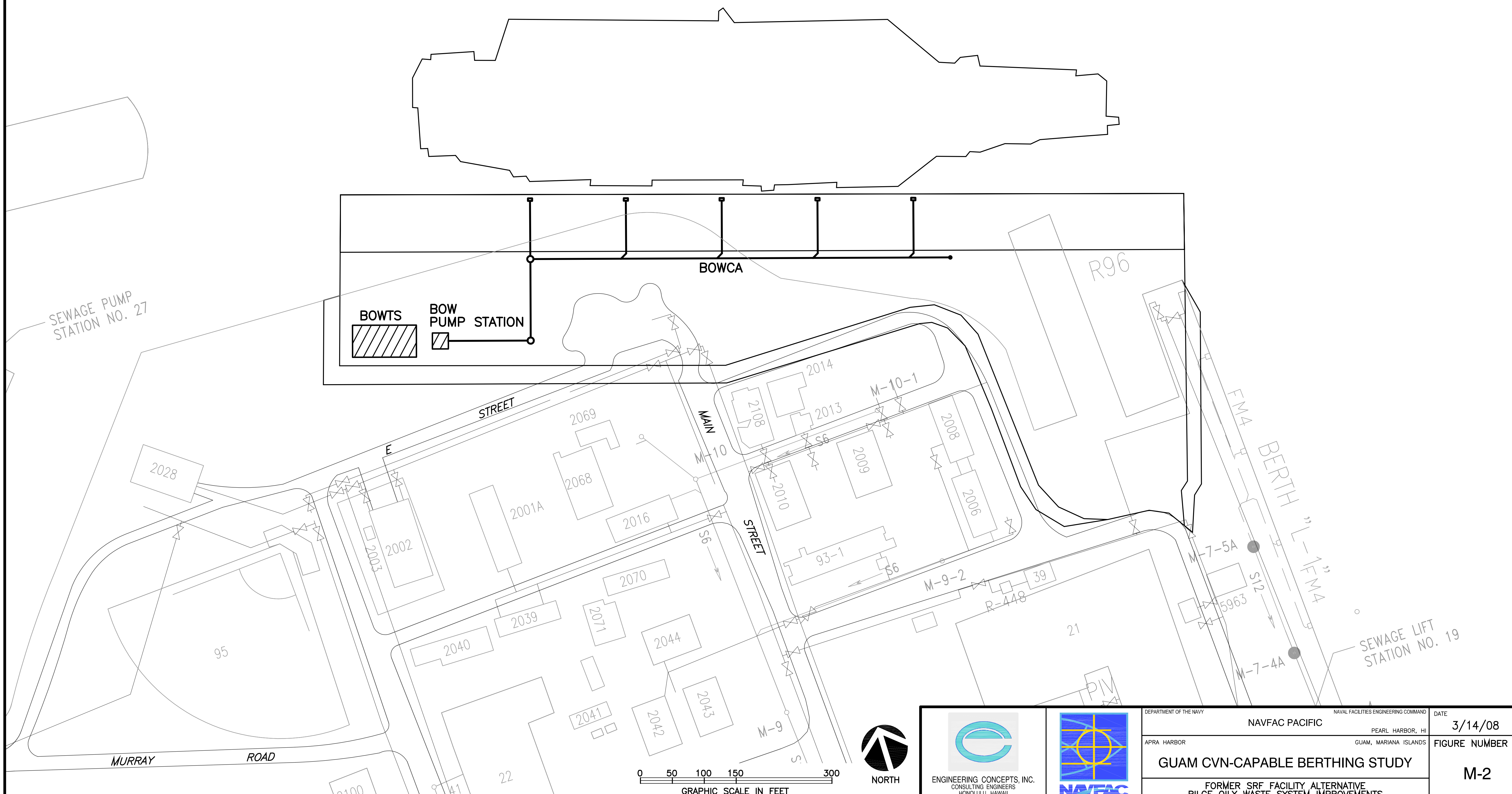
APRA HARBOR · GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY		FIGURE NUMBER M-1
APRA HARBOR NAVAL COMPLEX WASTEWATER SYSTEM SCHEMATIC		



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GUAM CVN-CAPABLE BERTHING STUDY

FORMER SRF FACILITY ALTERNATIVE
BILGE OILY WASTE SYSTEM IMPROVEMENTS

DATE	3/14/08
FIGURE NUMBER	M-2

Mar 05, 2008-10:04am
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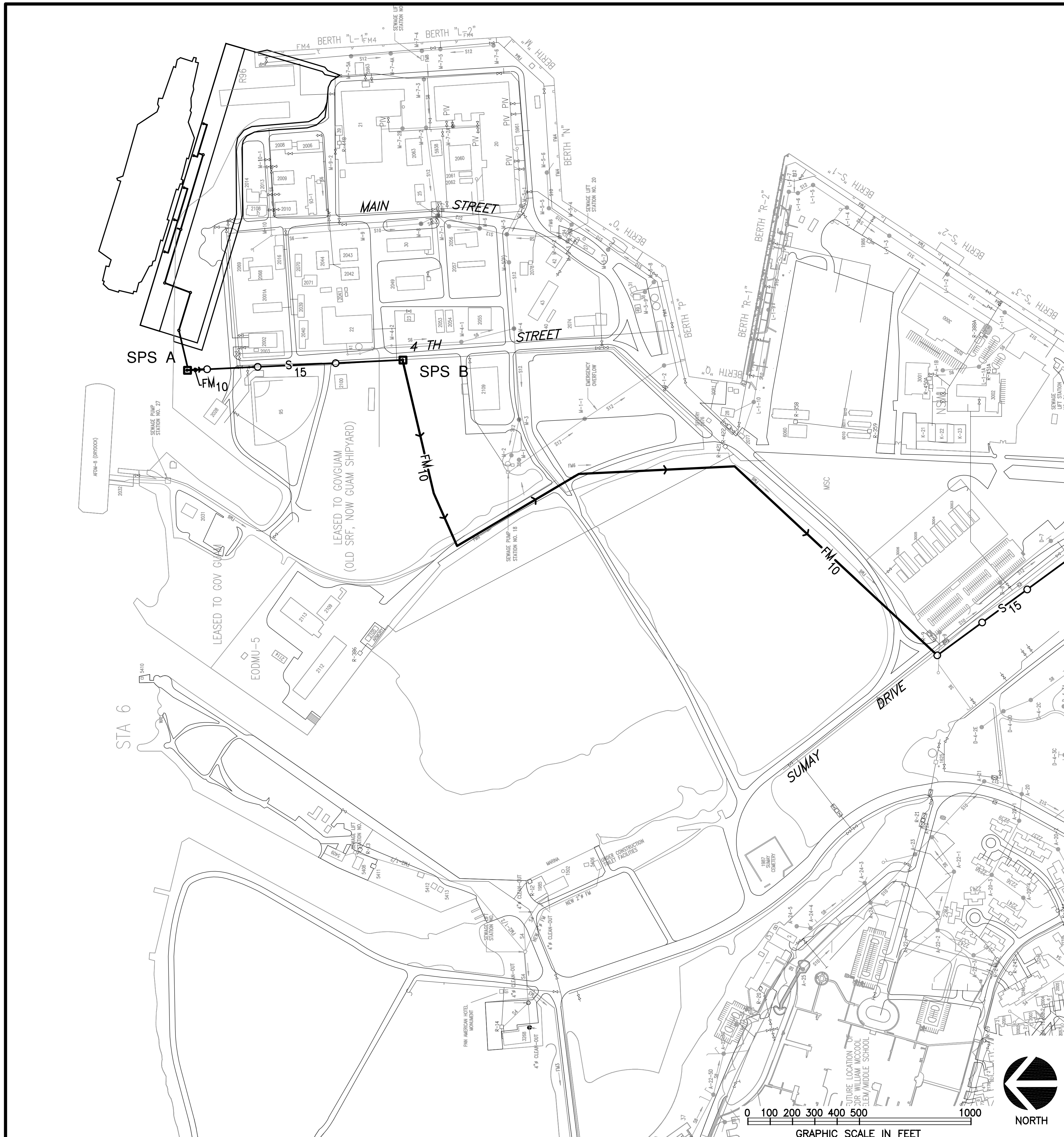

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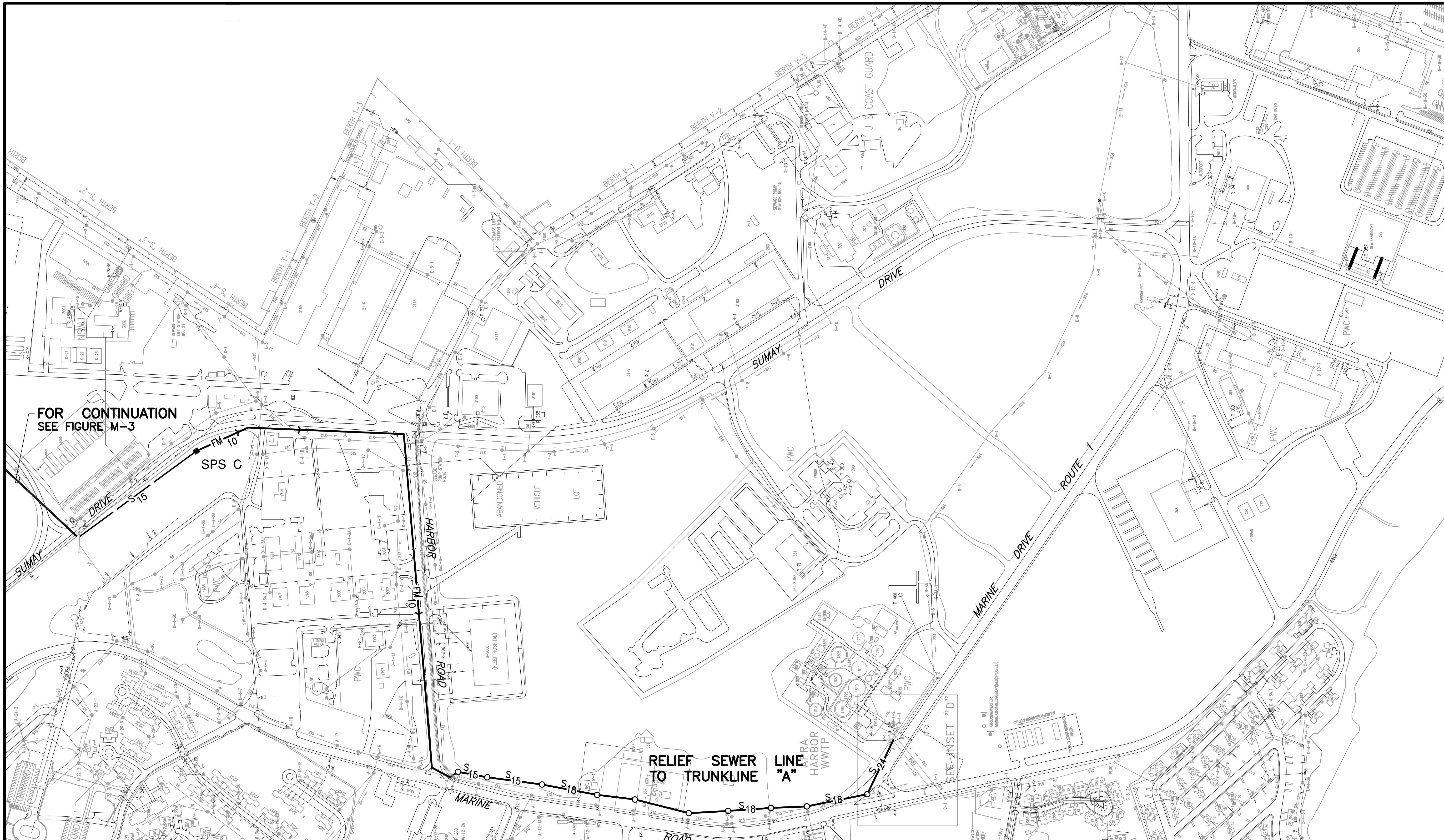
GUAM CVN-CAPABLE BERTHING STUDY

FORMER SRF FACILITY ALTERNATE
WASTEWATER SYSTEM IMPROVEMENTS (SHT. 1 OF 2)

DATE 3/14/08

FIGURE NUMBER M-3

Mar 05, 2008-10:06am
N:\CAD\DWG\2007\0735-GUAM CVN BERTHING\FIGURES\fig-m3&m4.dwg



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FORMER SRF FACILITY ALTERNATIVE
WASTEWATER SYSTEM IMPROVEMENTS (SHT. 2 OF 2)

DATE 3/14/08

FIGURE NUMBER M-4

Mar 05, 2008-10:06am
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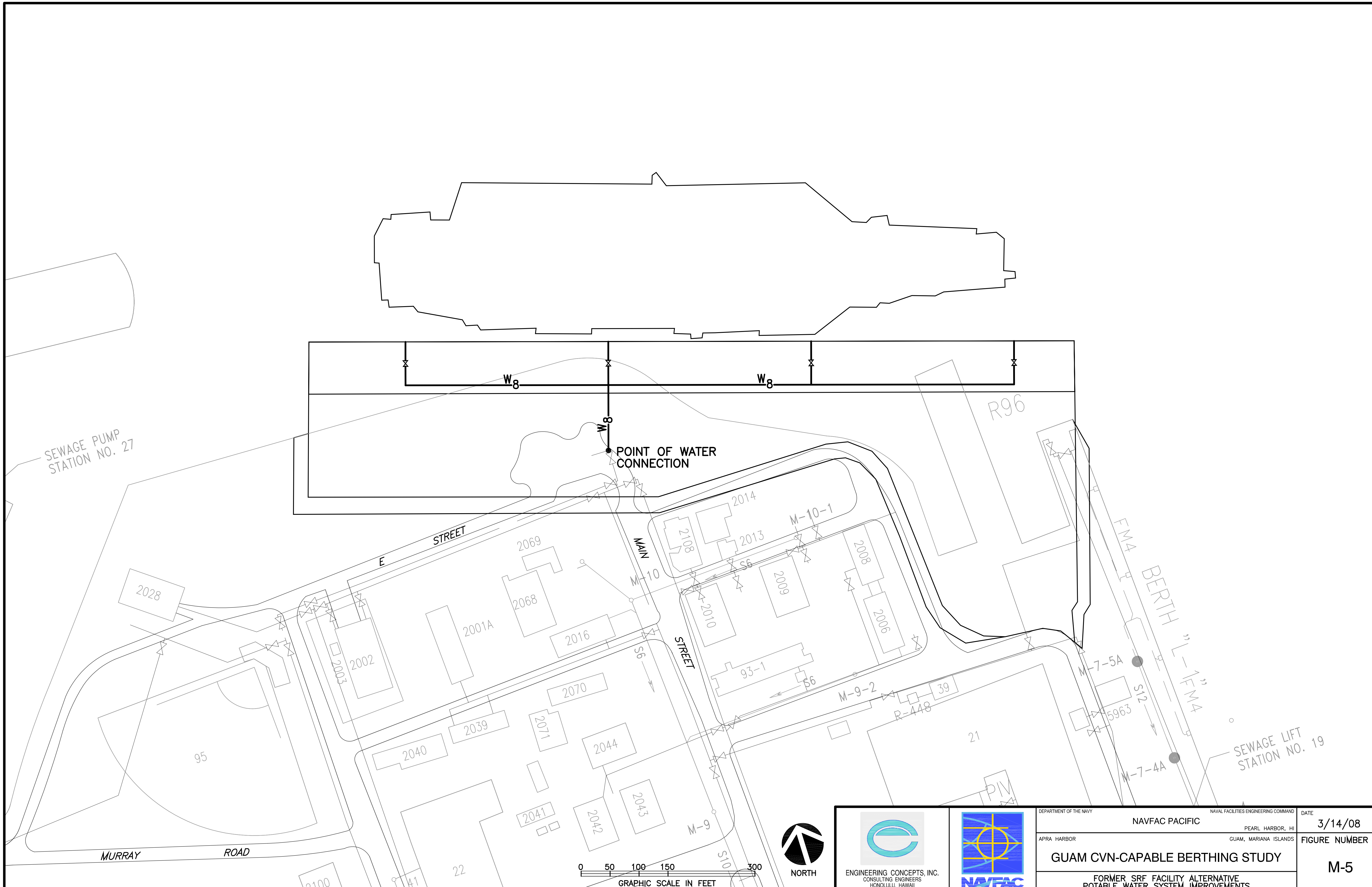

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FORMER SRF FACILITY ALTERNATIVE
POTABLE WATER SYSTEM IMPROVEMENTS

DATE 3/14/08

FIGURE NUMBER M-5

Mar 05, 2008-10:08am
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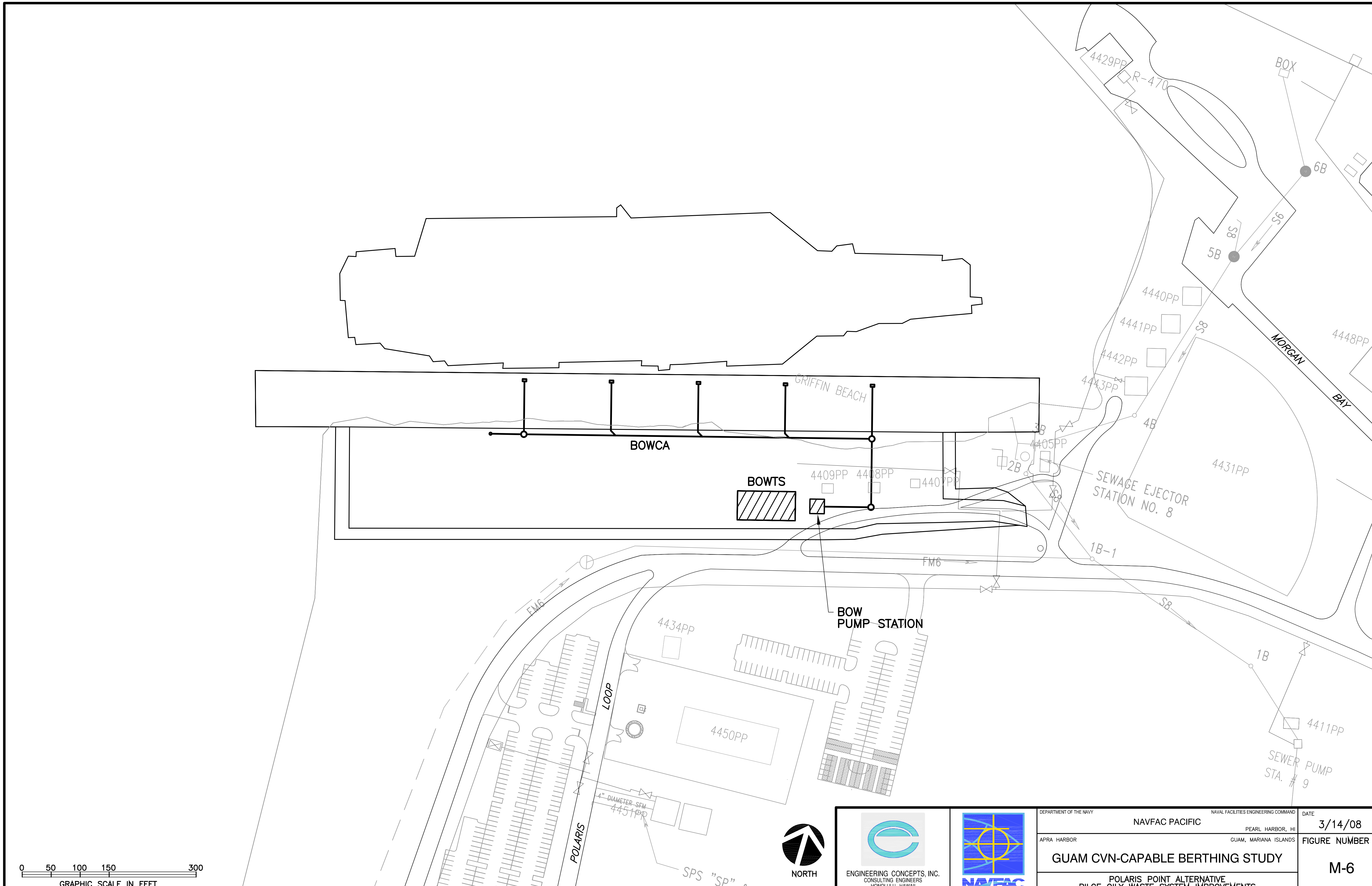

Mar 05, 2008-10:09am
N:\CAD\DWG\2007\0735-GUAM CVN BERTHING\FIGURES\fig-m6.dwg

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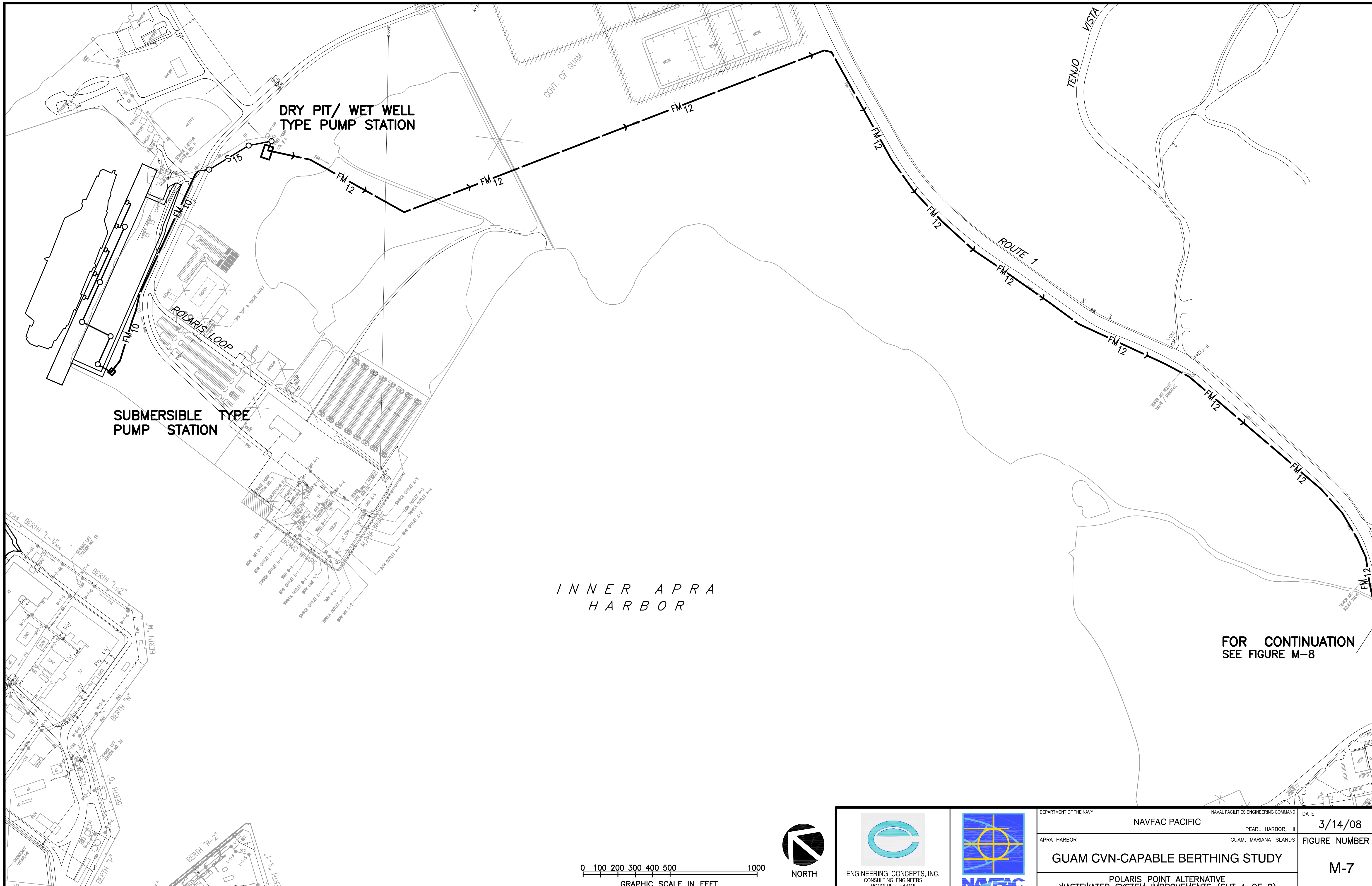
DEPARTMENT OF THE NAVY — NAVFAC PACIFIC — NAVAL FACILITIES ENGINEERING COMMAND, PEARL HARBOR, HI	DATE	3/14/08
APRA HARBOR — GUAM, MARIANA ISLANDS	FIGURE NUMBER	
GUAM CVN-CAPABLE BERTHING STUDY POLARIS POINT ALTERNATIVE BILGE OILY WASTE SYSTEM IMPROVEMENTS		M-6



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GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
WASTEWATER SYSTEM IMPROVEMENTS (SHT 1 OF 2)

DATE 3/14/08

FIGURE NUMBER M-7

Mar 05, 2008-10:10am
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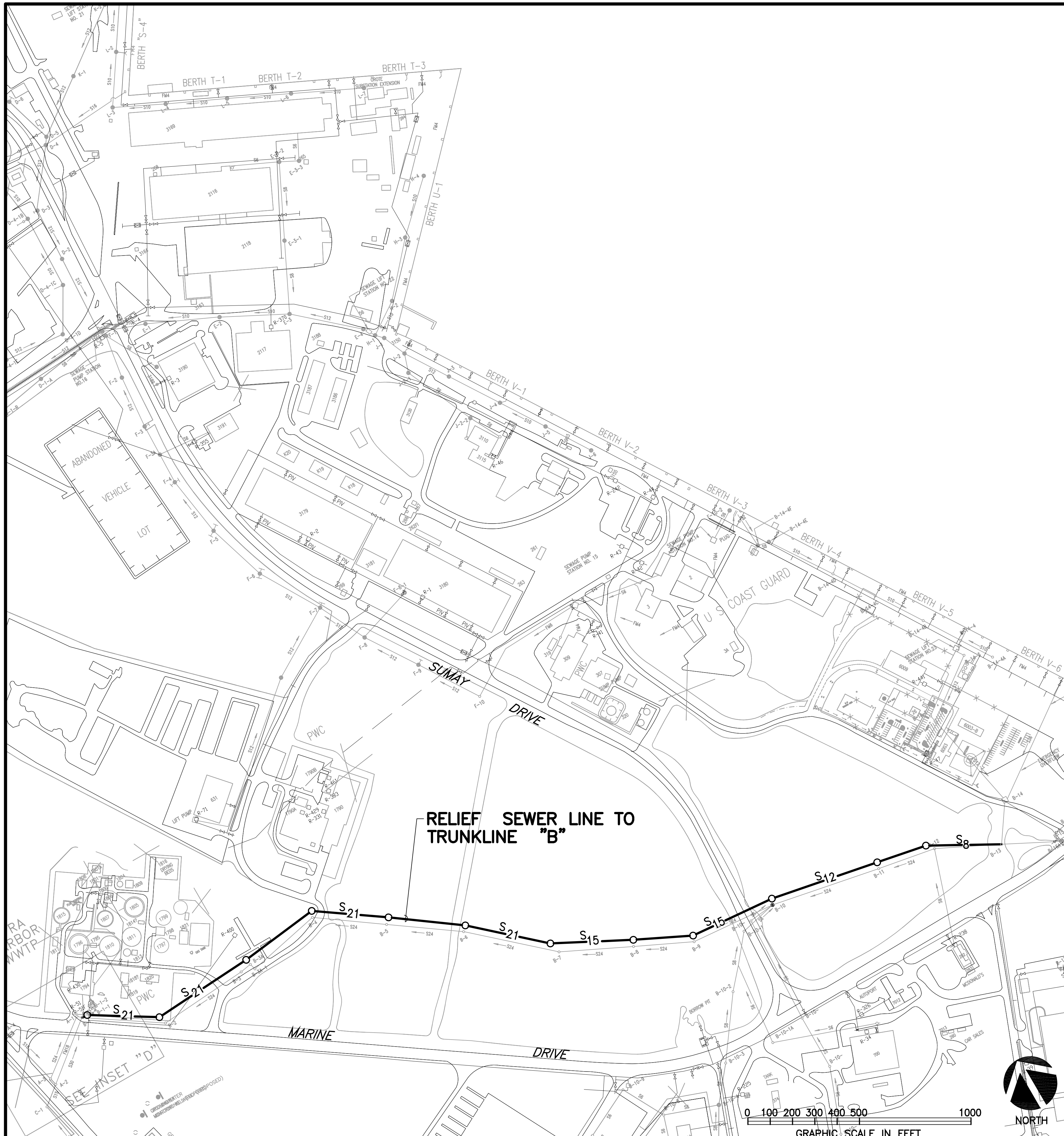

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GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
WASTEWATER SYSTEM IMPROVEMENTS (SHT 2 OF 2)

DATE 3/14/08

FIGURE NUMBER M-8

Mar 05, 2008-10:11am
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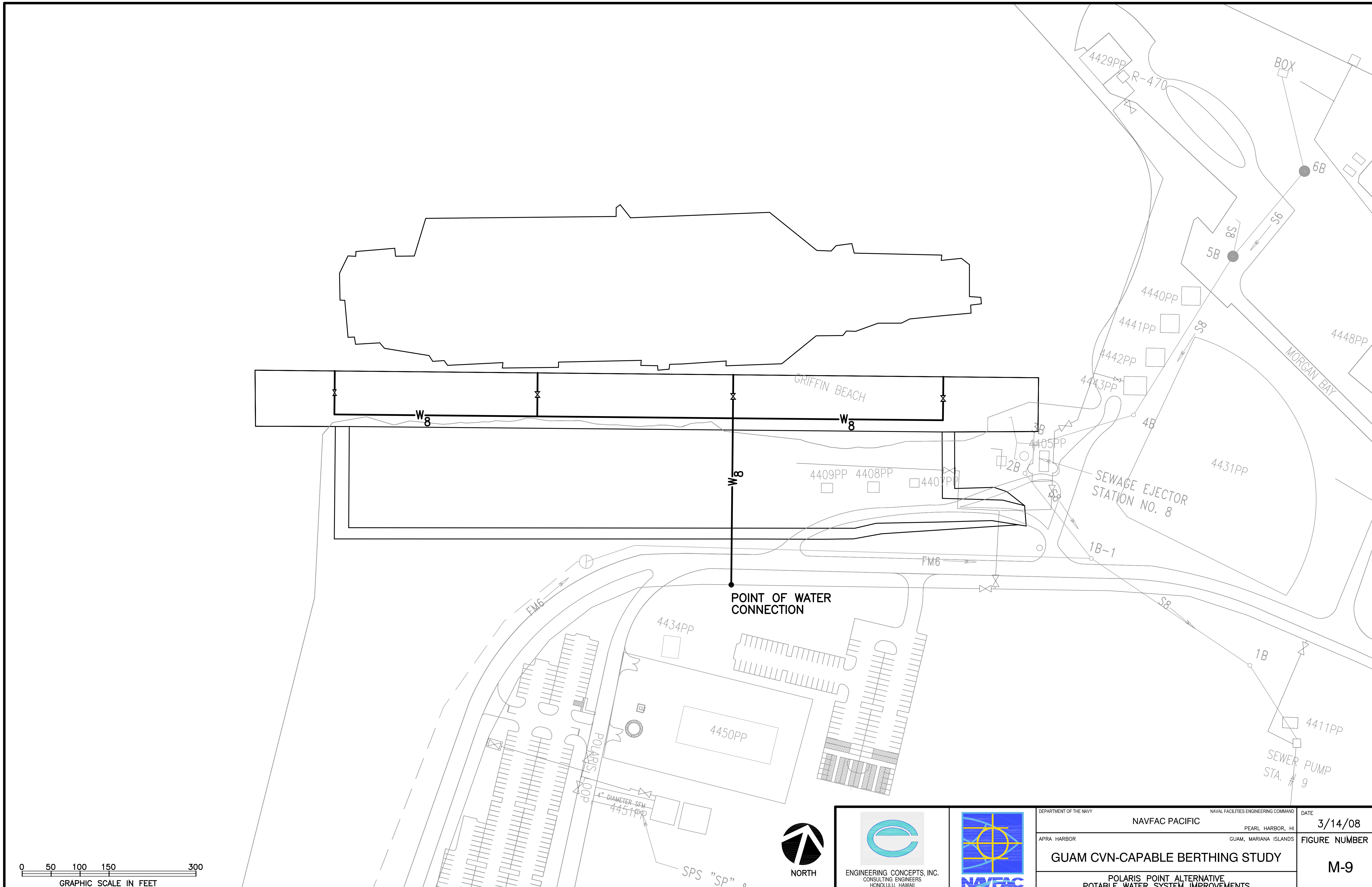

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GUAM CVN-CAPABLE BERTHING STUDY

POLARIS POINT ALTERNATIVE
POTABLE WATER SYSTEM IMPROVEMENTS

DATE 3/14/08

FIGURE NUMBER M-9

Mar 05, 2008-10:12am
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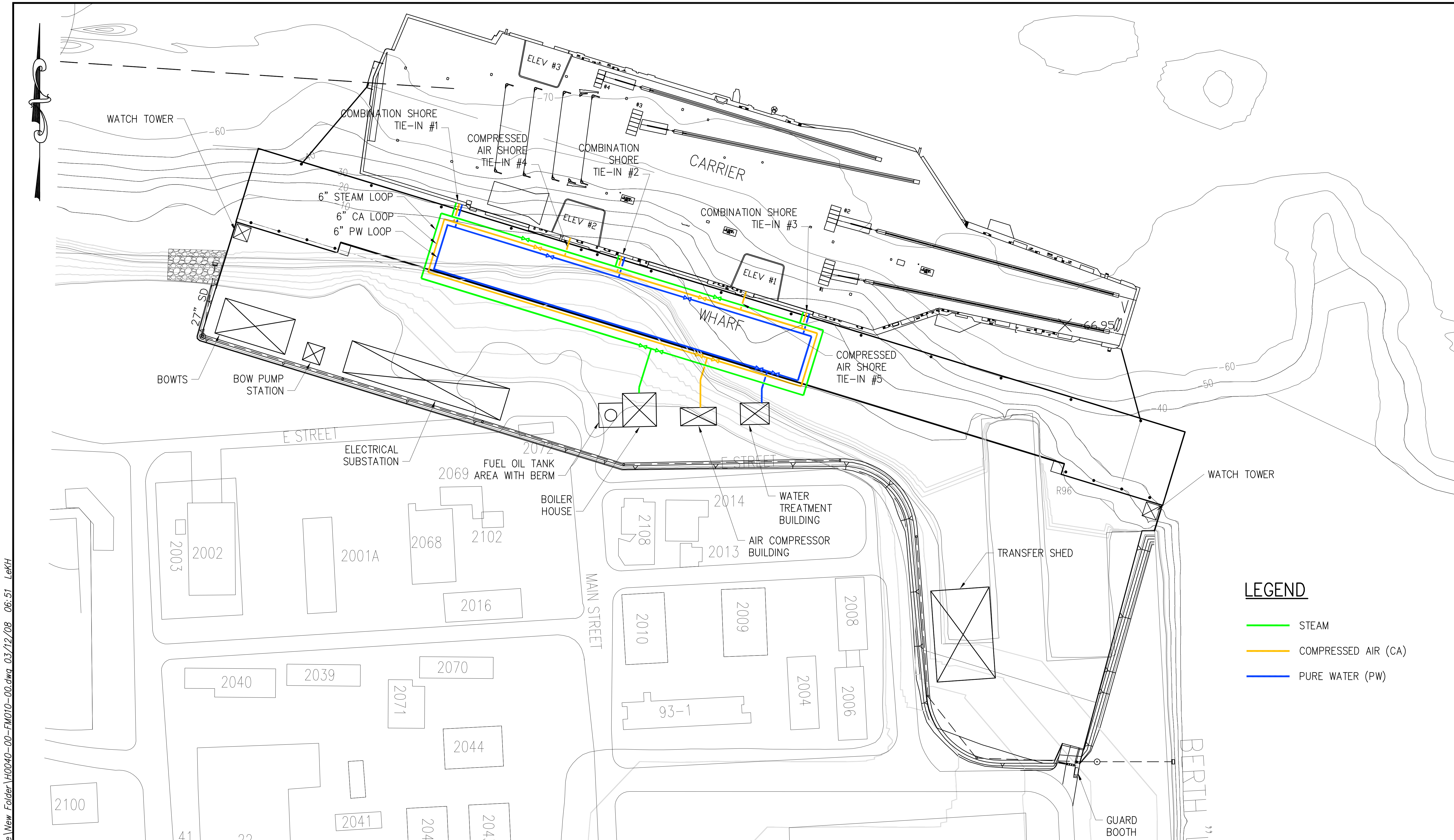

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ALTERNATIVE 1 – FORMER SRF FACILITY
STEAM, PURE WATER AND COMPRESSED AIR SYSTEM

DATE 03/14/08

FIGURE NUMBER M-10

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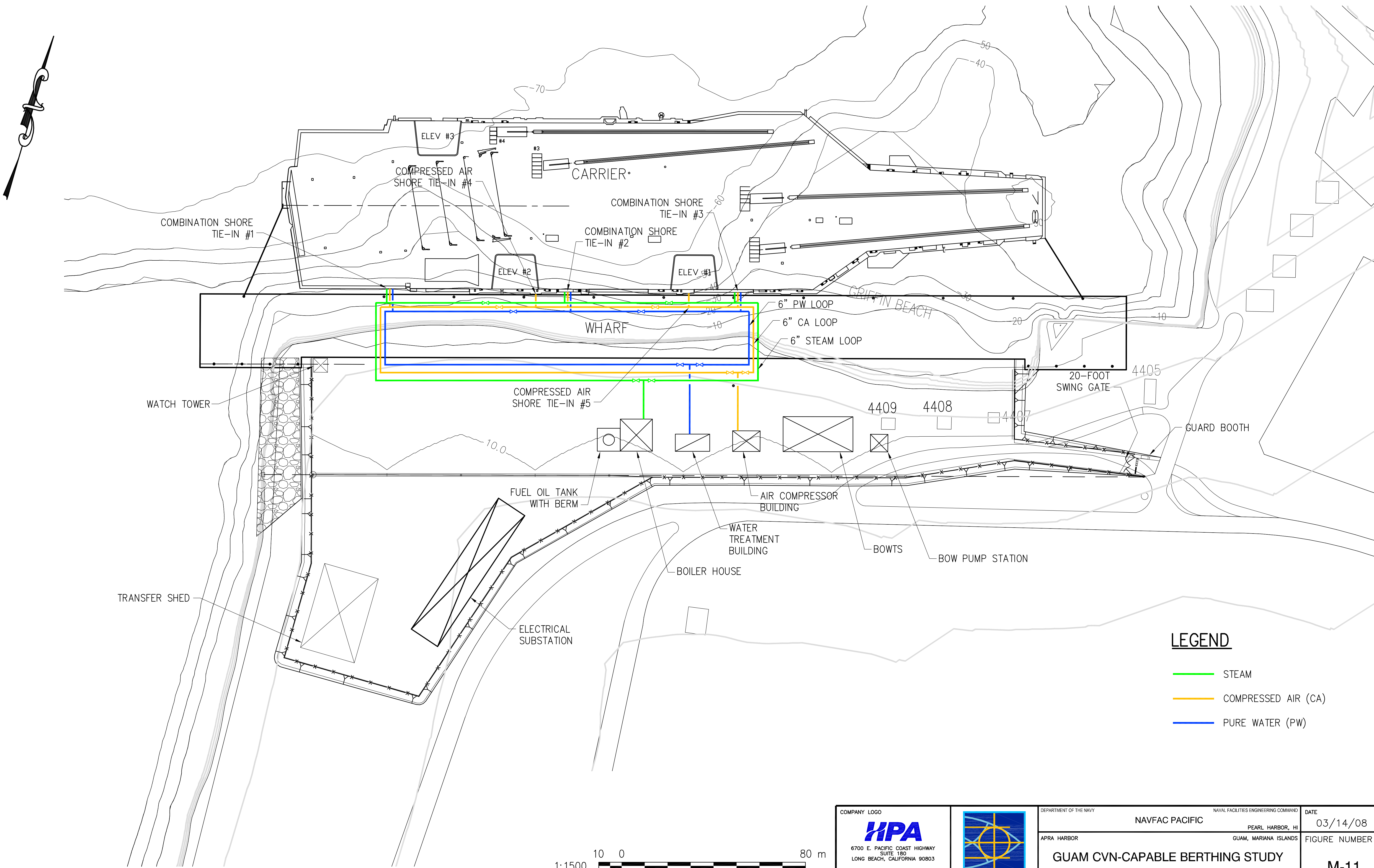

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ALTERNATIVE 2 – POLARIS POINT PARALLEL TO SHORE
STEAM, PURE WATER AND COMPRESSED AIR SYSTEM

DATE 03/14/08

FIGURE NUMBER M-11

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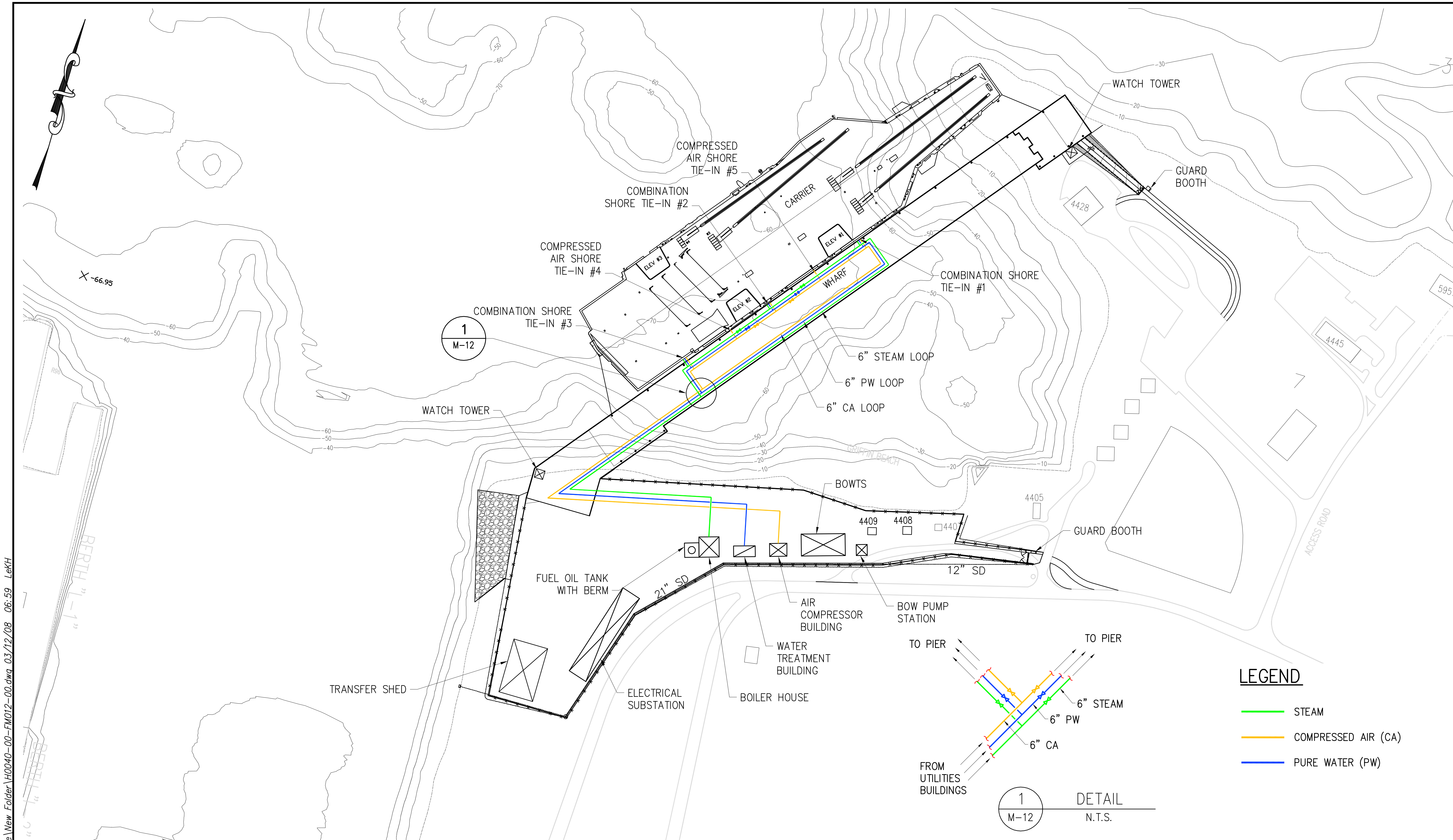

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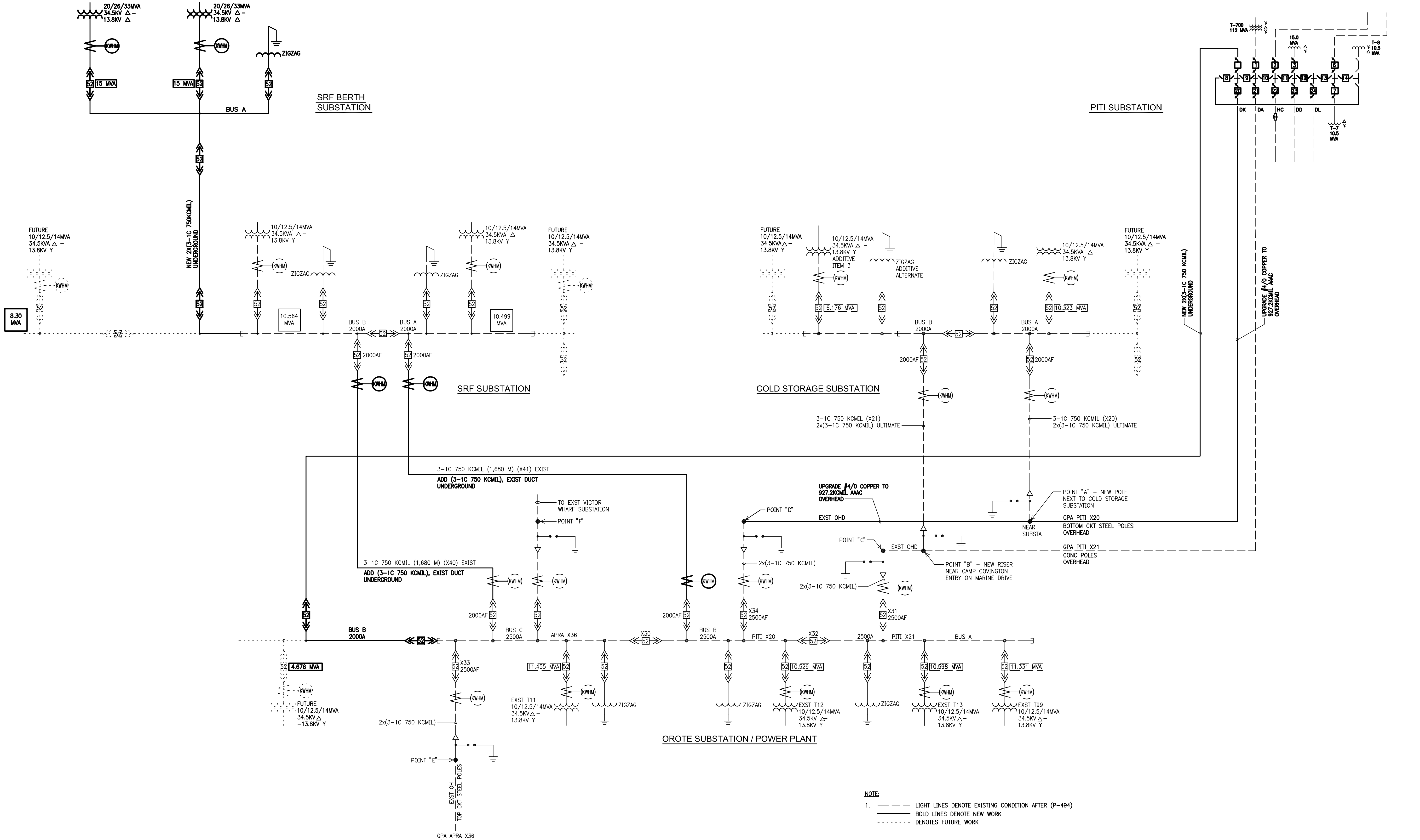
ALTERNATIVE 3 – POLARIS POINT DIAGNONAL OFFSHORE
STEAM, PURE WATER AND COMPRESSED AIR SYSTEM

DATE 3/14/08

FIGURE NUMBER M-12

1 ALTERNATIVE 1 – SRF BERTH ELECTRICAL SITE PLAN
NO SCALE

COMPANY LOGO: CONSULTING ELECTRICAL ENGINEERS	NAVFAC	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
		APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 1 – SRF BERTH ELECTRICAL SITE PLAN	FIGURE NUMBER E-1A



NOTE:

1. — — — LIGHT LINES DENOTE EXISTING CONDITION AFTER (P-494)
——— BOLD LINES DENOTE NEW WORK
- - - - - DENOTES FUTURE WORK

1 ALTERNATIVE 1 – SRF BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM

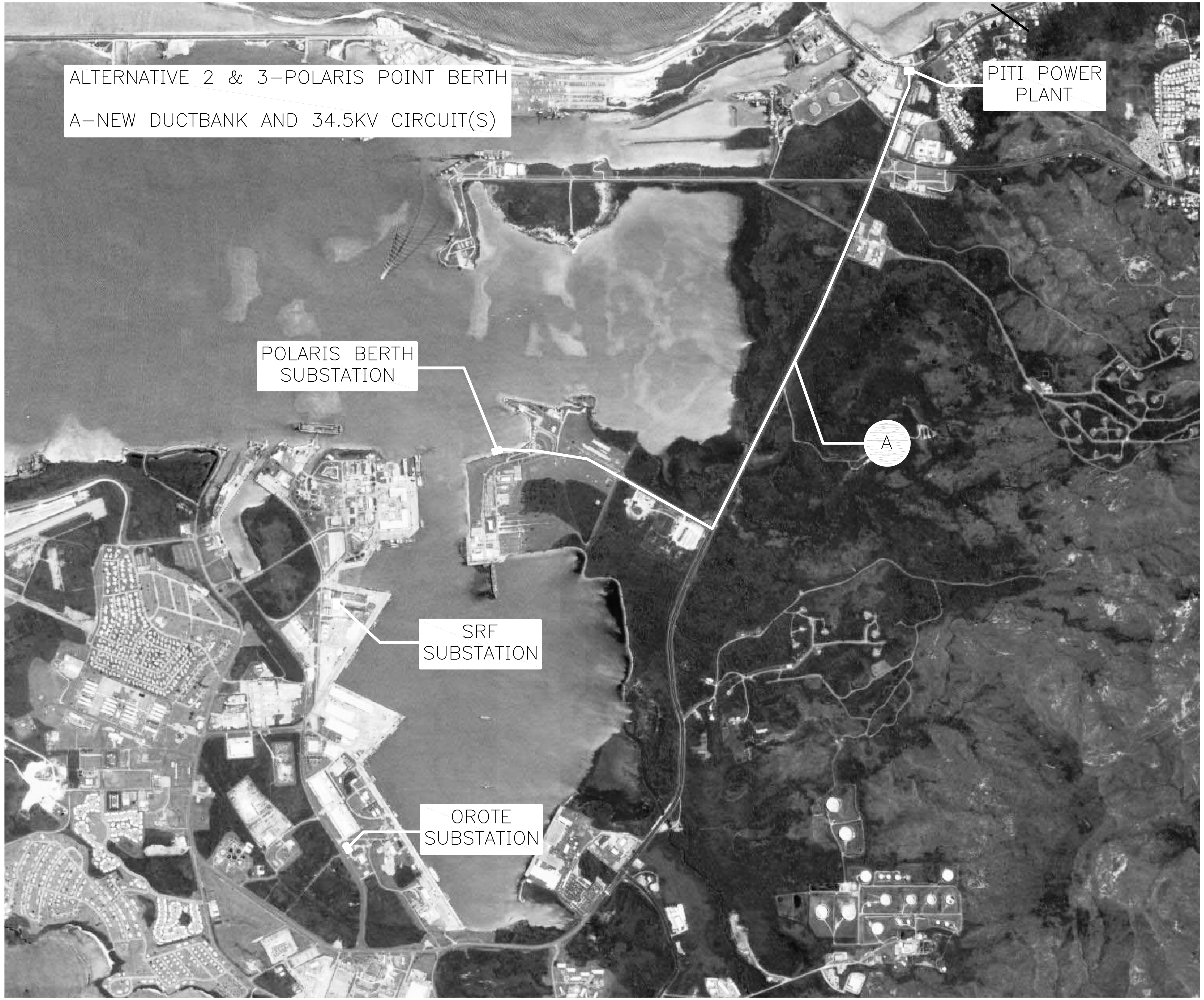
NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 1 – SRF BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM	FIGURE NUMBER E-1B

1 ALTERNATIVE 1 – SRF BERTH COMMUNICATIONS SYSTEM SITE PLAN

NO SCALE

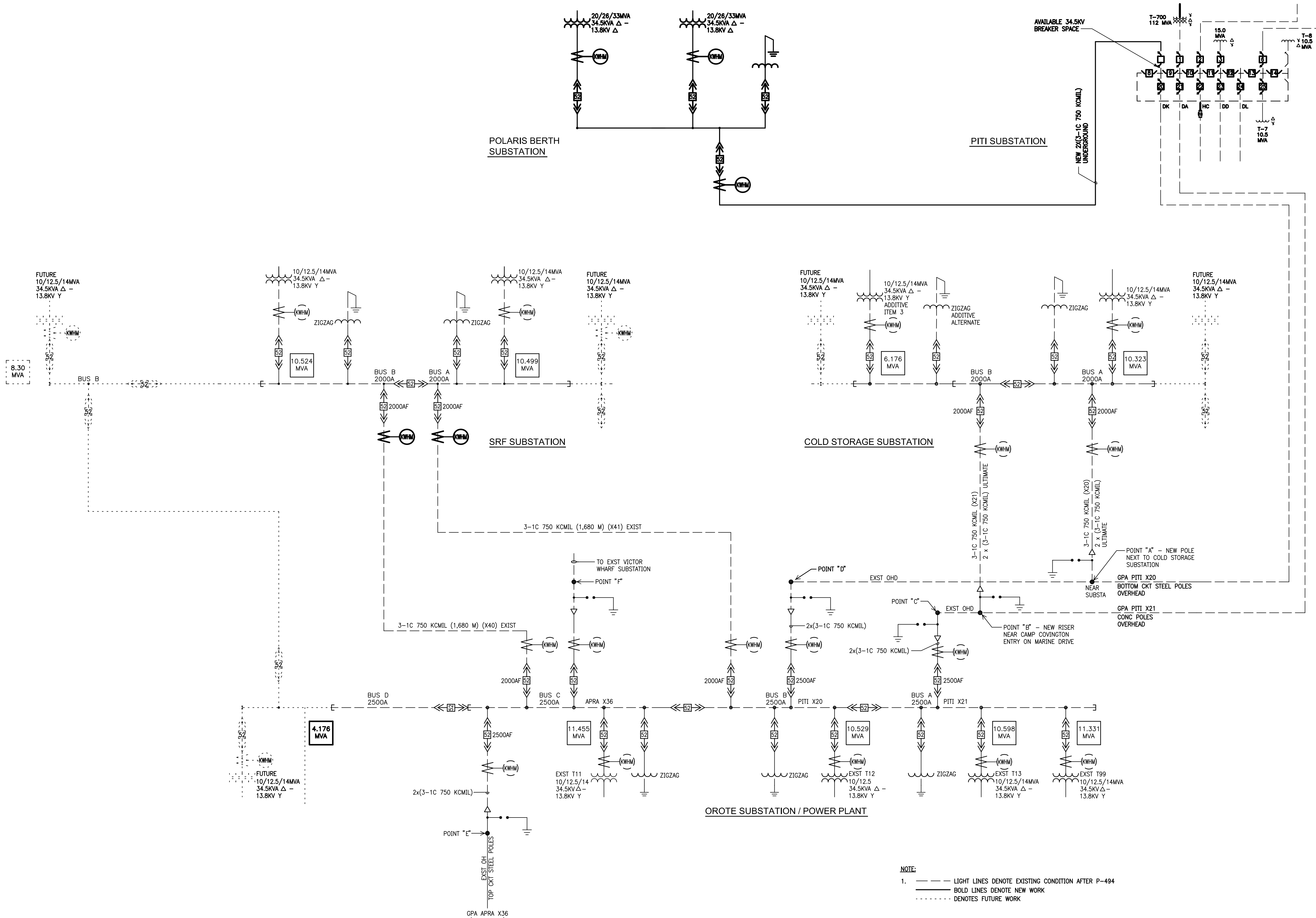
COMPANY LOGO	NAVFAC	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS		APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 1 – SRF BERTH COMMUNICATIONS SYSTEM SITE PLAN	FIGURE NUMBER E-1C



1 ALTERNATIVE 2 & 3 – POLARIS POINT BERTH ELECTRICAL SITE PLAN

NO SCALE

COMPANY LOGO	DEPARTMENT OF THE NAVY — NAVFAC PACIFIC — NAVAL FACILITIES ENGINEERING COMMAND, PEARL HARBOR, HI		DATE 03/14/08
	APRA HARBOR — GUAM, MARIANA ISLANDS		FIGURE NUMBER
	GUAM CVN-CAPABLE BERTHING STUDY		E-2A
	ALTERNATIVE 2 & 3 – POLARIS POINT BERTH ELECTRICAL SITE PLAN		



1 ALTERNATIVE 2 & 3 – POLARIS POINT BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM

NO SCALE

COMPANY LOGO

CONSULTING ELECTRICAL ENGINEERS

NAVFAC

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

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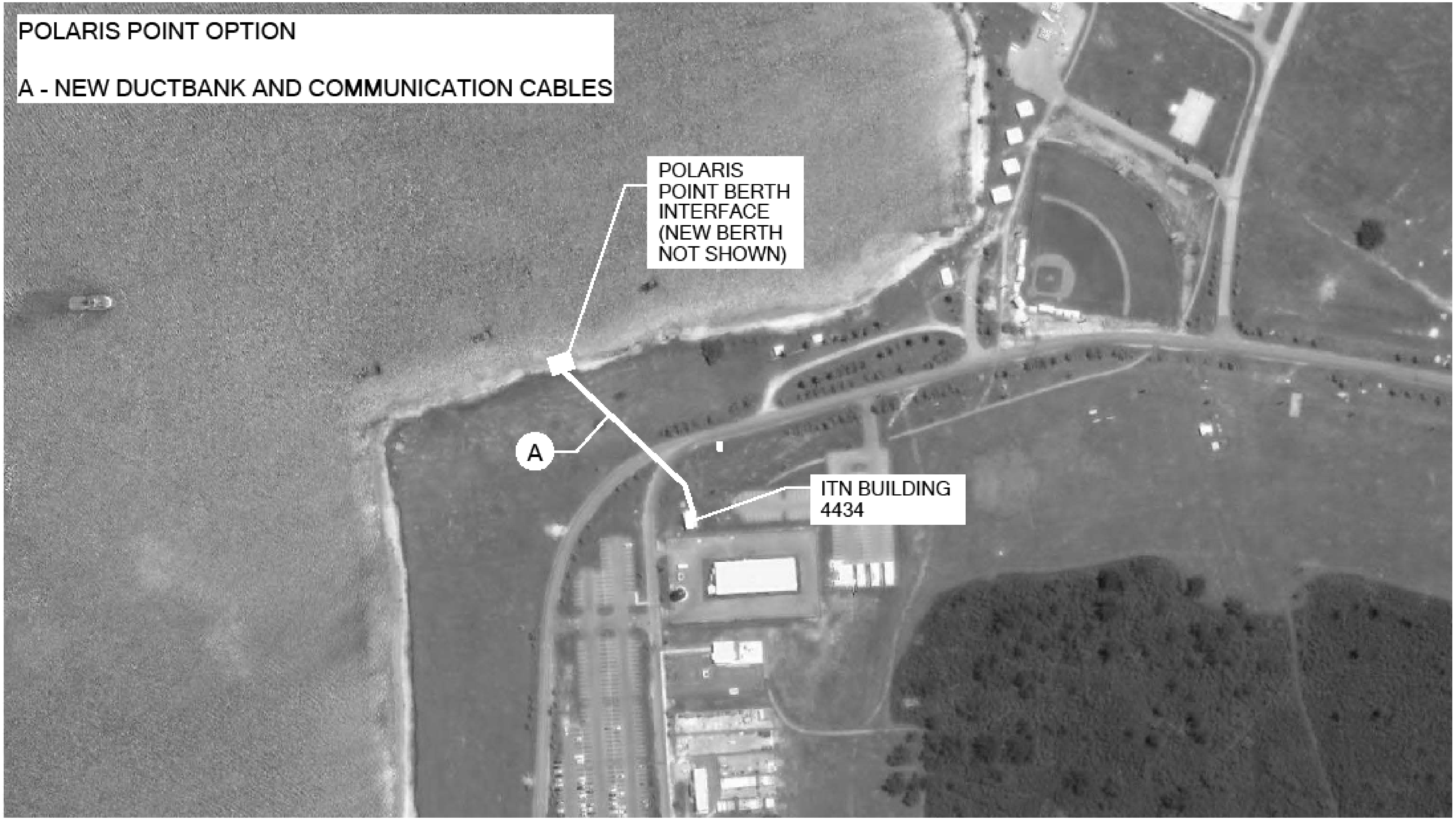
APRA HARBOR — GUAM, MARIANA ISLANDS

GUAM CVN-CAPABLE BERTHING STUDY

ALTERNATIVE 2 & 3 – POLARIS POINT BERTH 34.5KV SYSTEM ONE-LINE DIAGRAM

DATE 03/14/08

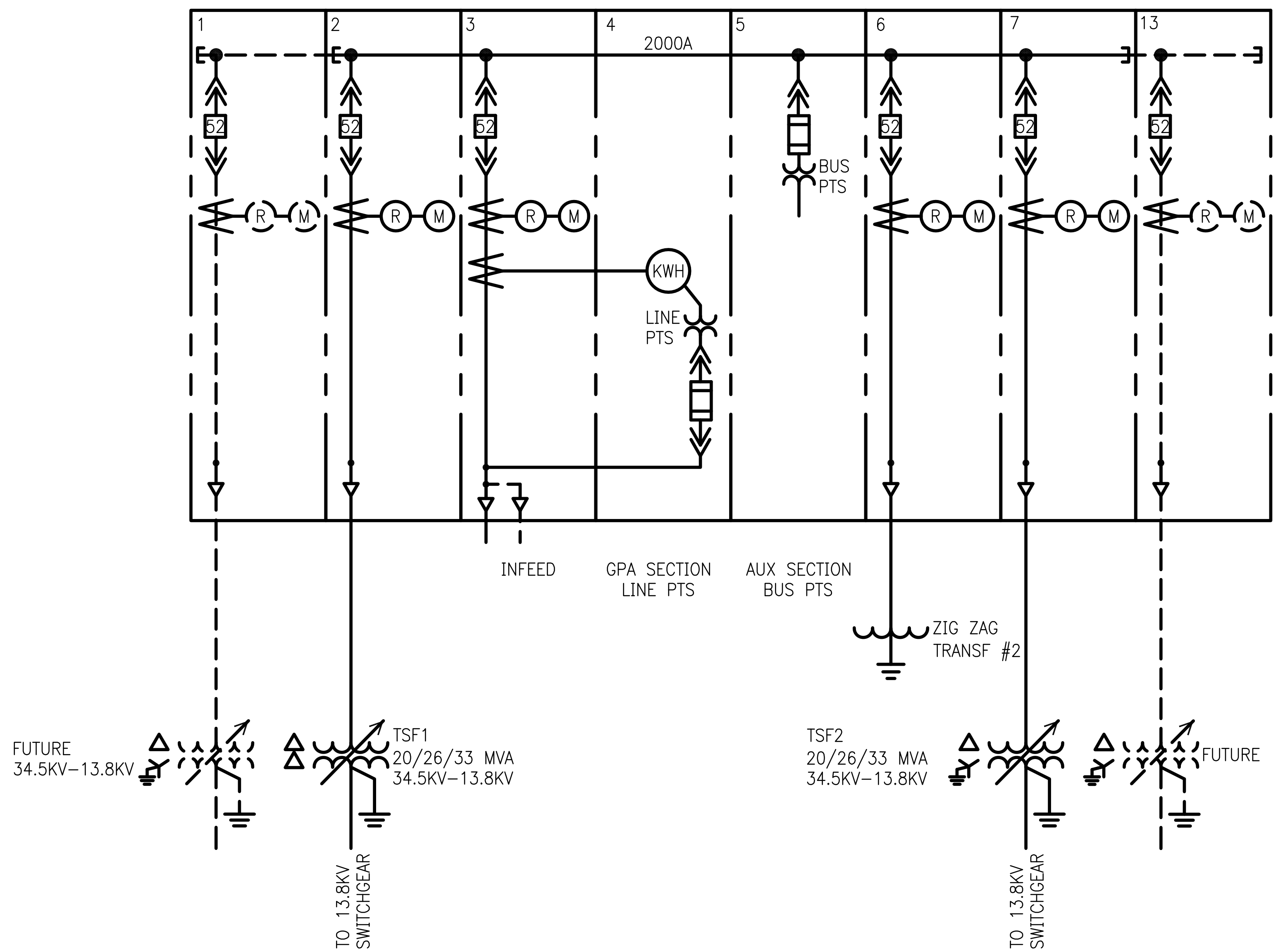
FIGURE NUMBER E-2B



1 ALTERNATIVE 2 & 3 – POLARIS POINT BERTH COMMUNICATIONS SYSTEM SITE PLAN

NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
		APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY ALTERNATIVE 2 & 3 – POLARIS POINT BERTH COMMUNICATIONS SYSTEM SITE PLAN	FIGURE NUMBER E-2C



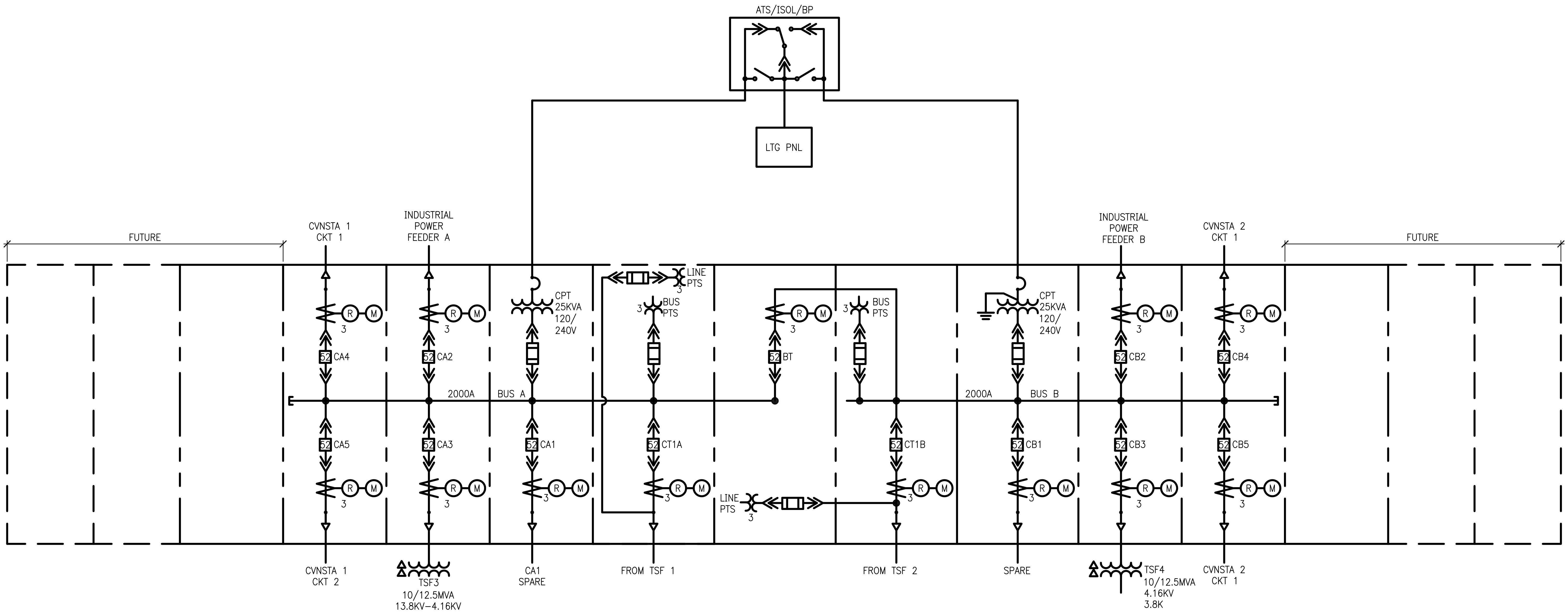
NOTES:

1. ——— BOLD LINES DENOTE NEW WORK
   – – – – DENOTES FUTURE WORK

2. CTS WILL BE MULTI–RATIO; CTS FOR KWHM'S SHALL BE REVENUE GRADE.

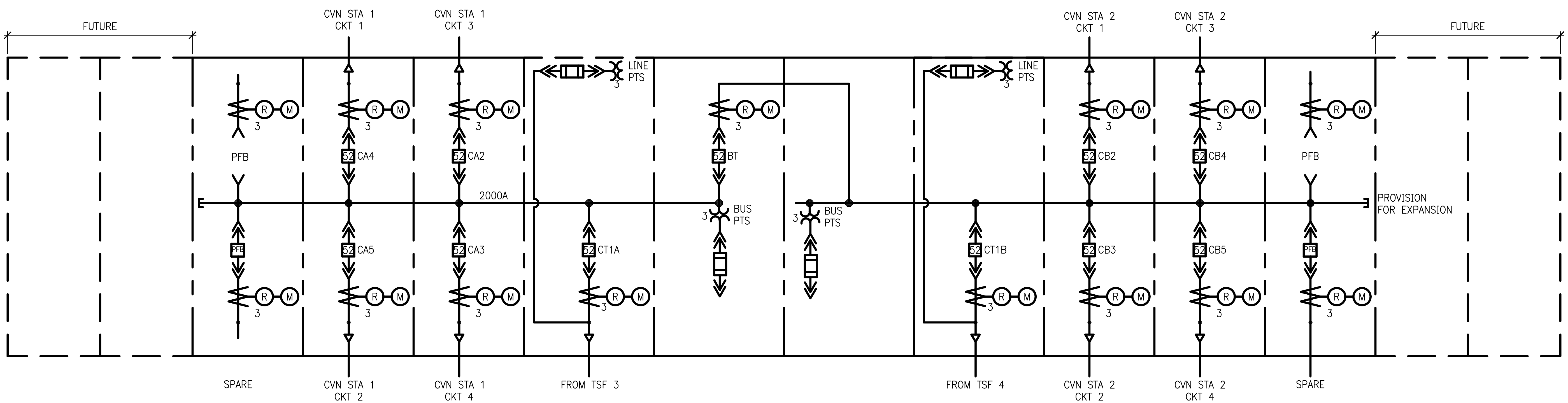
1 BERTH SUBSTATION
34.5KV SWITCHGEAR ONE–LINE DIAGRAM
NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY — NAVFAC PACIFIC — NAVAL FACILITIES ENGINEERING COMMAND, PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION 34.5KV SWITCHGEAR ONE–LINE DIAGRAM	FIGURE NUMBER E-3



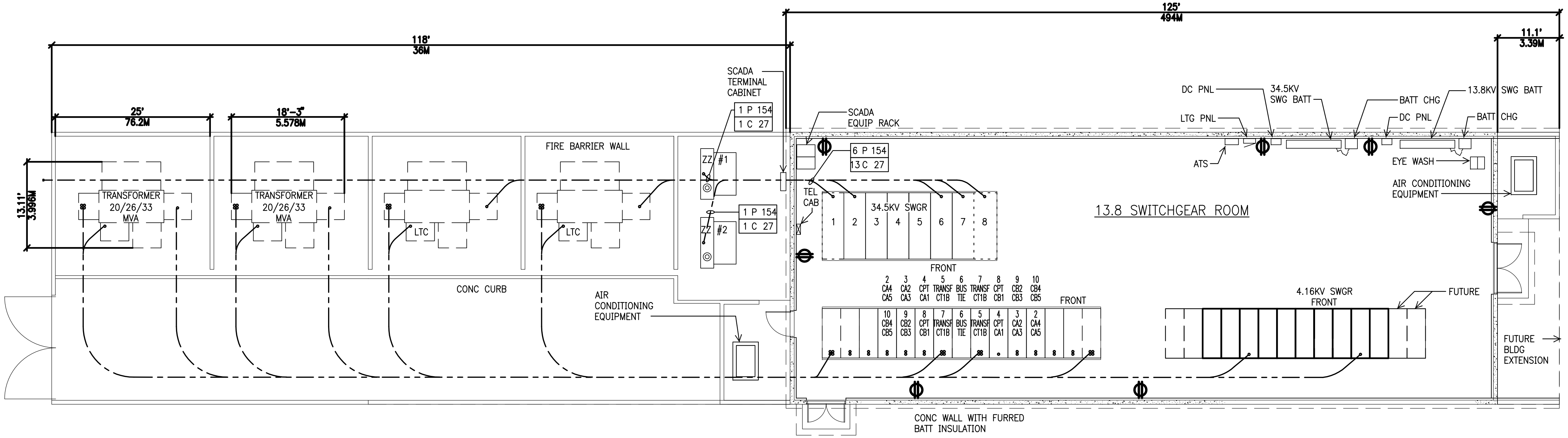
1 BERTH SUBSTATION
13.8KV SWITCHGEAR ONE–LINE DIAGRAM
NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION 13.8KV SWITCHGEAR ONE–LINE DIAGRAM	FIGURE NUMBER E-4



1 BERTH SUBSTATION
4.16KV SWITCHGEAR ONE-LINE DIAGRAM
NO SCALE

COMPANY LOGO	DEPARTMENT OF THE NAVY / NAVAL FACILITIES ENGINEERING COMMAND NAVFAC PACIFIC PEARL HARBOR, HI		DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	APRA HARBOR / GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION 4.16KV SWITCHGEAR ONE-LINE DIAGRAM	NAVFAC	FIGURE NUMBER E-5



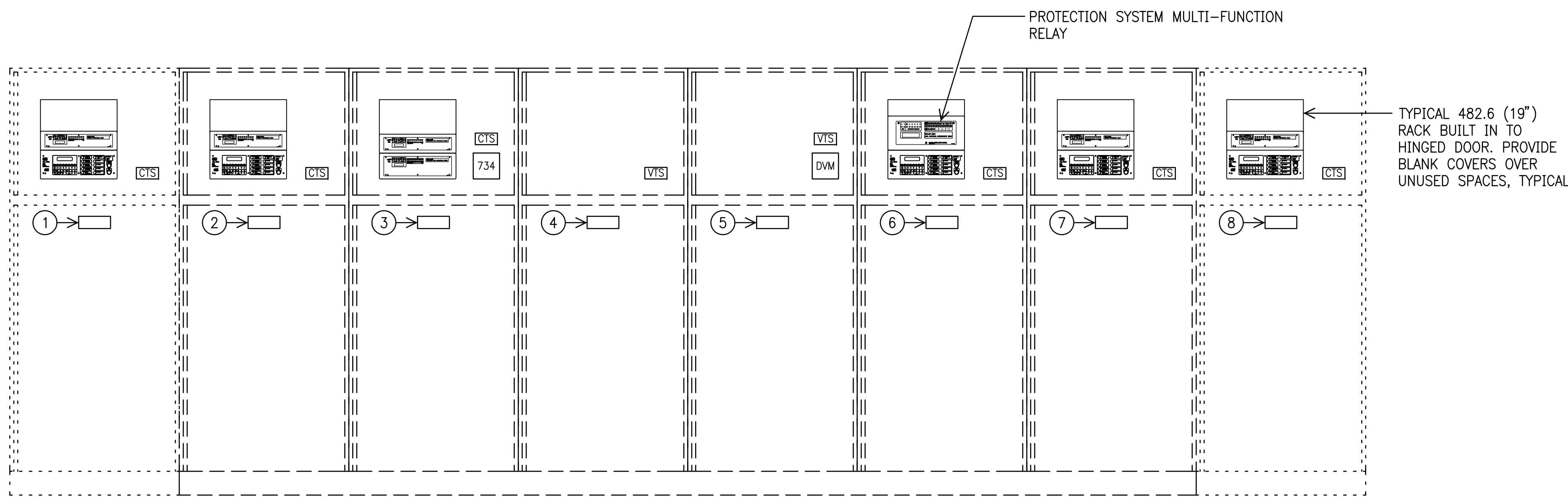
GRAPHIC SCALE

0 5 10 15 20 25 m

1:250

(1) BERTH SUBSTATION BUILDING ELECTRICAL EQUIPMENT PLAN
NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY — NAVFAC PACIFIC — NAVAL FACILITIES ENGINEERING COMMAND, PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	APRA HARBOR — GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION BUILDING ELECTRICAL EQUIPMENT PLAN	FIGURE NUMBER E-6



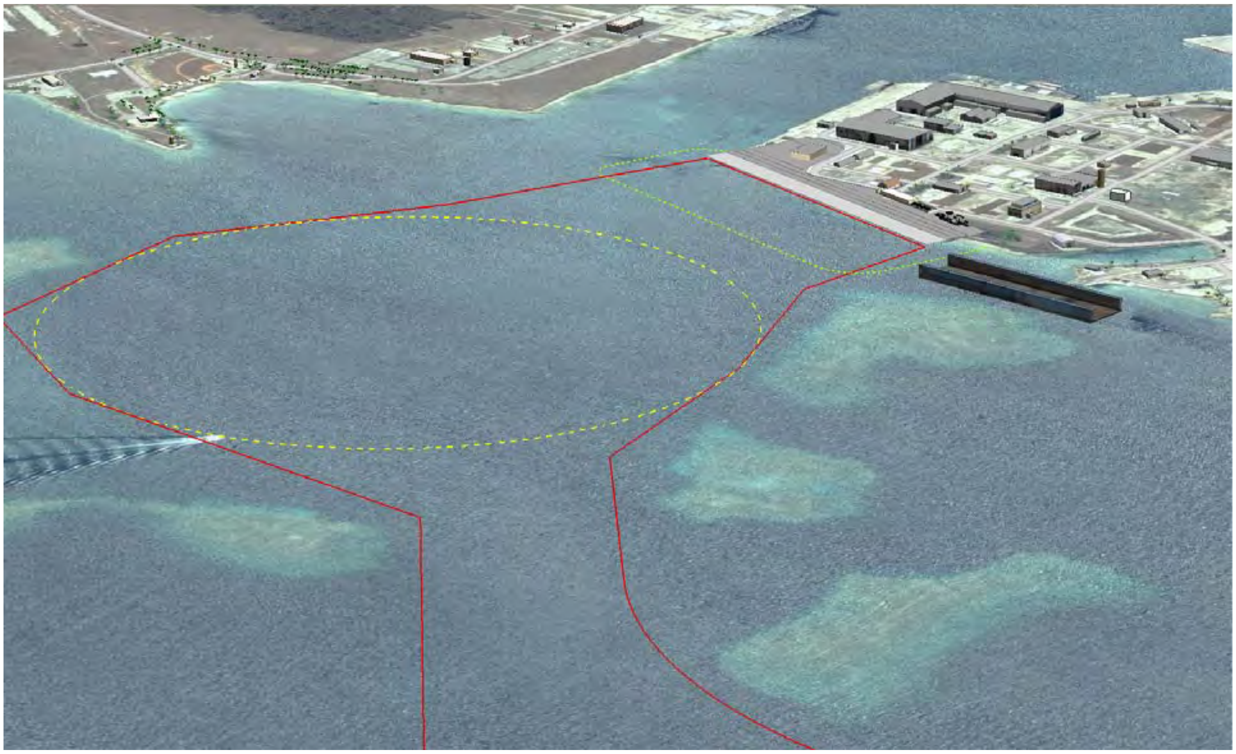
1 BERTH SUBSTATION 34.5KV SWITCHGEAR ELEVATION
NO SCALE

COMPANY LOGO		DEPARTMENT OF THE NAVY NAVFAC PACIFIC NAVAL FACILITIES ENGINEERING COMMAND PEARL HARBOR, HI	DATE 03/14/08
CONSULTING ELECTRICAL ENGINEERS	NAVFAC	APRA HARBOR GUAM, MARIANA ISLANDS GUAM CVN-CAPABLE BERTHING STUDY BERTH SUBSTATION 34.5KV SWITCHGEAR ELEVATION	FIGURE NUMBER E-7

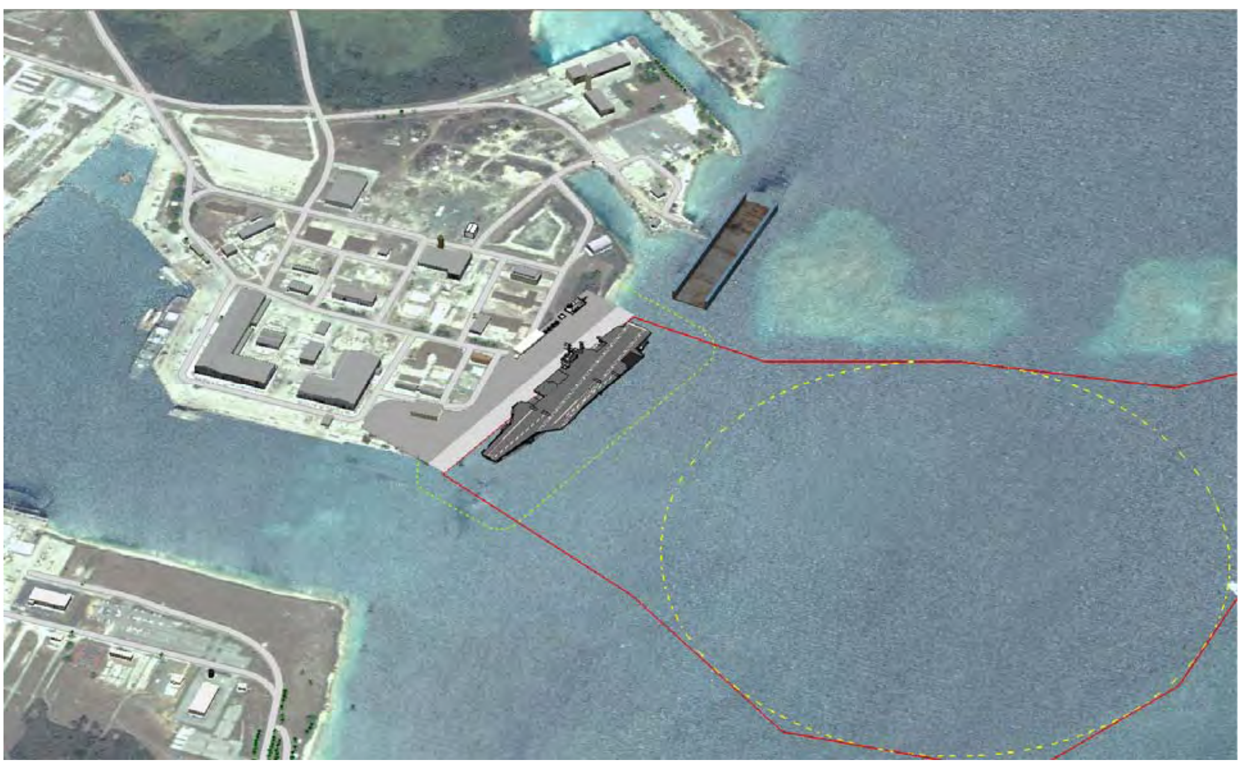
APPENDIX A

3D ANIMATIONS (CD Enclosed)
AND 3D MODEL IMAGES

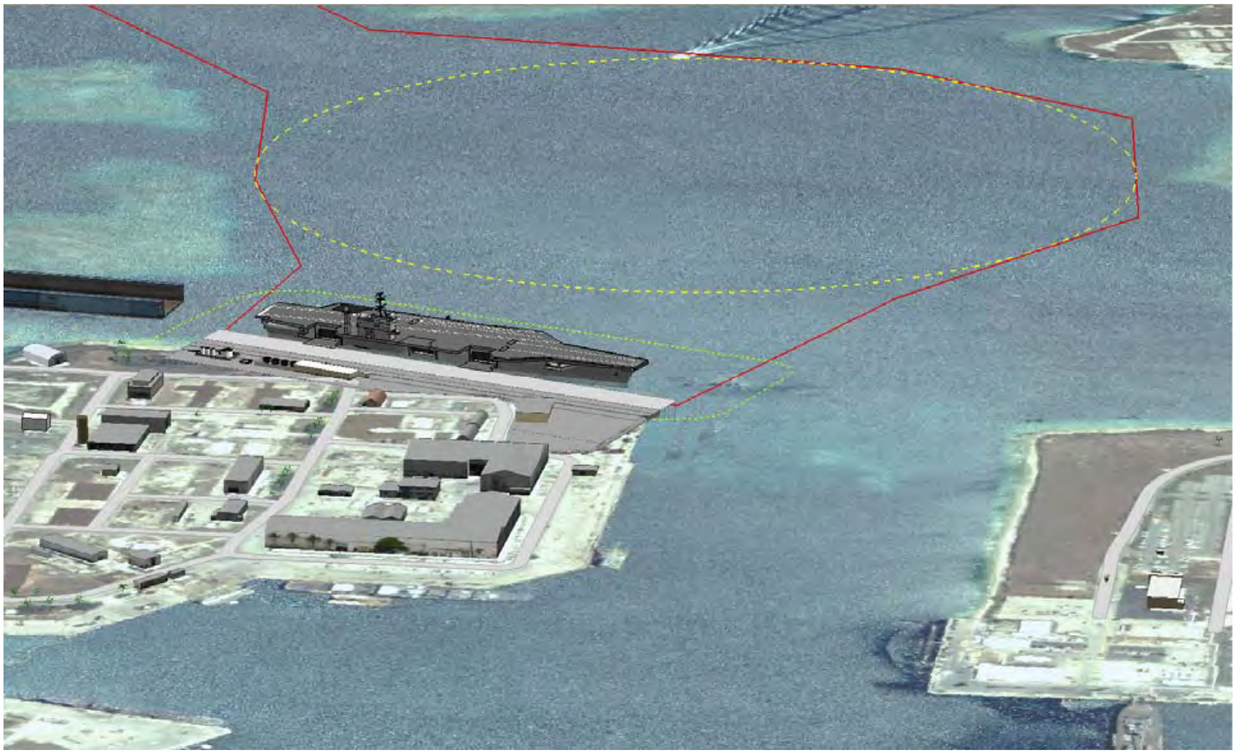
Alternative 1 – Former SRF

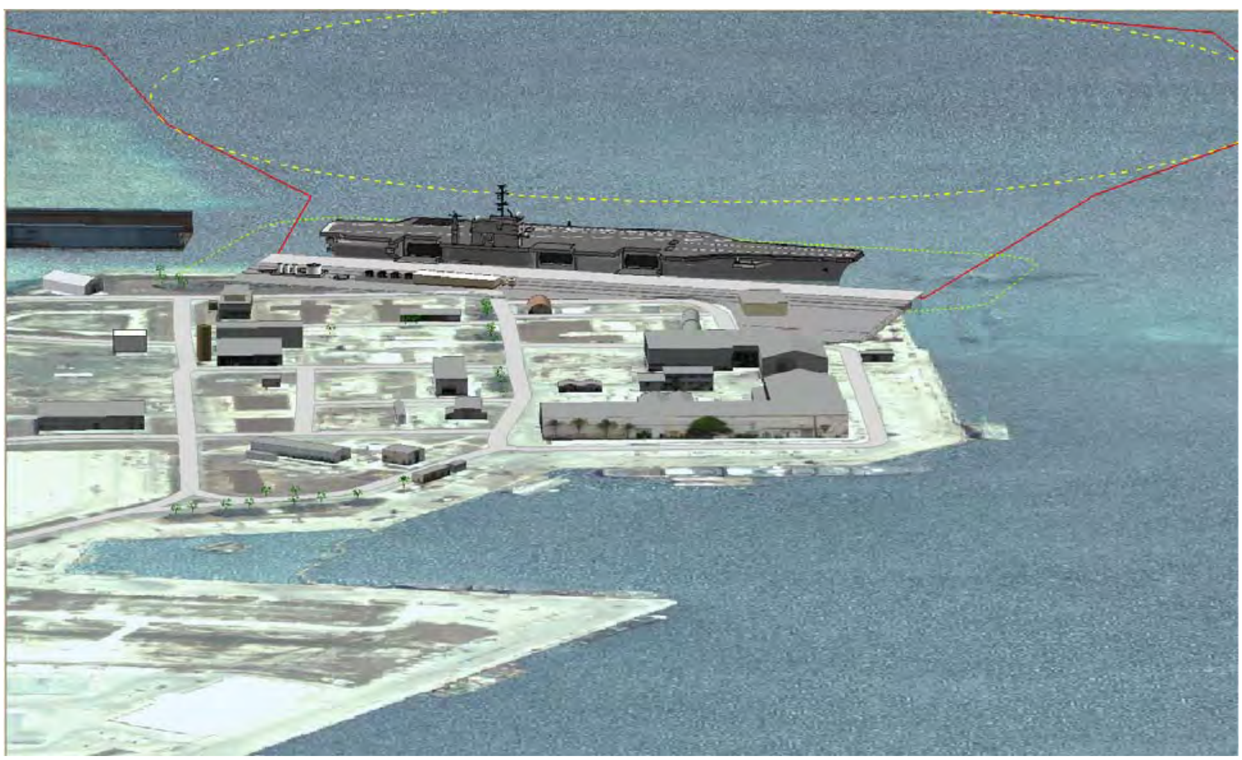


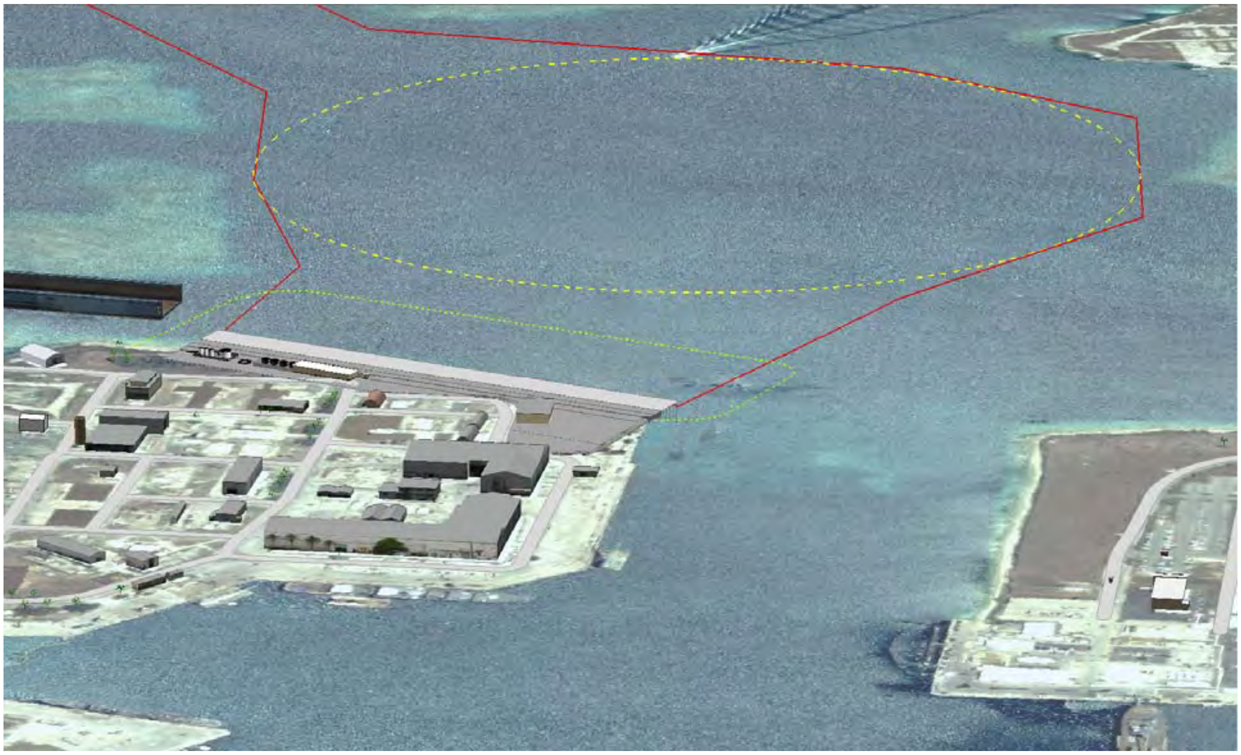
Alternative 1 – Image 1



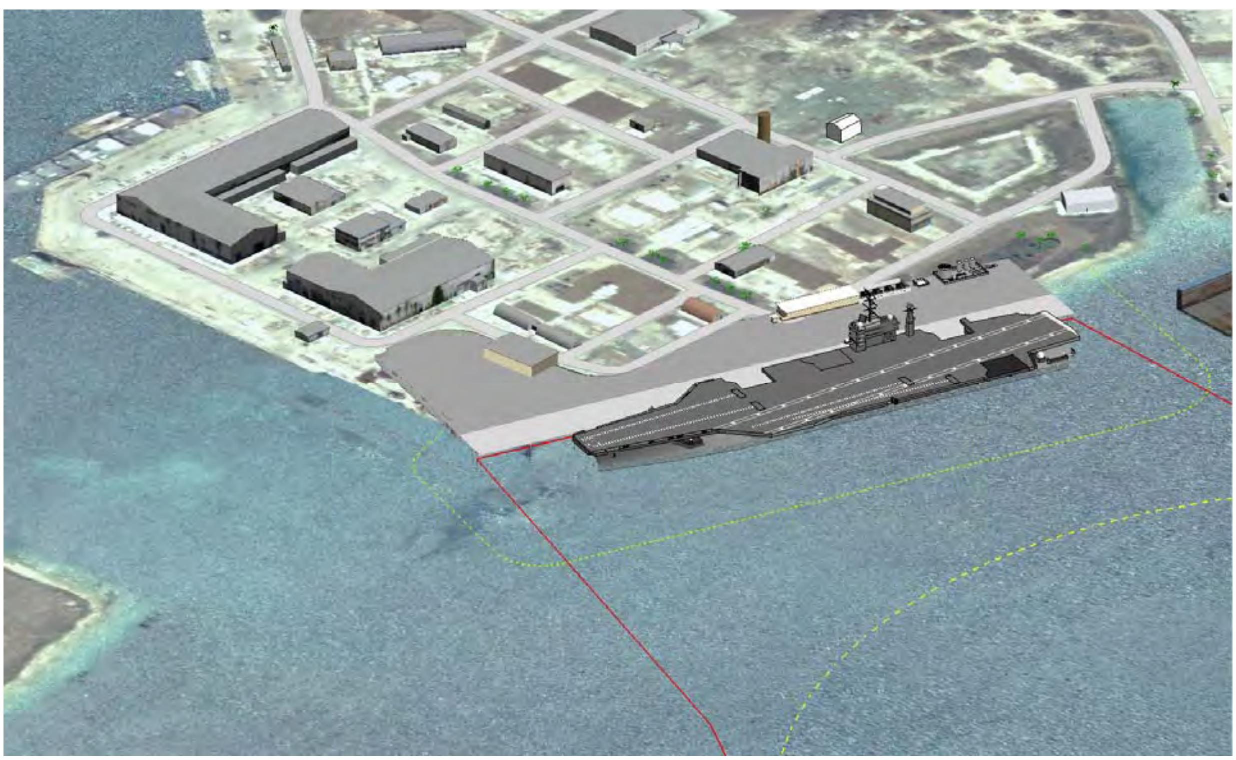
Alternative 1 – Image 2


Alternative 1 – Image 3


Alternative 1 – Image 4



Alternative 1 – Image 5

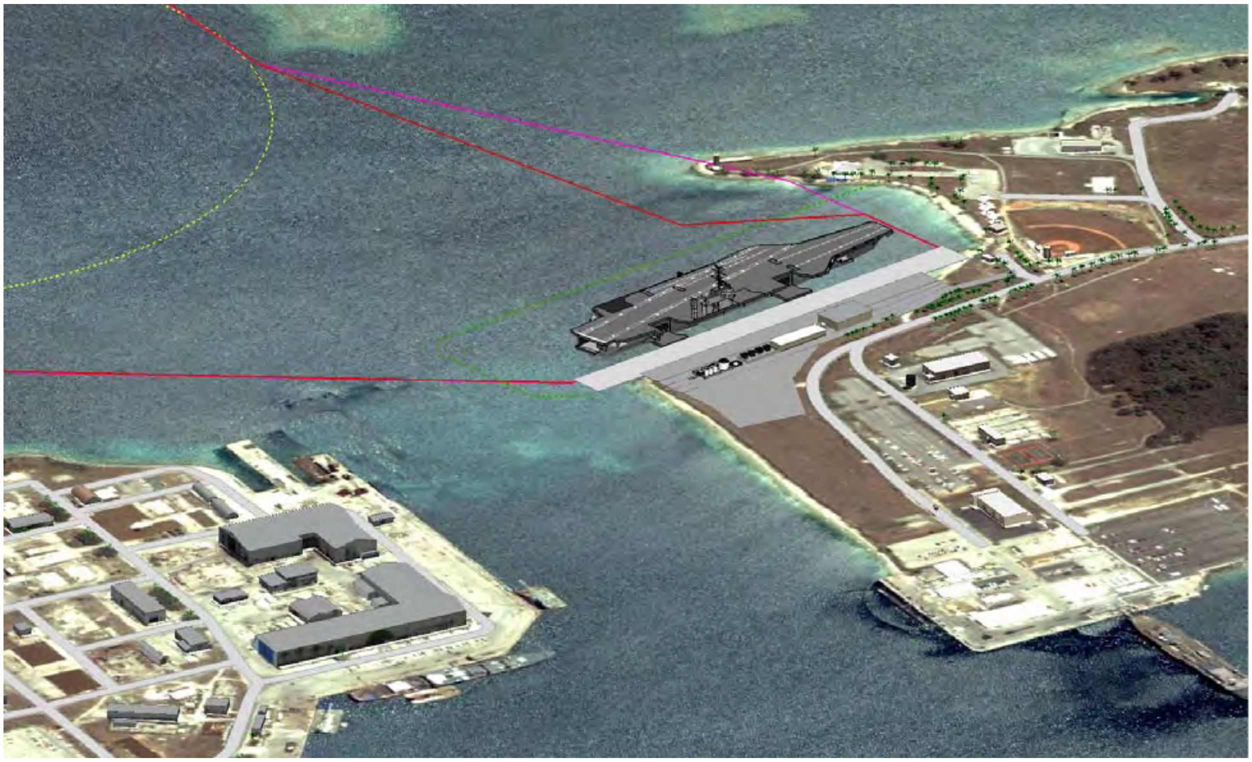


Alternative 1 – Image 6

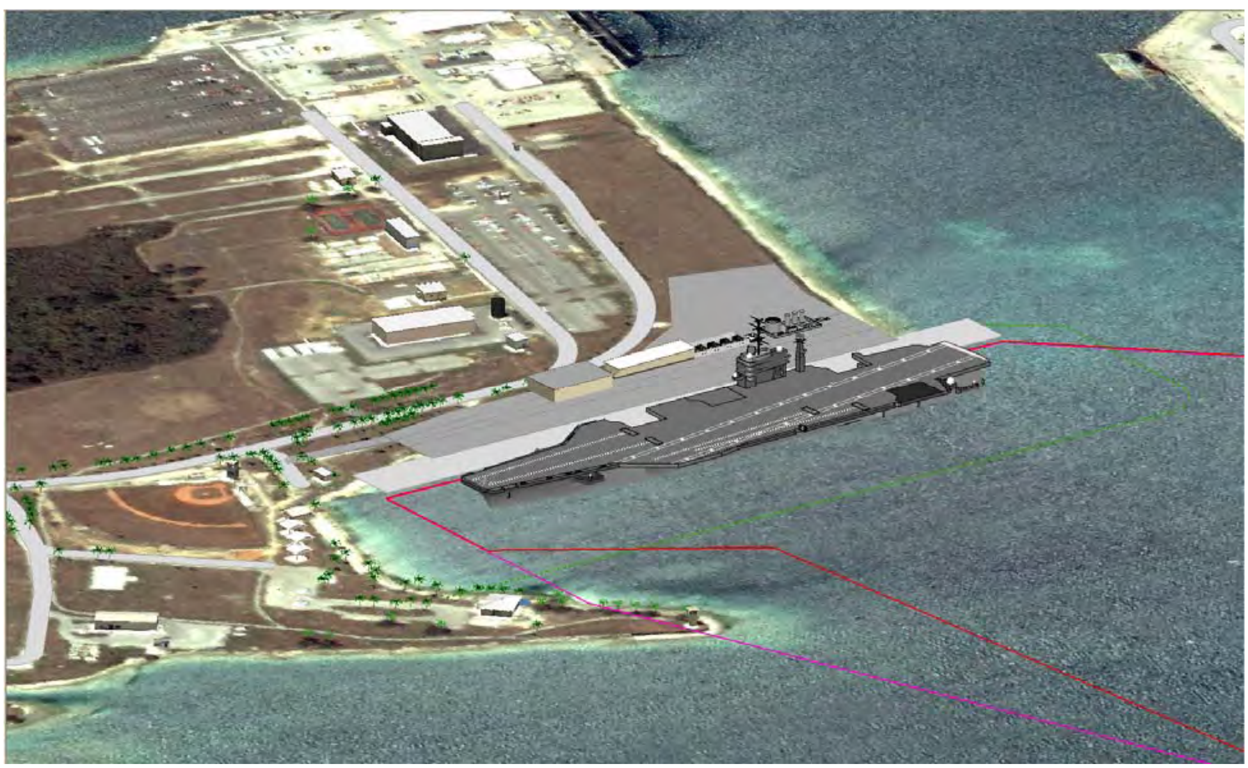
Alternative 2 – Polaris Point Parallel to Shore

Alternative 2 – Image 1

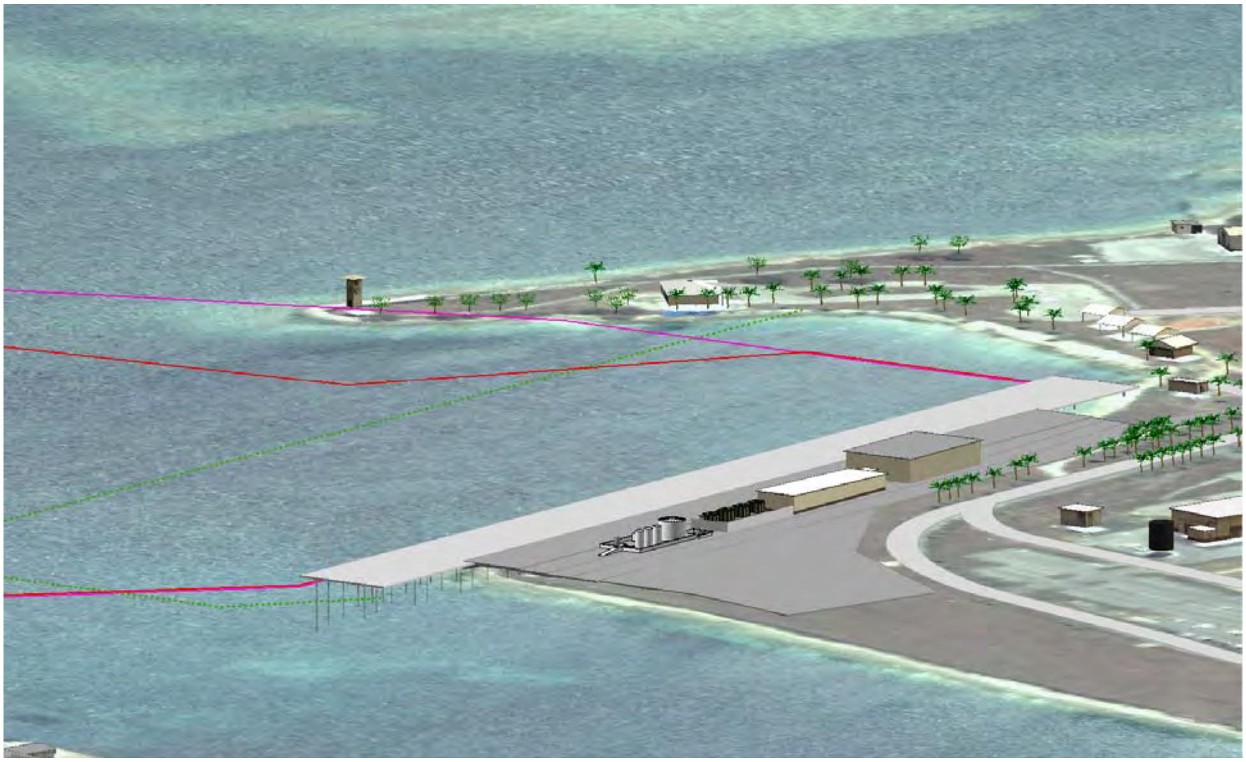
Alternative 2 – Image 2

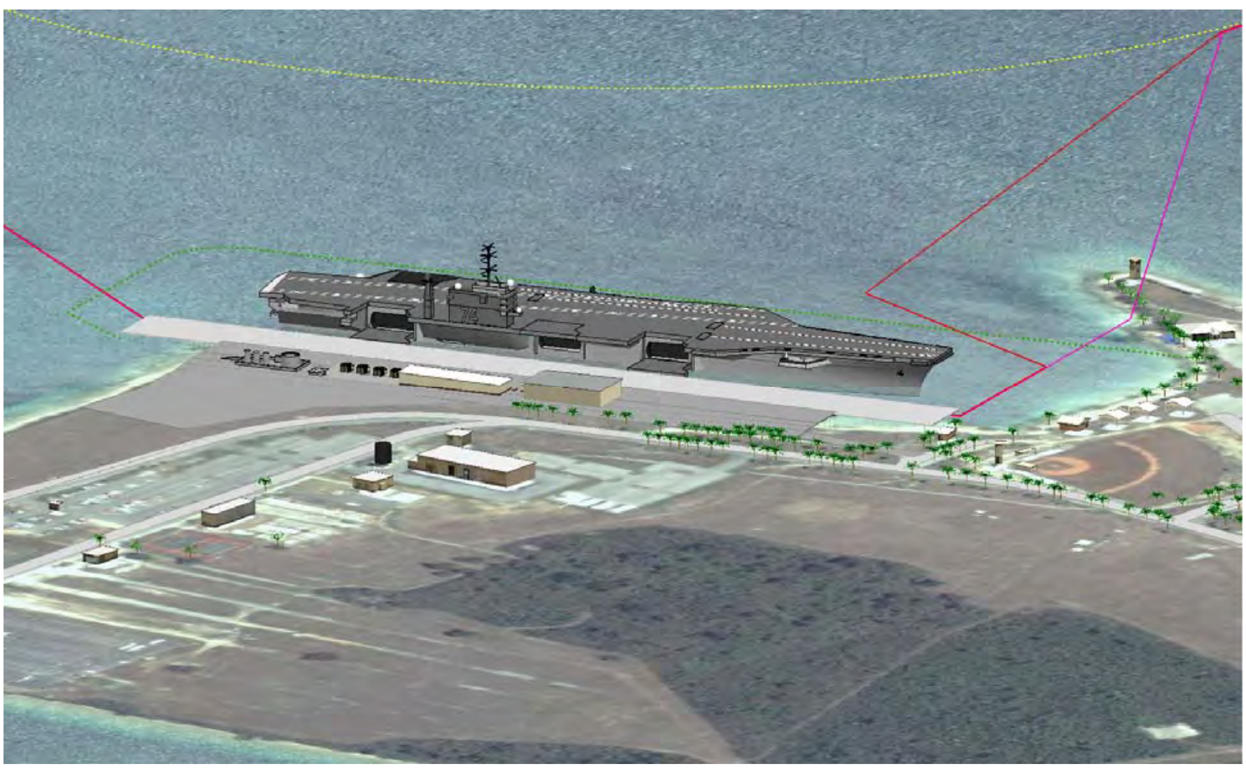


Alternative 2 – Image 3



Alternative 2 – Image 4

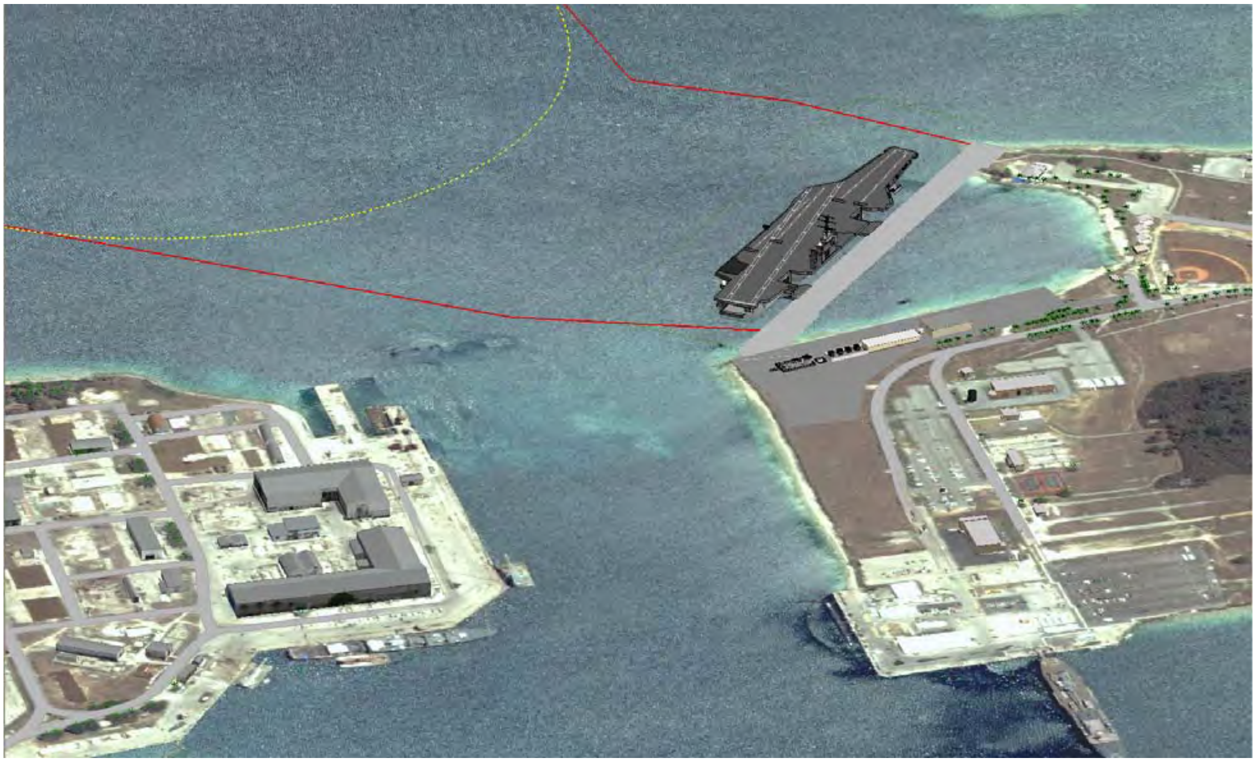

Alternative 2 – Image 5


Alternative 2 – Image 6

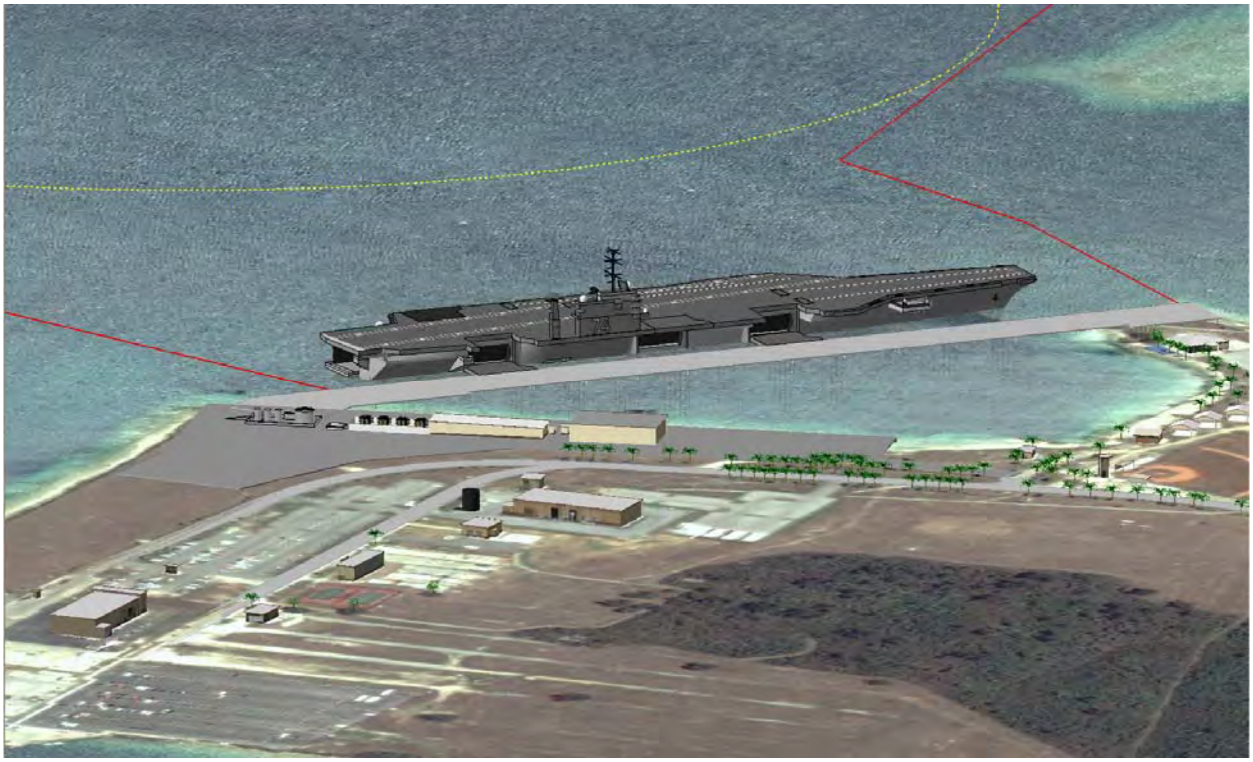
Alternative 3 – Polaris Point Diagonal Offshore

Alternative 3 – Image 1

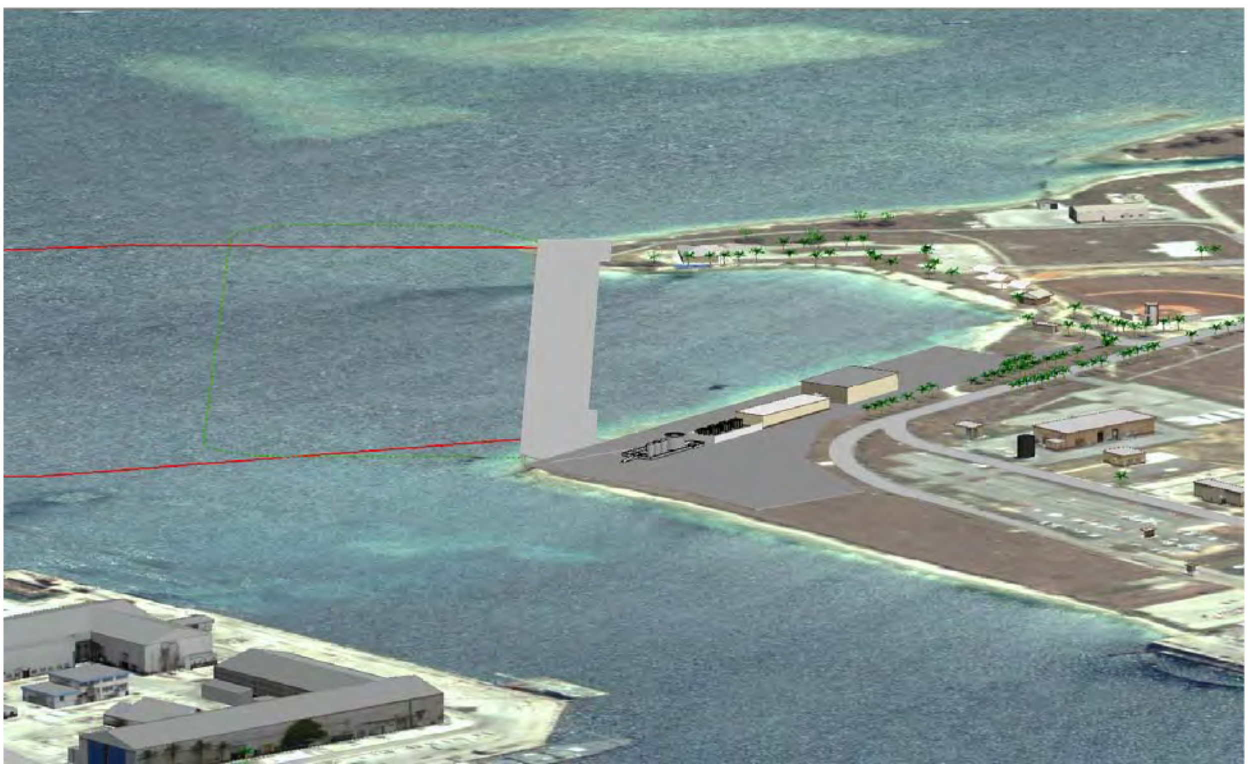
Alternative 3 – Image 2


Alternative 3 – Image 3


Alternative 3 – Image 4



Alternative 3 – Image 5



Alternative 3 – Image 6

APPENDIX B

COST ESTIMATES

APPENDIX B

Alternative 1 - Former SRF

Description	Qty	Unit	Unit Cost	Costs
Alternate #1: Former SRF Facility				
Project General Conditions				
Construction General Conditions				
General Conditions	1	ls	16,381,286	16,381,286
Construction General Conditions	**1**	**ls**		**16,381,286**
Mobilization / Demobilization / Housing				
Mobilization / Demobilization	1	ls	9,307,549	9,307,549
Contractor Workforce Housing and Per Diem Costs				
Mobilization / Demobilization / Housing	**1**	**ls**		**9,307,549**
Dredging				
Dredging - SRF Channel Option #1				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 342,200		cu yd	20.26	6,932,392
Overdredge 136,700		cu yd	20.26	2,769,310
Dredge Disposal - uplands	478,900	cu yd	40.52	19,403,404
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		
Land Filling Material Handling	-	cu yd		
Dredging - SRF Channel Option #1	**478,900**	**cu yd**	**84**	**40,339,256**
Wharf Struture				
Steel Pipe Piles at Main Pier Structure				
Material - Pipe - 24" diameter - .62" wall - 156 #/lf	33,060	lf	663	21,919,860
Material - Rebar Cage	248,713	lbs	1.81	450,946
Material - Fill Concrete	1,082	cu yd	608	657,585
Installation - Piles	410	ea	39,909	16,362,632
Installation - Rebar	248,713	lbs	1.09	271,298
Installation - Concrete	1,082	cu yd	85.02	91,995
Steel Pipe Piles at Main Pier Structure	**410**	**ea**	**96,962**	**39,754,316**

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Cast In Place Concrete at Deck				
Concrete Material - 126,750 sf Deck	10,000	cu yd	608	6,077,491
Rebar	2,500	Tns	3,626	9,065,591
Formwork	143,000	sf	46.14	6,598,499
Installation -rebar	2,500	Tns	2,182	5,454,042
Installation - concrete	10,000	cu yd	143	1,432,388
Cast In Place Concrete at Deck	**10,000**	**cu yd**	**2,863**	**28,628,012**
CVN Camel / Fender Structure				
Piles	18,000	lf	193	3,480,745
Camels - (steel load transfer float)	3	unit	2,092,800	6,278,400
6 lf Diameter Foam Filled Fenders	12	ea	184,166	2,209,997
Pile Installation	120	ea	5,157	618,799
Camel / Fender Assembly	12	ea	36,612	439,347
Brows	3	ea	920,832	2,762,496
CVN Camel / Fender Structure	**1**	**ls**		**15,789,784**
Miscellaneous Metals				
Materials	66,250	lbs	10.13	671,056
Installation	66,250	lbs	10.13	671,056
Miscellaneous Metals	**66,250**	**lbs**	**20.26**	**1,342,113**
100 Ton Bollards				
Materials	13	ea	141,808	1,843,506
Installation	13	ea	40,517	526,716
100 Ton Bollards	**13**	**ea**	**182,325**	**2,370,222**
200 Ton Storm Bollards				
Materials	8	ea	202,583	1,620,664
Installation	8	ea	40,517	324,133
200 Ton Storm Bollards	**8**	**ea**	**243,100**	**1,944,797**
Cathodic Protection and Special Coatings				
Berth	1	ls	3,038,746	3,038,746
Cathodic Protection and Special Coatings	**1**	**ls**		**3,038,746**

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Marine Revetment				
Wharf Revetment				
Quarry Stone Fill Procurment and Transportation	41,961	cu yd	81.03	3,400,235
Quarry Stone Fill Placement	41,961	cu yd	60.77	2,550,176
Riprap Stone Procurment and Transportation	19,815	cu yd	153.96	3,050,779
Riprap Stone Placement	19,815	cu yd	60.77	1,204,255
Wharf Revetment	**61,776**	**cu yd**	**165**	**10,205,445**
Sitework				
Site Work				
PCC Cut-Off Wall Extension	27	cu yd	2,076.88	56,076
Demolish and Remove Aspahlt Concrete Pavement	634	cu yd	79.62	50,476
Disposal of Pavement Material	634	cu yd	40.52	25,688
Demolish and Remove Watchtower	75	cu yd	750.01	56,251
Demolish and Remove One Story Building	720	sf	178.27	128,357
Disposal of Building Demolition Material + fees	275	cu yd	202.58	55,710
Scarify and Recompact Site	204,160	sf	13.13	2,680,086
Hydroseed 2:1 Slope	2,031	sy	1.50	3,036
Armor Stone - 3' thick, 500 lbss. Size	335	cu yd	182.32	61,079
Armor Stone - Placement	335	cu yd	81.03	27,146
Fill Material Importation (dredge disposal)	52,040	cu yd	20.26	1,054,242
Grading - Fill, Placeent and Compact	52,040	cu yd	102.10	5,313,380
Pavement - 3" Aspahlt Concrete, 10" Base	28,600	sy	111.66	3,193,584
Pavement Material - Aspahlt Concrete	4,542	ton	130.97	594,906
Pavement Material - Base	8,294	cu yd	83.61	693,508
Road Stripe - 4" Width	53	lf	1.13	60
Traffic Control Signs	2	ea	3,687.01	7,374
Catch Basins - 2' x 2'	7	ea	13,208.41	92,459
Side Inlet - 4' Length	1	ea	16,773.88	16,774
Aspahlt Concrete Curb - 6" Height	7	ton	1,359.69	9,518
Pre-Cast Concrete Curb, 6" with 18" Gutter	18	lf	501.96	9,035
Pre-Cast Concrete Sidewalk - 4" Thick	12	cu yd	2,390.48	28,686
Pre-Cast Concrete Swale - 4' Width, 4" Thick	6,020	sf	46.99	282,853
Reinforced Concrete Pipe Storm Drain - 12" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 18" Dia.	511	lf	381.87	195,135
Reinforced Concrete Pipe Storm Drain - 21" Dia.	306	lf	405.66	124,133
Reinforced Concrete Pipe Storm Drain - 24" Dia.	434	lf	429.48	186,393
Reinforced Concrete Pipe Storm Drain - 27" Dia.	295	lf	460.21	135,761
Reinforced Concrete Pipe Storm Drain - 30" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 33" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 36" Dia.	-	lf		-
CDS Inline PMSU 40 / 30 Separator	2	ea	27,470.26	54,941
CDS Inline PMSU 30 / 30 Separator	-	ea		-
CDS Inline PMSU 40 / 40 Separator	-	ea		-

Description	Qty	Unit	Unit Cost	Costs
Pre-Cast Concrete Outfall Structure	1	ea	6,361.11	6,361
Hardened Security Fencing	1,495	lf	343.27	513,190
Security Chain Link Fence	115	lf	345.20	39,698
Pedestrian Gate	1	ea	1,256.01	1,256
Swing Gate - Double, 20-foot Opening	1	ea	20,825.54	20,826
Retractable Bollards - 4 Units	1	set	124,953.22	124,953
Traffic Spikes	1	set	16,773.88	16,774
Floating Barriers for FPCON Charlie/Delta	2,900	lf	542.92	1,574,475
Floating Barrier Sea Anchorage	7	ea	359,698.34	2,517,888
Land Anchors for Floating Barriers	-	ea		-
Wharf Anchorage for Floating Barriers	-	ea		-
MWR Improvements	4	ac	1,012,915.20	4,051,661
Site Work	**1**	**ls**		**24,003,729**
Buildings				
Guard Booth				
Guard Booth	1	ea	287,760	287,760
Guard Booth	**1**	**ls**		**287,760**
Security Watch Tower				
Security Watch Tower - 20' x 20 'x 50' Height	2	ea	500,702	1,001,405
Security Watch Tower	**2**	**ea**		**1,001,405**
Transit Shed				
Transit Shed	10,000	sf	432	4,316,400
Transit Shed	**1**	**ls**		**4,316,400**
Air compressor shed				
Air compressor Shed	1,200	sf	863	1,035,936
Air compressor shed	**1**	**ls**		**1,035,936**
Water Treatment Building				
Water Treatment Building	1,250	sf	863	1,079,100
Water Treatment Building	**1**	**ls**		**1,079,100**
Boiler House				
Boiler House	2,116	sq ft	863	1,826,700
Boiler House	**1**	**ls**		**1,826,700**

Description	Qty	Unit	Unit Cost	Costs
Mechanical				
Steam Generation				
312 HP 150psi Scotch Marine	2	ea	517,802	1,035,605
Low Nox Burner	2	ea	65,637	131,274
10,500 MBH 150 psi Deaerator	1	ea	287,668	287,668
w/ feedwater pumpset & controls	1	ea	34,115	34,115
Flash Tank HP condensate	1	ea	18,232	18,232
Flash Tank IP condensate	1	ea	18,232	18,232
Flash Tank LP condensate	1	ea	18,232	18,232
Condensate forwarding system	1	lot	24,472	24,472
Boiler Stack and Breeching	2	ea	22,284	44,568
Metering Station	1	ea	18,783	18,783
Boiler Stack 24" diam	50	lf	658	32,920
Barometric damper	2	ea	2,299	4,599
Steam Piping 6"	1,200	lf	232	278,155
Steam Piping 8"	200	lf	327	65,329
Steam Piping 4" and smaller	500	lf	139	69,608
Condensate piping 2"	100	lf	86	8,630
8" 150# gate valve	2	ea	12,661	25,323
8" 150# Check valve	2	ea	12,256	24,513
6" 150# gate valve	4	ea	8,549	34,196
4" 150# gate valve	3	ea	5,531	16,592
Pressure reducing station	2	lot	34,642	69,283
8" and 6" fitting allowance	1	lot	116,708	116,708
4" and smaller allowance	1	lot	23,186	23,186
6" Concrete Pads	15	cu yd	1,145	17,171
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Steam Generation	**1**	**sys**		**2,420,619**
Fuel Train				
2gpm fuel pumpset	1	ea	3,841	3,841
2500 gal Day Tank w/level cntrls	1	ea	27,369	27,369
Fuel Oil Storage Tank	1	ea	121,226	121,226
2" A106 Piping	300	lf	86	25,890
Fittings allowance	1	lot	18,147	18,147
Fuel Oil Specialties allowance	1	lot	15,437	15,437
Fuel Train	**1**	**ls**		**211,911**
Compressed Air				
2400 scfm (125psi) dplx compressor	3	ea	457,838	1,373,513
Dessicant Dryer skid	1	ea	429,476	429,476
Air Receiver skid	1	ea	130,869	130,869
6" concrete pads	7	cu yd	1,145	8,013
6" welded steel piping	1,200	lf	232	278,155
4" welded steel piping	50	lf	139	6,961
2" and smaller SW steel pipe	500	lf	74	36,789
6" piping fitting allowance	1	lot	94,444	94,444

Description	Qty	Unit	Unit Cost	Costs
4" piping fitting allowance	1	lot	2,319	2,319
2" and smaller fitting allowance	1	lot	12,160	12,160
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Compressed Air	**1**	**ls**		**2,375,923**
Water Treatment				
Packaged Water Treatment	20,000	gpd	235	4,708,840
Water Treatment	**1**	**ls**		**4,708,840**
Exterior Piping				
6" Ductile Iron Pipe	1,200	lf	118	141,241
10" Ductile Iron Pipe	250	lf	171	42,694
Pipe excavation & backfill	250	lf	12	3,029
Pipe Bedding 10" pipe	250	lf	10	2,472
Pipe Bedding 6" pipe	200	lf	4	859
Exterior Piping	**1**	**ls**		**190,294**
Boiler Room DDC System	1	lot	121,550	121,550
Work Station	1	ea	34,488	34,488
Application software	1	lot	17,390	17,390
Boiler Room DDC System	**1**	**ls**		**173,427**
Alternate #1: Former SRF Facility				**$ 212,733,569**

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
ELECTRICAL COST SUMMARY - SRF								
GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
GPA UPGRADE PITI X20 LINE								1,500,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (POLARIS ROAD TO OROTE SS)								13,523,810
34.5 KV CONDUCTORS (OROTE SS TO SRF SS)								3,900,618
34.5 KV EXT FROM SRF BERTH TO SRF SS								6,078,431
OROTE SUBSTATION ADDITION								380,000
SRF SUBSTATION ADDITION								760,000
BERTH SUBSTATION								15,712,000
MWR SERVICE								75,000
BERTH COMMUNICATIONS								1,182,533
BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS								1,000,000
TOTAL ELECTRICAL COST								**54,860,263**
ESCALATION TO OCTOBER 2011 (1.0867)								**59,616,648**
FROM OTHER APPROPRIATIONS								
IDS								25,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
GPA PITI 34.5 KV SWITCHING STATION UPGRADE							100000	100,000
SUBTOTAL GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
GPA UPGRADE PITI X20 LINE							1500000	1,500,000
SUBTOTAL GPA UPGRADE PITI X20 LINE								1,500,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								
Sawcut	6012	M					10	60,962
Trench and Haul	2098	CM					69	144,930
152 Sch 40 PVC	6012	M					44	266,031
Concrete (Thermal)	412	CM					344	141,773
Backfill (Thermal)	1553	CM					316	490,919
Thermal Testing	16	EA					1000	16,000
Restore pavement	1698	SM					43	73,388
Manhole	13	EA					42000	546,000
Conductor. 750 kcmil, 38 kV EPR	19840	M					320	6,348,800
Conductor. #4/0 SDBC	3306	M					26	85,956
MV Splice	39	EA					1068	41,652
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					500000	500,000
Misc Tape, Fasteners, Hardware	1	LS					872534	872,534
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (POLARIS ROAD TO OROTE SS)								
Sawcut	9020	M					10	91,463
Trench and Haul	3148	CM					69	217,464
152 Sch 40 PVC	9020	M					44	399,135
Concrete (Thermal)	617	CM					344	212,316
Backfill (Thermal)	2330	CM					316	736,536
Thermal Testing	24	EA					1000	24,000
Restore pavement	2548	SM					43	110,125
Manhole	19	EA					42000	798,000
Conductor. 750 kcmil, 38 kV EPR	29770	LM					320	9,526,400
Conductor. #4/0 SDBC	4961	LM					26	128,986
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					1229437	1,229,437
SUBTOTAL 34.5 KV FDR (POLARIS ROAD TO OROTE SS)								13,523,810
34.5 KV CONDUCTORS (OROTE SS TO SRF SS)								
Conductor. 750 kcmil, 38 kV EPR	10692	M					320	3,421,440
Conductor. #4/0 SDBC	3240	M					26	84,240
MV Splice	6	EA					1068	6,408
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					354602	354,602
SUBTOTAL 34.5 KV CONDUCTORS (OROTE SS TO SRF SS)								3,900,618
34.5 KV EXT FROM SRF BERTH TO SRF SS								
Sawcut	2200	M					10	22,308
Trench and Haul	923	CM					69	63,761
6" Sch 40 PVC	4400	M					44	194,700
Concrete (Thermal)	253	CM					344	87,060
Backfill (Thermal)	569	CM					316	179,867
Thermal Testing	7	EA					1000	7,000
Restore pavement	622	SM					43	26,883

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Manhole	5	EA					42000	210,000
Conductor. 750 kcmil, 38 kV EPR	14520	M					320	4,646,400
Conductor. #4/0 SDBC	2420	M					26	62,920
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Misc Tape, Fasteners, Hardware	1	LS					552585	552,585
SUBTOTAL 34.5 KV EXT FROM SRF BERTH TO SRF SS								6,078,431
OROTE SUBSTATION ADDITION								
34.5 kV Bus Tie Breaker Section	1	EA					190000	190,000
34.5 kV Express Feeder Section	1	EA					190000	190,000
SUBTOTAL SRF SUBSTATION ADDITION								380,000
SRF SUBSTATION ADDITION								
34.5 kV Bus Tie Breaker Section	1	EA					190000	190,000
34.5 kV Express Feeder Section	3	EA					190000	570,000
SUBTOTAL SRF SUBSTATION ADDITION								760,000
BERTH SUBSTATION								
34.5 kV Vacuum Switchgear	2	EA					2380000	4,760,000
34.5 kV Grounding Transformer	1	EA					260000	260,000
34.5 kV Station Service	1	EA					50000	50,000
Substation Building	1	EA					1300000	1,300,000
SCADA	1	EA					100000	100,000
20/26/33 MVA Transformer	2	EA					2000000	4,000,000
13.8 kV Vacuum Switchgear	2	EA					546000	1,092,000
12/16/20 MVA Transformer	2	EA					1500000	3,000,000
4.16 kV Switchgear	2	EA					325000	650,000
Industrial Power	1	EA					300000	300,000
480V Switchgear	1	EA					200000	200,000
SUBTOTAL BERTH SUBSTATION								15,712,000
MWR SERVICE							75000	75,000
SUBTOTAL MWR SERVICE								75,000
BERTH COMMUNICATIONS								
103 Sch 40 PVC	7600	M					30	228,000
Innerduct	3800	M					10	38,000
Trench and Backfill	1520	CM					147	223,440
Concrete	385	CM					334	128,590
NCTS Cabling Costs	1	LS					400000	400,000
Communications Handhole	24	EA					500	12,000
Communications Mound	3	EA					15000	45,000
Misc Tape, Fasteners, Hardware	1	LS					107503	107,503
SUBTOTAL BERTH COMMUNICATIONS								1,182,533
BERTH POWER DISTRIBUTION								
POWER MOUND AND CONNECTION	4	EA					75000	300,000
SUBTOTAL BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER							750000	750,000
SUBTOTAL SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS							1000000	1,000,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

DECEMBER 2007
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
SUBTOTAL GENERAL CONDITIONS								1,000,000

BUDGET ESTIMATE SUMMARY SHEET

TITLE:	CVN BERTHING FEASIBILITY STUDY - SEWER & BILGE OILY WASTE SYSTEM UPGRADES (FORMER SRF FACILITY)	DATE:	FEBRUARY 2008
INSTALLATION:	U.S. NAVBASE, GUAM	DATE ESCALATED TO:	OCTOBER 2011
LOCATION:	AGANA, GUAM	DESIGN STATUS:	FEASIBILITY STUDY
		ESCALATION FACTOR:	1.0867
PREPARED BY:	Engineering Concepts, Inc.	AREA COST FACTOR:	---

DESCRIPTION	UNIT	QUANTITY	UNIT COST (OCT 2007)	TOTAL COST (OCT 2007)	2011 COST TRANSFERRED TO 1391 Sum (Rnd, 10K)
NEW BILGE OILY WASTE COLLECTION SYSTEM & TREATMENT FACILITY				4,213,000	4,580
Bilge Oily Waste Collection Ashore	LS	1	767,000	(767,000)	
Bilge Oily Waste Pump Station	LS	1	766,000	(766,000)	
Bilge Oily Waste Treatment System	LS	1	2,530,000	(2,530,000)	
Technical Operating Manuals	LS	1	150,000	(150,000)	
WASTEWATER COLLECTION SYSTEM IMPROVEMENTS				17,942,420	19,500
Ship Wastewater Collection Ashore	LS	1	646,000	(646,000)	
Submersible Pump Station A	LS	1	2,576,000	(2,576,000)	
10-inch Force Main A	M	30	820	(24,600)	
15-inch Gravity Sewer Line A	M	274	4,590	(1,257,660)	
Submersible Pump Station B	LS	1	2,576,000	(2,576,000)	
10-inch Force Main B	M	1,067	820	(874,940)	
15-inch Gravity Sewer Line B	M	244	4,590	(1,119,960)	
Submersible Pump Station C	LS	1	2,576,000	(2,576,000)	
10-inch Force Main C	M	945	820	(774,900)	
15-inch Relief Sewer Line along Marine Drive	M	139	4,590	(638,010)	
18-inch Relief Sewer Line along Marine Drive	M	575	6,230	(3,582,250)	
24-inch Relief Sewer Line along Marine Drive	M	110	9,510	(1,046,100)	
Technical Operating Manuals	LS	1	250,000	(250,000)	
WATER SYSTEM IMPROVEMENTS				512,250	560
Supply Lateral to Pier (8-inch)	M	35	750	(26,250)	
Pierside Water Lines & Outlets (8 and 6 inch lines)	LS	1	486,000	(486,000)	
SUPPORTING FACILITIES				300,000	330
Electrical Utilities	LS	1	300,000	(300,000)	
SUBTOTAL*					**24,970**
* Includes Overhead, Profit, Bond & Insurance, GRT, & Prime Mark-up on subcontract					

APPENDIX B

Alternative 2 - Polaris Point Parallel to Shore

Description	Qty	Unit	Unit Cost	Costs
Alternate #2: Polaris Point Parallel to Shore				
Project General Conditions				
Construction General Conditions				
General Conditions	1	ls	17,838,846	17,838,846
Construction General Conditions	**1**	**ls**		**17,838,846**
Mobilization				
Mobilization / Demobilization	1	ls	10,135,708	10,135,708
Contractor Workforce Housing and Per Diem Costs	1	ls	-	-
Mobilization	**1**	**ls**		**10,135,708**
Dredging - Alternative 2A				
Dreging - Polaris Marginal Wharf - Reduced Impact				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 587,700		cu yd	20.26	11,905,805
Overdredge 170,300		cu yd	20.26	3,449,989
Dredge Disposal - uplands	758,000	cu yd	40.52	30,711,589
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		-
Land Filling Material Handling	-	cu yd		-
Dreging - Polaris Marginal Wharf - Reduced Impact	**758,000**	**cu yd**	**76**	**57,301,534**
Wharf Struture				
Steel Pipe Piles at Main Pier Structure				
Material - Pipe - 24" diameter - .62" wall - 156 #/lf	33,060	lf	663	21,919,860
Material - Rebar Cage	248,713	lbs	1.81	450,946
Material - Fill Concrete	1,082	cu yd	608	657,585
Installation - Piles	410	ea	39,909	16,362,632
Installation - Rebar	248,713	lbs	1.09	271,298
Installation - Concrete	1,082	cu yd	85.02	91,995
Steel Pipe Piles at Main Pier Structure	**410**	**ea**	**96,962**	**39,754,316**

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Cast In Place Concrete at Deck				
Concrete Material - 126,750 sf Deck	10,000	cu yd	608	6,077,491
Rebar	2,500	Tns	3,626	9,065,591
Formwork	143,000	sf	46.14	6,598,499
Installation -rebar	2,500	Tns	2,182	5,454,042
Installation - concrete	10,000	cu yd	143	1,432,388
Cast In Place Concrete at Deck	**10,000**	**cu yd**	**2,863**	**28,628,012**
CVN Camel / Fender Structure				
Piles	18,000	lf	193	3,480,745
Camels - (steel load transfer float)	3	unit	2,092,800	6,278,400
6 lf Diameter Foam Filled Fenders	12	ea	184,166	2,209,997
Pile Installation	120	ea	5,157	618,799
Camel / Fender Assembly	12	ea	36,612	439,347
Brows	3	ea	920,832	2,762,496
CVN Camel / Fender Structure	**1**	**ls**		**15,789,784**
Miscellaneous Metals				
Materials	66,250	lbs	10.13	671,056
Installation	66,250	lbs	10.13	671,056
Miscellaneous Metals	**66,250**	**lbs**	**20.26**	**1,342,113**
100 Ton Bollards				
Materials	13	ea	141,808	1,843,506
Installation	13	ea	40,517	526,716
100 Ton Bollards	**13**	**ea**	**182,325**	**2,370,222**
200 Ton Storm Bollards				
Materials	8	ea	202,583	1,620,664
Installation	8	ea	40,517	324,133
200 Ton Storm Bollards	**8**	**ea**	**243,100**	**1,944,797**
Cathodic Protection and Special Coatings				
Berth	1	ls	3,038,746	3,038,746
Cathodic Protection and Special Coatings	**1**	**ls**		**3,038,746**

Description	Qty	Unit	Unit Cost	Costs
Marine Revetment				
Wharf Revetment				
Quarry Stone Fill Procurment and Transportation	41,961	cu yd	81.03	3,400,235
Quarry Stone Fill Placement	41,961	cu yd	60.77	2,550,176
Riprap Stone Procurment and Transportation	19,815	cu yd	153.96	3,050,779
Riprap Stone Placement	19,815	cu yd	60.77	1,204,255
Wharf Revetment	**61,776**	**cu yd**	**165**	**10,205,445**
Sitework				
Site Work				
PCC Cut-Off Wall Extension	-	cu yd		-
Demolish and Remove Aspahlt Concrete Pavement	3,570	cu yd	79.62	284,226
Disposal of Pavement Material	3,570	cu yd	40.52	144,644
Demolish and Remove Watchtower	-	cu yd		-
Demolish and Remove One Story Building	1,200	sf	178.27	213,928
Disposal of Building Demolition Material	310	cu yd	202.58	62,801
Scarify and Recompact Site	304,000	sf	13.13	3,990,724
Hydroseed 2:1 Slope	2,717	sy	1.50	4,062
Armor Stone - 3' thick, 500 lbss. Size	1,385	cu yd	182.32	252,520
Armor Stone - Placement	1,385	cu yd	81.03	112,231
Fill Material Importation (dredge disposal)	62,475	cu yd	20.26	1,265,638
Grading - Fill, Placeent and Compact	62,475	cu yd	102.10	6,378,813
Pavement - 3" Aspahlt Concrete, 10" Base	29,295	sy	111.66	3,271,190
Pavement Material - Aspahlt Concrete	4,440	ton	130.97	581,503
Pavement Material - Base	8,110	cu yd	83.61	678,097
Road Stripe - 4" Width	207	lf	1.13	235
Traffic Control Signs	4	ea	3,687.01	14,748
Catch Basins - 2' x 2'	5	ea	13,208.41	66,042
Side Inlet - 4' Length	1	ea	16,773.88	16,774
Aspahlt Concrete Curb - 6" Hieght	20	ton	1,359.69	27,194
Pre-Cast Concrete Curb, 6" with 18" Gutter	189	lf	501.96	94,870
Pre-Cast Concrete Sidewalk - 4" Thick	11	cu yd	2,390.48	26,295
Pre-Cast Concrete Swale - 4' Width, 4" Thick	4,028	sf	46.99	189,258
Reinforced Concrete Pipe Storm Drain - 12" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 18" Dia.	339	lf	381.87	129,454
Reinforced Concrete Pipe Storm Drain - 21" Dia.	210	lf	405.66	85,189
Reinforced Concrete Pipe Storm Drain - 24" Dia.	210	lf	429.48	90,190
Reinforced Concrete Pipe Storm Drain - 27" Dia.	210	lf	460.21	96,644
Reinforced Concrete Pipe Storm Drain - 30" Dia.	271	lf	490.98	133,056
Reinforced Concrete Pipe Storm Drain - 33" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 36" Dia.	-	lf		-
CDS Inline PMSU 40 / 30 Separator	-	ea		-
CDS Inline PMSU 30 / 30 Separator	1	ea	27,470.26	27,470
CDS Inline PMSU 40 / 40 Separator	-	ea		-

Description	Qty	Unit	Unit Cost	Costs
Pre-Cast Concrete Outfall Structure	1	ea	6,361.11	6,361
Hardened Security Fencing	1,872	lf	343.27	642,604
Security Chain Link Fence	134	lf	345.20	46,257
Pedestrian Gate	1	ea	1,256.01	1,256
Swing Gate - Double, 20-foot Opening	1	ea	20,825.54	20,826
Retractable Bollards - 4 Units	1	ea	124,953.22	124,953
Traffic Spikes	1	ea	16,773.88	16,774
Floating Barriers for FPCON Charlie/Delta	2,916	lf	542.92	1,583,162
Floating Barrier Sea Anchorage	5	ea	359,698.34	1,798,492
Land Anchors for Floating Barriers	-	ea		-
Wharf Anchorage for Floating Barriers	-	ea		-
MWR Improvements	2.4	ac	1,012,915.20	2,430,996
Site Work	**1**	**ls**		**24,909,474**
Buildings				
Guard Booth				
Guard Booth	1	ea	287,760	287,760
Guard Booth	**1**	**ls**		**287,760**
Security Watch Tower				
Security Watch Tower - 20' x 20 'x 50' Height	2	ea	500,702	1,001,405
Security Watch Tower	**2**	**ea**		**1,001,405**
Transit Shed				
Transit Shed	10,000	sf	432	4,316,400
Transit Shed	**1**	**ls**		**4,316,400**
Air compressor shed				
Air compressor shed	1,200	sf	863	1,035,936
Air compressor shed	**1**	**ls**		**1,035,936**
Water Treatment Building				
Water Treatment Building	1,250	sf	863	1,079,100
Water Treatment Building	**1**	**ls**		**1,079,100**
Boiler House				
Boiler House	2,116	sq ft	863	1,826,700
Boiler House	**1**	**ls**		**1,826,700**

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Mechanical				
Steam Generation				
312 HP 150psi Scotch Marine	2	ea	517,802	1,035,605
Low Nox Burner	2	ea	65,637	131,274
10,500 MBH 150 psi Deaerator	1	ea	287,668	287,668
w/ feedwater pumpset & controls	1	ea	34,115	34,115
Flash Tank HP condensate	1	ea	18,232	18,232
Flash Tank IP condensate	1	ea	18,232	18,232
Flash Tank LP condensate	1	ea	18,232	18,232
Condensate forwarding system	1	lot	24,472	24,472
Boiler Stack and Breeching	2	ea	22,284	44,568
Metering Station	1	ea	18,783	18,783
Boiler Stack 24" diam	50	lf	658	32,920
Barometric damper	2	ea	2,299	4,599
Steam Piping 6"	1,200	lf	232	278,155
Steam Piping 8"	200	lf	327	65,329
Steam Piping 4" and smaller	500	lf	139	69,608
Condensate piping 2"	100	lf	86	8,630
8" 150# gate valve	2	ea	12,661	25,323
8" 150# Check valve	2	ea	12,256	24,513
6" 150# gate valve	4	ea	8,549	34,196
4" 150# gate valve	3	ea	5,531	16,592
Pressure reducing station	2	lot	34,642	69,283
8" and 6" fitting allowance	1	lot	116,708	116,708
4" and smaller allowance	1	lot	23,186	23,186
6" Concrete Pads	15	cu yd	1,145	17,171
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Steam Generation	**1**	**sys**		**2,420,619**
Fuel Train				
2gpm fuel pumpset	1	ea	3,841	3,841
2500 gal Day Tank w/level cntrls	1	ea	27,369	27,369
Fuel Oil Storage Tank	1	ea	121,226	121,226
2" A106 Piping	300	lf	86	25,890
Fittings allowance	1	lot	18,147	18,147
Fuel Oil Specialties allowance	1	lot	15,437	15,437
Fuel Train	**1**	**ls**		**211,911**
Compressed Air				
2400 scfm (125psi) dplx compressor	3	ea	457,838	1,373,513
Dessicant Dryer skid	1	ea	607,749	607,749
Air Receiver skid	1	ea	130,869	130,869
6" concrete pads	7	cu yd	1,145	8,013
6" welded steel piping	1,200	lf	232	278,155
4" welded steel piping	50	lf	139	6,961
2" and smaller SW steel pipe	500	lf	74	36,789
6" piping fitting allowance	1	lot	94,444	94,444

Description	Qty	Unit	Unit Cost	Costs
4" piping fitting allowance	1	lot	2,319	2,319
2" and smaller fitting allowance	1	lot	12,160	12,160
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Compressed Air	**1**	**ls**		**2,554,196**
Water Treatment				
Packaged Water Treatment	20,000	gpd	235	4,708,840
4" welded steel piping	**1**	**ls**		**4,708,840**
Exterior Piping				
6" Ductile Iron Pipe	1,200	lf	118	141,241
10" Ductile Iron Pipe	250	lf	171	42,694
Pipe excavation & backfill	250	lf	12	3,029
Pipe Bedding 10" pipe	250	lf	9	2,299
Pipe Bedding 6" pipe	200	lf	4	802
Exterior Piping	**1**	**ls**		**190,065**
Boiler Room DDC System	1	lot	121,550	121,550
Work Station	1	ea	34,488	34,488
Application software	1	lot	17,390	17,390
Boiler Room DDC System	**1**	**ls**		**173,427**
Alternate #2A: Polaris Point Parallel to Shore				**$ 233,065,355**
Dredging Alternative 2				
Dreging - Polaris Marginal Wharf				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 803,700		cu yd	20.26	16,281,599
Overdredge 189,500		cu yd	20.26	3,838,949
Dredge Disposal - uplands	993,200	cu yd	40.52	40,241,095
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		-
Land Filling Material Handling	-	cu yd		-
Dreging - Polaris Marginal Wharf	**993,200**	**cu yd**	**72**	**71,595,793**
Alternate #2: Polaris Point Parallel to Shore				**$ 247,359,615**

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
ELECTRICAL COST SUMMARY - POLARIS POINT								
GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								6,795,268
BERTH SUBSTATION								15,712,000
MWR SERVICE								75,000
BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS								1,000,000
TOTAL ELECTRICAL COST								**35,244,526**
ESCALATION TO OCTOBER 2011 (1.0867)								**38,300,226**
FROM OTHER APPROPRIATIONS								
IDS								25,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
GPA PITI 34.5 KV SWITCHING STATION UPGRADE							100000	100,000
SUBTOTAL GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								
Sawcut	6012	M					10	60,962
Trench and Haul	2098	CM					69	144,930
152 Sch 40 PVC	6012	M					44	266,031
Concrete (Thermal)	412	CM					344	141,773
Backfill (Thermal)	1553	CM					316	490,919
Thermal Testing	16	EA					1000	16,000
Restore pavement	1698	SM					43	73,388
Manhole	13	EA					42000	546,000
Conductor. 750 kcmil, 38 kV EPR	19840	M					320	6,348,800
Conductor. #4/0 SDBC	3306	M					26	85,956
MV Splice	39	EA					1068	41,652
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					500000	500,000
Misc Tape, Fasteners, Hardware	1	LS					872534	872,534
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								
Sawcut	2460	M					10	24,944
Trench and Haul	1032	CM					69	71,291
152 Sch 40 PVC	4920	M					44	217,710
Concrete (Thermal)	283	CM					344	97,383
Backfill (Thermal)	636	CM					316	201,046
Thermal Testing	8	EA					1000	8,000
Restore pavement	695	SM					43	30,038
Manhole	5	EA					42000	210,000
Conductor. 750 kcmil, 38 kV EPR	16240	M					320	5,196,800
Conductor. #4/0 SDBC	2706	M					26	70,356
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					617752	617,752
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								6,795,268
BERTH SUBSTATION								
34.5 kV Vacuum Switchgear	2	EA					2380000	4,760,000
34.5 kV Grounding Transformer	1	EA					260000	260,000
34.5 kV Station Service	1	EA					50000	50,000
Substation Building	1	EA					1300000	1,300,000
SCADA	1	EA					100000	100,000
20/36/33 MVA Transformer	2	EA					2000000	4,000,000
13.8 kV Vacuum Switchgear	2	EA					546000	1,092,000
12/16/20 MVA Transformer	2	EA					1500000	3,000,000
4.16 kV Switchgear	2	EA					325000	650,000
Industrial Power	1	EA					300000	300,000
480V Switchgear	1	EA					200000	200,000
SUBTOTAL BERTH SUBSTATION								15,712,000
MWR SERVICE							75000	75,000
SUBTOTAL MWR SERVICE								75,000
BERTH COMMUNICATIONS								
103 Sch 40 PVC	600	M					30	18,000
Innerduct	300	M					10	3,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Trench and Backfill	120	CM					147	17,640
Concrete	30	CM					334	10,020
NCTS Cabling Costs	1	LS					250000	250,000
Communications Handhole	4	EA					400	1,600
Communications Mound	3	EA					15000	45,000
B4434-Marine Drive Connection	1350	M					360	486,000
Misc Tape, Fasteners, Hardware	1	LS					83126	83,126
SUBTOTAL BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								
POWER MOUND AND CONNECTION	4	EA					75000	300,000
SUBTOTAL BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER							750000	750,000
SUBTOTAL SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS							1000000	1,000,000
SUBTOTAL GENERAL CONDITIONS								1,000,000

BUDGET ESTIMATE SUMMARY SHEET

TITLE:	CVN BERTHING FEASIBILITY STUDY - SEWER & BILGE OILY WASTE SYSTEM UPGRADES (POLARIS POINT PARALLEL & DIAGONAL CONFIGURATIONS)	DATE:	FEBRUARY 2008
INSTALLATION:	U.S. NAVBASE, GUAM	DATE ESCALATED TO:	OCTOBER 2011
LOCATION:	AGANA, GUAM	DESIGN STATUS:	FEASIBILITY STUDY
		ESCALATION FACTOR:	1.0867
PREPARED BY:	Engineering Concepts, Inc.	AREA COST FACTOR:	---

DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL COST	COST TRANSFERRED TO 1391 Sum (Rnd, 10K)
NEW BILGE OILY WASTE COLLECTION SYSTEM & TREATMENT FACILITY				4,213,000	4,580
Bilge Oily Waste Collection Ashore	LS	1	767,000	(767,000)	
Bilge Oily Waste Pump Station	LS	1	766,000	(766,000)	
Bilge Oily Waste Treatment System	LS	1	2,530,000	(2,530,000)	
Technical Operating Manuals	LS	1	150,000	(150,000)	
WASTEWATER COLLECTION SYSTEM IMPROVEMENTS				22,685,050	24,660
Ship Wastewater Collection Ashore	LS	1	607,000	(607,000)	
Submersible Pump Station	LS	1	2,576,000	(2,576,000)	
10-inch Force Main	M	396	820	(324,720)	
15-inch Gravity Sewer Line	M	159	4,590	(729,810)	
Dry Pit / Wet Well Type Pump Station	LS	1	6,669,000	(6,669,000)	
12-inch Force Main	M	4,130	980	(4,047,400)	
8-inch Relief Sewer Line along Marine Drive	M	92	2,930	(269,560)	
12-inch Relief Sewer Line along Marine Drive	M	234	3,950	(924,300)	
15-inch Relief Sewer Line along Marine Drive	M	304	4,590	(1,395,360)	
21-inch Relief Sewer Line along Marine Drive	M	710	6,890	(4,891,900)	
Technical Operating Manuals	LS	1	250,000	(250,000)	
WATER SYSTEM IMPROVEMENTS				552,750	610
Supply Lateral to Pier (8-inch)	M	89	750	(66,750)	
Pierside Water Lines & Outlets (8 and 6 inch lines)	LS	1	486,000	(486,000)	
SUPPORTING FACILITIES				250,000	280
Electrical Utilities	LS	1	250,000	(250,000)	
SUBTOTAL*					**30,130**
* Includes Overhead, Profit, Bond & Insurance, GRT, & Prime Mark-up on subcontract					

APPENDIX B

Alternative 3 - Polaris Point Diagonal Offshore

Description	Qty	Unit	Unit Cost	Costs
Alternate #3: Polaris Point Diagonal Offshore				
Project General Conditions				
Construction General Conditions				
General Conditions	1	ls	21,030,245	21,030,245
Construction General Conditions	**1**	**ls**		**21,030,245**
Mobilization				
Mobilization / Demobilization	1	ls	11,949,003	11,949,003
Contractor Workforce Housing and Per Diem Costs	1	ls		-
Mobilization	**1**	**ls**		**11,949,003**
Dredging				
Dredging - Polaris Point Offshore Berth				
Dredge Mobilization	1	ls	9,208,320	9,208,320
Dredging 503,700		cu yd	20.26	10,204,108
Overdredge 168,700		cu yd	20.26	3,417,576
Dredge Disposal - uplands	672,400	cu yd	40.52	27,243,367
Aids to Navigation	1	ls	2,025,830	2,025,830
Rip Rap Removal	-	cu yd		-
Land Filling Material Handling	-	cu yd		-
Dredging - Polaris Point Offshore Berth	**672,400**	**cu yd**	**77**	**52,099,201**
Wharf Struture				
Steel Pipe Piles at Main Pier Structure				
Material - Pipe - 30" diameter - .62" wall - 196 #/lf	41,278	lf	832	34,353,823
Material - Rebar Cage	267,440	lbs	1.81	484,900
Material - Fill Concrete	1,145	cu yd	608	695,873
Installation - Piles	457	ea	53,212	24,317,798
Installation - Rebar	267,440	lbs	1.09	291,726
Installation - Concrete	1,145	cu yd	85.02	97,351
Steel Pipe Piles at Main Pier Structure	**457**	**ea**	**131,819**	**60,241,471**

COST ESTIMATE

Description	Qty	Unit	Unit Cost	Costs
Cast In Place Concrete Deck				
Concrete Material - 144,000 Deck Area	12,600	cu yd	608	7,657,639
Rebar	3,150	Tns	3,626	11,422,645
Formwork	163,248	sf	46.14	7,532,810
Installation -rebar	3,150	Tns	2,182	6,872,093
Installation - concrete	12,600	cu yd	143	1,804,809
Cast In Place Concrete Deck	**12,600**	**cu yd**	**2,801**	**35,289,995**
CVN Camel / Fender Structure				
Piles	18,000	lf	193	3,480,745
Camels	3	unit	2,092,800	6,278,400
6 lf Diameter Foam Filled Fenders	12	ea	184,166	2,209,997
Pile Installation	120	ea	5,157	618,799
Camel / Fender Assembly	12	ea	36,612	439,347
Brows	3	ea	920,832	2,762,496
CVN Camel / Fender Structure	**1**	**ls**		**15,789,784**
Miscellaneous Metals				
Materials	66,250	lbs	10.13	671,056
Installation	66,250	lbs	10.13	671,056
Miscellaneous Metals	**66,250**	**lbs**	**20.26**	**1,342,113**
100 Ton Bollards				
Materials	13	ea	141,808	1,843,506
Installation	13	ea	40,517	526,716
100 Ton Bollards	**13**	**ea**	**182,325**	**2,370,222**
200 Ton Storm Bollards @ Land Structure				
Materials	8	ea	202,583	1,620,664
Installation	8	ton	40,517	324,133
200 Ton Storm Bollards @ Land Structure	**8**	**ea**		**1,944,797**
Cathodic Protection and Special Coatings				
Berth	1	ls	4,051,661	4,051,661
Cathodic Protection and Special Coatings	**1**	**ls**		**4,051,661**

Description	Qty	Unit	Unit Cost	Costs
Landside Abutment Piling - Both Land Connections				
Material - Pipe - 48" diameter - .75" wall - 385 #/lf - 39 ea @ 50 lf	1,950	lf	1,333.71	2,600,726
Material - Rebar Cage	22,823	lbs	1.81	41,381
Material - Fill Concrete	852	cu yd	607.75	517,802
Installation - Piles	39	ea	8,616.53	336,045
Installation - Rebar	22,823	lbs	1.09	24,896
Installation - Concrete	852	cu yd	85.02	72,440
Landside Abutment Piling - Both Land Connections	**1**	**ls**		**3,593,289**
Landside Transition Deck				
Deck Area	20,480	sf		-
30" Diameter Piling	10,780	lf	996.26	10,739,665
Deck, Cap and Piling Concrete	4,000	cu yd	3,241.33	12,965,315
Landside Transition Deck	**1**	**ls**		**23,704,980**
Marine Revetment				
Wharf Revetment				
Quarry Stone Fill Procurment and Transportation	9,169	cu yd	81.03	743,014
Quarry Stone Fill Placement	9,169	cu yd	60.77	557,261
Riprap Stone Procurment and Transportation	4,330	cu yd	153.96	666,652
Riprap Stone Placement	4,330	cu yd	60.77	263,152
Wharf Revetment	**13,499**	**cu yd**	**165**	**2,230,079**
Sitework				
Site Work				
PCC Cut-Off Wall Extension	-	cu yd		-
Demolish and Remove Aspahlt Concrete Pavement	892	cu yd	79.62	71,017
Disposal of Pavement Material	892	cu yd	40.52	36,141
Demolish and Remove Watchtower	-	cu yd		-
Demolish and Remove One Story Building	-	sf		-
Disposal of Building Demolition Material + fees	225	cu yd	202.58	45,581
Scarify and Recompact Site	303,447	sf	13.13	3,983,464
Hydroseed 2:1 Slope	1,568	sy	1.50	2,344
Armor Stone - 3' thick, 500 lbss. Size	1,482	cu yd	182.32	270,205
Armor Stone - Placement	2,902	cu yd	81.03	235,173
Fill Material Importation (dredge disposal)	40,002	cu yd	20.26	810,379
Grading - Fill, Placeent and Compact	24,698	cu yd	102.10	2,521,712
Pavement - 3" Aspahlt Concrete, 10" Base	29,295	sy	111.66	3,271,190
Pavement Material - Aspahlt Concrete	4,542	ton	130.97	594,906
Pavement Material - Base	8,294	cu yd	83.61	693,508
Road Stripe - 4" Width	262	lf	1.13	297
Traffic Control Signs	8	ea	3,687.01	29,496
Catch Basins - 2' x 2'	4	ea	13,208.41	52,834
Side Inlet - 4' Length	1	ea	16,773.88	16,774
Aspahlt Concrete Curb - 6" Height	26	ton	1,359.69	35,352

Description	Qty	Unit	Unit Cost	Costs
Pre-Cast Concrete Curb, 6" with 18" Gutter	189	lf	501.96	94,870
Pre-Cast Concrete Sidewalk - 4" Thick	13	cu yd	2,390.48	31,076
Pre-Cast Concrete Swale - 4' Width, 4" Thick	4,080	sf	46.99	191,701
Reinforced Concrete Pipe Storm Drain - 12" Dia.	339	lf	334.26	113,315
Reinforced Concrete Pipe Storm Drain - 18" Dia.	361	lf	381.87	137,855
Reinforced Concrete Pipe Storm Drain - 21" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 24" Dia.	231	lf	429.48	99,209
Reinforced Concrete Pipe Storm Drain - 27" Dia.	279	lf	460.21	128,398
Reinforced Concrete Pipe Storm Drain - 30" Dia.	248	lf	490.98	121,763
Reinforced Concrete Pipe Storm Drain - 33" Dia.	-	lf		-
Reinforced Concrete Pipe Storm Drain - 36" Dia.	-	lf		-
CDS Inline PMSU 40 / 30 Separator	-	ea		-
CDS Inline PMSU 30 / 30 Separator	1	ea	27,470.26	27,470
CDS Inline PMSU 40 / 40 Separator	-	ea		-
Pre-Cast Concrete Outfall Structure	1	ea	6,361.11	6,361
Hardened Security Fencing	2,323	lf	343.27	797,419
Security Chain Link Fence	973	lf	345.20	335,881
Pedestrian Gate	1	ea	1,256.01	1,256
Swing Gate - Double, 20-foot Opening	2	ea	20,825.54	41,651
Retractable Bollards - 4 Units	2	ea	124,953.22	249,906
Traffic Spikes	2	ea	16,773.88	33,548
Floating Barriers for FPCON Charlie/Delta	3,494	lf	542.92	1,896,971
Floating Barrier Sea Anchorage	8	ea	359,698.34	2,877,587
Land Anchors for Floating Barriers	-	ea		-
Wharf Anchorage for Floating Barriers		ea		-
MWR Improvements	2.4	ac	1,012,915.20	2,430,996
Site Work	**1**	**ls**		**22,287,606**
Buildings				
Guard Booth				
Guard Booth	2	ea	287,760	575,520
Guard Booth	**1**	**ls**		**575,520**
Security Watch Tower				
Security Watch Tower - 20' x 20 'x 50' Height	2	ea	500,702	1,001,405
Security Watch Tower	**2**	**ea**		**1,001,405**
Transfer Shed				
Transfer Shed	10,000	sf	432	4,316,400
Transfer Shed	**1**	**ls**		**4,316,400**
Air compressor shed				
Air compressor shed	1,200	sf	863	1,035,936
Air compressor shed	**1**	**ls**		**1,035,936**

Description	Qty	Unit	Unit Cost	Costs
Water Treatment Building				
Water Treatment Building	1,250	sf	863	1,079,100
Water Treatment Building	**1**	**ls**		**1,079,100**
Boiler House				
Boiler House	2,116	sq ft	863	1,826,700
Boiler House	**1**	**ls**		**1,826,700**
Mechanical				
Steam Generation				
312 HP 150psi Scotch Marine	2	ea	517,802	1,035,605
Low Nox Burner	2	ea	65,637	131,274
10,500 MBH 150 psi Deaerator	1	ea	287,668	287,668
w/ feedwater pumpset & controls	1	ea	34,115	34,115
Flash Tank HP condensate	1	ea	18,232	18,232
Flash Tank IP condensate	1	ea	18,232	18,232
Flash Tank LP condensate	1	ea	18,232	18,232
Condensate forwarding system	1	lot	24,472	24,472
Boiler Stack and Breeching	2	ea	22,284	44,568
Metering Station	1	ea	18,783	18,783
Boiler Stack 24" diam	50	lf	658	32,920
Barometric damper	2	ea	2,299	4,599
Steam Piping 6"	1,200	lf	232	278,155
Steam Piping 8"	200	lf	327	65,329
Steam Piping 4" and smaller	500	lf	139	69,608
Condensate piping 2"	100	lf	86	8,630
8" 150# gate valve	2	ea	12,661	25,323
8" 150# Check valve	2	ea	12,256	24,513
6" 150# gate valve	4	ea	8,549	34,196
4" 150# gate valve	3	ea	5,531	16,592
Pressure reducing station	2	lot	34,642	69,283
8" and 6" fitting allowance	1	lot	116,708	116,708
4" and smaller allowance	1	lot	23,186	23,186
6" Concrete Pads	15	cu yd	1,145	17,171
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Steam Generation	**1**	**sys**		**2,420,619**
Fuel Train				
2gpm fuel pumpset	1	ea	3,841	3,841
2500 gal Day Tank w/level cntrls	1	ea	27,369	27,369
Fuel Oil Storage Tank	1	ea	121,226	121,226

Description	Qty	Unit	Unit Cost	Costs
2" A106 Piping	300	lf	86	25,890
Fittings allowance	1	lot	18,147	18,147
Fuel Oil Specialties allowance	1	lot	15,437	15,437
Fuel Train	**1**	**sys 211,911**		
Compressed Air				
2400 scfm (125psi) dplx compressor	3	ea	457,838	1,373,513
Dessicant Dryer skid	1	ea	607,749	607,749
Air Receiver skid	1	ea	130,869	130,869
6" concrete pads	7	cu yd	1,145	8,013
6" welded steel piping	1,200	lf	232	278,155
4" welded steel piping	50	lf	139	6,961
2" and smaller SW steel pipe	500	lf	74	36,789
6" piping fitting allowance	1	lot	94,444	94,444
4" piping fitting allowance	1	lot	2,319	2,319
2" and smaller fitting allowance	1	lot	12,160	12,160
Pipe excavation & backfill	200	lf	12	2,423
Pipe Bedding 6" pipe	200	lf	4	802
Compressed Air	**1**	**sys 2,554,196**		
Water Treatment				
Packaged Water Treatment	20,000	gpd	235	4,708,840
Water Treatment	**1**	**sys 4,708,840**		
Exterior Piping				
6" Ductile Iron Pipe	1,200	lf	118	141,241
10" Ductile Iron Pipe	250	lf	171	42,694
Pipe excavation & backfill	250	lf	12	3,029
Pipe Bedding 10" pipe	250	lf	9	2,299
Pipe Bedding 6" pipe	200	lf	4	802
Exterior Piping	**1**	**ls**		**190,065**
Boiler Room DDC System				
Boiler Room DDC System	1	lot	121,550	121,550
Work Station	1	ea	34,488	34,488
Application software	1	lot	17,390	17,390
Boiler Room DDC System	**1**	**ls**		**173,427**
Alternate #3: Polaris Point Diagonal Offshore				**$ 278,018,566**

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
ELECTRICAL COST SUMMARY - POLARIS POINT								
GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								6,795,268
BERTH SUBSTATION								15,712,000
MWR SERVICE								75,000
BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS								1,000,000
TOTAL ELECTRICAL COST								**35,244,526**
ESCALATION TO OCTOBER 2011 (1.0867)								**38,300,226**
FROM OTHER APPROPRIATIONS								
IDS								25,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
GPA PITI 34.5 KV SWITCHING STATION UPGRADE							100000	100,000
SUBTOTAL GPA PITI 34.5 KV SWITCHING STATION UPGRADE								100,000
34.5 KV FDR (PITI TO POLARIS POINT ROAD)								
Sawcut	6012	M					10	60,962
Trench and Haul	2098	CM					69	144,930
152 Sch 40 PVC	6012	M					44	266,031
Concrete (Thermal)	412	CM					344	141,773
Backfill (Thermal)	1553	CM					316	490,919
Thermal Testing	16	EA					1000	16,000
Restore pavement	1698	SM					43	73,388
Manhole	13	EA					42000	546,000
Conductor. 750 kcmil, 38 kV EPR	19840	M					320	6,348,800
Conductor. #4/0 SDBC	3306	M					26	85,956
MV Splice	39	EA					1068	41,652
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					500000	500,000
Misc Tape, Fasteners, Hardware	1	LS					872534	872,534
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								9,597,872
34.5 KV FDR (MARINE CORP DR TO POLARIS SS)								
Sawcut	2460	M					10	24,944
Trench and Haul	1032	CM					69	71,291
152 Sch 40 PVC	4920	M					44	217,710
Concrete (Thermal)	283	CM					344	97,383
Backfill (Thermal)	636	CM					316	201,046
Thermal Testing	8	EA					1000	8,000
Restore pavement	695	SM					43	30,038
Manhole	5	EA					42000	210,000
Conductor. 750 kcmil, 38 kV EPR	16240	M					320	5,196,800
Conductor. #4/0 SDBC	2706	M					26	70,356
MV Splice	15	EA					1068	16,020
MV Termination	6	EA					1488	8,928
Traffic Management	1	LS					25000	25,000
Misc Tape, Fasteners, Hardware	1	LS					617752	617,752
SUBTOTAL 34.5 KV FDR (PITI TO POLARIS POINT ROAD)								6,795,268
BERTH SUBSTATION								
34.5 kV Vacuum Switchgear	2	EA					2380000	4,760,000
34.5 kV Grounding Transformer	1	EA					260000	260,000
34.5 kV Station Service	1	EA					50000	50,000
Substation Building	1	EA					1300000	1,300,000
SCADA	1	EA					100000	100,000
20/36/33 MVA Transformer	2	EA					2000000	4,000,000
13.8 kV Vacuum Switchgear	2	EA					546000	1,092,000
12/16/20 MVA Transformer	2	EA					1500000	3,000,000
4.16 kV Switchgear	2	EA					325000	650,000
Industrial Power	1	EA					300000	300,000
480V Switchgear	1	EA					200000	200,000
SUBTOTAL BERTH SUBSTATION								15,712,000
MWR SERVICE							75000	75,000
SUBTOTAL MWR SERVICE								75,000
BERTH COMMUNICATIONS								
103 Sch 40 PVC	600	M					30	18,000
Innerduct	300	M					10	3,000

COST ESTIMATE - ELECTRICAL

DD1391 - CVN BERTHING STUDY
NAVBASE
AGANA, GUAM

FEBRUARY 2008
HHMI CORPORATION
MELVIN H. YOKOTA

ITEM DESCRIPTION	QUANTITY		MATERIAL COST		LABOR COST		ENGINEERING ESTIMATE	
	NO.	UNIT	UNIT	TOTAL	UNIT	TOTAL	UNIT	TOTAL
Trench and Backfill	120	CM					147	17,640
Concrete	30	CM					334	10,020
NCTS Cabling Costs	1	LS					250000	250,000
Communications Handhole	4	EA					400	1,600
Communications Mound	3	EA					15000	45,000
B4434-Marine Drive Connection	1350	M					360	486,000
Misc Tape, Fasteners, Hardware	1	LS					83126	83,126
SUBTOTAL BERTH COMMUNICATIONS								914,386
BERTH POWER DISTRIBUTION								
POWER MOUND AND CONNECTION	4	EA					75000	300,000
SUBTOTAL BERTH POWER DISTRIBUTION								300,000
SITE LIGHTING AND EMERGENCY POWER							750000	750,000
SUBTOTAL SITE LIGHTING AND EMERGENCY POWER								750,000
GENERAL CONDITIONS							1000000	1,000,000
SUBTOTAL GENERAL CONDITIONS								1,000,000

BUDGET ESTIMATE SUMMARY SHEET

TITLE:	CVN BERTHING FEASIBILITY STUDY - SEWER & BILGE OILY WASTE SYSTEM UPGRADES (POLARIS POINT PARALLEL & DIAGONAL CONFIGURATIONS)	DATE:	FEBRUARY 2008
INSTALLATION:	U.S. NAVBASE, GUAM	DATE ESCALATED TO:	OCTOBER 2011
LOCATION:	AGANA, GUAM	DESIGN STATUS:	FEASIBILITY STUDY
		ESCALATION FACTOR:	1.0867
PREPARED BY:	Engineering Concepts, Inc.	AREA COST FACTOR:	---

DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL COST	COST TRANSFERRED TO 1391 Sum (Rnd, 10K)
NEW BILGE OILY WASTE COLLECTION SYSTEM & TREATMENT FACILITY				4,213,000	4,580
Bilge Oily Waste Collection Ashore	LS	1	767,000	(767,000)	
Bilge Oily Waste Pump Station	LS	1	766,000	(766,000)	
Bilge Oily Waste Treatment System	LS	1	2,530,000	(2,530,000)	
Technical Operating Manuals	LS	1	150,000	(150,000)	
WASTEWATER COLLECTION SYSTEM IMPROVEMENTS				22,685,050	24,660
Ship Wastewater Collection Ashore	LS	1	607,000	(607,000)	
Submersible Pump Station	LS	1	2,576,000	(2,576,000)	
10-inch Force Main	M	396	820	(324,720)	
15-inch Gravity Sewer Line	M	159	4,590	(729,810)	
Dry Pit / Wet Well Type Pump Station	LS	1	6,669,000	(6,669,000)	
12-inch Force Main	M	4,130	980	(4,047,400)	
8-inch Relief Sewer Line along Marine Drive	M	92	2,930	(269,560)	
12-inch Relief Sewer Line along Marine Drive	M	234	3,950	(924,300)	
15-inch Relief Sewer Line along Marine Drive	M	304	4,590	(1,395,360)	
21-inch Relief Sewer Line along Marine Drive	M	710	6,890	(4,891,900)	
Technical Operating Manuals	LS	1	250,000	(250,000)	
WATER SYSTEM IMPROVEMENTS				552,750	610
Supply Lateral to Pier (8-inch)	M	89	750	(66,750)	
Pierside Water Lines & Outlets (8 and 6 inch lines)	LS	1	486,000	(486,000)	
SUPPORTING FACILITIES				250,000	280
Electrical Utilities	LS	1	250,000	(250,000)	
SUBTOTAL*					**30,130**
* Includes Overhead, Profit, Bond & Insurance, GRT, & Prime Mark-up on subcontract					

APPENDIX C

Reference Project Criteria and Guidance Materials

CVN UTILITY REQUIREMENTS GUIDANCE

Exerpt 24 Sept. 07 Email

Douglas, Greg J.

From: Fukuda, Kalani M CIV NAVFAC PAC [kalani.fukuda@navy.mil]
Sent: Monday, September 24, 2007 10:48 AM
To: Sanehira, Todd S CIV NAVFAC PAC
Cc: Fukuda, Kalani M CIV NAVFAC PAC
Subject: RE: CVN Utility Requirements

Todd,

Just to keep track of things. Item 11 is resolved. Item 11, OWWO rate is 90 gpm.

Awaiting feedback on Item #1, Steam.

v/r,
Kalani

-----Original Message-----
From: Fukuda, Kalani M CIV NAVFAC PAC
Sent: Tuesday, September 18, 2007 14:33
To: Sanehira, Todd S CIV NAVFAC PAC
Cc: Fukuda, Kalani M CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

Todd,

As requested the attached Word file contains the utility demand requirements for the CVN 68 and 78. Below are comments on the various utilities.

1. STEAM: The steam is still undecided. I thought I got something on this from Frank Cole or Chris Fair, but I can't find an email. The CVN
78 is not normally required, but not sure if that is the case for the CVN 68. I just sent an email to Frank Cole on status of steam info.

2. POTABLE WATER: See Vic's email, "RE: CVN Utility Requirements"

3. PURE WATER: Study to recommend course of action.

4. FIRE FIGHTING WATER: Not required.

5. COOLING/FLUSHING WATER: Not required.

6. COMPRESSED AIR: Not required.

7. SHORE POWER: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.

8. SANITARY SEWER (CHT) DISCHARGE: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document.

9. TELEPHONE: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document. Consultant should be coordinating with NCTS and SPAWAR Guam.

10. TELECOMMUNICATIONS: IT21 or C4SIR requirements. Consultant should be coordinating with NCTS and SPAWAR Guam.

11. OILY WASTE/WASTE OIL (OWWO) DISCHARGE: See attached "CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM 21 Aug 07" document. Checking with Frank Cole on whether to provide lines for 90 or 180 gpm.

v/r,
Kalani

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Tuesday, September 04, 2007 2:51
To: Fukuda, Kalani M CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

info

-----Original Message-----
From: Pfarrer, Mark D CTR NAVFACHQ, BDD
Sent: Friday, August 31, 2007 13:10
To: Cole, Frank B CIV NAVFAC Lant
Subject: RE: CVN Utility Requirements

Frank,
Regarding #11. The OWWO rates were based on information provided to me during one of my utility meetings at the NGNN design reviews in Newport News. The OWWO system has two pumps, each 90 gpm. The system can operate, as required, with one or both, hence 90-180 gpm range. The NIMITZ Class ITG says 200 gpm. I suppose, though, that the CVN 78 could limit itself to 90 gpm if the shore installation requested it. I will ask PMS 378 if they can live with only 90 gpm in the FPC, and let you know what I find out. -- Mark

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Thursday, August 23, 2007 11:20
To: Pfarrer, Mark D CTR NAVFACHQ, BDD; Ebmeier, David A CIV NAVFAC Lant
Cc: Fukuda, Kalani M CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

Mark,
Could you look at my comments on items 2 & 11 below?
Dave,
Could you look at my comment 7 below?
Frank

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Thursday, August 23, 2007 11:06
To: Fukuda, Kalani M CIV NAVFAC PAC
Cc: Yao, Victor K CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43); Burke, Francis J CIV COMNAVAIRPAC, N43; Ishikawa, John K CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; 'Caplan, Faith R.'; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC ; Mun, Thomas J CIV NAVFAC PAC
Subject: FW: CVN Utility Requirements

Kalani,
Comments:
1. Steam - need direction from NAVSEA05/PMS312. Have they been tasked?

2. Potable Water - not sure why 235,000 gpd vs 185,000 gpd. I'll check with NAVFAC HQ BD ILS who prepared CVN78 FPC (they are in frequent contact with PMS378) 3. Pure Water - concur 4. Firefighting Water - concur 5. Cooling/Flushing Water - concur 6. Compressed Air - concur 7. Shore Power - I'll forward to Dave Ebmeier NAVFAC LANT for review/comment 8. CHT - concur 9. Telephone - concur 10. IT/COMM - concur 11. OWWO - 90-180 gpm is too much of a range. I'll check with NAVFAC HQ BD ILS who prepared CVN78 FPC (they are in frequent contact with PMS378) 12. HP Air - concur R/ Frank

-----Original Message-----
From: Fukuda, Kalani M CIV NAVFAC PAC
Sent: Tuesday, August 21, 2007 22:28
To: Yao, Victor K CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43); Burke, Francis J CIV COMNAVAIRPAC, N43; Cole, Frank B CIV NAVFAC Lant
Cc: Ishikawa, John K CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; 'Caplan, Faith R.'; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC ; Mun, Thomas J CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Subject: RE: CVN Utility Requirements

To All:

Went through the utility requirements list with the notes from the 13 Aug 07 teleconference and added in the CVN 78 requirements as I see it from the DRAFT Facility Planning, Rev 1, Jul 07. Also added in notes.

1. Steam needs further research as noted.

Victor,

Could you please review the water and wastewater requirements and let us know whether you agree with my recommendations.

Cliff/Francis Burke/Francis Suganuma/Frank Cole,

Any comments?

Thanks.

v/r,
Kalani

-----Original Message-----
From: Fukuda, Kalani M CIV NAVFAC PAC
Sent: Tuesday, August 21, 2007 11:54
To: Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43)
Cc: Ishikawa, John K CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Yao, Victor K CIV NAVFAC PAC ; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; 'Caplan, Faith R.'; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC ; Mun, Thomas J CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Subject: RE:

Francis/Cliff,

I agree with you, Francis, that we should plan for the CVN 78 along with the CVN 68 and other 480V vessels. Basically boils down to bringing in 30MVA power from GPA side of the house transform down to 13.8kV at Polaris Point/SRF area and then further stepping down to 4,160 V and 480 V. I am not sure whether GPA's current 34.5 kV lines running down Marine Corp Drive has the capacity to support the additional 30 MVA or even 21 MVA, if not then would have to look further upstream. Note the consultant would have to coordinate and work with GPA via NAVFAC Marianas in obtaining the 34.5kV, 30MVA power. Also I believe there will be stand-by power charges imposed by GPA for having the 30MVA power capacity available in their system. This will be a future operational cost. Obviously providing power to SRF area would be more costly than at Polaris Point.

v/r,
Kalani

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Tuesday, August 21, 2007 10:49
To: Fukuda, Kalani M CIV NAVFAC PAC
Cc: Ishikawa, John K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT; Yao, Victor K CIV NAVFAC PAC ; Hung, Benjamin C CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31); Sanden, Clifford R CIV (CPF N43); Caplan, Faith R.; Wong, Dominic W CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); Yamashita, Byrnes K CIV NAVFAC PAC
Subject:

Kalani,
Francis' short answer is that the Guam CVN Wharf should be designed to meet the requirements of the next class of CVN (CVN-78, "Ford" Class).
Pls re-engage CPF N43 to see if/how the requirements change.

Shucks, I thought we had a pretty good idea of the requirements to pass to the AE, but looks like we need to iterate. Not sure how much is really known, at this early stage, but it sounds like we'll need to provide 13.8kV, 4,150V, and 480V service (not simultaneously).

Others,
FYI, preliminary Facility Planning Criteria (FPC) document for CVN-78.

Eric

-----Original Message-----
From: Suganuma, Francis M. CIV (N01CE31)
Sent: Tuesday, August 21, 2007 10:05
To: Lee, Eric K CIV NAVFAC PAC ; Sanehira, Todd S CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Cc: Ishikawa, John K CIV NAVFAC PAC ; Rios, Jorge P (Pat) CAPT COMPACFLT
Subject: RE: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

thanks Eric for bringing this up... I meant to earlier on but failed to up to now. Yes, we should plan for CVN 78 Class. Regardless of homeport assignment (PAC vs. LANT) Guam will need to be able to support transient visits by all operational CVNs.

V/R, francis
****
Francis M. Suganuma
Commander, U.S. Pacific Fleet
Theater Assessment & Strategic Studies / BRAC Coordinator (N01CE31)
(808) 474-6460 / Cellular: (808) 478-7419 francis.suganuma@navy.mil
francis.suganuma@navy.smil.mil (SIPRNET)

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Monday, August 20, 2007 16:08
To: Sanehira, Todd S CIV NAVFAC PAC ; Fukuda, Kalani M CIV NAVFAC PAC
Cc: Ishikawa, John K CIV NAVFAC PAC ; Suganuma, Francis M. CIV (N01CE31)
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

Kalani,
CVN 78 projected to require 50% more shore power, at 13.8 kV - up to 30 MW with airwing onboard. I know that CVN 78 is a long way from being built, but pls confirm w/CPF wrt/the electrical requirement we need to satisfy at the Guam CVN wharf.

Eric

-----Original Message-----
From: Ching, Gary M CIV NAVFAC PAC On Behalf Of Ishizu, Wesley W CIV NAVFAC PAC
Sent: Monday, August 20, 2007 13:03
To: Lee, Eric K CIV NAVFAC PAC ; Lucero, Bernard M CIV NAVFAC PAC
Cc: Ishizu, Wesley W CIV NAVFAC PAC
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

fyi

-----Original Message-----
From: Hansen, Dean LCDR (NAVFACMAR)
[mailto:Dean.Hansen@navfacmar.navy.mil]
Sent: Monday, August 20, 2007 12:09
To: Ishizu, Wesley W CIV NAVFAC PAC; Gamez, Joshua J LT NAVFAC PAC, OP; Wakabayashi, Marvan R CIV NAVFAC PAC
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

Gents,
This was passed to me today...not sure whether this will impact the design criteria for the CVN wharf or not, but I thought I'd pass it along in case you haven't seen it yet.

vr/
DLH

-----Original Message-----
From: Suess, Matthew E. CDR (NAVFACMAR)
Sent: Tuesday, August 21, 2007 7:56 AM
To: Turner, Benjamin H. LT (NAVFACMAR)
Cc: Petersen, Michael C. (NAVFACMAR); Hawn, Eric J LCDR; Hansen, Dean LCDR (NAVFACMAR); Tomiak, Robert B. CDR (NAVFACMAR); Fuligni, Paul T.
CAPT (NAVFACMAR); Amato, Paul R. (NAVFACMAR)

Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

LT Turner,

Please forward this to the PWO when he returns and clears some space in his email inbox. No action required yet.

All,

Some interesting info on the new "Ford" class CVN. The issue of concern is how one installs a 40' brow with the flight deck almost directly above the lift point. More interesting are some of the specs on the ship (including 50% more shore power rqmt than a Nimitz-class). For that info, see the last document (CVN 78 FPC Jul0.pdf)

VR,

CDR Matt Suess
NAVFAC Marianas Ops
671-339-4260

-----Original Message-----
From: Cole, Frank B (NAVFAC LANT)
Sent: Monday, August 20, 2007 10:05 PM
To: Jackson, Mark W (NAVFAC SE); Washington, Julius C (NAVFAC SW); Bernotas, Scott A (NAVFAC NW); Worden, Rodney O (NAVFAC HI); Sommer, John T CDR NAVFACFE; Suess, Matthew E. CDR (NAVFACMAR); KurganCM@eu.navfac.navy.mil

Cc: Worcester, James A (NAVFAC LANT); Bolton, Philip N (NAVFAC LANT); Pfarrer, Mark D CTR NAVFACHQ, BDD
Subject: FW: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07
Importance: High

OPS Officers,
I am assisting NAVFAC HQ BD with a tasker to look at officer's brow installation on new generation aircraft carrier, CVN-78.

Expectation is that PMS378 will come to NAVFAC formally, by letter in the near future requesting our disposition on this issue.

Please forward this to your PWO's who have purview over the following installations: Mayport, San Diego (North Island), Everett, Bremerton, Puget Sound Naval Shipyard, Pearl Harbor, Guam, Yokosuka, Busan (Korea), Changi (Singapore), Rota (Spain), and Jebel Ali (UAE). Also request that PWO's advise me of receipt of this information.

This is more of a "heads up" at this time. As I receive input this week from local players and setup our next local meeting, I will keep PWO's in the loop. May need to solicit their input as well.

R/FBC
Frank B. Cole, Jr., PE
Spec Asst for Waterfront & Harbors
NAVFAC Atlantic
Code CIENG
757-322-4203
frank.cole@navy.mil

-----Original Message-----
From: Cole, Frank B CIV NAVFAC Lant
Sent: Wednesday, August 15, 2007 12:22
To: Stewart, Janet K CIV NAVFAC Lant; Aguiar, Joseph R CIV Navy Crane Center, 07; Washbourne, David M CIV 710, C710; Watters, Timothy D CIV NNSY, C740; Langlois, Jim LT NAVFAC MidLant, 250; Theisz, Eddy L CIV ENG SEWELLS PT/YRKTWN DESIGN; Kelly, Howard D CIV NAVFAC Lant; Hawkinson, Sandra L CIV NS Norfolk Port OPS; Soto, Leticia LT Navfac MidLant, OPS; Allen,

Eric J CIV NAVFAC MIDLANT; Bell, Carl A CIV; Schindler, Ron E CIV; Jones, Joseph F Jr CIV; Macias, Kail S CIV (NAVFACHQ); Pfarrer, Mark D CTR NAVFACHQ, BDD; Dean, Clay CONT (NAVFACHQ); Jones, Leonard R CIV SEA 04L

Cc: Iselin, Steven R SES NAVFACHQ; Gott, Joseph E CIV (NAVFACHQ)
Subject: CVN-78 OFFICER'S BROW MEETING - NAVSTA NORFOLK 15 AUG 07

All,
Meeting was held today to discuss potential problems with (Lead Design Yard) LDY proposed method of installing officer's brow on CVN-78.
List of attendees is attached. Slide presentations are attached.
Latest draft of CVN-78 Facilities Planning Criteria is attached.

Key points from meeting:
*   By this email, I am requesting comments on LDY proposed method. Specifically, detail issues/concerns, follow-on questions, and alternative solutions. As discussed, Joe Aquiar will consolidate comments from crane community and forward to me. Need to have this input back by 22 Aug 07.

*   Joe Aquiar mentioned that additional organizations from NNSY should be aware of this, and that he would forward information
*   LT Soto will provide me list of PWO's so that I can forward this

information and have them develop positions, similar to exercise we are going through here at Norfolk. When I transmit this information to them, I will solicit typical pier sections.

*   I will work with NAVFAC HQ to setup our next meeting, which we expect to include representatives from LDY.

R/FBC
Frank B. Cole, Jr., PE
Spec Asst for Waterfront & Harbors
NAVFAC Atlantic
Code CIENG
757-322-4203
frank.cole@navy.mil

<<CVN78_MTG.PDF>> <<19 Jul 07_Final Officer's Gang Way Summary.ppt>> <<CVN-78_OFFICER'S BROW.ppt>> <<CVN 78 FPC Jul07.pdf>>

CVN POWER REQUIREMENTS GUIDANCE

Exerpt CPF Email Guidance 21 Nov. 07

Douglas, Greg J.

From: Koemmpel, Kenneth J CIV PSNS/IMF, Code 312SP [kenneth.koemmpel@navy.mil]
Sent: Wednesday, November 21, 2007 10:59 AM
To: Suganuma, Francis M. CIV (N01CE31)
Cc: Burke, Francis J CIV COMNAVAIRPAC, 312; Gist, Walter J SES CIV NAVSEA 08 NR; Nix, Bruce L PSNS/IMF, NRRO; Morris, Andrew T CIV NAVSEA 08P; Gray, William W CIV Code 2340; Fogelson, Leslie A CIV Code 2340, Code 2340; Angell, Mark E CIV Code 2340, Code 2340
Subject: Power Requirements for a CVN at Guam

Francis,

I have not seen your e-mail with the Guam CVN power requirements question "What redundant power source is required for a CVN Transit berth at Guam?"

A single line source will be acceptable. The requirement for a double transformer with 21MVA capability for each tramsformer is required. The transformers will need to be larger than 21MVA to address heat loads etc. At Yokosuka we are installing 25 MVA transformers. Because of the tranient nature of the conops for the Guam CVN berth onboard backup power will povide the necessary redundant power just like it does when the ship is at sea. Please let me know if you have additional questions.

Ken Koemmpel

CORAL MITIGATION GUIDANCE

Resource Agency Response to NAVFAC Information Requests Made at the CVN Briefing Meeting.

25 March 08

Resource Agency Response to NAVFAC Information Requests Made at the CVN Briefing Meeting
March 25, 2008

1. Mitigation Cost Estimate

Without additional information, we believe that a worst-case scenario must be used to determine mitigation requirements. It may be possible to relax the worst-case scenario with additional appropriate data and adequate time to conduct appropriate analyses.

We have used the Kilo Wharf project as a basis for estimating the CVN mitigation. This project is similar in that it is a large dredging project in Apra Harbor that has undergone mitigation developed through the cooperative efforts of the Navy and Federal and Territorial resource agencies.

Using a worst case scenario for the proposed CVN project and estimates from Kilo Wharf we derive the following:

Kilo Wharf cost/acre

Estimated full cost of Mitigation[1] =	$8.2 Million
Area of direct damage from dredging =	4.7 acres
Cost per acre for mitigation[2] =	$1.74 Million/acre

[1]Cost used is for the total cost of the mitigation project (as estimated by the resource agencies) and not the funded cost. In the view of the resource agencies, the Kilo Wharf mitigation project is under-funded.
[2]This cost figure accounts for the ~20 acres of reef indirectly impacted by the Kilo Wharf project.

Worst Case Estimates for CVN project

Two estimates were derived for the CVN project. The first estimate is derived from the alternative with the largest potential environmental impact (Polaris Point Parallel – full width). The second estimate is derived from the preferred alternative identified at the March 25, 2008 meeting (Polaris Point Parallel – reduced impact).

Total dredged area (Polaris Point Parallel – full width) = 251,800 m-sq = 62.22 acres
Cost for Mitigation = $1.74 Million/acre * 62.22 acres = $108.26 Million

Total dredge area (Polaris Point Parallel – reduced impact) = 238,400 m-sq = 58.91 acres
Cost for Mitigation = $1.74 Million/acre * 58.91 acres = $102.5 Million

These estimates were made with the following caveats:

1. This is a worst case estimate that assumes all dredge area will be coral reef and all area is permanently lost.
2. These estimates are only for the CVN pier project and do not take into account losses associated with Inner Apra Harbor projects, such as the amphibious landing ramps and other inner harbor dredging. Information on the acreage to be dredged for these projects was not available.

3. Monitoring for the success of the mitigation is required under Army Corps regulation and should be included in the up-front cost of the mitigation project. An appropriate coral reef mitigation project will most likely have a long time line and the determination of success may take a decade or more. The resource agencies wish to ensure that appropriate funding to conduct this essential part of the mitigation project is appropriately allocated.

Finally, we believe it is imperative that the mitigation funding come from a source that will allow it to be used for the actions for which it is intended. Limitations of use associated with MILCON funding created difficulties during the Kilo Wharf project, and efforts should be made to ensure that appropriate funding sources are used. Additionally, an effort must be made to ensure that sufficient funding to complete the mitigation project is available at the start of the project; no additional funding for the mitigation project should need to be requested in out years.

2. Additional Survey Needs

In order to meet individual agency mandates, the resource agencies believe it is important to be involved in the data collection for projects of this size and scope. The work at Kilo Wharf, with lessons learned, should serve as a model for this cooperative effort.

It is critical that the resource agencies view the site. Having first hand experience will improve the cooperative effort. The resource agencies will be able to provide more timely and accurate information/recommendations.

To meet these goals, we would request assistance from the Dept of Navy that would enable us to participate as a full partner in the field. Assistance with any issues that would facilitate the completion of field work in timely manner, especially issues associated with funding, site access, and inclusion of Navy personnel as part of the survey effort.

Some additional data needs include, but may not be limited to:

1. Detailed size-frequency information for corals
2. Data on coral reef functional groups
3. An index of coral health
4. Comprehensive macro-invertebrate and algal inventory data
5. Sediment characterization, including at minimum size, composition, biologically-relevant chemistry (e.g., pore water nutrients), and toxicity.

We request that these specific data needs be developed and collected through a cooperative effort between the Navy and the federal and territorial resource agencies.

3. Information Necessary to reduce worst-case estimate

Information needed to reduce the worst case scenario would include, but may not be limited to:

1. Design plans that have a stable footprint. We acknowledge that plans change, but every time the footprint of the plan is shifted, it becomes difficult to reduce the area of impact to the "actual" foot print. (The worst case scenario tires to account for all possible damage in the project area). Additional, a detailed description of how dredging and construction/fill activities will be conducted (e.g., number of anchors, types of lines deployed, if anchors will be moved and how frequently, mitigation measures for anchors and sediments, etc.) is necessary.
2. Estimated recovery potential for the coral reef environment. Mitigation is for both acres lost and the duration for which it is lost. Recovery potential for reefs that are not permanently removed needs to be determined. This requires a greater understanding of ecosystem function/processes including information such as the potential for new recruitment and juvenile survival to adulthood. This information must be collected based on the project design in order to adequately assess the impact in a scientifically sound manner (see #1).
3. Accurate oceanographic information, examining all levels of the water column, is needed. Any sediment impact analysis needs to account for varying sediment particle size (smaller particles tend to have longer suspension times and a larger adverse ecological effect). If Kilo Wharf is any indication, the acreage of reef indirectly affected will be larger than the acreage directly affected. If these areas can be identified, the impacts determined, and the recovery potential estimated, the worst case scenario can be reduced.
4. A clear and realistic description of the anticipated impacts from activities. This should be based on data where possible or supporting literature from a tropical reefs systems when directly applicable data for Apra Harbor is not available (e.g., sediment mortality rates from different sized particles)

4. Participants for the CVN working group

We recommend the following individuals/agencies be part of this group:

Michael Molina, Dwayne Minton (USFWS)
Gerry Davis, Steve Kolinski (NMFS)
Wendy Wiltse (USEPA)
Paul Bassler, Tino Augon, Jay Guttierez (Guam Dept Ag.)
Guam Bureau of Statistics and Plans (Vanie Lujan(?))
Guam EPA (Mike Gawel (?))
Local Navy Contact (Guam)
Appropriate NAVFAC and other Navy personnel

CVN UTILITIES GUIDANCE

CVN 68 UTILITY RQMTS with CVN 78 NOTES FOR GUAM

21 Aug 07

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

ASSUMPTIONS:

- Guam visits vary in length between short 1-2 day visits up to 21 days.
- For visits less than 7 days, it is likely that one reactor would remain operating and the ship would stay on its own power. However, the ship would still connect to pier potable water, shore steam and CHT.
- For visits less than 7 days, the embarked air wing would stay aboard.
- Only emergent/voyage repairs will be conducted in Guam.
- For visits of longer duration (up to 21 days), a portion of the air wing may move ashore. However, a large portion will remain onboard the CVN.
- In the absence of a CVN, other ships/submarines may tie up at the CVN capable berth.

1. STEAM.
Constant Load: 7,000 lb/hr
Quality: Certified Pure, 150 psi

Comment [f1]: Need to understand how this is derived. ITG indicates 50,000 pph at 10 deg Celsius which includes steam heating requirements. Need to understand the basis for that and ensure that it reflects that the air wing is embarked.

CVN 78: Normally not required.

NOTE: Per Frank Cole, NAVFAC Lant, 14 Aug 07 email:

```
Summary
*     Values in TN-1702 and subsequently published in Mil-Hdbk 1025/2 are the
only ones we really have a basis for as they were metered
*     Beginning in 1994 and to present, we have stuck with the 50,000 pph
total as directed by AIRPAC/NAVSEA/PMS312
*     50,000 pph seems excessive; might be worth revisiting with
NAVSEA/PMS312 to see if number could be reduced
```

Recommendation: 50,000 pph does seem to be excessive and believe that most of it is for space heating. Guam will not get to the point of requiring space heating. Recommend NAVSEA/PMS312 be consulted on requirement.

****

2. POTABLE WATER.
Normal Requirement with ships Compliment: ~~100,000~~ 185,000 gpd
Station Location (ft): 300 S, 540 S
Station Height (ft): 36
EPA Approved, 40 psi (residual)

Comment [f2]: Agreed that the "air wing embarked" value of 185,000 gpd should be used. For Guam, need to know is this a question of creating additional capacity/infrastructure or running pipe to the selected berth?

CVN 78: Normally 225 gpm @ 30-40 psi; 235,000 gpd

NOTE: Unless directed otherwise, provide potable requirement for 235,000 gpd.

RECOMMENDATION: Provide for potable water demands per CVN 78 requirements.

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

****

3. PURE WATER.
Quality: Certified Pure
150 gpm and 20,000 gpd

CVN 78: Per DRAFT CVN 78 FPC, pure water provided via tanker truck. Controlled pure water: 100 gpm up to 20,000 gpd. Grade A pure water: two connection 28-56 gpm per connection.

RECOMMENDATION: Study should provide recommendation on course of action.

Comment [f3]: Permanent facility not required and given the assumptions regarding maintenance, the requirement will not likely be more than ½ of this value. PSNS action to review history for CVNs tied up at Pier L/M at NASNI and Evertt and Pier D in PSNS to define anticipated requirement. It is anticipated that the result can be met by temporary means and the study should identify both the anticipated requirement as well as identification of how it will be met. If the selected berth is at Polaris Point, it may be worth checking to see if there is justification for pursuing a permanent facility that supports both submarines and the CVN.

****

4. FIRE FIGHTING WATER.
Not required. Per UFC 4-150-02 for active berths fire fighting water to be provided by ships own pumps, unless directed otherwise. Shore-side fire fighting water is required at shipyard/repair piers.

CVN 78: None required.

Comment [f4]: Concur. No requirement.

****

5. COOLING/FLUSHING WATER.
Not required. Per UFC 4-150-02 for active berths cooling/flushing water to be provided by ships own pumps, unless directed otherwise. Shore-side cooling/flushing water is required at shipyard/repair piers.

CVN 78: None required.

Comment [f5]: Concur. No requirement.

****

6. COMPRESSED AIR.
Quality: ~~125 psig~~ None required. Provided with portable units as required.
Pressure: ~~2,400 scfm~~
Minimum Branch Size: ~~4 in~~
Minimum Outlet Risers per Berth: ~~5~~

CVN 78: LP provided by portable unit.

Comment [f6]: No requirement anticipated. Level of maintenance can either be supported from ship's air or in infrequent cases where that cannot be supported, shipyard will lease or buy portable units. Should only be considered for inclusion at the berth if capacity already exists and the requirement only results in piping to the berth.

****

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

7. SHORE POWER.

No. of Stations	Station Location (ft)	Station Height (ft)	Voltage Am	pacity Per Station	Remarks
1 5	48 S	30	4,160	1,440	CVN Pwr
1 7	04 S	30	4,160	1,440	CVN Pwr
2	296 S	30	480	4,000	Per ITG 480 V power for other vessels
2	1016 S	40	480	4,000	Per ITG 480 V power for other vessels

Comment [f7]: 480V shore power not required for the CVN. However, CPF indicated a desire that the requirements reflect the potential for berthing an LHA/LHD. Should be called out as a non-CVN requirement. Should be built to support transition later to 13.8KV requirement of CVN 78 and beyond—ie whatever can be included now to support that additional requirement later at as low a cost as possible. CNAF will id the anticipated 13.8 kv requirement for consideration.

CVN 78: 30MW @ 13.8 kV (Two 15 MW stations) with air wing.

RECOMMENDATION: Provide 13.8 kV power for the CVN 78, 4,160 V power for CVN 68 and 480 V power for other vessels.

****

8. SANITARY SEWER (CHT) DISCHARGE.

PUMP STATION	PUMP PU	MP RATING	DISCHARGE CONNECTION SIZE
1 1A		400 gpm	4"
1B		400 gpm	
2 2A		400 gpm	
2B		400 gpm	

Comment [f8]: Should be shown as 1200 gpm (3 CHT pumps at 400 gpm max)

CVN 78: Forward, stbd side: 250 gpm; Aft, stbd side: 500 gpm.

RECOMMENDATION: Provide CHT requirements for CVN 68, which has a larger output of 1,200 gpm.

****

9. TELEPHONE.

Comment [f9]: Concur

Active Lines: 60 pr
Cable Size at Berth: 200 pr
(Coordinate with NCTS Guam N2, Karl Bruner.)

CVN 78: 60 pr min, 100 pr max.

RECOMMENDATION: Provide telephone requirements per CVN 68, which has the largest requirement.

CVN 68 UTILITY REQUIREMENTS WITH CVN 78 NOTES FOR GUAM
Results of 13 Aug phoncon between PSNS, CNAF N43, CPF N43, CNAF N8, NAVFAC PAC

****
10. TELECOMMUNICATIONS – IT21 or C4SIR requirements.
Coordinate with SPAWARS Guam and NCTS Guam.

CVN 78: Digital T-1/ISDN, 2 lines.

RECOMMENDATION: Coordinate with SPAWARS Guam and NCTS Guam.

****
11. OILY WASTE/WASTE OIL (OWWO) DISCHARGE.

PUMP STATION	PUMP	PUMP RATING, GPM	PEAK GPD	AVE GPD	DISCHARGE CONNECION SIZE
1 1A		90	80,000	35,000	2.5 in
1B		90			

CVN 78: 90 – 180 gpm.

RECOMMENDATION: Provide per CVN 78 requirements.
****
12. HIGH PRESSURE AIR.
Quality: Chapter 9490 NSTM
Average Demand: 3,000 – 4,500 psi

CVN 78: HP none required.

Comment [f10]: Concur

Comment [f11]: No requirement anticipated. Level of maintenance can either be supported from ship's HP air or in infrequent cases where that cannot be supported, shipyard will lease or buy portable units. Should only be considered for inclusion at the berth if capacity already exists and the requirement only results in piping to the berth.

EHSS GUIDANCE

Email Correspondence

Randy Girdwood (SPAWAR) to Eric Lee (NAVFAC PAC). 30 Jan 08

Randy Girdwood (SPAWAR) to Eric Lee (NAVFAC PAC). 02 Apr 08

Richard Cofer (NAVFAC Lant) to Joseph Condin (NAVFAC PAC), with attachments. 17 Mar 08

From: Randy Girdwood [randy@spawar.navy.mil]
Sent: Wednesday, January 30, 2008 2:34 PM
To: Lee, Eric K CIV NAVFAC PAC ; Douglas, Greg J.
Cc: Lucas, Jolie C.; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

I concur with your statement / breakout.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 29, 2008 6:14 PM
To: Douglas, Greg J.
Cc: Lucas, Jolie C.; Randy Girdwood; Omiya, Laurie M CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Greg,
Just confirming that we will incorporate EHSS costs into the appropriate cost categories on the 1391. I believe that the $200K infrastructure costs should be part of the MCON costs, $300K + $250K for equipment procurement, design, and installation should be OPN equipment costs.

Randy/Laurie,
Pls confirm proper fund sources.

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Monday, January 14, 2008 8:41
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Omiya, Laurie M CIV NAVFAC PAC ;
randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

Thanks for the pics.

Comments inserted below.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Wednesday, January 09, 2008 12:29 PM
To: Randy Girdwood
Cc: Douglas, Greg J.; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Providing figures, fyi.

Sounds like a $750K figure would be reasonable, since the MCON just needs to provide for the additional coverage required, not an initial EHSS that covers all of Guam's needs. I assume that the procurement and installation is done via SPAWAR Contract?

RG: The procurement and installation is done by a mix of SPAWAR and Contractor Personnel. We'll work with the local FEC for the infrastructure / minor construction.

1. Could you give an approximate breakdown - infrastructure vs. equipment&installation, and the funding source?

RG: Approximate breakdown: $200k infrastructure; 300k equipment; 250k engineering/installation.

-If all infrastructure/equipment/installation would be provided from central funding, then we don't need a breakdown. We just need to identify the total system and the cost (on the 1391) as "from other appropriations."

RG: Typically, everything is covered under centralized funding. However, we can work with other methods.

-If the MCON needs to provide just the infrastructure, then we need to know the breakdown to increase the construction portion of the MCON, and identify the remaining cost from other appropriations.

RG: The rough breakout is provided, just in case.

2. If, by some miracle, the CVN Wharf was funded ahead of the primary EHSS installation, could you accelerate Guam's EHSS installation?

RG: The decision is at the CNIC / NAVFAC level - and it all comes done to funding. We can execute in about 18 months after funds receipt.

Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Wednesday, January 09, 2008 7:21
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

During our site visit, we'll take the eventual carrier pier into consideration for the site layout. If an additional remote sensor site is required (for adequate coverage) on the carrier pier as part of MCON effort, a reasonable SWAG is $750k for the infrastructure, equipment, and installation.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 08, 2008 6:29 PM
To: Randy Girdwood; Douglas, Greg J.
Cc: Douglas, Greg J.
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Thanks for reply.

I'm asking about an EHSS, which would be required as part of an MCON, so it's possible the MCON should include the infrastructure costs. The proposed MCON is for a CVN-capable wharf in Guam, and I understand that
policies require and EHSS for CVN wharves.

Operators would like the project in FY11/12, but at over $400mil, it might not be funded, soon. It's possible that you may actually install an Apra Harbor EHSS, before the MCON is completed.

The proposed wharf sites are to either side of the channel to the inner harbor. If you did install a EHSS, don't know if these areas would be covered. If not we'd have to install an additional system as part of the MCON.

Should we just add the EHSS infrastructure costs to the MCON, to be conservative? I guess we need to identify the EHSS equipment costs, as well.

Let me know what you think/recommend.

Eric Lee
Base Development
NAVFAC Pacific
808-472-1170

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Tuesday, January 08, 2008 7:33
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET); randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

The notional budget for the Guam installation is $2.5M. This is for a turn-key installation, from design through system turnover. Typically, the infrastructure costs (foundations, power, telemetry) are much less than the MILCON threshold - and is covered by the $2.5M. However, if there is new construction planned, we can provide input on what is needed to support the system.

Note that the EHSS project has received seed funding under the ATFP Ashore Program to develop a Base Electronics System Engineering Plan (BESEP) to protrect Apra Harbor. I have loosely scheduled a site visit in 2008 to initiate the planning phase.

Kind regards,

Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Monday, January 07, 2008 8:00 PM
To: Randy@spawar.navy.mil
Cc: Douglas, Greg J.; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Can you help us with a budget estimate for an EHSS?

We are writing a 1391 for a CVN-capable wharf in Guam. I understand that EHSS is a requirement for a CVN wharf. We need to include the cost in the 1391.

I have copied Greg Douglas, who represents our consultant who is doing the study and preparing the 1391.

Greg,
Pls contact Randy, unless you already have a reliable estimate.

Joe/Laurie,
Should this EHSS be considered MCON cost, or Collateral Equipment?

Thanks,
Eric Lee
Base Development
NAVFAC Pacific

-----Original Message-----
From: Lefebvre, Paul (NAVFAC ESC)
Sent: Monday, January 07, 2008 7:37
To: Lee, Eric K CIV NAVFAC PAC
Cc: Nixon, Chip (NFESC)
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Hi Eric!

Happy New Year to you, too.

Recommend contacting Randy Girdwood at SPAWAR:

ELECTRONIC HARBOR SECURITY
SYSTEM (EHSS) - SPAWAR
Randy@spawar.navy.mil 619-553-5033
Baxter@spawar.navy.mil 619-553-6697

Please let me know if you have further questions on port security or other topics. Plan to be your way late this month.

Paul

Paul F. Lefebvre
Regional Operations Coordinator
NAVFAC Engineering Service Center
805-982-3548
805-340-8288 cell

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Monday, January 07, 2008 9:27
To: Lefebvre, Paul (NAVFAC ESC)
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Happy New Year, Paul!
Do you have an NFESC POC for EHSS? Pg 12 mentions that a system is

being evaluated. We are doing a 1391 for a CVN Wharf in Guam and I believe EHSS is a requirement. Would like to discuss the requirement and estimated cost w/an expert.

Eric

-----Original Message-----
From: Kamimoto, Clyde H CIV NAVFAC PAC
Sent: Sunday, January 06, 2008 9:03
To: Ishizu, Wesley W CIV NAVFAC PAC; Yamashita, Byrnes K CIV NAVFAC PAC ; Simpkins, Vanessa F CIV NAVFAC PAC; Len, Peter C CIV NAVFAC PAC; Lucero, Bernard M CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Ching, Gary M CIV NAVFAC PAC; Wakabayashi, Marvan R CIV NAVFAC PAC ; Ching, Clayton Y CIV NAVFAC PAC ; Yamagata, Jocelyn C CIV NAVFAC PAC; Shimabukuro, Mark T CIV NAVFAC PAC ; Nakamoto, Wayne S CIV NAVFAC PAC ; Andre Lee (E-mail); Bill Neville (NFM) (william.neville@navfacmar.navy.mil); Neville, Bill CIV NAVFAC SE; Cheryl Milligan; Curtis Wong (curtis.wong@navfacfe.navy.mil); Fukawa, Janice A CIV NAVFAC HI, BD; Hansen, Dean LCDR (NAVFACMAR); Karsten Koch (karsten.koch@navfacfe.navy.mil); Karthik Bharat (karthik.bharat@navfacfe.navy.mil); Kotoshirodo, Carrie L CIV NAVFAC HI, OPHBD2; LCDR Eric Hawn (eric.hawn@navfacmar.navy.mil); Tanaka, Lynn K. T., NAVFAC Hawaii, ARE2; Miyashiro, Glenn M CIV NAVFAC HI, OPHBD1; Rey; Johnston, Steven K CIV NAVFAC HI, BD; Brunner Matthew D LTJG (Sasebo); 'Capili, Cesar Jose (NSFDG N5)'; Clements, John J CIV NAVFACFE; dmkreag@atsugi.navy.mil; Lenny Kim; LT Troy Brown (troy.brown@fe.navy.mil); Mike Lavielle; rosario.alba@cfao.navy.mil; Yuko Ebina; Zenger, Scott A CIV NAVFAC HI, PRB
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

-----Original Message-----
From: Fauber, Sally L CTR NAVFACHQ ATFP
Sent: Thursday, January 03, 2008 8:02
To: Baldwin, Charles L CIV NAVFAC EURSWA; Bernard, Mike CIV SPAWARSYSCEN Charleston SC J633; Brawun, Charles; Butters, Robert L CIV NF Planning Dept; Castro, Ernesto LT (SPSC); Cohen, Robert M LCDR NAVFAC MIDLANT; Daniels, Vernon CIV SPAWAR, J742; Dellalibera, Frank (NFESC); Dominy, Russell O CIV NAVFAC SW, PRTH; Edwards, Brian CIV ,SPAWARSYSCEN; Edwards, Dennis E CDR NAVFAC SE; Evans, Gary L SPAWAR; Glimme, Todd S CIV SPAWAR,SSC SD; Goddeau, Nicholas; Guthmuller, Harry L CIV NSWC PC; Hawkinson, Sandra L CIV NS Norfolk Port OPS; Huneycutt, Ralph K CIV Spawar; Ickes, Warren L CIV NAVSTA Pearl Harbor, N9; Iuvale, Andrew B. CIV N01AT; Jackson, Glen P LCDR COMSUBFOR, N9FP; johnnysn@spawar.navy.mil; kaness@spawar.navy.mil; Kinsey, Chris CMDR ESC09; Kurgan, Christopher M CDR NAVFAC Europe; Lederer, Cliff (NFESC); Lefebvre, Paul (NAVFAC ESC); Lines, Cliffton J LCDR COMSUBFOR, N9FP; Mahlie, Rick Spawar; Mauk, Michael CIV NWSCHS 091; Messock, Richard (NFESC); Morgan, Allan SPAWAR; mwong@spawar.navy.mil; Peeples, David CIV SPAWARSYSCEN Charleston SC J742; randy@spawar.navy.mil; Reed, William E SPAWAR, 543WR; Rourk, Rodney R. CIV (742); Rusek, Ronald M CTR NAVFAC MW, OPS; Senter, Eli; Shebaro,

Ziad; Shebaro, Ziad; Smith, John W CIV Spawar, 742; Walter, Paul G. CIV SPAWARSYSCEN; Ward, Carlene; Zielinski, Greg CAPT, NFESC CO; Aguilera, Susanah CIV NAVFAC SW; All, JC CIV NAVFAC SE; Breen, Amanda A CIV NAVFACHQ; Anderson, Victor (NFESC); Andvik, Brian K CIV NAVFAC NW; Tjoumas, Angelo G CIV HQ Engineer Ops Center; Barcus, Richard S CAPT CNRMA, N9; Bautista, Emmanuel CDR NAVFAC NW, Ops; Brion, Voltaire H CDR NSSC Commanding Officer; Steven Brooks; Brown, Edward W CAPT NAVFAC SE, Executive Officer; Bryan, Mike CIV NAVFAC HQ, BDD; Carmichael, Ronald B CIV NAVSEA; Carr, Scott; Cavileer, D; Clarke, Michael T CIV (NFESCDET); Cole, Frank B CIV NAVFAC Lant; Conroy, Raymond B CIV NNSY, C1120; Cooperman, Mitchell B CIV NAVFAC MIDLANT BD BLC; coopers@nsa.naples.navy.mil; Danis, Kurt D CTR USA USNORTHCOM HQs J34; Kim, Darrell M CIV NAVFAC; Krejdovsky, Dave S CIV NSWCDD, Z23; Day, John S CAPT PEO LMW; DiNobile, Steven J CAPT Naval Station Norfolk, Commanding Officer; Duke, Russell NDW; Eckstrom, Reed A CAPT CNIC HQ, N15; Edwards, Henry B CDR USFF, N3-AT5S; Erickson, Martin CIV USFF, N803; erik.karlson@me.navy.mil; Fauber, Sally L CTR NAVFACHQ ATFP; Foskett, David CIV COMNAVREGNW Port Operations N3; Griffin, Terry CIV Commander Navy Region SE; Grimes, Jeff J CIV CNRNE, 912; Gross, R D CIV (BANG); Hayhurst, Jeffrey K CDR NAVSTA Norfolk, N32; hidehiko.akashi.ja@navfacfe.navy.mil;
Howard, Albert CDR (CNATRA); Ishizu, Wesley W CIV NAVFAC PAC; McConnell, Joseph J CIV NAVFACHQ ; Joyner, Selinda C CIV NAVFACHQ Acquisition, ACQ; Kamimoto, Clyde H CIV NAVFAC PAC ; Kelly, David J CDR Base Support, 100B; Korn, Chris; Draper, Kraig P. USNCIV NAVFACHQ; Lambert, Eugene H CIV NAVSTA Norfolk; Lawrence.Garcia@me.navy.mil; Lehman, Larry CIV CNRNW, Public Safety; Levy, Will CIV NDW; Lister, Scott R CAPT NAVFACHQ OFP, OF; Fleischmann, Lori CIV (NAVFACHQ); Lynch, John J CIV NAVFAC Lant; Macias, Kail S CIV (NAVFACHQ); Maki; Marion, Dennis S LT NAVSTA Norfolk, N93; mark.scott@me.navy.mil; Markey, Jeff H CIV NAVFAC MW PWD GL FMD; Schenck, Marshall H CIV HQ Engineer Ops Center; Martin, Steve W SPAWAR; Fields, Mike D CIV NAVFACHQ, ATFP; Essoglou, Milon CIV (NAVFACHQ); Murdock, Tracey E CAPT; Murley, Steve P CTR CNIC HQ, N7; Nelson, Lasandra CIV CNIC HQ, N3; nishimurag@eu.navfac.navy.mil; Oakley, Harold O CTR NAVFACHQ, ATFP; Orzell, Michael S CDR USFF, N3-AT5P; Jay, Otis C CIV HQ Engineer Ops Center; Perez, Manuel (NFESC); peter.novick@fe.navy.mil; Petro, George CAPT USFF, N803; phillipsa@eu.navfac.navy.mil; Pine, Pam G CIV USFF, N3-AT3R; Pregel, Tony A CAPT NAVFAC Lant; Pyle, Loyd E JR CAPT; Reid, Michael Anthony CIV HQ 00, ATFP; Robishaw, Richard W CIV NAVFACHQ; richard.w.neely@eu.navy.mil; Rodriguez, Jose J CDR NSA Norfolk, N142; Saum, Mike CDR PWD Norfolk; Schelfhout, Stephen J CIV NSWC PC; Shaw, Claude B CIV CNRH, N3; Smith, Eric CTR CNIC; Sontag, Charles R CIV NBK Bangor, N93; Soto, Leticia LT Navfac MidLant, OPS; steven.chan@me.navy.mil; Iselin, Steven SES NAVFACHQ, ED; steven.koepsell@navfacfe.navy.mil; Thompson, Wil L LCDR USFF, N3-AT3O; Toth, Bruce CIV Commander Navy Region SE; Valle, Timothy W CIV NRMW/NAVSTA EMO N37; Van de Voorde, Jim R CTR NAVFACHQ, ATFP; Vesterman, John E CDR USFF, N3-AT3; Keip, Vincent J CIV HQ Engineer Ops Center; Whitehouse, John CIV CNRH, N37; Whitteker Sam CIV; Ennis, Wilson E CIV HQ Engineer Ops Center; Wright, O CIV USFF, N3-ATB; Albright, Deborah Civ NAVFAC; Arkwright, Michele G CIV PEO LMW; Ayling, Michael CTR CNIC HQ, N3; Bailey, Mark E CIV NSWCDL, Z11;

baxter@spawar.navy.mil; Cherepon, Glen J CIV NAVFAC SW; Clanahan, Chuck CIV CNIC HQ, N3AT; Cofer, Richard J CIV NAVFAC Lant; Coker, Christine L CIV NAVBASE Kitsap, N9; Coleman, Joseph W CIV NAVSEA HQ, SEA 05; Condlin, Joseph R CIV NAVFAC PAC ; Croson, Matthew Franklin LT; Crouch, David A (NFESC); Cullen, William P CAPT CNIC HQ, N3; Davis, Jackie M CIV USFF, N3/N5C1; Davis, Jim W CIV USFF, N3-AT5; DeVisser, Alexandra (NFESC); Douvres, Matthew A CIV CNRSW; Duong, Anh N CIV CNO N3AT13; Ermovick, Tony CAPT NAVFAC MIDLANT; Fontan, Will C CIV NSWCDD, Z23; Funn, John V CDR NAVSEA, PMS480; Galloway, John P SES PEO LMW; Gauthier, Ron SPAWAR; Gibson, Jack R CIV NAVFAC SW; Goodin, Glenn CIV NSWCDL, Z23; Goldberg, Barbara M CTR NS Newport, N424; Golie, Carl CIV CNIC HQ, N3AT; Grower, Jason P. LT CNO N3AT3; Hagen, Mark D LTJG NAVFAC MIDLANT; Haseltine, David K CIV CNRSE, N3AT; Hellman, David H CAPT OASN (I&E) BRAC PMO; Hulse, Richard L CIV CNO, N3AT; Huskey, Jeffrey CIV CNIC HQ, N6; Jones, Pat CIV CNIC HQ, N3; Larson, Jonathan CTR CNIC HQ, N57; Leigh, Lori CIV NFESC; Lester, Frank CIV Force Protection Program Manager; Lutz, Marjorie CIV CNIC HQ, N3; Macinski, Michael J CAPT CNO, N3AT; McIntyre, Owen CIV CNIC HQ, N3; Meyers, Michael J CIV, N8S&T; Morrissey, Shawn B. CIV CNRH, N3; Mueller, Tim CIV (CPF N34); Naiser, Donald CDR CNIC HQ, N3; Newton, Rick P CDR CNIC HQ, N3; Nixon, Chip (NFESC); Nolan, Richard J CIV CNIC HQ, N3; Oboyle, Thomas J CIV (NFESCDET); Peterson, Leila K CTR CNIC, N3; Phillips, Jon R LT NSSC NORFOLK; Piepgrass, Dan J CIV CNIC HQ, N3; Pittman, John R CIV (NFESCDET); Powell, Chris S CDR USFF, N3-AT5; Reid, Michael Anthony CIV HQ 00, ATFP; Risley, Jim CIV CNIC HQ; Schuler, Al CIV LMW; Seelig, William N CIV (NFESCDET); Shultz, Daniel CDR, Commanding Officer; Siegel, Jonathan B CIV NAVFAC MIDLANT; Sinder, Mark CTR CNIC HQ, OPS; Spruill, John SPAWAR; Stark, Stephen E CTR CNI HQ, Public Safety; Tausig, Wayne (NFESC); Thomsen, James E SES PEO LMW; Tullos, Rex CDR CNIC; Viggiano, Mike (NFESC) NAVFAC; Vitale, Philip CIV (NAVFAC); Wagner, William John GS13 CNRMA; Whittier, Kim CIV NAVFAC; Wyckoff, Russell CDR CNRMA, N3; Yoshikawa, Stacie A CIV 250, 2523; Zahorbenski, Theodore S CIV SPAWAR Old Towne; Armstrong, Ayana D. OPR NAVFACWASH; Bastinelli, Peter CIV NAVFAC Lant; Bernotas, Scott CDR NAVFAC NW, BANG; Blankenship, Art CIV NSWCDL, Z06; Bowling, Gina CTR CNIC N3, Emergency Management; Carter, Dareyl CWO3 NAVSTA Mayport N32; Charters, Tom CIV SPAWARSYSCEN SAN DIEGO 2838; Cooper, Ted J CONT NSWC, PC; Cunha, Jim CAPT CNO, N3AT; Finnegan, Joseph T CTR CNIC HQ, N3; Fitzgibbon, Steven W CIV NSWC PC; Flotten, Brandy C NAVAIR; Fung, Daniel S CIV NAVFAC SW; Gilmore, Charles OPERATIONS, PDPS; Hartmann, Beth L CDR NAVFAC MW, XO; Horning, Spencer H CIV NAVFAC NW; Johnson, Henry D CIV SPAWAR; Laderer, David A LCDR CNRMA; Lee, Robert E CIV; Lillard, John D SPAWAR; Little, Maureen (NFESC); Londergan, Diana CIV Spawar 742DL; Lustig, Edward A Jr CIV NAVSURFWARCENDIV, E314; Lynch, Richard D CIV NAVFAC SE; McCracken, Alicia G CTR PEO LMW; McGraw, Jennifer CIV NAVSEA PEO LMW; Miller, Allen CIV NFESC; Mitchell, John CIV SPAWAR, OT11 1852E; Moorefield, Carlton; Mule, Leonard W CIV NF CIVIL STRUC BRANCH SP/YT; Palmer, Stephen E CTR USFF, N3-AT5P4; Robb, Jeffrey A CIV NAVFAC SE; Searight, Jonathan CIV SPAWARSYSCEN Charleston SC J63C; Seiter, Scott; Sergienko, Eric CDR; Smith, David M CDR NAVFAC Southeast, RE Staff; Sparks, Stevenson L CIV NAVFAC NW; Summers, Doug CIV NAVSURFWARCENDIV, CRANE Code 8056; Tate, Ann E SES NSWCDL, C92; Torres, Luis A CIV

NAVFAC; Troffer, Michael A CIV EODTECHDIV; Varnava, Andrew (NFESC); Yingling, Theresa L CIV NAVSEA PEO LMW; Zeller, Charles A CIV NAVSURFWARCENDIV Crane, Code JXNF
Subject: 2008-01-03 Waterside Security System Bi-Weekly Report

>V/r,
>Sally Fauber
>Anti-Terrorism/Force Protection (AT/FP)
>Phone: 202-685-9356
DSN: 325-9356
>Email: sally.fauber.ctr@navy.mil

From: Randy Girdwood [randy@spawar.navy.mil]
Sent: Wednesday, April 02, 2008 6:32 PM
To: Lee, Eric K CIV NAVFAC PAC
Subject: RE: Guam CVN - clarifications

Eric,

My apology for the delay. A brief, written description of EHSS follows.

"The Electronic Harbor Security System (EHSS) is designed to protect Navy ships in port from waterborne attacks. The EHSS is part of the Commander, Navy Installation Command / Naval Facilities Engineering Command Anti-terrorism Force Protection Ashore program under the Waterfront Protection capability area. EHSS is designed to work with waterfront barriers as part of a layered defense to protect U.S. Navy ships in port against waterborne attacks. The principal function of the EHSS is to aid existing security personnel with the tasks of detecting, classifying, assessing, and responding to waterborne threats. The EHSS is an integrated system composed of Commercial-Off-The-Shelf (COTS) and Government-Off-The-Shelf equipment."

I'm not clear what additional information is required for the CVN project, at this point. Most of the EHSS work will be completed outside the MILCON effort. After our upcoming site visit, we can provide much better information on site selections that include coverage of the carrier pier. If the preferred location is on the pier, we can provide additional details.
The main requirement for a pier installation will be power and fiber-optics / conduits. During a similar installation, we had to run a separate conduit runs down the length of the pier since the existing capacity was completely used. Ideally, that could be incorporated into the design. The tower and generator will require some footprint, but these shouldn't negatively impact the pier design.

Break-break, new subject:

Earlier, I spoke with Mr. Roy Kinsey from SPAWARSYSCEN Charleston. Reportedly, he received year-end funding from CNIC last year that was placed on contract. Those funds are targeted to install a wireless network and possibly some cameras on the waterfront. His group has meetings scheduled with the N6 during the week of 14 April 2008. I'm considering moving our site visit for EHSS to overlap - it looks like there may be some synergy between the two projects.

Questions:
1. Do you see any issues with an EHSS site visit during the week of 14 Apr?
2. Can you provide the contact information for the NAVBASE Guam SECO?
3. Can you provide the contact information for the Public Works

Officer?

Thanking you in advance.

Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Monday, March 24, 2008 6:10 PM
To: randy@spawar.navy.mil; Baxter@spawar.navy.mil
Cc: Douglas, Greg J.
Subject: RE: Guam CVN - clarifications

Randy,
Have not heard back from you. Left a phone message, too. Could you privide
a little bit of general info on ehss, so we can include in our report. We
will be stating that EHSS is required for the CVN wharf, and provide cost
estimates as previously discussed. We need to include a paragraph or so to
describe what we might be talking about wrt EHSS.

Thanks,
Eric

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Thursday, March 13, 2008 9:33
To: randy@spawar.navy.mil
Cc: Douglas, Greg J.
Subject: FW: Guam CVN - clarifications

Randy,

Can you provide some general info on EHSS, and the kind of system that might
be employed at a Guam CVN Wharf?

Pls see questions b. and c., below.

To refresh your memory, even assuming an EHSS for the Inner Apra Harbor, due
to the location of the CVN wharves (outside the channel to Inner Apra Harbor)

Thanks,
Eric Lee

-----Original Message-----
From: Douglas, Greg J. [mailto:GJDouglas@tecinc.com]
Sent: Tuesday, March 11, 2008 10:39
To: Lee, Eric K CIV NAVFAC PAC
Cc: Muslin, Dan; Stewart, Warren; Lucas, Jolie C.
Subject: Guam CVN - clarifications

Eric,

One outstanding issue came up today:

1. We spoke at length with Warren Stuart this morning, and they (Halcrow) did not get clear direction regarding the use of electronic surveillance equipment. They have included the floating barriers (PSB's), but have thus far left out the EHSS. You provided us with direction to include EHSS costs in the 1391, and I had (incorrectly) assumed this came down from work Halcrow had been engaged in. The attached email is the final correspondence we had on the EHSS system. This was direction for TEC to include costs in the 1391, but no direction with regard to the narrative, description of the EHSS, etc.

a. What is the final determination regarding EHSS?

b. What should Halcrow include in the narrative for the EHSS system?

c. What type of system do the costs noted in the attached email cover?

d. Were the "fund sources" confirmed by Randy/Laurie as noted in the email?

Re: Steam:

We discussed the steam issue at length today as well. Warren and his team are reviewing the email string now.

I believe we are still in favor of leaving the costs in as they are now, particularly at this programmatic level, to ensure adequate funds are available. There is more inherent risk with retrofitting old equipment to

new uses, and costs can be unpredictable. My concern is with 1b and 1c
below (excerpt from email string). The existing equipment at SRF needs to
be repaired and upgraded.

Can you provide further, clear direction on this item?

"

Please help us to ensure we understand clearly, by verifying the following:

1a. Are both boilers going to be 250 HP (after the Kilo wharf boiler is
moved)? YES, PLEASE SEE ITEM 1.

1b. Are both boilers going to be fully operational, prior to the CVN wharf
(earliest completion would be 2013)? YES, PLEASE PREPARE DD1391 FOR PROJECT
TO REPAIR/UPGRADE EXSISTING BOILER PLANT AT SRF.

1c. Is (will) all associated equipment complete and in good operating
condition? ASSOCIATED EQUIPMENT FROM KILO WHARF BOILER PLANT IS IN GOOD
OPERATING CONDITIONS. THE EXISTING ASSOCIATED EQUIPMENT AT SRF NEEDED TO BE
REPAIR.

1d. Have (will) the existing SRF steam lines been replaced since 2004?
STEAM LINE WAS REPLACED FROM LIMA TO ROMEO IN 2003.

If the answers to 1a., 1b., 1c., 1d. are all "yes," then we can remove all
steam-related costs.

"

Thanks.

Best Regards,

Greg Douglas

TEC Inc.

514 Via De La Valle, Suite 308

Solana Beach, CA 92075

Ph. (858) 509-3157

Fax (858) 509-3157

Cell (858) 829-6096

Email: gjdouglas@tecinc.com

From: Cofer, Richard J CIV NAVFAC Lant [richard.cofer@navy.mil]
Sent: Monday, March 17, 2008 5:07 AM
To: Condlin, Joseph R CIV NAVFAC PAC
Cc: Lee, Eric K CIV NAVFAC PAC ; Lynch, John J CIV NAVFAC Lant
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report
Signed By: There are problems with the signature. Click the signature button for details.

Follow Up Flag: Follow up
Flag Status: Flagged

Attachments: OPNAVINST 5530 14D (30 JAN 07) - Final.pdf; UFC 4-025-01 Waterfront Security Ver A.pdf

OPNAVINST) 14D (30 JAN 0 UFC 4-025-01 aterfront Securi

Joe,

Requirements for protection of waterfront assets are not dictated by Unified
Facility Criteria, it is rooted in DoD and Navy Policy/Regulations. See
OPNAVINST 5530.14D Table VIII-1, Security of Waterfront Assets Matrix in
U.S. Navy Controlled Ports. The 5530 14D is attached.

CVN is classified as a "Priority B" asset. Priority B assets require
electronic water/waterside security system (CCTV, associated alarms, surface
craft or swimmer detection, underwater detection). Water barriers are
required to prevent direct unchallenged access from small boat attacks.

Attached is the current Draft of the Waterfront Security UFC. You have a
copy of the old one.

Regards,

Richard Cofer, P.E.
NAVFAC Atlantic, ATFP
6506 Hampton Blvd
Norfolk, VA 23508-1278
757-322-4447
http://www.wbdg.org/references/pa_dod_eico.php

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error please notify the sender by return e-mail and delete this message from
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-----Original Message-----
From: Condlin, Joseph R CIV NAVFAC PAC
Sent: Friday, March 14, 2008 17:32
To: Lynch, John J CIV NAVFAC Lant; Cofer, Richard J CIV NAVFAC Lant
Cc: Lee, Eric K CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report
Importance: High

I'm working with planners for the Guam DPRI build-up. I need to get a copy
of any upcoming UFC drafts for electronic harbor security, water barriers,
waterfront security, i.e., UFC 4-012-18. If you have any draft UFCs coming
out please forward a copy via e-mail.

DPRI is sensitive. Please keep "close hold".

Regards,
Joe Condlin

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC
Sent: Tuesday, March 11, 2008 11:23
To: Condlin, Joseph R CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Joe,
As we discussed, thanks for the help.

Just want to be sure I'm not adding nice-to-haves, vs. requirements.

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Thursday, January 31, 2008 8:04
To: Lee, Eric K CIV NAVFAC PAC
Cc: randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

I can't say definitively. I believe the UFC (at least the draft version from
a few years ago) required waterfront protection (barriers and EHSS) for
Priority B assets. Regrettably, I can't cite chapter and verse.

Hope that helps.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Wednesday, January 30, 2008 8:17 PM
To: Randy Girdwood
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
I was assuming that an EHSS is required, for a CVN berth. Is this truly a
requirement, and if so, what is the reference criteria?

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Wednesday, January 30, 2008 12:34
To: Lee, Eric K CIV NAVFAC PAC ; 'Douglas, Greg J.'
Cc: 'Lucas, Jolie C.'; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

I concur with your statement / breakout.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 29, 2008 6:14 PM
To: Douglas, Greg J.
Cc: Lucas, Jolie C.; Randy Girdwood; Omiya, Laurie M CIV NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Greg,
Just confirming that we will incorporate EHSS costs into the appropriate
cost categories on the 1391. I believe that the $200K infrastructure costs
should be part of the MCON costs, $300K + $250K for equipment procurement,
design, and installation should be OPN equipment costs.

Randy/Laurie,
Pls confirm proper fund sources.

Thanks,
Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Monday, January 14, 2008 8:41
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Omiya, Laurie M CIV NAVFAC PAC ; randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

Thanks for the pics.

Comments inserted below.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Wednesday, January 09, 2008 12:29 PM
To: Randy Girdwood
Cc: Douglas, Greg J.; Omiya, Laurie M CIV NAVFAC PAC
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Providing figures, fyi.

Sounds like a $750K figure would be reasonable, since the MCON just needs to
provide for the additional coverage required, not an initial EHSS that
covers all of Guam's needs. I assume that the procurement and installation

is done via SPAWAR Contract?

RG: The procurement and installation is done by a mix of SPAWAR and Contractor Personnel. We'll work with the local FEC for the infrastructure /
minor construction.

1. Could you give an approximate breakdown - infrastructure vs. equipment&installation, and the funding source?

RG: Approximate breakdown: $200k infrastructure; 300k equipment; 250k engineering/installation.

-If all infrastructure/equipment/installation would be provided from central
funding, then we don't need a breakdown. We just need to identify the total
system and the cost (on the 1391) as "from other appropriations."

RG: Typically, everything is covered under centralized funding. However, we
can work with other methods.

-If the MCON needs to provide just the infrastructure, then we need to know
the breakdown to increase the construction portion of the MCON, and identify
the remaining cost from other appropriations.

RG: The rough breakout is provided, just in case.

2. If, by some miracle, the CVN Wharf was funded ahead of the primary EHSS
installation, could you accelerate Guam's EHSS installation?

RG: The decision is at the CNIC / NAVFAC level - and it all comes done to
funding. We can execute in about 18 months after funds receipt.

Eric

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Wednesday, January 09, 2008 7:21
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

During our site visit, we'll take the eventual carrier pier into consideration for the site layout. If an additional remote sensor site is
required (for adequate coverage) on the carrier pier as part of MCON effort,
a reasonable SWAG is $750k for the infrastructure, equipment, and installation.

R/Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Tuesday, January 08, 2008 6:29 PM
To: Randy Girdwood; Douglas, Greg J.
Cc: Douglas, Greg J.
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Thanks for reply.

I'm asking about an EHSS, which would be required as part of an MCON, so
it's possible the MCON should include the infrastructure costs. The proposed MCON is for a CVN-capable wharf in Guam, and I understand that
policies require and EHSS for CVN wharves.

Operators would like the project in FY11/12, but at over $400mil, it might
not be funded, soon. It's possible that you may actually install an Apra
Harbor EHSS, before the MCON is completed.

The proposed wharf sites are to either side of the channel to the inner
harbor. If you did install a EHSS, don't know if these areas would be covered. If not we'd have to install an additional system as part of the
MCON.

Should we just add the EHSS infrastructure costs to the MCON, to be conservative? I guess we need to identify the EHSS equipment costs, as
well.

Let me know what you think/recommend.

Eric Lee
Base Development
NAVFAC Pacific

808-472-1170

-----Original Message-----
From: Randy Girdwood [mailto:randy@spawar.navy.mil]
Sent: Tuesday, January 08, 2008 7:33
To: Lee, Eric K CIV NAVFAC PAC
Cc: 'Douglas, Greg J.'; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M
CIV NAVFAC PAC ; Seelig, William N CIV (NFESCDET);
randy@spawar.navy.mil
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Eric,

The notional budget for the Guam installation is $2.5M. This is for a turn-key installation, from design through system turnover. Typically, the infrastructure costs (foundations, power, telemetry) are much less than the MILCON threshold - and is covered by the $2.5M. However, if there is new construction planned, we can provide input on what is needed to support the system.

Note that the EHSS project has received seed funding under the ATFP Ashore Program to develop a Base Electronics System Engineering Plan (BESEP) to protrect Apra Harbor. I have loosely scheduled a site visit in 2008 to initiate the planning phase.

Kind regards,

Randy Girdwood
SPAWARSYSCEN San Diego
619-553-5033

-----Original Message-----
From: Lee, Eric K CIV NAVFAC PAC [mailto:eric.k.lee@navy.mil]
Sent: Monday, January 07, 2008 8:00 PM
To: Randy@spawar.navy.mil
Cc: Douglas, Greg J.; Condlin, Joseph R CIV NAVFAC PAC ; Omiya, Laurie M CIV
NAVFAC PAC
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Randy,
Can you help us with a budget estimate for an EHSS?

We are writing a 1391 for a CVN-capable wharf in Guam. I understand

that
EHSS is a requirement for a CVN wharf. We need to include the cost in the
1391.

I have copied Greg Douglas, who represents our consultant who is doing the
study and preparing the 1391.

Greg,
Pls contact Randy, unless you already have a reliable estimate.

Joe/Laurie,
Should this EHSS be considered MCON cost, or Collateral Equipment?

Thanks,
Eric Lee
Base Development
NAVFAC Pacific

-----Original Message-----
From: Lefebvre, Paul (NAVFAC ESC)
Sent: Monday, January 07, 2008 7:37
To: Lee, Eric K CIV NAVFAC PAC
Cc: Nixon, Chip (NFESC)
Subject: RE: 2008-01-03 Waterside Security System Bi-Weekly Report

Hi Eric!

Happy New Year to you, too.

Recommend contacting Randy Girdwood at SPAWAR:

ELECTRONIC HARBOR SECURITY
SYSTEM (EHSS) - SPAWAR
Randy@spawar.navy.mil 619-553-5033
Baxter@spawar.navy.mil 619-553-6697

Please let me know if you have further questions on port security or other
topics. Plan to be your way late this month.

Paul

Paul F. Lefebvre
Regional Operations Coordinator
NAVFAC Engineering Service Center
805-982-3548
805-340-8288 cell

-----Original Message-----

From: Lee, Eric K CIV NAVFAC PAC
Sent: Monday, January 07, 2008 9:27
To: Lefebvre, Paul (NAVFAC ESC)
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

Happy New Year, Paul!
Do you have an NFESC POC for EHSS? Pg 12 mentions that a system is being
evaluated. We are doing a 1391 for a CVN Wharf in Guam and I believe EHSS
is a requirement. Would like to discuss the requirement and estimated cost
w/an expert.

Eric

-----Original Message-----
From: Kamimoto, Clyde H CIV NAVFAC PAC
Sent: Sunday, January 06, 2008 9:03
To: Ishizu, Wesley W CIV NAVFAC PAC; Yamashita, Byrnes K CIV NAVFAC PAC ;
Simpkins, Vanessa F CIV NAVFAC PAC; Len, Peter C CIV NAVFAC PAC; Lucero,
Bernard M CIV NAVFAC PAC ; Lee, Eric K CIV NAVFAC PAC ; Ching, Gary M CIV
NAVFAC PAC; Wakabayashi, Marvan R CIV NAVFAC PAC ; Ching, Clayton Y CIV
NAVFAC PAC ; Yamagata, Jocelyn C CIV NAVFAC PAC; Shimabukuro, Mark T CIV
NAVFAC PAC ; Nakamoto, Wayne S CIV NAVFAC PAC ; Andre Lee (E-mail); Bill
Neville (NFM) (william.neville@navfacmar.navy.mil); Neville, Bill CIV NAVFAC
SE; Cheryl Milligan; Curtis Wong (curtis.wong@navfacfe.navy.mil); Fukawa,
Janice A CIV NAVFAC HI, BD; Hansen, Dean LCDR (NAVFACMAR); Karsten Koch
(karsten.koch@navfacfe.navy.mil); Karthik Bharat
(karthik.bharat@navfacfe.navy.mil); Kotoshirodo, Carrie L CIV NAVFAC HI,
OPHBD2; LCDR Eric Hawn (eric.hawn@navfacmar.navy.mil); Tanaka, Lynn K. T.,
NAVFAC Hawaii, ARE2; Miyashiro, Glenn M CIV NAVFAC HI, OPHBD1; Rey;
Johnston, Steven K CIV NAVFAC HI, BD; Brunner Matthew D LTJG (Sasebo);
'Capili, Cesar Jose (NSFDG N5)'; Clements, John J CIV NAVFACFE;
dmkreag@atsugi.navy.mil; Lenny Kim; LT Troy Brown
(troy.brown@fe.navy.mil);
Mike Lavielle; rosario.alba@cfao.navy.mil; Yuko Ebina; Zenger, Scott A CIV
NAVFAC HI, PRB
Subject: FW: 2008-01-03 Waterside Security System Bi-Weekly Report

-----Original Message-----
From: Fauber, Sally L CTR NAVFACHQ ATFP
Sent: Thursday, January 03, 2008 8:02
To: Baldwin, Charles L CIV NAVFAC EURSWA; Bernard, Mike CIV SPAWARSYSCEN
Charleston SC J633; Brawun, Charles; Butters, Robert L CIV NF Planning Dept;
Castro, Ernesto LT (SPSC); Cohen, Robert M LCDR NAVFAC MIDLANT; Daniels,
Vernon CIV SPAWAR, J742; Dellalibera, Frank (NFESC); Dominy, Russell O CIV
NAVFAC SW, PRTH; Edwards, Brian CIV ,SPAWARSYSCEN; Edwards, Dennis E CDR
NAVFAC SE; Evans, Gary L SPAWAR; Glimme, Todd S CIV SPAWAR,SSC SD; Goddeau,
Nicholas; Guthmuller, Harry L CIV NSWC PC; Hawkinson, Sandra L CIV NS
Norfolk Port OPS; Huneycutt, Ralph K CIV Spawar; Ickes, Warren L CIV NAVSTA
Pearl Harbor, N9; Iuvale, Andrew B. CIV N01AT; Jackson, Glen P LCDR
COMSUBFOR, N9FP; johnnysn@spawar.navy.mil; kaness@spawar.navy.mil; Kinsey,
Chris CMDR ESC09; Kurgan, Christopher M CDR NAVFAC Europe; Lederer, Cliff
(NFESC); Lefebvre, Paul (NAVFAC ESC); Lines, Cliffton J LCDR COMSUBFOR,
N9FP; Mahlie, Rick Spawar; Mauk, Michael CIV NWSCHS 091; Messock, Richard
(NFESC); Morgan, Allan SPAWAR; mwong@spawar.navy.mil; Peeples, David CIV
SPAWARSYSCEN Charleston SC J742; randy@spawar.navy.mil; Reed, William E
SPAWAR, 543WR; Rourk, Rodney R. CIV (742); Rusek, Ronald M CTR NAVFAC MW,
OPS; Senter, Eli; Shebaro, Ziad; Shebaro, Ziad; Smith, John W CIV Spawar,
742; Walter, Paul G. CIV SPAWARSYSCEN; Ward, Carlene; Zielinski, Greg CAPT,
NFESC CO; Aguilera, Susanah CIV NAVFAC SW; All, JC CIV NAVFAC SE; Breen,
Amanda A CIV NAVFACHQ; Anderson, Victor (NFESC); Andvik, Brian K CIV NAVFAC
NW; Tjoumas, Angelo G CIV HQ Engineer Ops Center; Barcus, Richard S CAPT
CNRMA, N9; Bautista, Emmanuel CDR NAVFAC NW, Ops; Brion, Voltaire H CDR NSSC
Commanding Officer; Steven Brooks; Brown, Edward W CAPT NAVFAC SE, Executive
Officer; Bryan, Mike CIV NAVFAC HQ, BDD; Carmichael, Ronald B CIV NAVSEA;
Carr, Scott; Cavileer, D; Clarke, Michael T CIV (NFESCDET); Cole, Frank B
CIV NAVFAC Lant; Conroy, Raymond B CIV NNSY, C1120; Cooperman,

Mitchell B
CIV NAVFAC MIDLANT BD BLC; coopers@nsa.naples.navy.mil; Danis, Kurt D CTR
USA USNORTHCOM HQs J34; Kim, Darrell M CIV NAVFAC; Krejdovsky, Dave S CIV
NSWCDD, Z23; Day, John S CAPT PEO LMW; DiNobile, Steven J CAPT Naval Station
Norfolk, Commanding Officer; Duke, Russell NDW; Eckstrom, Reed A CAPT CNIC
HQ, N15; Edwards, Henry B CDR USFF, N3-AT5S; Erickson, Martin CIV USFF,
N803; erik.karlson@me.navy.mil; Fauber, Sally L CTR NAVFACHQ ATFP; Foskett,
David CIV COMNAVREGNW Port Operations N3; Griffin, Terry CIV Commander Navy
Region SE; Grimes, Jeff J CIV CNRNE, 912; Gross, R D CIV (BANG); Hayhurst,
Jeffrey K CDR NAVSTA Norfolk, N32;
hidehiko.akashi.ja@navfacfe.navy.mil;
Howard, Albert CDR (CNATRA); Ishizu, Wesley W CIV NAVFAC PAC; McConnell,
Joseph J CIV NAVFACHQ ; Joyner, Selinda C CIV NAVFACHQ Acquisition, ACQ;
Kamimoto, Clyde H CIV NAVFAC PAC ; Kelly, David J CDR Base Support, 100B;
Korn, Chris; Draper, Kraig P. USNCIV NAVFACHQ; Lambert, Eugene H CIV NAVSTA
Norfolk; Lawrence.Garcia@me.navy.mil; Lehman, Larry CIV CNRNW, Public
Safety; Levy, Will CIV NDW; Lister, Scott R CAPT NAVFACHQ OFP, OF;
Fleischmann, Lori CIV (NAVFACHQ); Lynch, John J CIV NAVFAC Lant; Macias,
Kail S CIV (NAVFACHQ); Maki; Marion, Dennis S LT NAVSTA Norfolk, N93;
mark.scott@me.navy.mil; Markey, Jeff H CIV NAVFAC MW PWD GL FMD; Schenck,
Marshall H CIV HQ Engineer Ops Center; Martin, Steve W SPAWAR; Fields, Mike
D CIV NAVFACHQ, ATFP; Essoglou, Milon CIV (NAVFACHQ); Murdock, Tracey E
CAPT; Murley, Steve P CTR CNIC HQ, N7; Nelson, Lasandra CIV CNIC HQ, N3;
nishimurag@eu.navfac.navy.mil; Oakley, Harold O CTR NAVFACHQ, ATFP; Orzell,
Michael S CDR USFF, N3-AT5P; Jay, Otis C CIV HQ Engineer Ops Center; Perez,
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phillipsa@eu.navfac.navy.mil; Pine, Pam G CIV USFF, N3-AT3R; Pregel, Tony A
CAPT NAVFAC Lant; Pyle, Loyd E JR CAPT; Reid, Michael Anthony CIV HQ 00,
ATFP; Robishaw, Richard W CIV NAVFACHQ; richard.w.neely@eu.navy.mil;
Rodriguez, Jose J CDR NSA Norfolk, N142; Saum, Mike CDR PWD Norfolk;
Schelfhout, Stephen J CIV NSWC PC; Shaw, Claude B CIV CNRH, N3; Smith,

Eric
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MidLant, OPS; steven.chan@me.navy.mil; Iselin, Steven SES NAVFACHQ, ED;
steven.koepsell@navfacfe.navy.mil; Thompson, Wil L LCDR USFF, N3-AT3O; Toth,
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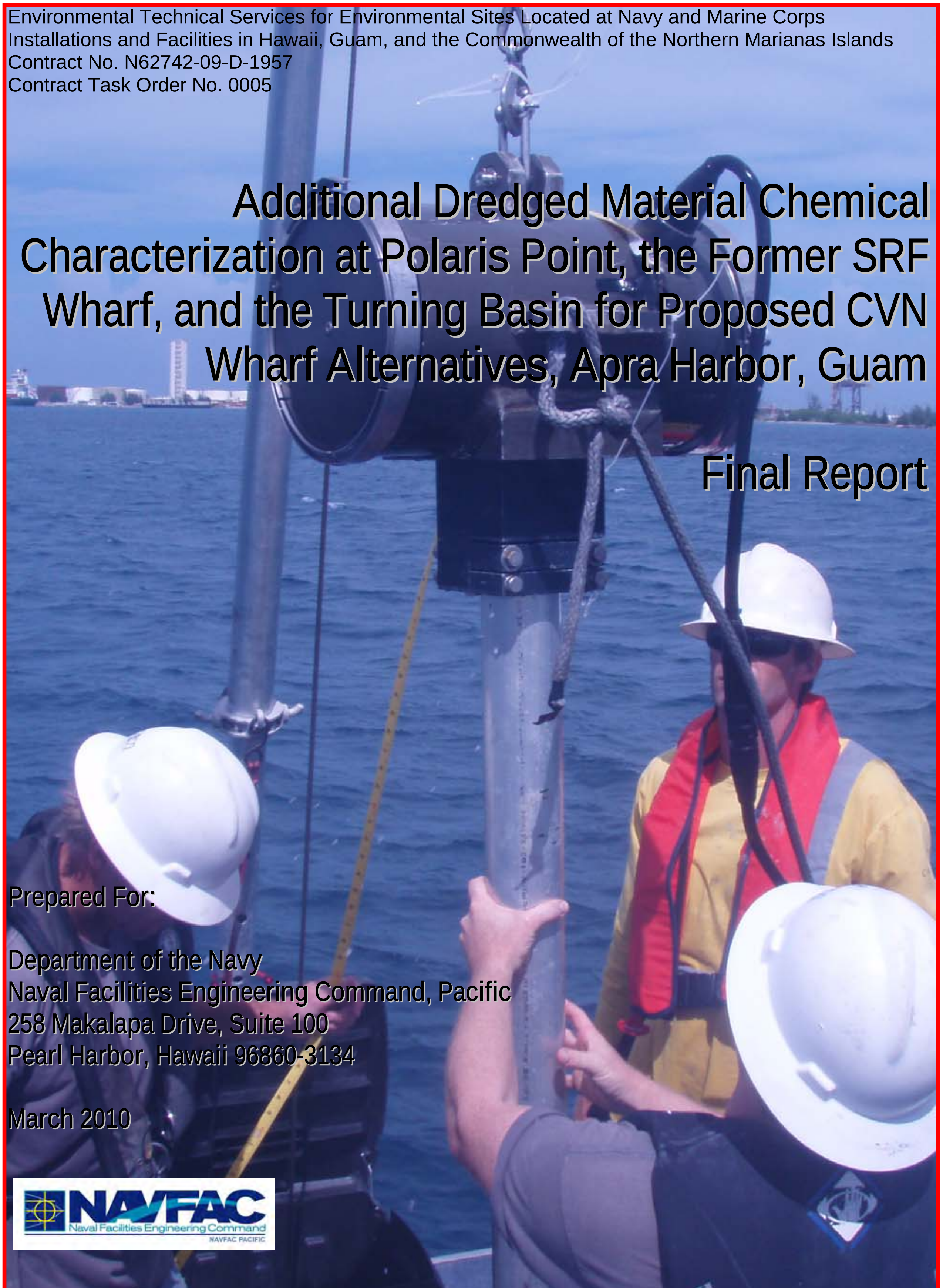
N37; Van de Voorde, Jim R CTR NAVFACHQ, ATFP; Vesterman, John E CDR USFF,
N3-AT3; Keip, Vincent J CIV HQ Engineer Ops Center; Whitehouse, John CIV
CNRH, N37; Whitteker Sam CIV; Ennis, Wilson E CIV HQ Engineer Ops Center;
Wright, O CIV USFF, N3-ATB; Albright, Deborah Civ NAVFAC; Arkwright, Michele
G CIV PEO LMW; Ayling, Michael CTR CNIC HQ, N3; Bailey, Mark E CIV NSWCDL,
Z11; baxter@spawar.navy.mil; Cherepon, Glen J CIV NAVFAC SW; Clanahan, Chuck
CIV CNIC HQ, N3AT; Cofer, Richard J CIV NAVFAC Lant; Coker, Christine L CIV
NAVBASE Kitsap, N9; Coleman, Joseph W CIV NAVSEA HQ, SEA 05; Condlin, Joseph
R CIV NAVFAC PAC ; Croson, Matthew Franklin LT; Crouch, David A (NFESC);
Cullen, William P CAPT CNIC HQ, N3; Davis, Jackie M CIV USFF, N3/N5C1;
Davis, Jim W CIV USFF, N3-AT5; DeVisser, Alexandra (NFESC); Douvres, Matthew
A CIV CNRSW; Duong, Anh N CIV CNO N3AT13; Ermovick, Tony CAPT NAVFAC
MIDLANT; Fontan, Will C CIV NSWCDD, Z23; Funn, John V CDR NAVSEA, PMS480;
Galloway, John P SES PEO LMW; Gauthier, Ron SPAWAR; Gibson, Jack R CIV
NAVFAC SW; Goodin, Glenn CIV NSWCDL, Z23; Goldberg, Barbara M CTR NS
Newport, N424; Golie, Carl CIV CNIC HQ, N3AT; Grower, Jason P. LT CNO N3AT3;
Hagen, Mark D LTJG NAVFAC MIDLANT; Haseltine, David K CIV CNRSE, N3AT;
Hellman, David H CAPT OASN (I&E) BRAC PMO; Hulse, Richard L CIV CNO, N3AT;
Huskey, Jeffrey CIV CNIC HQ, N6; Jones, Pat CIV CNIC HQ, N3; Larson,
Jonathan CTR CNIC HQ, N57; Leigh, Lori CIV NFESC; Lester, Frank CIV Force
Protection Program Manager; Lutz, Marjorie CIV CNIC HQ, N3; Macinski,
Michael J CAPT CNO, N3AT; McIntyre, Owen CIV CNIC HQ, N3; Meyers, Michael J
CIV, N8S&T; Morrissey, Shawn B. CIV CNRH, N3; Mueller, Tim CIV (CPF N34);
Naiser, Donald CDR CNIC HQ, N3; Newton, Rick P CDR CNIC HQ, N3; Nixon, Chip
(NFESC); Nolan, Richard J CIV CNIC HQ, N3; Oboyle, Thomas J CIV (NFESCDET);
Peterson, Leila K CTR CNIC, N3; Phillips, Jon R LT NSSC NORFOLK;

Piepgrass,
Dan J CIV CNIC HQ, N3; Pittman, John R CIV (NFESCDET); Powell, Chris S CDR
USFF, N3-AT5; Reid, Michael Anthony CIV HQ 00, ATFP; Risley, Jim CIV CNIC
HQ; Schuler, Al CIV LMW; Seelig, William N CIV (NFESCDET); Shultz, Daniel
CDR, Commanding Officer; Siegel, Jonathan B CIV NAVFAC MIDLANT; Sinder, Mark
CTR CNIC HQ, OPS; Spruill, John SPAWAR; Stark, Stephen E CTR CNI HQ, Public
Safety; Tausig, Wayne (NFESC); Thomsen, James E SES PEO LMW; Tullos, Rex CDR
CNIC; Viggiano, Mike (NFESC) NAVFAC; Vitale, Philip CIV (NAVFAC); Wagner,
William John GS13 CNRMA; Whittier, Kim CIV NAVFAC; Wyckoff, Russell CDR
CNRMA, N3; Yoshikawa, Stacie A CIV 250, 2523; Zahorbenski, Theodore S CIV
SPAWAR Old Towne; Armstrong, Ayana D. OPR NAVFACWASH; Bastinelli, Peter CIV
NAVFAC Lant; Bernotas, Scott CDR NAVFAC NW, BANG; Blankenship, Art CIV
NSWCDL, Z06; Bowling, Gina CTR CNIC N3, Emergency Management; Carter, Dareyl
CWO3 NAVSTA Mayport N32; Charters, Tom CIV SPAWARSYSCEN SAN DIEGO 2838;
Cooper, Ted J CONT NSWC, PC; Cunha, Jim CAPT CNO, N3AT; Finnegan, Joseph T
CTR CNIC HQ, N3; Fitzgibbon, Steven W CIV NSWC PC; Flotten, Brandy C NAVAIR;
Fung, Daniel S CIV NAVFAC SW; Gilmore, Charles OPERATIONS, PDPS; Hartmann,
Beth L CDR NAVFAC MW, XO; Horning, Spencer H CIV NAVFAC NW; Johnson, Henry D
CIV SPAWAR; Laderer, David A LCDR CNRMA; Lee, Robert E CIV; Lillard, John D
SPAWAR; Little, Maureen (NFESC); Londergan, Diana CIV Spawar 742DL; Lustig,
Edward A Jr CIV NAVSURFWARCENDIV, E314; Lynch, Richard D CIV NAVFAC SE;
McCracken, Alicia G CTR PEO LMW; McGraw, Jennifer CIV NAVSEA PEO LMW;
Miller, Allen CIV NFESC; Mitchell, John CIV SPAWAR, OT11 1852E; Moorefield,
Carlton; Mule, Leonard W CIV NF CIVIL STRUC BRANCH SP/YT; Palmer, Stephen E
CTR USFF, N3-AT5P4; Robb, Jeffrey A CIV NAVFAC SE; Searight, Jonathan CIV
SPAWARSYSCEN Charleston SC J63C; Seiter, Scott; Sergienko, Eric CDR; Smith,
David M CDR NAVFAC Southeast, RE Staff; Sparks, Stevenson L CIV NAVFAC NW;
Summers, Doug CIV NAVSURFWARCENDIV, CRANE Code 8056; Tate, Ann E SES NSWCDL,

C92; Torres, Luis A CIV NAVFAC; Troffer, Michael A CIV EODTECHDIV; Varnava,
Andrew (NFESC); Yingling, Theresa L CIV NAVSEA PEO LMW; Zeller, Charles A
CIV NAVSURFWARCENDIV Crane, Code JXNF
Subject: 2008-01-03 Waterside Security System Bi-Weekly Report

>V/r,
>Sally Fauber
>Anti-Terrorism/Force Protection (AT/FP)
>Phone: 202-685-9356
DSN: 325-9356
>Email: sally.fauber.ctr@navy.mil



Environmental Technical Services for Environmental Sites Located at Navy and Marine Corps Installations and Facilities in Hawaii, Guam, and the Commonwealth of the Northern Marianas Islands
Contract No. N62742-09-D-1957
Contract Task Order No. 0005

Additional Dredged Material Chemical Characterization at Polaris Point, the Former SRF Wharf, and the Turning Basin for Proposed CVN Wharf Alternatives, Apra Harbor, Guam

Final Report

Prepared For:

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
Pearl Harbor, Hawaii 96860-3134

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NAVFAC
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March 2010

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
COC	Chain-of-Custody
COMNAVMARIANAS	Commander, U.S. Naval Forces Marianas
CRM	Certified Reference Materials
CVN	Carrier Vessel, Nuclear
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
EIS	Environmental Impact Statement
ELAP	Environmental Laboratory Accreditation Program
ER-L	Effects Range Low
ER-M	Effects Range Median
ER-Mq	Effects Range Median Quotient
GC/ECD	Gas Chromatography-Electron Capture Detector
GC/MS	Gas Chromatography-Mass Spectrometry
GPS	Global Positioning System
ICP-MS	Inductively Coupled Plasma - Mass Spectrometer
ID	Identification
LCS/LCSD	Laboratory Control Sample/Laboratory Control Sample Duplicate
MDL	Method Detection Limit
MLLW	Mean Lower Low Water
MRL	Method Reporting Limit
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NELAP	National Environmental Laboratory Accreditation Program
OTM	Ocean Testing Manual
PAHs	Polynuclear Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
QA	Quality Assurance
QC	Quality Control
RIM	Regional Implementation Manual
RL	Reporting Limit
RPD	Relative Percent Difference
SAP	Sampling and Analysis Plan
SIM	Selected Ion Monitoring
SM	Standard Methods
SOP	Standard Operating Procedure
SRF	Ship Repair Facility
SVOC	Semi-Volatile Organic Compounds
TOC	Total Organic Carbon
TRPH	Total Recoverable Petroleum Hydrocarbons
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	U.S. Environmental Protection Agency

cy	cubic yards
ft	feet or foot

L	liter
mg/kg	milligrams/kilogram
mm	millimeters
µg/kg	micrograms/kilogram

EXECUTIVE SUMMARY

Apra Harbor, Guam, is a strategic, forward deployed base for the U.S. Armed Forces and is home to the Commander, U.S. Naval Forces Marianas (COMNAVMARIANAS). Currently, the Apra Harbor Naval Complex provides a base for the Military Sealift Command, Maritime Pre-positioning Ship Squadron 3, Submarine Squadron 15, and the U.S. Navy Public Works Center. The majority of the Apra Harbor Naval Complex's wharves and mission support facilities are located around Inner Apra Harbor.

To maintain its mission and operational preparedness, the Navy requires dredging within the Apra Harbor complex to ensure sufficient water depth for future berthing and ship loading requirements of new classes of vessels transiting through and potentially based at Guam. To accommodate deeper draft vessels, the Navy proposes construction dredging for the development of a deep water wharf at one of two alternative sites within the harbor, as well as within a turning basin and along an access fairway to the selected site. The two sites under consideration include Polaris Point and a site north of the former Navy Ship Repair Facility (SRF), both located within Outer Apra Harbor.

The purpose of this study was to delineate the distribution and magnitude of chemicals of potential concern within material to be dredged from the two alternative sites (Area 2 – Former SRF Wharf and Area 3 – Polaris Point) for the development of a deep water wharf in Apra Harbor, Guam. Material from the turning basin for these sites was also evaluated (Area 1).

Sediment samples were analyzed for physical and chemical parameters, including general chemistry, metals, semi-volatile organic compounds (polynuclear aromatic hydrocarbons [PAHs], phenols, and phthalates), organochlorine pesticides, polychlorinated biphenyls (PCBs), and organotins. Results were compared to effects range-low (ER-L) and effects range-median (ER-M) sediment quality guidelines, as established. For the majority of analytes, concentrations were either not detected or lower than ER-L values. Only three metals, two PAH compounds, four organochlorine pesticides and total detectable PCBs exceeded ER-Ls in any of the samples. Only two occurrences of a single analyte exceeding the ER-M value occurred (4,4'-DDT).

When compared to other recent Tier III dredged material evaluations in Apra Harbor (Weston Solutions and Belt Collins 2007), results indicate that although some ER-L exceedances were observed for various trace metals and trace organics and ER-M exceedances were observed for one chlorinated pesticide, it is likely if sediments from the proposed Polaris Point or SRF Wharf dredge footprints were evaluated according to guidance outlined in the Ocean Testing Manual (United States. Environmental Protection Agency [USEPA] and United States Army Corps of Engineers [USACE] 1991) and/or Inland Testing Manual (USEPA and USACE 1998) they would be deemed suitable for ocean disposal or upland placement, assuming a practicable beneficial use option was not available.

1.0 INTRODUCTION

The United States' Territory of Guam, strategically located in the western Pacific Ocean, serves as a forward deployed base for the U.S. Armed Forces (Figure 1-1). Centrally located on Guam's west coast, the Apra Harbor Naval Complex provides a base for the Military Sealift Command, Maritime Pre-positioning Ship Squadron 3, Submarine Squadron 15, and the U.S. Navy Public Works Center and is home to the Commander, U.S. Naval Forces Marianas (COMNAVMARIANAS). The majority of the Apra Harbor Naval Complex's wharves and mission support facilities are located around Inner Apra Harbor.

The Navy proposes to construct a new deep water wharf in Apra Harbor, Guam to provide for a transient nuclear powered aircraft carrier (CVN), the largest ship in the Navy's fleet. To accommodate the deeper drafts of the current aircraft carrier class (the USS Nimitz Class [CVN 68]) and the next generation aircraft carrier class (the Gerald R. Ford Class [CVN 78]), the Navy proposes construction dredging for the development of a deep water wharf at one of two alternative sites, as well as within a turning basin and along an access fairway to the potential sites within the harbor. The two sites under consideration include Polaris Point and a site north of the former Navy Ship Repair Facility (SRF). Both of these sites are located in Outer Apra Harbor (Figure 1-2).

In 2006, the Navy initiated a reconnaissance level investigation to determine potential environmental issues associated with the management of dredge materials from the proposed wharf sites by performing a chemical and physical characterization study of sediment from those areas (Weston Solutions and Belt Collins Hawaii 2006). The study included the collection and chemical and physical analyses of sediment core samples positioned to spatially represent the chemical and physical nature of material to be potentially dredged from Polaris Point, the Former SRF Wharf, and the Turning Basin proposed dredge footprints. Three locations were sampled at the Former SRF Wharf, five locations at Polaris Point, and six locations in the Turning Basin. When compared to established regulatory levels used to assess the potential biological significance of elevated contaminants in sediments (Effects Range-Low [ER-L] and Effects Range-Median [ER-M]), sediment contamination was low in all samples analyzed (generally less than the ER-L). Only Nickel, found in sediment from Polaris Point, and total polychlorinated biphenyls (PCBs), detected in material from the Former SRF Wharf, were measured at levels above the corresponding ER-L values but were still found at levels below the ER-M values. Polynuclear aromatic hydrocarbons (PAHs) were detected at levels below the ER-L values in samples from all three areas. Other analytes, including chlorinated pesticides, organotins, phenols, and phthalates were either not detected or were estimated at levels below their respective reporting limits.

The low chemical concentrations found in sediment samples from Polaris Point, the Former SRF Wharf, and the Turning Basin were consistent with those in material found suitable for ocean disposal on a recent Tier III evaluation of dredge material from several locations within Inner and Outer Apra Harbor, Guam (Weston Solutions and Belt Collins Hawaii 2007). In this Tier III study, chemical concentrations in sediment from areas found suitable for ocean disposal were generally low, but some analytes exceeded comparable ER-M values. Based on this comparison, ocean disposal of dredge material from both Polaris Point and the Former SRF Wharf alternative dredge footprints is likely suitable for ocean disposal. Further testing of sediments from

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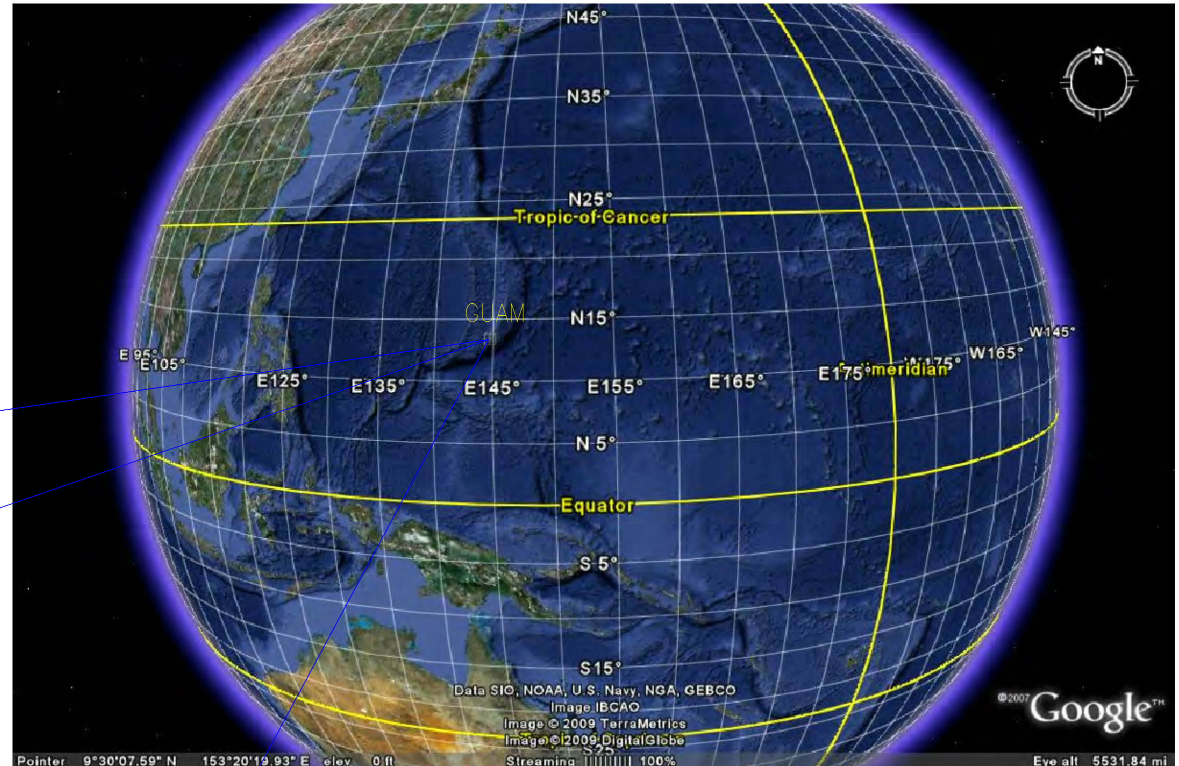

REFERENCES: GOOGLE EARTH, 2009

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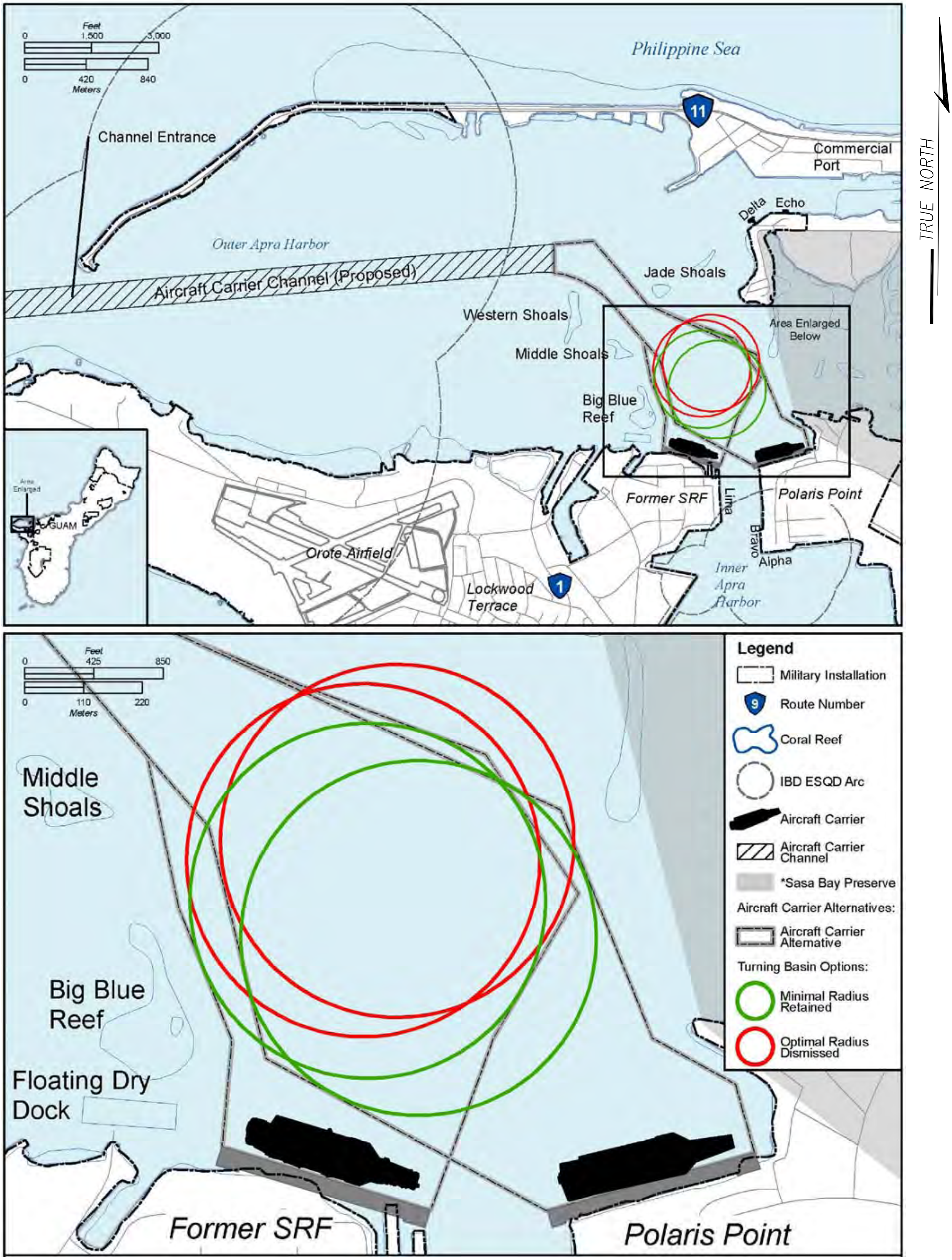
FIGURE TITLE: PROJECT LOCATION MAP APRA HARBOR, GUAM		FIGURE NO.: 1-1



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MAR 2010		
FIGURE TITLE:	ALTERNATE VESSEL APPROACH AREAS TO POLARIS POINT AND THE FORMER SRF WHARF	FIGURE NO.: 1-2

REFERENCES: TEC, 2009

individual station locations in the two alternative dredge footprints as described in this report further delineate the chemical and physical characteristics of sediment from these two alternative dredge areas and enhance the Environmental Impact Statement (EIS) being developed for this program. In addition, as part of the overall construction program to create a deep water wharf in Apra Harbor, the Navy has identified the need for a Tier III evaluation of dredge material from the site selected for development into a deep water wharf to make a final determination on suitability for ocean disposal. Once an alternative is selected and a final design completed, the full Tier III evaluation will be used to establish suitability of material for ocean disposal as part of the permit application process.

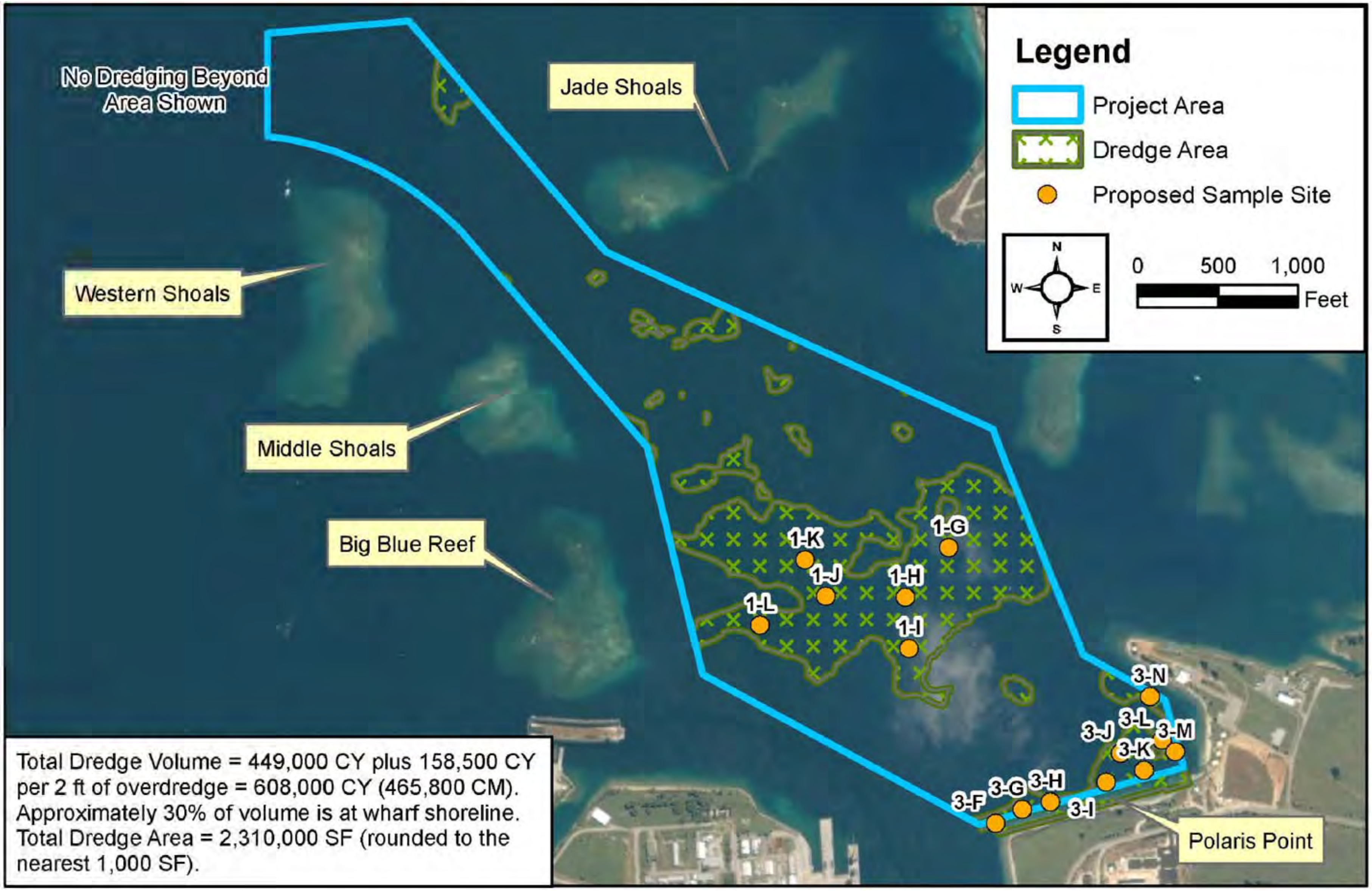
1.1 Purpose

This study included an additional examination of physical and chemical properties of the proposed dredged material to assist in the selection of either Polaris Point (preferred) or the Former SRF Wharf for development into a deep water wharf within Apra Harbor, Guam. The results of this study, in conjunction with the 2006 data, will be incorporated into a larger EIS for the construction of the deep water wharf in Apra Harbor.

1.2 Project Alternatives

The potential wharf site at Polaris Point is located in Outer Apra Harbor at the northern end of Polaris Point in a cove situated east of the Inner Harbor entrance channel. Steel sheet pile caisson foundations from the former wharf lay offshore from this site where current water depths in the area range from -20 to -80 feet (ft) mean lower low water (MLLW). The dredge footprint for this potential site includes the area fronting the wharf, a turning basin northwest of the site, and an access fairway extending from the turning basin northwest toward the Outer Apra Harbor entrance (Figure 1-3). If this site is selected, dredging will occur to -49.5 ft MLLW, with approximately 449,000 cubic yards (cy) of material removed and managed from the area fronting the wharf, the Turning Basin, and the access fairway. With a 2 ft overdredge included, the total volume is approximately 608,000 cy of dredge material. These dredge volumes are based on bathymetry surveys conducted in 2005 (Sea Engineering 2005).

The Former SRF Wharf site is located in Outer Apra Harbor west of the Inner Harbor entrance channel and north of the former Navy SRF complex, which is currently the Guam Shipyard. Water depths in this area range from -20 to -73 ft MLLW. The dredge footprint for this potential site includes the area fronting the wharf and the same turning basin and access fairway identified for the Polaris Point site (Figure 1-4). Like Polaris Point, if this site is selected, dredging will occur to -49.5 ft MLLW, with approximately 342,000 cy of material removed and managed from the area fronting the wharf, the Turning Basin, and the access fairway. With a 2 ft overdredge included, the dredge volume is approximately 479,000 cy of dredge material. These volumes are based on bathymetry surveys conducted in 2005 (Sea Engineering 2005).



REFERENCES: TEC, 2009

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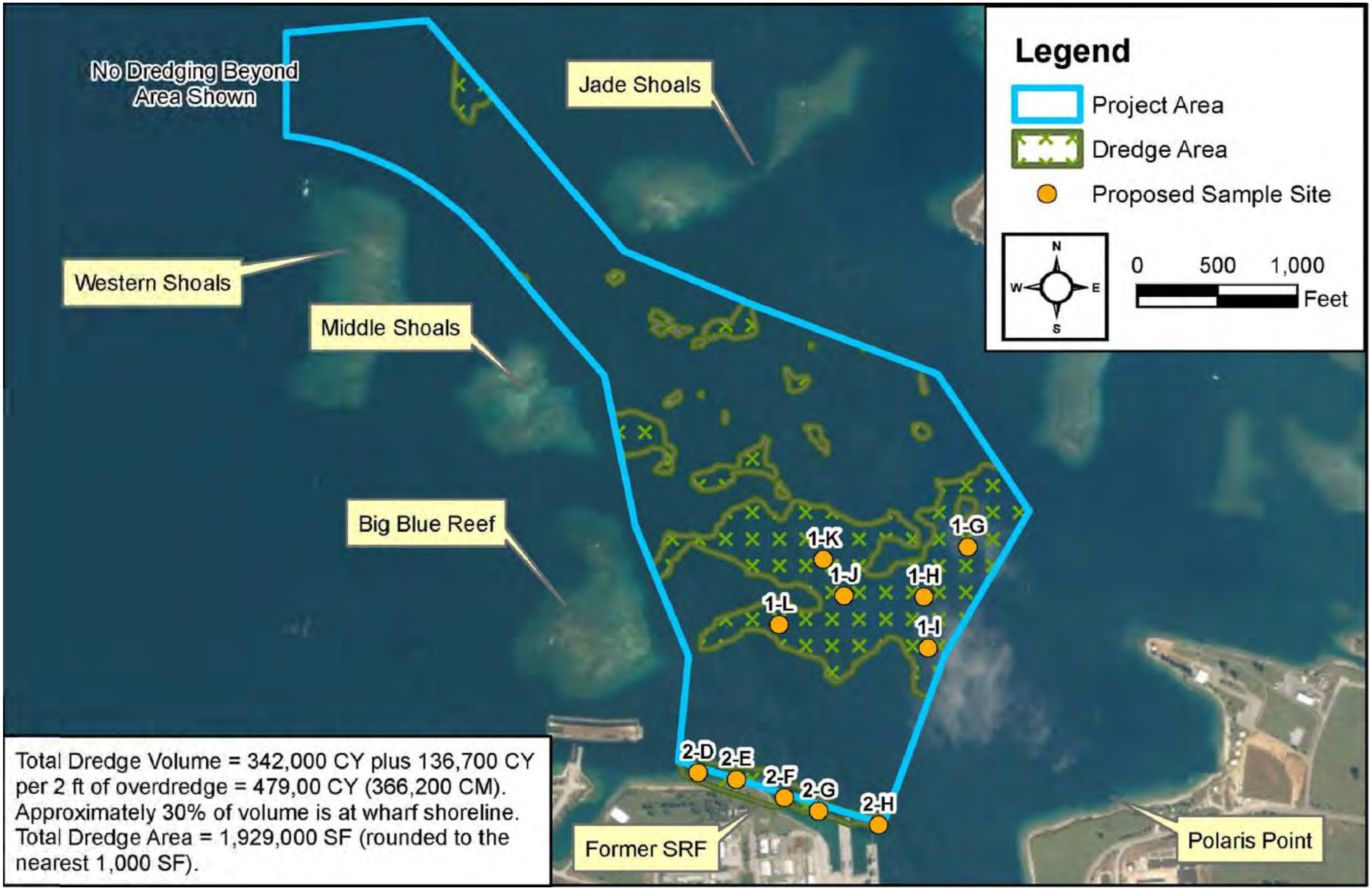
FIGURE TITLE: POLARIS POINT WHARF ALTERNATIVE- DREDGE FOOTPRINT AND PROPOSED SAMPLE LOCATIONS FOR THE PROPOSED WHARF AREA AND TURNING BASIN		FIGURE NO.: 1-3



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MAR 2010	ADDITIONAL DREDGED MATERIAL CHEMICAL CHARACTERIZATION AT POLARIS POINT, THE FORMER SRF WHARF, AND THE TURNING BASIN FOR PROPOSED CVN WHARF ALTERNATIVES, APRA HARBOR, GUAM	
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REFERENCES: TEC, 2009

2.0 MATERIALS AND METHODS

2.1 Field Collection Program for Sediment Core Samples

2.1.1 Sampling Locations and Depths

Sediment core samples were attempted to the construction depth of -49.5 ft MLLW plus 2 ft overdredge (i.e. -51.5 ft MLLW) at 20 locations within the dredging footprints for the two alternative wharf sites. The 20 locations were positioned in three separate areas with five sample locations at the Former SRF Wharf, nine locations at Polaris Point, and six locations in the Turning Basin (Figure 2-1). At each location, material from the entire sediment core was collected to create an individual core location sample for subsequent physical and chemical analysis. In addition, sediment from each two-foot horizon along the length of the core (0-2 ft, 2-4 ft, 4-6 ft, 6-8 ft, etc.) was collected and archived frozen for potential future analysis.

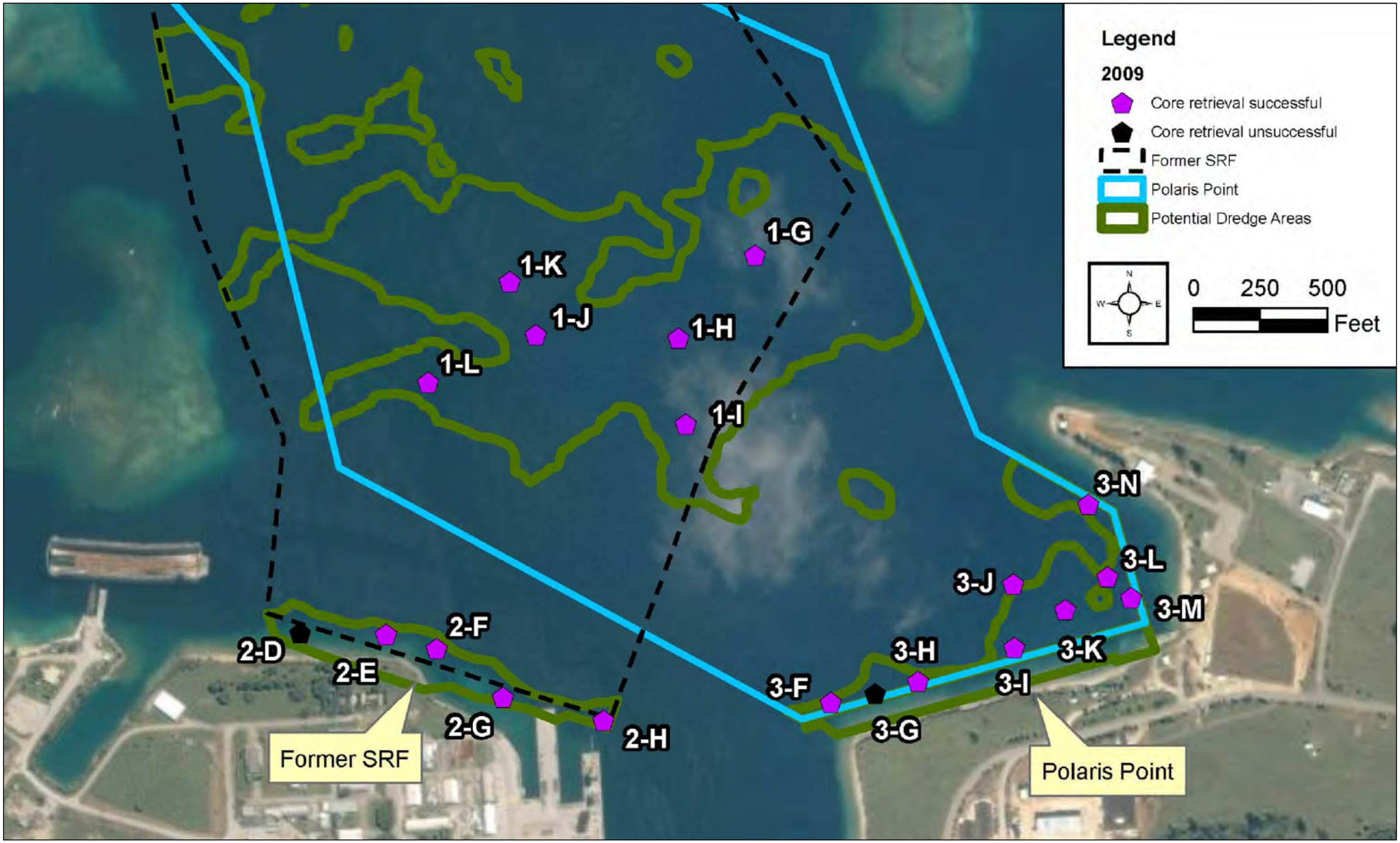
The placement of sample locations when combined with the historical locations evaluated in 2006 was designed to provide high spatial resolution to determine the chemical and physical nature of bottom material in the areas to be potentially dredged. However, because the Navy had previously identified live coral reef beds in Apra Harbor, sampling activities did not occur in these reef bed areas in order to protect these sensitive habitats. Sample locations were determined using a coral map created by Navy research divers in March 2006.

The target core locations, target lengths, number of cores, and core identifications (ID) are described in the sampling and analysis plan (SAP) (Weston Solutions and Element Environmental 2009). The target lengths of these cores were based on a bathymetric survey performed in October 2005. The actual core lengths differed based on encountered bathymetry at the time of sample collection.

Sediment cores were collected to -51.5 ft MLLW unless refusal was encountered. Refusal was defined as less than 2 inches of penetration per minute. If refusal was encountered, the vessel was moved and a second core attempted. If refusal was encountered again, additional cores were not attempted unless operational problems were suspected. One core per location was sufficient to ensure an adequate volume of material (~ 4 liter [L]) for all required testing and archival.

2.1.2 Core Collection Equipment

Sediment cores were attempted using an electric vibracore deployed from the *MV Hihimanu*, a work barge owned and operated by Pacifica Workboats. The vibracore was equipped with a four-inch outer diameter aluminum barrel and stainless steel cutter head (Figure 2-2). The standard system was capable of collecting cores up to 20 ft long and was equipped to handle greater depths, up to an additional 10 ft (more than sufficient to cover the target sampling depths identified for this project).



DATE:	PROJECT TITLE:
MAR 2010	ADDITIONAL DREDGED MATERIAL CHEMICAL CHARACTERIZATION AT POLARIS POINT, THE FORMER SRF WHARF, AND THE TURNING BASIN FOR PROPOSED CVN WHARF ALTERNATIVES, APRA HARBOR, GUAM
FIGURE TITLE: STATION LOCATIONS FOR SEDIMENT CORE SAMPLES AT POLARIS POINT AND THE FORMER SRF WHARVES, APRA HARBOR, GUAM	FIGURE NO.: 2-1

Figure 2-2. Vibracore Sampling

2.1.3 Navigation

For all cores, station locations were pre-plotted as provided in the SAP. Station locations were determined using a Garmin Global Positioning System (GPS). The GPS was accurate to $\pm$ 14-18 ft. There were no failures of the GPS during the course of the sampling event. All final station locations were recorded in the field using positions from the GPS.

2.1.4 Sediment Collection

2.1.4.1 Core Handling

Each sample was retrieved, and the dredged material sample was extruded from the core barrel onto polyethylene-lined collection trays on the vessel platform. Following extrusion, each core was examined by a qualified scientist and photographed. All pertinent information and observations were recorded onto field data sheets (Appendix A). Sediment for environmental testing was placed into clean containers, labeled (project name, date, sample ID, analysis, and preservative where applicable), logged into a field chain-of-custody (COC) form, and placed into a cooler. Core samples remained on ice and in the dark until shipped using expedited delivery service to the appropriate laboratories for analyses (Table 2-1).

2.1.4.2 Geologic Description

As each core was collected, a qualified scientist classified and logged the sediment cores according to the Unified Soil Classification System (USCS). The geologic description of each core included the texture, odor, color, length, approximate grain size distribution, plasticity characteristics of the fine-grained fraction, and any evident stratification of the sediment.

2.1.5 Sample Processing and Storage

The sediment cores were processed in the field immediately after collection. After the core was classified and photographed, sediment from the length of the entire core (up to the dredge depth) was collected into a stainless steel bowl and homogenized to a uniform consistency using a stainless steel mixing apparatus. The sample was then placed into certified clean glass jars with Teflon-lined lids for chemical and physical analysis. In addition, sub-samples from each core were collected at every two foot horizon along the length of the core (0-2 ft, 2-4 ft, 4-6 ft, etc.). These horizon samples were placed into certified clean glass jars with Teflon lined lids to be archived frozen in the event that further delineation of chemical contamination is required.

2.1.6 Shipping

Prior to shipping, sample containers were placed in re-sealable plastic bags and securely packed inside the cooler with ice packs or crushed ice. Prior to shipping, COC forms were completed, inserted into re-sealable plastic bags, and placed inside their respective coolers. All cooler lids were securely taped shut. Samples were delivered to the appropriate analytical laboratories listed in Table 2-1. The table also shows the particular analyses performed by each laboratory as well as the point of contact and pertinent shipping information.

Table 2-1. Analytical Laboratories, Points of Contact, and Shipping Information

Laboratory	Analyses Performed	Point of Contact	Shipping Information
Weston Solutions, Inc. Carlsbad, CA	Grain size analysis	Ms. Olga Weaver (760) 795-6977	Weston Solutions, Inc. 2433 Impala Dr. Carlsbad, CA 92010
Calscience Environmental Laboratories	Chemical and physical analysis except grain size	Ms. Danielle Gonsman (714) 895-5494	Calscience Environmental Laboratories 7440 Lincoln Way Garden Grove, CA 92841

2.1.7 Documentation and Chain-of-Custody

Samples were considered to be in custody if they were (1) in the custodian's possession or view, or (2) retained in a secured place (under lock) with restricted access. The principal documents used to identify samples and to document possession were COC records, field logbooks, and field tracking forms. COC procedures were used for all samples throughout the collection, transport, and analytical process and for all data and data documentation, whether in hard copy or electronic format.

COC procedures were initiated during sample collection. A COC record was provided with each sample or sample group. Each person who had custody of the samples signed the form and ensured that the samples were not left unattended unless properly secured. Documentation of sample handling and custody included the following:

- Sample identifier
- Sample collection date and time
- Any special notations on sample characteristics
- Initials of the person collecting the sample
- Date the sample was sent to the laboratory
- Shipping company and waybill information

The completed COC form was placed in a plastic envelope that traveled inside the ice chest containing the listed samples. The COC form was signed by the person transferring custody of the samples. The condition of the samples was recorded by the receiver. COC records were included in the final analytical report prepared by the laboratory, and were considered an integral part of that report.

2.1.8 Decontamination of Field and Laboratory Equipment

All vibracore equipment was cleaned prior to sampling. Between stations, the core barrel and deck of the vessel were rinsed with site water. Before creating each composite, all stainless steel utensils (stainless steel bowls, spoons, spatulas, mixers, and other utensils) were cleaned with soapy water, rinsed with site water, and then rinsed three times with deionized water.

2.1.9 Quality Assurance Procedures

Weston's quality control (QC) staff performs periodic audits to ensure that test conditions, data collection, and test procedures are conducted in accordance with Weston's standard operating procedures (SOPs). Weston's SOPs have been audited and approved by an independent United States Environmental Protection Agency (USEPA)-approved laboratory and placed in the quality assurance (QA) file as well as laboratory files.

2.1.9.1 Field Collection and Sample Handling

All relevant project information and field measurements were recorded on customized water-proof core log data forms. A daily field log was maintained, and formal COC procedures were followed and documented. All sampling equipment was cleaned between sample stations. Samples were double-bagged, and both inner and outer bags labeled. Samples were held on ice until delivery to the appropriate analytical laboratory. COC forms were prepared in the field during sediment collection by Weston's personnel.

2.1.9.2 Chemical and Physical Characteristics of Dredged Materials

Methods

Chemical analyses were performed using QC criteria specified in Methods for Chemical Analysis of Water and Wastes (USEPA 1983) and Test Methods for Evaluating Solid Waste (SW-846) (USEPA 1986), in California state-certified and nationally-accredited laboratories (California Environmental Laboratory Accreditation Program [ELAP] Certificate #1230 and National Environmental Laboratory Accreditation Program [NELAP] Certificate #03220CA). Organotins were analyzed by Krone *et al.* (1989) while Total Solids and Ammonia were performed in accordance with Standard Methods (SM). Atterberg Limits and specific gravity were performed in accordance with American Society for Testing and Materials (ASTM) methodology and guidelines (ASTM 2000), and internal QA/QC criteria established by the core (i.e., physical) analysis laboratory. Grain size analyses performed by Weston were consistent with internal QC criteria.

Performance objectives were evaluated via the use of standard/certified reference materials or laboratory control samples, method blanks, surrogates, spiked samples, duplicate samples, and internal QC samples. Precision and accuracy objectives were established for method reporting limits (MRLs), spike recoveries, and duplicate analyses.

Blanks

Laboratory contamination introduced during method use was assessed through the analysis of procedural or method blanks on a minimum frequency of one per batch or matrix type. It is assumed that the procedural blank represents a constant background contamination that affects standards and samples identically and therefore are handled similar to a sample including the addition of the same reagents, contact with the same type of vessels and processed with the same procedure.

Accuracy

Accuracy of analytical measurements is the degree of closeness based on percent recovery calculations between measured values and the actual or true value and includes a combination of reproducibility error and systematic bias due to sampling and analytical operations. Accuracy of the project data was indicated by analysis of matrix spikes, surrogate spikes, certified reference materials, blank spikes and/or laboratory control samples/materials on a minimum frequency of one per batch.

Matrix spike samples were employed to assess the effect a particular sample matrix has on the accuracy of a measurement. It is prepared by adding a known amount of the target analyte(s) to an aliquot of the field sample. Matrix spikes indicate the bias of analytical measurements due to chemical interferences inherent in the matrix. If the matrix spike recovery does not fall within the QA acceptance criteria, it may be an indication of sample matrix interferences. However, it should be noted that any matrix interference may only be present in the field sample used for the matrix spike and may not be extrapolated to the entire batch of samples.

Surrogate spikes are added to every sample (including QC samples) and used to examine the overall efficiency of the method from sample preparation through extraction and analysis. The success in recovery of surrogates is applicable to groups of analytes similar in chemical characteristics to each surrogate. The use of several surrogate standards in a sample enables determination of whether there is an interference influencing one of the standards.

Blank spikes and laboratory control spikes demonstrate performance of the preparation method on a clean matrix void of interferences. The laboratory control spike is performed in a matrix specifically addressed by the particular method while the blank spike is performed in DI water, making these recoveries a better indicator of the efficiency of the method *per se*.

Precision

Precision is the agreement among a set of replicate measurements without assumption of knowledge of the true value. Precision of sample results and analytical measurements is based on relative percent difference (RPD) calculations between repeated values. Precision of the project data was determined by analysis of duplicate matrix spikes, blank spikes, laboratory control spikes and/or duplicate test sample analysis on a minimum frequency of one per batch.

2.2 Physical and Chemical Analyses

Physical and chemical analytes measured in this testing program were selected to provide data on potential chemicals of concern in Outer Apra Harbor dredged material. These data will be used in the determination of a feasible alternative for a deep water wharf in Apra Harbor. The target analytes and associated method detection limits (MDLs) are described in the SAP (Weston and Element Environmental 2009). The analytes that were measured for this project are consistent with standard sediment characterization evaluations and based on guidance for performing dredged material evaluations as outlined in the Ocean Testing Manual (OTM; USEPA and United States Army Corps of Engineers [USACE] 1991) and Regional Implementation Manual (RIM) for the State of Hawaii (USEPA Region IX and USACE Honolulu District 1997).

2.2.1 Physical Analyses

Physical characteristics of the dredged material included grain size, total solids, specific gravity and Atterberg limits. Grain size was analyzed to determine the general size classes that make up the sediment (e.g., gravel, sand, silt, and clay). The frequency distribution of the size ranges (reported in millimeters [mm]) of the sediment is reported in the final data report. Grain size was conducted using the gravimetric procedure described in Plumb (1981). Specific gravity was measured using ASTM Method D854-98, Standard Test Method for Specific Gravity of Soils (ASTM 1998). Total solids were also measured to convert concentrations of the chemical parameters from a wet-weight to a dry-weight basis. Total solids were determined by SM 2540B (SM 1997). Per request by the Navy, sediment physical property analyses (Atterberg limits) was analyzed by ASTM method D4318-98, Determination of Liquid Limit, Plastic Limit and Plasticity Index of Soils (ASTM 2003).

2.2.2 Chemical Analyses

Sediment samples were analyzed for priority pollutants including semi-volatile organics (SVOCs), metals, organochlorine pesticides, PCBs, organotins, total recoverable petroleum hydrocarbons (TRPH), oil and grease, total and dissolved sulfides, and total organic carbon (TOC). The list of chemical parameters to be measured in this testing program were selected to provide data on potential chemicals of concern in dredge material and are identical to the 2006 study for comparative purposes. To minimize salt interference, the following analyses were performed as recommended by the OTM (USEPA and USACE 1991).

The analysis for priority pollutant metals (with the exception of mercury) were conducted using an inductively coupled plasma emissions spectrometer equipped with a mass detector (ICP-MS), in accordance with USEPA Method 6020 (USEPA 2004). Mercury analysis was conducted by cold-vapor atomic absorption in accordance with USEPA Method 7471A (USEPA 1994). The colorimetric analysis for total and dissolved sulfides followed USEPA Method 376.2M (USEPA 1978). Oil and grease and TRPH were measured by Freon extraction and infrared spectrophotometeric detection using USEPA Method 413.2M (USEPA 1983) and USEPA Method 418.1M (USEPA 1983), respectively.

The TOC, made up of volatile and nonvolatile organic compounds, were determined by carbonaceous analyzer using USEPA Method 9060A (USEPA 2004). Volatile solids were determined by muffle furnace using USEPA Method 160.4M (USEPA 1971).

SVOC (including PAHs and phenols) and PCB congeners were analyzed by gas chromatography-mass spectrometry with selected ion monitoring (GC/MS SIM), using USEPA Method 8270C SIM (USEPA 1996). This followed serial extraction of most neutral, acidic, and basic organic compounds with methylene chloride and gel permeation column cleanup procedures. Organochlorine pesticides were analyzed using USEPA 8081A (USEPA 1996) and Aroclors with USEPA Method 8082 (USEPA 1996) by gas chromatography-electron capture detector (GC/ECD). The analytical method used to determine organotins involved methylene chloride extraction, followed by Grignard derivatization and analyzed by GC/MS (Krone et al., 1989). Ammonia was analyzed by titration using SM 4500-NH3 B/C (M) (SM 1993).

2.2.2.1 PCB Aroclor vs. PCB Congener Analytical Methods

Historically, PCB quantification has been Aroclor-based, with total PCB concentrations expressed in terms of Aroclors. The packed columns of early methods could not resolve individual congeners, so chromatographers instead estimated components of samples against an Aroclor standard. The analyst was required to select the Aroclor whose chromatogram most closely resembled that of the sample. More current Aroclor-based methods utilize capillary columns and highly selective detectors that offer quantitative alternatives (Eganhouse and Gossett, 1991). These include the measurement of PCB peaks in the sample against the most similar Aroclor standard and the measurement of a small number of chromatographically dominant congeners designated as “marker” peaks for each of several Aroclors. Despite these refinements, Aroclor-based determinations rely on the subjective visual determination of Aroclor speciation as well as the assumption that environmentally or metabolically weathered samples accurately reflect the composition and toxicity of the Aroclor standards used to quantify them. Additionally, most toxic PCB congeners form only a small proportion of the total PCB concentration and are unlikely to be accurately estimated using an Aroclor-based method.

Concern over the accuracy of Aroclor-based measurements on compositionally modified samples coupled with advancements in analytical chemistry techniques have led to congener-specific PCB analysis. Congener-specific PCB analysis eliminates the reference to Aroclors altogether by quantifying individual congeners present in a sample against congener standards rather than Aroclor standards. This approach allows for analytical and reporting versatility of up to all 209 theoretically possible congeners, subject to some technical limitations on the ability to resolve a handful that co-elute. Congener-specific methods are becoming preferred for PCB analysis as they circumvent both the visually subjective nature of the pattern-recognition technique and the need to make assumptions about the influence of sample weathering associated with the Aroclor-based method. The objective nature of congener-based PCB analysis can yield more accurate results for environmental samples whose PCB composition is not identical with that of the Aroclors. Moreover, they can provide information on the environmental distribution of individual compounds that can be used to elucidate relative importance of natural processes affecting the fate of PCBs.

Further, the OTM (USEPA and USACE 1991) acknowledges the potential errors involved in the quantification of PCBs as Aroclors and recommends the quantification of PCB congeners in project samples.

Given this, laboratory results of PCB congeners were used exclusively to assess the PCB content of all samples analyzed for this project.

3.0 RESULTS

3.1 Dredged Material Sample Collection

Vibracore sampling was conducted between December 8 and December 10, 2009 at four to eight locations within each of the three dredge footprint areas from the Turning Basin and the two alternative wharf sites at the Former SRF Wharf and Polaris Point. At each location, material from the entire sediment core was collected to create an individual core location sample for subsequent physical and chemical analysis. A total of 18 stations out of the 20 planned stations were successfully sampled. Two stations were not sampled due to refusal at the surface that prevented further recovery. The target core recovery length was not achieved at 16 stations due to the presence of coral fragments that prevented further recovery.

Field coordinates, number of cores per station, depth of penetration relative to the mudline (i.e., the sediment surface), depth of recovery relative to the mudline, and core length retained for each station location are summarized in Table 3-1. Actual locations of the sampling stations are illustrated in Figure 2-1. Samples were visually homogeneous (i.e., no stratification greater than two feet was apparent). Field core logs and core photos are provided in Appendix A and Appendix B.

3.2 Analytical Results

3.2.1 Physical and Chemical Characteristics of Dredged Material

Results of physical and chemical analyses for sediments collected within the dredging footprints for the two alternative wharf sites are discussed below. All results are expressed in dry weight unless otherwise indicated. Target detection limits are provided in the Work Plan (Weston Solutions and Element Environmental 2009); actual detection limits and raw data for the analyses are provided in Appendix C.

Results of chemical analyses of project dredged materials were compared to Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values developed by Long et al. (1995). The effects range values are helpful in assessing the potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analyses. Briefly, these values were developed from a large data set where results of both benthic organism effects (e.g., amphipod toxicity tests) and chemical analysis were available for individual samples. The ER-L was then calculated as the lower 10th percentile of the observed effects concentrations and the ER-M as the 50th percentile of the observed effects concentrations. While these values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. The ER-L and ER-M sediment quality values are included for comparative purposes only.

In addition, ER-M values were used to calculate a mean ER-M quotient (ER-Mq). The concentration of each constituent was divided by its ER-M value to produce a quotient, or proportion of the ER-M equivalent to the magnitude by which the ER-M value is exceeded or not

Table 3-1. Field Coordinates, Sample Depths and Vibracore Recoveries for Samples Collected in the Vicinity of Polaris Point and SRF Wharves.

Station ID	Attempt	Latitude – Decimal Degrees North (NAD83)	Longitude – Decimal Degrees East (NAD83)	Water Depth (Feet)	Target Sampling Depth (Feet)	Actual Depth Sampled (Feet)	Penetration (Feet)	Final Core Length (Feet)	Core Length Retained for Analysis (Feet)	Comments
1-G	1	13.44747	144.66605	47.2	51.5	53.2	6	2.5	2.5	
1-H	1	13.44661	144.66525	47.0	51.5	53.0	6	6	4.5	
1-I	1	13.44573	144.66534	46.3	51.5	49.3	3	1	0	Refusal at 3.0'; sample not retained
	2	13.44573	144.66534	46.2	51.5	48.2	2	1.6	1.6	
1-J	1	13.44663	144.66376	45.9	51.5	51.9	6	5.9	5.6	
1-K	1	13.44717	144.66348	46.7	51.5	50.2	3.5	3.5	3.5	Coral fragments prevent further recovery
1-L	1	13.44612	144.66263	45.9	51.5	50.9	5	5	5	
2-D	1	13.44355	144.66132	43.1	51.5	47.1	4	0	0	Sample washed out during retrieval
	2	13.44355	144.66132	43.1	51.5	43.1	0	0	0	Refusal at surface due to rocks; no sample collected
	3	13.44372	144.66119	44.2	51.5	45.2	1	0.3	0	Refusal at surface due to rocks and coral fragments; no sample collected
2-E	1	13.44354	144.66222	45.8	51.5	50.8	5	1	1	Refusal at 5.0'; sample had a lot of coral fragments
	2	13.44354	144.66222	45.8	51.5	47.8	2	0.5	0	Refusal at 2.0'; sample not retained; instead used sample from first attempt
2-F	1	13.44340	144.66275	45.6	51.5	52.1	6.5	2.3	2.3	Coral fragments prevent further recovery
2-G	1	13.44291	144.66345	44.8	51.5	49.8	5	4	4	Refusal at 4.0'; coral fragments prevent further recovery
2-H	1	13.44268	144.66451	44.0	51.5	48.0	4	2	2	Coral fragments prevent further recovery
3-F	1	13.44289	144.66689	45.1	51.5	49.1	4	2.4	2	Coral fragments prevent further recovery
3-G	1	13.44300	144.66733	45.0	51.5	51.5	0	0	0	Unable to penetrate sediment layer; no sample collected
3-H	1	NA	NA	44.8	51.5	NA	NA	NA	NA	Not positioned on correct sampling coordinates; no sample collected
	2	13.44311	144.66780	43.7	51.5	49.2	5.5	2.3	2.3	Coral fragments prevent further recovery
3-I	1	13.44347	144.66881	43.2	51.5	49.2	6	3.7	3.7	Coral fragments prevent further recovery
3-J	1	13.44412	144.66879	39.4	51.5	43.4	4	1.6	1.6	Coral fragments prevent further recovery
3-K	1	13.44383	144.66936	37.5	51.5	39.5	2	0	0	Sample washed out during retrieval
	2	13.44383	144.66936	37.5	51.5	39.5	2	0.5	0	Coral fragments prevent any recovery; no sample collected
	3	13.44386	144.66934	37.5	51.5	38.5	1	1	1	Coral fragments prevent further recovery
3-L	1	13.44420	144.66978	49.0	51.5	53.0	4	2.6	2.5	
3-M	1	13.44399	144.67003	47.6	51.5	53.6	6	6	2.9	Petroleum odor present upon retrieval
3-N	1	13.44494	144.66957	43.3	51.5	46.3	3	2	2	Coral fragments prevent further recovery

exceeded. The mean ER-Mq for each group of constituents was then calculated by summing the ER-Mqs for each constituent and then dividing by the total number of ER-Mqs assessed. The mean ER-Mq represents an assessment of the cumulative sediment chemistry relative to the threshold values for each station.

For certain pesticide compounds (i.e., dieldrin) the ER-L (0.02 μg/kg) are so low as to make it largely impractical to detect them in typical harbor sediments using standard EPA-approved analytical procedures.

3.2.2 Area 1 – Turning Basin

A total of six stations represented Area 1, the area comprised of the Turning Basin. Sediments consisted of predominantly fine-grained material at station 1G-C (77.8%), comprised of 56.9% silt and 20.9% clay to predominately coarse-grained material at station 1K-C (89.2%), comprised of 74.0% sand and 15.2% gravel (Table 3-2). Total solids were similar and ranged from 67.5% at station 1H-C to 78.8% at station 1L-C. TOC ranged from 0.55% at 1I-C to 1.3% at stations 1J-C and 1L-C. Specific gravity was also similar ranging from 2.79 at 1L-C to 2.86 at station 1K-C.

Ammonia was detected from 0.78 mg/kg (dry weight) at station 1G-C to 1.3 mg/kg (dry weight) at station 1K-C. Total sulfides were not detected at the indicated laboratory reporting limit. Although oil and grease were not detected, TRPH was detected at one station, 1G-C.

None of the metals analyzed had measured concentrations greater than their respective ER-M or even ER-L values. Arsenic, chromium, copper, lead, nickel and zinc were detected at every station in Area 1. Cadmium, mercury and silver were typically not detected in samples from Area 1. Metals concentrations were similar across all samples collected from Area 1. The mean ER-Mq for metals ranged from 0.034 at station 1J-C to 0.045 at station 1G-C.

All remaining analytes, including PAHs, phenols, phthalates, chlorinated pesticides, PCBs (Aroclors and individual congeners), and organotins were not detected in any of the Area 1 samples.

3.2.3 Area 2 – SRF Wharf

A total of four stations represented Area 2, the area comprised of the Former SRF Wharf. Sediments consisted of predominantly coarse-grained material ranging from 83.4% at station 2F-C, comprised of 71.9% sand and 11.5% gravel to 92.2% coarse-grained material at station 2G-C, comprised of 87.4% sand and 4.8% gravel (Table 3-2). Total solids were similar and ranged from 70.7 % at station 2F-C to 74.1% at station 2H-C. TOC ranged from 0.59 % at 2G-C to 1.5 % at station 2E-C. Specific gravity was also similar ranging from 2.81 at 2E-C to 2.85 at station 2G-C.

Ammonia was detected from 0.76 mg/kg (dry weight) at station 2G-C to 3.6 mg/kg (dry weight) at station 2F-C. Total sulfides ranged from non-detect at the indicated laboratory reporting limit at stations 2E-C and 2G-C to 0.14 mg/kg (dry weight) at station 2F-C. Oil and grease ranged from non-detect at the indicated laboratory reporting limit at stations 2G-C to 30 mg/kg (dry weight) at station 2E-C. TRPH also ranged from non-detect at the indicated laboratory reporting limit at stations 2F-C and 2G-C to 35 mg/kg (dry weight) at station 2E-C.

None of the metals analyzed had measured concentrations greater than their respective ER-M or even ER-L values with the exception of mercury at station 2H-C (0.152 mg/kg), which slightly exceeded the ER-L of 0.15 mg/kg but was well below the ER-M of 0.71 mg/kg. Cadmium and silver were not detected in the Area 2 samples. In general, metal concentrations were similar across all stations in Area 2 with the exception of station 2G-C which typically had metals concentrations an order of magnitude less than the other three stations. The mean ER-Mq for metals ranged from 0.038 at station 2G-C to 0.106 at station 2H-C.

Only two individual PAH compounds were detected at concentrations above their ER-L values in one sample (2G-C) from Area 2. Acenaphthene was measured at a concentration of 22 µg/kg and fluorene was measured at a concentration of 37 µg/kg, which exceeded their ER-Ls of 16 µg/kg and 19 µg/kg, respectively. Multiple other PAH compounds were detected in samples from stations 2E-C, 2G-C and 2H-C at concentrations below their ER-L values. Total detectable PAHs ranged from non-detect at station 2F-C to 984 µg/kg at station 2H-C. With the exception of station 2E-C where no phthalates were detected, at least one phthalate was detected at low concentrations in each of the remaining three Area 2 samples. Individual pesticides were below laboratory method reporting limits at all stations with the exception of 4,4'-DDE (2.6 µg/kg), and total detectable DDTs (9.9 µg/kg) which exceeded the corresponding ER-Ls of 2.2 µg/kg and 1.58 µg/kg respectively, as well as 4,4'-DDT (7.3 µg/kg) which exceeded the corresponding ER-M of 7.0 µg/kg, in station 2E-C. Concentrations of total PCB congeners were either below laboratory method reporting limits or were detected at low levels. The only station with detected total PCB congener concentrations exceeding the ER-L value was 2H-C (114.4 ug/kg) but the measured concentration was well below the ER-M value (180 ug/kg). None of the phenol and organotin analytes were detected in any of the samples from Area 2.

3.2.4 Area 3 – Polaris Point

A total of six stations represented Area 3, the area comprised of Polaris Point. Sediments were predominantly coarse-grained material with the exception of station 3M-C which was predominantly fine-grained material (61.6%), comprised of 27.0% silt and 34.6% clay (Table 3-2). Total solids were similar and ranged from 65.3% at station 3J-C to 77% at station 3H-C. TOC ranged from 0.51% at 3H-C to 3.3% at station 3M-C. Specific gravity was also similar ranging from 2.76 at 3M-C to 2.83 at stations 3F-C and 3K-C.

Ammonia was detected from 1.1 mg/kg (dry weight) at station 3H-C to 6.8 mg/kg (dry weight) at station 3F-C. Total sulfides were not detected at the indicated laboratory method reporting limit with the exception of station 3J-C with 0.46 mg/kg (dry weight). Oil and grease ranged from non-detect at the indicated laboratory reporting limit at stations 3H-C, 3I-C, and 3N-C to 6500 mg/kg (dry weight) at station 3M-C. TRPH ranged from non-detect at the indicated laboratory method reporting limit at stations 3H-C, 3I-C, and 3N-C to 5500 mg/kg (dry weight) at station 3M-C.

Table 3-2. Summary of Physical Measurements and Chemistry Analytical Results of Individual Cores from Project Area Sediments, Apra Harbor, Guam, with a Comparison to ER-L and ER-M Sediment Quality Guidelines.

Parameter	Units	ERL	ERM	1G-C	1H-C	1I-C	1J-C	1K-C	1L-C	2E-C	2F-C	2G-C	2H-C	3F-C	3H-C	3I-C	3J-C	3K-C	3L-C	3M-C	3N-C
Physical																					
Gravel	%			0.4	8.3	4.5	24.1	15.2	30.2	58.9	11.5	4.8	19.2	5.7	27.4	19.8	32.9	9.8	1.7	4.8	13.7
Sand	%			21.7	24.3	65.0	50.9	74.0	30.0	26.8	71.9	87.4	69.8	89.0	67.1	51.2	22.0	65.7	64.7	33.6	48.6
Silt	%			56.9	40.9	21.7	12.6	6.7	19.8	6.6	8.4	3.2	4.4	1.5	1.8	17.6	18.2	18.6	17.6	27.0	17.0
Clay	%			20.9	26.6	8.8	12.4	4.1	20.0	7.7	8.2	4.6	6.6	3.8	3.8	11.4	26.8	5.9	15.9	34.6	20.7
Liquid Limit	-			32.7	32.8	23.9	26.9	26.0	38.1	30.9	4.2	21.9	26.0	29.1	18.3	19.2	55.1	24.2	30.9	51.4	44.5
Plastic Limit	-			21.5	21.2	NA	18.6	NA	19.3	23.6	NA	NA	NA	NA	NA	NA	23.0	NA	21.6	20.3	20.7
Plasticity Index	-			11.2	11.6	NP	8.3	NP	18.8	7.3	NP	NP	NP	NP	NP	NP	32.1	NP	9.3	31.1	23.8
USCS Classification	-			CL	CL	NP	CL	NP	CL	ML	NP	NP	NP	NP	NP	NP	CH	NP	CL	CH	CL
Specific Gravity	-			2.81	2.81	2.82	2.82	2.86	2.79	2.81	2.82	2.85	2.82	2.83	2.80	2.82	2.82	2.83	2.82	2.76	2.77
General Chemistry																					
Ammonia (as N)	mg/kg			0.78	1.2	1.1	1.2	1.3	1.2	2	3.6	0.76	1.5	6.8	1.1	0.83	1.3	3.5	1.2	1.2	1.3
Carbon, Total Organic	%			1.1	0.89	0.55	1.3	0.93	1.3	1.5	0.76	0.59	1.1	0.73	0.51	1.7	2	1.2	1	3.3	2.7
Oil and Grease	mg/kg			<5.5	<5.9	<5.3	<5.5	<5.5	<5.1	30	14	<5.4	24	18	<5.2	<5.9	41	15	66	6500	<6.0
Solids, Total	%			72.1	67.5	75.2	73	72.8	78.8	70.9	70.7	74	74.1	65.9	77	67.4	65.3	67.2	71.5	67.6	66.8
Solids, Volatile	%			6.4	9.8	6.2	14	10	19	3.2	3.5	3	4.2	2.7	5.8	6.5	9.3	2.8	7.4	17	14
Sulfide, Dissolved	mg/kg			<0.082	<0.088	<0.079	<0.081	<0.082	<0.075	<0.084	<0.084	<0.080	<0.080	<0.090	<0.077	<0.088	<0.091	<0.088	<0.083	<0.088	<0.089
Sulfide, Total	mg/kg			<0.12	<0.12	<0.11	<0.12	<0.12	<0.11	<0.12	0.14	<0.11	0.13	<0.13	<0.11	<0.12	0.46	<0.13	<0.12	<0.12	<0.13
TRPH	mg/kg			21	<6.0	<5.4	<5.5	<5.5	<5.1	35	<5.7	<5.5	21	29	<5.2	<6.0	38	22	60	5500	<6.0
Trace Metals																					
Arsenic	mg/kg	8.2	70	3.38	3.42	2.66	3.54	2.21	3.69	4.53	3.75	2.75	6.78	4.03	2.48	4.16	6.49	7.47	5.75	6.78	6.01
Cadmium	mg/kg	1.2	9.6	<0.00623	<0.00666	<0.00598	<0.00616	0.958	<0.00570	<0.00634	<0.00636	<0.00607	<0.00607	<0.00682	<0.00584	<0.00667	0.175	<0.00669	0.151	0.354	<0.00673
Chromium	mg/kg	81	370	20.2	20.5	11.1	10.6	5.34	15.7	16.1	10.9	7.26	20	5.45	8.3	12.2	28.1	14.5	32.7	39.4	22.6
Copper	mg/kg	34	270	6.2	5.39	3.99	4.22	3.1	4.2	27	21.6	7	24.3	5.42	6.21	6.28	11.4	8.95	27.6	43.3	9.38
Lead	mg/kg	46.7	218	3.34	2.71	3.22	1.9	2.23	1.59	18.1	23.8	4.42	28.4	7.95	9.32	6.49	2.77	18.5	32	47.1	5.08
Mercury	mg/kg	0.15	0.71	<0.0180	<0.0192	0.0318	<0.0178	<0.0178	<0.0165	0.123	0.106	0.0314	0.152	0.0395	0.0269	0.0327	<0.0199	0.0713	0.152	0.0474	<0.0194
Nickel	mg/kg	20.9	51.6	11.5	11.4	7.94	8.42	7.17	10.3	10.7	12.3	8.48	11.8	7.55	9.98	11.1	16.9	10.3	15.3	20	14.8
Silver	mg/kg	1	3.7	<0.00490	<0.00523	<0.00470	<0.00484	0.189	<0.00448	<0.00498	<0.00500	<0.00477	<0.00477	<0.00536	<0.00459	<0.00524	<0.00541	<0.00526	<0.00494	<0.00523	<0.00529
Zinc	mg/kg	150	410	11.5	9.97	7.7	9.36	5.99	7.93	46.5	29	10.5	55.5	15.8	20.1	18.1	22.1	34.2	74.7	175	17.4
Polynuclear Aromatic Hydrocarbons																					
1-Methylnaphthalene	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.7	<2.8	<2.7	<2.5	<2.7	<2.7
2-Methylnaphthalene	µg/kg	70	670	<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
Acenaphthene	µg/kg	16	500	<2.6	<2.7	<2.5	<2.5	<2.5	<2.3	<2.6	<2.6	22	<2.5	<2.8	<2.4	<2.7	<2.8	<2.8	<2.6	<2.7	<2.8
Acenaphthylene	µg/kg	44	640	<2.3	<2.4	<2.2	<2.3	<2.3	<2.1	<2.3	<2.3	20	<2.2	<2.5	<2.1	<2.4	<2.5	<2.5	<2.3	<2.4	<2.5
Anthracene	µg/kg	85.3	1100	<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	<2.5	<2.5	<2.4	19	<2.7	<2.3	<2.7	<2.8	<2.7	15	<2.7	<2.7
Benzo (a) Anthracene	µg/kg	261	1600	<3.0	<3.2	<2.9	<2.9	<3.0	<2.7	17	<3.0	<2.9	92	<3.3	<2.8	<3.2	<3.3	34	36	80	<3.2
Benzo (a) Pyrene	µg/kg	430	1600	<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	21	<2.5	<2.4	84	33	<2.3	<2.6	<2.7	38	42	82	21
Benzo (b) Fluoranthene	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	23	<2.5	<2.4	87	33	<2.3	<2.7	<2.8	36	38	100	20

Parameter	Units	ERL	ERM	1G-C	1H-C	1I-C	1J-C	1K-C	1L-C	2E-C	2F-C	2G-C	2H-C	3F-C	3H-C	3I-C	3J-C	3K-C	3L-C	3M-C	3N-C
Benzo (g,h,i) Perylene	µg/kg			<2.6	<2.7	<2.5	<2.5	<2.5	<2.3	15	<2.6	<2.5	51	22	<2.4	<2.7	<2.8	26	27	52	<2.8
Benzo (k) Fluoranthene	µg/kg			<3.5	<3.7	<3.3	<3.4	<3.4	<3.2	26	<3.5	<3.4	92	30	<3.2	<3.7	<3.8	44	50	88	22
Chrysene	µg/kg	384	2800	<2.8	<3.0	<2.7	<2.8	<2.8	<2.6	21	<2.9	<2.8	91	16	<2.7	<3.0	<3.1	44	50	75	<3.1
Dibenz (a,h) Anthracene	µg/kg	63.4	260	<2.7	<2.9	<2.6	<2.7	<2.7	<2.5	<2.8	<2.8	<2.6	<2.6	<3.0	<2.5	<2.9	<3.0	<2.9	<2.7	<2.9	<2.9
Fluoranthene	µg/kg	600	5100	<2.6	<2.8	<2.5	<2.6	<2.6	<2.4	30	<2.7	<2.6	180	<2.9	<2.5	<2.8	<2.9	61	75	130	<2.8
Fluorene	µg/kg	19	540	<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	37	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
Indeno (1,2,3-c,d) Pyrene	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	15	<2.5	<2.4	57	26	<2.3	<2.7	<2.8	28	26	48	<2.7
Naphthalene	µg/kg	160	2100	<2.6	<2.7	<2.5	<2.5	<2.5	<2.3	<2.6	<2.6	<2.5	<2.5	<2.8	<2.4	<2.7	17	<2.8	<2.6	<2.7	<2.8
Phenanthrene	µg/kg	240	1500	<2.6	<2.8	<2.5	<2.6	<2.6	<2.4	<2.7	<2.7	<2.6	81	<2.9	<2.5	<2.8	<2.9	<2.8	50	<2.8	<2.8
Pyrene	µg/kg	665	2600	<3.5	<3.7	<3.3	<3.4	<3.4	<3.2	28	<3.5	190	150	19	<3.2	<3.7	<3.8	55	73	220	<3.7
Total Detectable PAHs	µg/kg	4022	44792	<2.3	<2.4	<2.2	<2.3	<2.3	<2.1	196	<2.3	269	984	179	<2.1	<2.4	17	366	482	875	63
Phenols																					
2,4,5-Trichlorophenol	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
2,4,6-Trichlorophenol	µg/kg			<1.8	<1.9	<1.7	<1.8	<1.8	<1.6	<1.8	<1.8	<1.8	<1.8	<2.0	<1.7	<1.9	<2.0	<1.9	<1.8	<1.9	<1.9
2,4-Dichlorophenol	µg/kg			<1.9	<2.0	<1.8	<1.8	<1.9	<1.7	<1.9	<1.9	<1.8	<1.8	<2.0	<1.8	<2.0	<2.1	<2.0	<1.9	<2.0	<2.0
2,4-Dimethylphenol	µg/kg			<2.3	<2.4	<2.2	<2.3	<2.3	<2.1	<2.3	<2.3	<2.2	<2.2	<2.5	<2.1	<2.4	<2.5	<2.5	<2.3	<2.4	<2.5
2,4-Dinitrophenol	µg/kg			<75	<80	<72	<74	<74	<68	<76	<76	<73	<73	<82	<70	<80	<83	<80	<75	<80	<81
2-Chlorophenol	µg/kg			<2.3	<2.4	<2.2	<2.3	<2.3	<2.1	<2.3	<2.3	<2.2	<2.2	<2.5	<2.1	<2.4	<2.5	<2.5	<2.3	<2.4	<2.5
2-Methylphenol	µg/kg			<2.2	<2.4	<2.1	<2.2	<2.2	<2.0	<2.3	<2.3	<2.2	<2.2	<2.4	<2.1	<2.4	<2.5	<2.4	<2.2	<2.4	<2.4
2-Nitrophenol	µg/kg			<2.1	<2.2	<2.0	<2.1	<2.1	<1.9	<2.1	<2.1	<2.0	<2.0	<2.3	<1.9	<2.2	<2.3	<2.2	<2.1	<2.2	<2.2
3/4-Methylphenol	µg/kg			<2.2	<2.4	<2.1	<2.2	<2.2	<2.0	<2.3	<2.3	<2.2	<2.2	<2.4	<2.1	<2.4	<2.5	<2.4	<2.2	<2.4	<2.4
4,6-Dinitro-2-Methylphenol	µg/kg			<96	<100	<92	<95	<95	<88	<98	<98	<94	<93	<110	<90	<100	<110	<100	<97	<100	<100
4-Chloro-3-Methylphenol	µg/kg			<1.9	<2.1	<1.9	<1.9	<1.9	<1.8	<2.0	<2.0	28	<1.9	<2.1	<1.8	<2.1	<2.1	<2.1	<2.0	<2.1	<2.1
4-Nitrophenol	µg/kg			<89	<95	<85	<88	<88	<81	<90	<91	<86	<86	<97	<83	<95	<98	<95	<90	<95	<96
Pentachlorophenol	µg/kg			<75	<80	<72	<74	<74	<69	<76	<76	<73	<73	<82	<70	<80	<83	<80	<76	<80	<81
Phenol	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.7	<2.8	<2.7	<2.5	<2.7	<2.7
Phthalate																					
Bis(2-Ethylhexyl) Phthalate	µg/kg			<4.3	<4.6	<4.1	<4.2	<4.3	<3.9	<4.4	<4.4	<4.2	20	<4.7	<4.0	<4.6	<4.7	29	<4.3	25	<4.6
Butyl Benzyl Phthalate	µg/kg			<4.4	<4.7	<4.2	<4.3	<4.3	<4.0	<4.4	<4.5	270	16	<4.8	<4.1	<4.7	<4.8	<4.7	<4.4	<4.7	<4.7
Di-n-Butyl Phthalate	µg/kg			<2.9	<3.1	<2.8	<2.9	<2.9	<2.7	<3.0	<3.0	<2.8	<2.8	<3.2	<2.7	<3.1	<3.2	<3.1	<2.9	<3.1	<3.1
Di-n-Octyl Phthalate	µg/kg			<4.0	<4.3	<3.9	<4.0	<4.0	<3.7	<4.1	<4.1	<3.9	<3.9	<4.4	<3.8	<4.3	<4.4	<4.3	<4.1	<4.3	<4.3
Diethyl Phthalate	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	18	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Dimethyl Phthalate	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	44	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
Chlorinated Pesticides																					
2,4'-DDD	µg/kg			<0.28	<0.30	<0.27	<0.28	<0.28	<0.25	<0.28	<0.28	<0.27	<0.27	<0.30	<0.26	<0.30	<0.31	<0.30	<0.28	<0.30	<0.30
2,4'-DDE	µg/kg			<0.25	<0.26	<0.24	<0.24	<0.24	<0.23	<0.25	<0.25	<0.24	<0.24	<0.27	<0.23	<0.26	<0.27	<0.26	<0.25	<0.26	<0.27
2,4'-DDT	µg/kg			<0.19	<0.21	<0.19	<0.19	<0.19	<0.18	<0.20	<0.20	<0.19	<0.19	<0.21	<0.18	<0.21	<0.21	<0.21	<0.20	<0.21	<0.21
4,4'-DDD	µg/kg	2	20	<0.36	<0.38	<0.34	<0.35	<0.35	<0.33	<0.36	<0.36	<0.35	<0.35	<0.39	<0.34	<0.38	<0.40	1.5	<0.36	<0.38	<0.39
4,4'-DDE	µg/kg	2.2	27	<0.42	<0.45	<0.40	<0.41	<0.41	<0.38	2.6	<0.42	<0.41	<0.41	<0.46	<0.39	<0.45	<0.46	<0.45	2.1	<0.44	<0.45
4,4'-DDT	µg/kg	1	7	<0.45	<0.49	<0.44	<0.45	<0.45	<0.42	7.3	<0.46	<0.44	<0.44	<0.50	<0.43	<0.49	<0.50	24	2.4	<0.49	<0.49

Parameter	Units	ERL	ERM	1G-C	1H-C	1I-C	1J-C	1K-C	1L-C	2E-C	2F-C	2G-C	2H-C	3F-C	3H-C	3I-C	3J-C	3K-C	3L-C	3M-C	3N-C
Aldrin	µg/kg			<0.43	<0.46	<0.41	<0.42	<0.42	<0.39	<0.44	<0.44	<0.42	<0.42	<0.47	<0.40	<0.46	<0.47	<0.46	<0.43	<0.46	<0.46
Alpha Chlordane	µg/kg			<0.36	<0.38	<0.34	<0.35	<0.35	<0.33	<0.36	<0.36	<0.35	<0.35	<0.39	<0.34	<0.38	<0.40	<0.38	<0.36	<0.38	<0.39
Alpha-BHC	µg/kg			<0.41	<0.44	<0.39	<0.40	<0.40	<0.37	<0.41	<0.42	<0.40	<0.40	<0.45	<0.38	<0.44	<0.45	<0.44	<0.41	<0.44	<0.44
Beta-BHC	µg/kg			<0.35	<0.38	<0.34	<0.35	<0.35	<0.32	<0.36	<0.36	<0.34	<0.34	<0.39	<0.33	<0.38	<0.39	<0.38	<0.36	<0.38	<0.38
Chlordane	µg/kg			<5.6	<5.9	<5.3	<5.5	<5.5	<5.1	<5.7	<5.7	<5.4	<5.4	<6.1	<5.2	<5.9	<6.1	<6.0	18	<5.9	<6.0
Cis-nonachlor	µg/kg			<0.75	<0.80	<0.72	<0.74	<0.74	<0.68	<0.76	<0.76	<0.73	<0.73	<0.82	<0.70	<0.80	<0.82	<0.80	<0.75	<0.80	<0.81
Delta-BHC	µg/kg			<0.44	<0.47	<0.42	<0.44	<0.44	<0.40	<0.45	<0.45	<0.43	<0.43	<0.48	<0.41	<0.47	<0.49	<0.47	<0.44	<0.47	<0.48
Dieldrin	µg/kg	0.02	8	<0.31	<0.34	<0.30	<0.31	<0.31	<0.29	<0.32	<0.32	<0.31	<0.31	<0.34	<0.29	<0.34	<0.35	<0.34	<0.32	<0.34	<0.34
Endosulfan I	µg/kg			<0.49	<0.53	<0.47	<0.49	<0.49	<0.45	<0.50	<0.50	<0.48	<0.48	<0.54	<0.46	<0.53	<0.55	<0.53	<0.50	<0.53	<0.53
Endosulfan II	µg/kg			<0.24	<0.26	<0.23	<0.24	<0.24	<0.22	<0.25	<0.25	<0.24	<0.24	<0.27	<0.23	<0.26	<0.27	<0.26	<0.25	<0.26	<0.26
Endosulfan Sulfate	µg/kg			<0.36	<0.39	<0.35	<0.36	<0.36	<0.33	<0.37	<0.37	<0.36	<0.35	<0.40	<0.34	<0.39	<0.40	<0.39	<0.37	<0.39	<0.39
Endrin	µg/kg			<0.28	<0.30	<0.27	<0.28	<0.28	<0.26	<0.28	<0.29	<0.27	<0.27	<0.31	<0.26	<0.30	<0.31	<0.30	<0.28	<0.30	<0.30
Endrin Aldehyde	µg/kg			<0.27	<0.29	<0.26	<0.27	<0.27	<0.25	<0.28	<0.28	<0.26	<0.26	<0.30	<0.25	<0.29	<0.30	<0.29	<0.27	<0.29	<0.29
Endrin Ketone	µg/kg			<0.42	<0.45	<0.40	<0.41	<0.41	<0.38	<0.42	<0.42	<0.41	<0.41	<0.46	<0.39	<0.45	<0.46	<0.45	<0.42	<0.44	<0.45
Gamma Chlordane	µg/kg			<0.36	<0.38	<0.34	<0.35	<0.35	<0.33	<0.36	<0.36	<0.35	<0.35	<0.39	<0.34	<0.38	<0.40	<0.38	1.7	<0.38	<0.39
Gamma-BHC	µg/kg			<0.32	<0.34	<0.30	<0.31	<0.31	<0.29	<0.32	<0.32	<0.31	<0.31	<0.35	<0.30	<0.34	<0.35	<0.34	<0.32	<0.34	<0.34
Heptachlor	µg/kg			<0.31	<0.33	<0.30	<0.31	<0.31	<0.28	<0.31	<0.32	<0.30	<0.30	<0.34	<0.29	<0.33	<0.34	<0.33	<0.31	<0.33	<0.33
Heptachlor Epoxide	µg/kg			<0.25	<0.27	<0.24	<0.25	<0.25	<0.23	<0.26	<0.26	<0.25	<0.25	<0.28	<0.24	<0.27	<0.28	<0.27	<0.26	<0.27	<0.28
Methoxychlor	µg/kg			<0.23	<0.25	<0.22	<0.23	<0.23	<0.21	<0.24	<0.24	<0.23	<0.23	<0.25	<0.22	<0.25	<0.26	<0.25	<0.23	<0.25	<0.25
Total Detectable Chlordane (a,g)	µg/kg	0.5	6	<0.36	<0.38	<0.34	<0.35	<0.35	<0.33	<0.36	<0.36	<0.35	<0.35	<0.39	<0.34	<0.38	<0.4	<0.38	1.7	<0.38	<0.39
Total Detectable DDTs	µg/kg	1.58	46.1	<0.19	<0.21	<0.19	<0.19	<0.19	<0.18	9.9	<0.2	<0.19	<0.19	<0.21	<0.18	<0.21	<0.21	25.5	4.5	<0.21	<0.21
Toxaphene	µg/kg			<12	<13	<11	<12	<12	<11	<12	<12	<11	<11	<13	<11	<13	<13	<13	<12	<13	<13
Trans-nonachlor	µg/kg			<0.76	<0.81	<0.73	<0.75	<0.75	<0.70	<0.77	<0.78	<0.74	<0.74	<0.83	<0.71	<0.81	<0.84	<0.82	<0.77	<0.81	<0.82
Aroclor PCBs																					
Aroclor-1016	µg/kg			<2.8	<3.0	<2.7	<2.8	<2.8	<2.6	<2.8	<2.9	<2.7	<2.7	<3.1	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Aroclor-1221	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	<2.8	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Aroclor-1232	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	<2.8	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Aroclor-1242	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	<2.8	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Aroclor-1248	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	<2.8	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Aroclor-1254	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	<2.8	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	220	<2.8	<3.0	<3.0
Aroclor-1260	µg/kg			<3.1	<3.3	<3.0	<3.1	<3.1	<2.8	140	<3.2	23	81	<3.4	<2.9	<3.3	<3.4	<3.3	48	<3.3	<3.3
Aroclor-1262	µg/kg			<2.8	<3.0	<2.7	<2.7	<2.7	<2.5	<2.8	<2.8	<2.7	<2.7	<3.0	<2.6	<3.0	<3.1	<3.0	<2.8	<3.0	<3.0
Total Aroclor	µg/kg			<2.8	<3	<2.7	<2.7	<2.7	<2.5	140	<2.8	23	81	<3	<2.6	<3	<3.1	220	48	<3	<3
PCB Congeners																					
PCB008	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.7	<2.8	<2.7	<2.5	3.7J	<2.7
PCB018	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.6	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
PCB028	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.4	<2.5	<2.3	<2.3	<2.6	<2.3	<2.6	<2.7	<2.6	<2.4	12	<2.6
PCB037	µg/kg			<2.5	<2.6	<2.4	<2.4	<2.4	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.5	3.5J	<2.7
PCB044	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.5	4.2J	<2.6
PCB049	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.4	<2.5	<2.3	<2.3	<2.6	<2.3	<2.6	<2.7	<2.6	<2.4	4.7J	<2.6

Parameter	Units	ERL	ERM	1G-C	1H-C	1I-C	1J-C	1K-C	1L-C	2E-C	2F-C	2G-C	2H-C	3F-C	3H-C	3I-C	3J-C	3K-C	3L-C	3M-C	3N-C
PCB052	µg/kg			<2.8	<3.0	<2.7	<2.8	<2.8	<2.6	<2.9	<2.9	<2.8	<2.7	<3.1	<2.6	<3.0	<3.1	<3.0	<2.8	5.1J	<3.0
PCB066	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.3	<2.3	<2.6	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
PCB070	µg/kg			<2.6	<2.8	<2.5	<2.6	<2.6	<2.4	<2.6	<2.6	<2.5	<2.5	<2.8	<2.4	<2.8	<2.9	<2.8	<2.6	3.1J	<2.8
PCB074	µg/kg			<2.5	<2.6	<2.4	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.5	<2.6	<2.6
PCB077	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.6	<2.3	<2.6	<2.7	<2.6	<2.4	<2.6	<2.6
PCB081	µg/kg			<2.5	<2.6	<2.4	<2.4	<2.4	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.7	<2.5	<2.6	<2.7
PCB087	µg/kg			<2.5	<2.6	<2.4	<2.4	<2.5	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.7	<2.7	<2.7	<2.5	<2.6	<2.7
PCB099	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	2.6J	<2.7	<2.3	<2.6	<2.7	<2.6	<2.5	<2.6	<2.6
PCB101	µg/kg			<2.6	<2.8	<2.5	<2.5	<2.6	<2.4	<2.6	<2.6	<2.5	<2.5	<2.8	<2.4	<2.8	<2.8	<2.8	<2.6	3J	<2.8
PCB105	µg/kg			<2.7	<2.9	<2.6	<2.6	<2.7	<2.4	<2.7	<2.7	<2.6	<2.6	<2.9	<2.5	<2.9	<3.0	<2.9	<2.7	<2.9	<2.9
PCB110	µg/kg			<2.3	<2.5	<2.2	<2.3	<2.3	<2.1	<2.3	<2.3	<2.2	<2.2	<2.5	<2.2	<2.5	<2.5	<2.5	<2.3	<2.5	<2.5
PCB114	µg/kg			<2.3	<2.5	<2.2	<2.3	<2.3	<2.1	<2.4	<2.4	<2.3	<2.3	<2.6	<2.2	<2.5	<2.6	<2.5	<2.4	<2.5	<2.5
PCB118	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.7	<2.7	<2.7	<2.5	3.2J	<2.7
PCB119	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.4	<2.4	<2.3	<2.3	<2.6	<2.2	<2.6	<2.6	<2.6	<2.4	<2.5	<2.6
PCB123	µg/kg			<2.3	<2.5	<2.2	<2.3	<2.3	<2.1	<2.4	<2.4	<2.3	<2.2	<2.5	<2.2	<2.5	<2.6	<2.5	<2.3	<2.5	<2.5
PCB126	µg/kg			<2.3	<2.4	<2.2	<2.2	<2.2	<2.1	<2.3	<2.3	<2.2	<2.2	<2.5	<2.1	<2.4	<2.5	<2.4	<2.3	8.8	<2.4
PCB128	µg/kg			<2.3	<2.4	<2.2	<2.3	<2.3	<2.1	<2.3	<2.3	<2.2	<2.2	<2.5	<2.1	<2.4	<2.5	<2.5	<2.3	<2.4	<2.5
PCB138/158	µg/kg			<4.9	<5.2	<4.7	<4.8	<4.8	<4.4	<4.9	<5.0	<4.7	11	<5.3	<4.6	<5.2	<5.4	<5.2	<4.9	<5.2	<5.2
PCB149	µg/kg			<2.3	<2.5	<2.2	<2.3	<2.3	<2.1	<2.4	<2.4	<2.3	7.6	<2.6	<2.2	<2.5	<2.6	<2.5	<2.4	2.9J	<2.5
PCB151	µg/kg			<2.4	<2.5	<2.3	<2.3	<2.3	<2.2	<2.4	<2.4	<2.3	3.6J	<2.6	<2.2	<2.5	<2.6	<2.5	<2.4	<2.5	<2.5
PCB153	µg/kg			<2.3	<2.5	<2.2	<2.3	<2.3	<2.1	3.1J	<2.4	<2.2	19	<2.5	<2.2	<2.5	<2.5	<2.5	<2.3	3.5J	<2.5
PCB156	µg/kg			<2.6	<2.8	<2.5	<2.6	<2.6	<2.4	<2.7	<2.7	<2.6	<2.6	<2.9	<2.5	<2.8	<2.9	<2.8	<2.7	<2.8	<2.9
PCB157	µg/kg			<2.5	<2.7	<2.4	<2.5	<2.5	<2.3	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.7	<2.8	<2.7	<2.5	<2.7	<2.7
PCB167	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.4	<2.4	<2.3	<2.3	<2.6	<2.2	<2.6	<2.6	<2.6	<2.4	<2.6	<2.6
PCB168	µg/kg			<2.2	<2.4	<2.1	<2.2	<2.2	<2.0	<2.2	<2.2	<2.1	<2.1	<2.4	<2.1	<2.4	<2.4	<2.4	<2.2	<2.4	<2.4
PCB169	µg/kg			<2.2	<2.3	<2.1	<2.1	<2.1	<2.0	<2.2	<2.2	<2.1	<2.1	<2.4	<2.0	<2.3	<2.4	<2.3	<2.2	<2.3	<2.3
PCB170	µg/kg			<2.0	<2.2	<1.9	<2.0	<2.0	<1.8	<2.1	<2.1	<2.0	11	<2.2	<1.9	<2.2	<2.2	<2.2	<2.0	<2.2	<2.2
PCB177	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.4	<2.4	<2.3	4.3J	<2.6	<2.2	<2.6	<2.6	<2.6	<2.4	<2.5	<2.6
PCB180	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	24	<2.6	<2.3	<2.6	<2.7	<2.6	<2.4	3.7J	<2.6
PCB183	µg/kg			<2.4	<2.5	<2.3	<2.3	<2.3	<2.2	<2.4	<2.4	<2.3	5.5J	<2.6	<2.2	<2.5	<2.6	<2.5	<2.4	<2.5	<2.5
PCB184	µg/kg			<2.4	<2.5	<2.3	<2.3	<2.3	<2.2	<2.4	<2.4	<2.3	<2.3	<2.6	<2.2	<2.5	<2.6	<2.5	<2.4	<2.5	<2.5
PCB187	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.4	<2.4	<2.3	12	<2.6	<2.2	<2.6	<2.6	<2.6	<2.4	<2.6	<2.6
PCB189	µg/kg			<2.3	<2.5	<2.2	<2.3	<2.3	<2.1	<2.4	<2.4	<2.3	<2.2	<2.5	<2.2	<2.5	<2.6	<2.5	<2.3	<2.5	<2.5
PCB194	µg/kg			<1.9	<2.0	<1.8	<1.9	<1.9	<1.7	<1.9	<1.9	<1.8	6.5J	<2.1	<1.8	<2.0	<2.1	<2.0	<1.9	<2.0	<2.0
PCB195	µg/kg			<2.2	<2.3	<2.1	<2.2	<2.2	<2.0	<2.2	<2.2	<2.1	2.8J	<2.4	<2.0	<2.3	<2.4	<2.3	<2.2	<2.3	<2.4
PCB201	µg/kg			<4.5	<4.9	<4.4	<4.5	<4.5	<4.2	<4.6	<4.6	<4.4	4.5J	<5.0	<4.3	<4.9	<5.0	<4.9	<4.6	<4.8	<4.9
PCB206	µg/kg			<2.6	<2.8	<2.5	<2.6	<2.6	<2.4	<2.6	<2.6	<2.5	<2.5	<2.8	<2.4	<2.8	<2.9	<2.8	<2.6	18	<2.8
PCB209	µg/kg			<2.4	<2.6	<2.3	<2.4	<2.4	<2.2	<2.5	<2.5	<2.4	<2.4	<2.7	<2.3	<2.6	<2.7	<2.6	<2.5	91	<2.6
Total PCBs	µg/kg	22.7	180	<1.9	<2	<1.8	<1.9	<1.9	<1.7	3.1	<1.9	<1.8	114.4	<2.1	<1.8	<2	<2.1	<2	<1.9	170.4	<2

Parameter	Units	ERL	ERM	1G-C	1H-C	1I-C	1J-C	1K-C	1L-C	2E-C	2F-C	2G-C	2H-C	3F-C	3H-C	3I-C	3J-C	3K-C	3L-C	3M-C	3N-C
Organotins																					
Monobutyltin	µg/kg			<0.85	<0.94	<0.81	<0.86	<0.81	<0.93	<0.83	<0.83	<0.81	<0.78	<0.89	<0.74	<0.91	<1.02	<0.81	<0.85	<0.94	<0.91
Dibutyltin	µg/kg			<1.78	<1.96	<1.70	<1.81	<1.68	<1.95	<1.73	<1.73	<1.69	<1.62	<1.85	<1.55	<1.90	<2.14	<1.70	<1.78	<1.97	<1.91
Tributyltin	µg/kg			<1.53	<1.69	<1.47	<1.56	<1.45	<1.68	<1.49	<1.49	<1.46	<1.40	<1.60	<1.34	<1.63	<1.84	<1.46	<1.53	<1.70	<1.64
Tetrabutyltin	µg/kg			<1.38	<1.52	<1.32	<1.40	<1.3	<1.51	<1.34	<1.34	<1.31	<1.25	<1.43	<1.20	<1.47	<1.66	<1.31	<1.38	<1.53	<1.48
Mean ER-Mq's by Station																					
Metals	-	-	-	0.045	0.044	0.035	0.034	0.043	0.039	0.087	0.081	0.038	0.106	0.041	0.045	0.050	0.071	0.072	0.125	0.167	0.061
PAHs[1]	-	-	-	0.001	0.002	0.001	0.001	0.001	0.001	0.005	0.002	0.018	0.025	0.004	0.001	0.002	0.002	0.009	0.013	0.020	0.003
Chlorinated Pesticides[2]	-	-	-	0.017	0.018	0.016	0.017	0.017	0.016	0.088	0.017	0.017	0.017	0.019	0.016	0.018	0.019	0.202	0.134	0.018	0.019
PCBs[3]	-	-	-	0.005	0.006	0.005	0.005	0.005	0.005	0.017	0.005	0.005	0.636	0.006	0.005	0.006	0.006	0.006	0.005	0.947	0.006
Overall ER-Mq by Station	-	-	-	0.017	0.017	0.014	0.014	0.017	0.015	0.049	0.026	0.019	0.196	0.017	0.017	0.019	0.025	0.072	0.069	0.288	0.022

< = Below the method reporting limit indicated

J = Analyte was detected at a concentration below the reporting limit and above the detection limit. Reported value was estimated.

[blue] = The measured concentration exceeds the analyte's respective ER-L value.

[peach] = The measured concentration exceeds the analyte's respective ER-M value.

[green] = The ER-L value is less than the method reporting limit

1 = Calculated from individual PAHs rather than Total Detectable PAHs

2 = Calculated from Total Detectable DDTs, Total Detectable Chlordane and Dieldrin

3 = Calculated from PCB Congeners

None of the metals analyzed had measured concentrations greater than their respective ER-M or even ER-L values with the exception of copper and lead (43.3 and 47.1 mg/kg) at station 3M-C and mercury (0.152 mg/kg) at station 3L-C, which slightly exceeded the ER-Ls of 34 mg/kg, 46.7 mg/kg, and 0.15 mg/kg respectively. Silver was not detected in any of the Area 3 samples. The mean ER-Mq for metals ranged from 0.041 at station 3F-C to 0.167 at station 3M-C.

None of the individual PAHs were detected at concentrations above their respective ER-L values. Multiple PAH compounds were detected in all but two samples (3H-C and 3I-C) from Area 3 at low levels. Total detectable PAHs ranged from non-detect to 875 µg/kg at station 3M-C. Only two stations (3K-C and 3M-C) had detectable concentrations of one phthalate (bis[2-ethylhexyl] phthalate) at low levels. Individual pesticides were either below laboratory method reporting limits or were detected at low levels with the exception of total detectable chlordane (1.7 µg/kg) in station 3L-C and total detectable DDTs in stations 3L-C and 3K-C (4.5 and 25.5 µg/kg, respectively), which exceeded the corresponding ER-Ls of 0.5 µg/kg and 1.58 µg/kg, respectively. Both pesticides were well below their corresponding ER-Ms. Concentrations of total PCB congeners were either below laboratory method reporting limits or were detected at low levels. The only station with measured PCB concentrations in excess of the ER-L was 3M-C with a concentration of 170.4 ug/kg, which is below the ER-M value of 180 ug/kg. None of the phenol and organotin analytes were detected in any of the samples from Area 3.

3.2.5 Quality Assurance/Quality Control Results

The process of QA/QC has two components: Quality Assurance (QA) - the system used to verify that the entire process is operating within acceptable limits and Quality Control (QC) - the mechanisms established to measure non-conforming method performance. Generally, analytical results were within corresponding project and/or laboratory QA/QC acceptance ranges and limits. A summary of QA procedures and QC findings, qualifications and exceptions are presented categorically by matrix below. QC sample type analyzed per matrix is summarized in Table 3-3. A QC summarization of the accuracy and precision results of matrix spikes are presented in Table 3-4.

3.2.5.1 Holding Times

All sediment samples were analyzed within method recommended holding times.

3.2.5.2 Blanks

Laboratory contamination introduced during method use was assessed through the analysis of procedural or method blanks on a minimum frequency of one per batch or matrix type. It is assumed that the procedural blank represents a constant background contamination that affects standards and samples identically and therefore are handled similar to a sample including the addition of the same reagents, contact with the same type of vessels and processed with the same procedure.

All sediment method/procedural blanks analytes were found to be below the indicated reporting limits demonstrating no significant contamination associated with the analytical procedures.

Table 3-3. Summary of Quality Control Samples Analyzed

Analyte	Blank	Blank Spike		Surrogate Spikes	Sample Duplicate	Matrix Spike		Laboratory Control Spike		Post Digestion Spike	
		1	2			1	2	1	2	1	2
Grain Size											
Atterberg Limits											
Specific Gravity											
TRPH	x					x	x	x			
Ammonia (as N)	x				x						
Carbon, Total Organic	x					x	x	x			
Oil and Grease	x					x	x	x			
Solids, Total	x				x						
Solids, Volatile					x						
Sulfide, Dissolved	x				x						
Sulfide, Total	x				x						
TRPH	x					x	x	x			
Trace Metals	x					x	x	x	x	x	x
Mercury (Hg)	x					x	x	x	x		
PAHs	x			x		x	x	x	x		
Phenols	x			x		x	x	x	x		
Phthalate	x			x		x	x	x	x		
Chlorinated Pesticides	x			x		x	x	x	x		
Aroclor PCBs	x			x		x	x	x	x		
PCB Congeners	x			x		x	x	x	x		
Organotins	x	x	x	x	x	x	x				

Table 3-4. Summary of Accuracy and Precision Results of Matrix Spikes

Sample ID	Method	Parameter	MS (%Rec.)	MSD (%Rec.)	Accuracy Limit (%)	Accuracy Accept.	RPD (%)	Precision Limit (%)	Precision Accept.	Qualifier
General Chemistry										
2H-C	EPA 413.2M	Oil and Grease	111	108	55-135	PASS	2	30	PASS	
1L-C	EPA 9060A	Carbon, Total Organic	76	78	75-125	PASS	1	25	PASS	
2H-C	EPA 418.1M	TRPH	114	114	55-135	PASS	0	30	PASS	
Trace Metals										
2H-C	EPA 6020	Arsenic	96	104	80-120	PASS	7	20	PASS	
2H-C	EPA 6020	Cadmium	91	95	80-120	PASS	5	20	PASS	
2H-C	EPA 6020	Chromium	87	87	80-120	PASS	0	20	PASS	
2H-C	EPA 6020	Copper	71	112	80-120	FAIL	25	20	FAIL	3,4
2H-C	EPA 6020	Lead	89	111	80-120	PASS	12	20	PASS	
2H-C	EPA 6020	Nickel	80	84	80-120	PASS	3	20	PASS	
2H-C	EPA 6020	Silver	84	80	80-120	PASS	4	20	PASS	
2H-C	EPA 6020	Zinc	87	73	80-120	FAIL	6	20	PASS	3

Sample ID	Method	Parameter	MS (%Rec.)	MSD (%Rec.)	Accuracy Limit (%)	Accuracy Accept.	RPD (%)	Precision Limit (%)	Precision Accept.	Qualifier
2H-C	EPA 7471A	Mercury	94	90	76-136	PASS	3	16	PASS	
Polynuclear Aromatic Hydrocarbons										
1I-C	EPA 8270C SIM	Acenaphthene	85	85	40-106	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	Benzo (a) Pyrene	80	80	17-163	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	Chrysene	79	79	17-168	PASS	0	20	PASS	
1I-C	EPA 8270C SIM	Fluoranthene	80	80	26-137	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	Fluorene	84	85	59-121	PASS	2	20	PASS	
1I-C	EPA 8270C SIM	Naphthalene	97	96	21-133	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	Phenanthrene	86	85	54-120	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	Pyrene	80	80	6-156	PASS	0	46	PASS	
Phenols										
1I-C	EPA 8270C SIM	2,4,6-Trichlorophenol	83	84	40-160	PASS	2	20	PASS	
1I-C	EPA 8270C SIM	2,4-Dichlorophenol	82	83	40-160	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	2-Methylphenol	77	78	40-160	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	2-Nitrophenol	76	76	40-160	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	4-Chloro-3-Methylphenol	92	94	40-160	PASS	1	20	PASS	
1I-C	EPA 8270C SIM	Phenol	84	84	40-160	PASS	0	20	PASS	
Phthalates										
1I-C	EPA 8270C SIM	Di-n-Butyl Phthalate	90	88	40-160	PASS	2	20	PASS	
1I-C	EPA 8270C SIM	Dimethyl Phthalate	87	87	40-160	PASS	0	20	PASS	
Chlorinated Pesticides										
2G-C	EPA 8081A	4,4'-DDD	86	137	50-135	FAIL	46	25	FAIL	4,3
2G-C	EPA 8081A	4,4'-DDE	101	154	50-135	FAIL	41	25	FAIL	4,3
2G-C	EPA 8081A	4,4'-DDT	90	139	50-135	FAIL	43	25	FAIL	4,3
2G-C	EPA 8081A	Aldrin	78	112	50-135	PASS	35	25	FAIL	4
2G-C	EPA 8081A	Alpha Chlordane	78	114	50-135	PASS	37	25	FAIL	4
2G-C	EPA 8081A	Alpha-BHC	69	110	50-135	PASS	47	25	FAIL	4
2G-C	EPA 8081A	Beta-BHC	52	87	50-135	PASS	51	25	FAIL	4
2G-C	EPA 8081A	Delta-BHC	78	111	50-135	PASS	35	25	FAIL	4
2G-C	EPA 8081A	Dieldrin	79	119	50-135	PASS	41	25	FAIL	4
2G-C	EPA 8081A	Endosulfan I	66	98	50-135	PASS	39	25	FAIL	4
2G-C	EPA 8081A	Endosulfan II	88	129	50-135	PASS	38	25	FAIL	4
2G-C	EPA 8081A	Endosulfan Sulfate	72	115	50-135	PASS	46	25	FAIL	4
2G-C	EPA 8081A	Endrin	93	147	50-135	FAIL	45	25	FAIL	4,3
2G-C	EPA 8081A	Endrin Aldehyde	72	72	50-135	PASS	1	25	PASS	
2G-C	EPA 8081A	Endrin Ketone	67	102	50-135	PASS	41	25	FAIL	4
2G-C	EPA 8081A	Gamma Chlordane	74	107	50-135	PASS	36	25	FAIL	4
2G-C	EPA 8081A	Gamma-BHC	70	111	50-135	PASS	46	25	FAIL	4
2G-C	EPA 8081A	Heptachlor	79	118	50-135	PASS	40	25	FAIL	4
2G-C	EPA 8081A	Heptachlor Epoxide	71	111	50-135	PASS	43	25	FAIL	4
2G-C	EPA 8081A	Methoxychlor	84	133	50-135	PASS	45	25	FAIL	4
Aroclor PCBs										
1I-C	EPA 8082	Aroclor-1016	92	96	50-135	PASS	4	25	PASS	
1I-C	EPA 8082	Aroclor-1260	70	68	50-135	PASS	1	25	PASS	

Sample ID	Method	Parameter	MS (%Rec.)	MSD (%Rec.)	Accuracy Limit (%)	Accuracy Accept.	RPD (%)	Precision Limit (%)	Precision Accept.	Qualifier
PCB Congeners										
2G-C	EPA 8270C SIM	PCB008	99	100	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB018	98	99	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB028	99	101	50-125	PASS	2	30	PASS	
2G-C	EPA 8270C SIM	PCB044	98	98	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB052	92	93	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB066	101	101	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB077	99	99	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB101	98	99	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB105	96	95	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB118	100	100	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB126	92	92	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB128	92	92	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB153	94	94	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB170	88	88	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB180	99	98	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB187	96	96	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB195	99	100	50-125	PASS	1	30	PASS	
2G-C	EPA 8270C SIM	PCB206	101	101	50-125	PASS	0	30	PASS	
2G-C	EPA 8270C SIM	PCB209	102	103	50-125	PASS	0	30	PASS	
Organotins										
2H-C	GC - FPD	Dibutyltin	93	94	0-165	PASS	0.7	30	PASS	
2H-C	GC - FPD	Monobutyltin	12	15	0-140	PASS	24	30	PASS	
2H-C	GC - FPD	Tetrabutyltin	104	103	74-115	PASS	1	30	PASS	
2H-C	GC - FPD	Tri-n-propyltin	115	110	65-140	PASS	4	30	PASS	
2H-C	GC - FPD	Tributyltin	99	95	45-139	PASS	4	30	PASS	
2H-C	GC - FPD	Tripentyltin	113	113	65-132	PASS	0	30	PASS	

3 = Recovery of the Matrix Spike (MS) or Matrix Spike Duplicate (MSD) compound was out of control due to matrix interference. The associated Laboratory Control Sample (LCS) and/or Laboratory Control Sample Duplicate (LCSD) were in control and, therefore, the sample data was reported without further clarification.

4 = The MS/MSD Relative Percent Difference (RPD) was out of control due to matrix interference. The LCS/LCSD RPD was in control and, therefore, the sample data was reported without further clarification.

3.2.5.3 Method Reporting Limits

Reporting limits (RLs) for target analytes measured in sediment samples were greater than or equal to method detection limits (MDLs) and above instrument detection limits as described by USEPA SW-846 protocol. Detection limits met regulatory screening guidelines.

3.2.5.4 Accuracy

One or more target trace metals in sample 2H-C (Lab Batch 091218S01) and chlorinated pesticides in sample 2G-C (Lab Batch 091218S03) resulted in matrix spike recoveries that were outside of established control limits due to sediment matrix interference. The associated post digestion spike and/or laboratory control sample spikes were within established control limits and therefore the sample data was reported without further action.

The PCB Aroclors and chlorinated pesticides surrogate recovery for decachlorobiphenyl in sample 3M-C (Lab Batches 091218L04 and 091218L03, respectively) were outside of established control limits due to sediment matrix interference. However, the additional PCB Aroclors and chlorinated pesticides surrogate, 2,4,5,6-tetrachloro-m-xylene was within established control limits in the sample. Furthermore, both surrogates were within established control limits for the associated method blank, therefore the sample data was reported without further action.

Likewise, the PCB Aroclors and chlorinated pesticides surrogate recovery for 2,4,5,6-tetrachloro-m-xylene in sample 2F-C (Lab Batches 091218L04 and 091218L03, respectively) were outside of established control limits due to sediment matrix interference. However, the additional PCB Aroclors and chlorinated pesticides surrogate, decachlorobiphenyl was within established control limits in the sample. Furthermore, both surrogates were within established control limits for the associated method blank, therefore the sample data was reported without further action.

The recovery for the PCB Congeners surrogate, 2,4,5,6-tetrachloro-m-xylene, was out of the established control limits for sample 1I-C (Lab Batch 091217L10). However, since PCB Congeners were not detected in the sample, and the method blank surrogate recovery was within the established control limits, the data were released with no further action.

Reported results for samples 2G-C, 2E-C, 3K-C, 3L-C, and 3M-C yielded inconsistent Aroclor PCB (Lab Batch 091218L04) and PCB Congener (Lab Batch 091217L10) concentrations, which is consistent with accuracy discrepancies inherent in Aroclor PCB analysis.

The laboratory identified other inconsistencies across other methods within the data set and re-prepared and re-analyzed additional samples aliquots for TOC (Lab Batch 91229TOCL1) and TRPH (Lab Batch 091215L02). In both instances, the re-analyses supported the original results. All other parameters were found to have acceptable accuracy recoveries, including results of blank-, matrix-, laboratory control sample-, post digestion- and surrogate spikes.

3.2.5.5 Precision

One or more target chlorinated pesticides in sample 2G-C (Lab Batch 091218S03) resulted in matrix spike RPDs that were outside of established control limits due to sediment matrix interference. The associated laboratory control sample spike RPDs were within established control limits and therefore the sample data was reported without further action.

All other parameters were found to have acceptable RPD values including results of duplicate sample analysis and duplicate blank-, matrix-, laboratory control sample-, post digestion- and surrogate spikes.

4.0 DISCUSSION

4.1 Comparison to 2006 Study

This study included an additional examination of physical and chemical properties of the proposed dredged material to assist in the selection of either Polaris Point (preferred) or the Former SRF Wharf for development into a deep water wharf within Apra Harbor, Guam. The placement of sample locations when combined with the historical locations evaluated in 2006 was designed to provide high spatial resolution to determine the chemical and physical nature of bottom material in the areas to be potentially dredged. Figure 4-1 illustrates the spatial coverage of sediment cores collected in the most recent study (2009) with those collected during the initial investigation (2006). It should be noted, in 2006, aliquots from individual cores were taken and combined to create a single Area composite sample in accordance with guidance provided in the OTM (USEPA and USACE 1991); whereas, in 2009, each core was analyzed separately to further delineate the spatial distribution of chemical contaminants in the proposed dredged material.

Table 4-1 outlines qualitative differences between results of the two studies. For each group of analytes, the number of ER-L or ER-M exceedances, if applicable, is presented along with the analytes of concern. Across both studies, only one analyte exceeded an ER-M value in two separate samples. For groups of analytes that do not have associated ER-L or ER-M values, a distinction was made if the analytes were detected at low concentrations versus those which were not detected.

Table 4-2 compares ER-Mq's for each group of analytes, as well as an overall ER-Mq, per area and year (i.e., by project). All of the ER-Mq's are well below one, suggesting the sediment quality (i.e., contaminant concentrations) is likely not impairing benthic communities. For the most part, ER-Mq's for each group of analytes within a given Area were similar between the two study years with the exception of PCB ER-Mq's. In 2006, the ER-Mq for PCBs in Area 1 was 0.003; whereas, in 2009, the ER-Mq was 0.123. This difference was due to the fact that in 2006, PCBs were not detected in the Area 3 composite sample; however, in 2009, one of the eight samples had PCB congener detections. The mean ER-Mq for each Area was consistent between the 2006 and 2009 investigations.

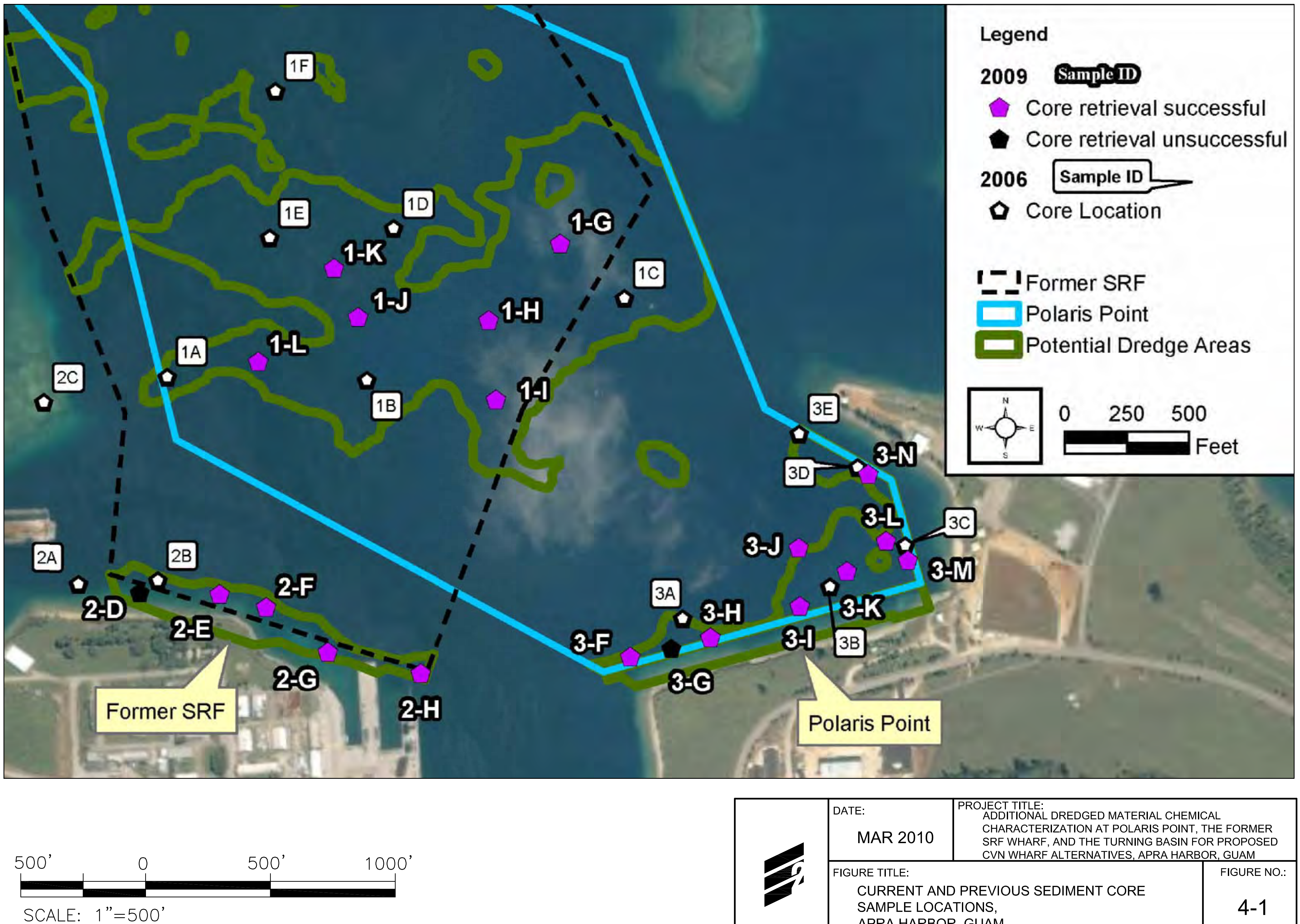
Table 4-1. Qualitative Comparison of 2006 and 2009 Physical and Chemistry Results Relative to ER-L and ER-M Sediment Quality Guidelines.

Analyte Group	Area 1		Area 2		Area 3	
	2006	2009	2006	2009	2006	2009
Physical	Coarse-grained	Predominantly Coarse-grained	Coarse-grained	Coarse-grained	Fine-grained	Predominantly Coarse-grained
General Chemistry	Typical	Typical	Typical	Typical	Typical	Typical
Metals	No ER-L Exceedances	No ER-L Exceedances	No ER-L Exceedances	1 ER-L Exceedance (Mercury)	1 ER-L Exceedance (Nickel)	3 ER-L Exceedances (Copper; Lead; Mercury)
PAHs	No ER-L Exceedances	No ER-L Exceedances	No ER-L Exceedances	2 ER-L Exceedances (Acenapthene; Fluorene)	No ER-L Exceedances	No ER-L Exceedances
Phenols	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected
Phthalates	Low Concentrations	Not Detected	Low Concentrations	Low Concentrations	Low Concentrations	Low Concentrations
Organochlorine Pesticides	Not Detected	Not Detected	Not Detected	2 ER-L Exceedances (4,4'-DDE; Total Detectable DDTs); 1 ER-M Exceedance (4,4'-DDT)	Not Detected	4 ER-L Exceedances (4,4'-DDT; Total Detectable Chlordane; Total Detectable DDTs (2)); 1 ER-M Exceedance (4,4'-DDT)
PCBs	Not Detected	Not Detected	No ER-L Exceedances	1 ER-L Exceedance (Total Detectable PCBs)	Not Detected	1 ER-L Exceedance (Total Detectable PCBs)
Organotins	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected	Not Detected

Table 4-2. Comparison of ER-Mq's for Each Analyte Group per Area between Study Years.

	2006			2009		
	Area 1	Area 2	Area 3	Area 1	Area 2	Area 3
Metals	0.030	0.056	0.086	0.040	0.078	0.079
PAHs	0.000	0.014	0.002	0.001	0.012	0.007
Pesticides	0.044	0.044	0.044	0.017	0.035	0.056
PCBs	0.003*	0.182	0.003*	0.005	0.166	0.123
Mean Overall ER-M Q	0.020	0.074	0.034	0.016	0.073	0.066

* ER-Mq recalculated from 2006 raw data. 2006 study summed all non-detect congeners using 1/2 detection limit resulting in an overestimation of ER-Mq. This study used the total PCB congener value reported by the laboratory.



DATE: MAR 2010	PROJECT TITLE: ADDITIONAL DREDGED MATERIAL CHEMICAL CHARACTERIZATION AT POLARIS POINT, THE FORMER SRF WHARF, AND THE TURNING BASIN FOR PROPOSED CVN WHARF ALTERNATIVES, APRA HARBOR, GUAM	
FIGURE TITLE: CURRENT AND PREVIOUS SEDIMENT CORE SAMPLE LOCATIONS, APRA HARBOR, GUAM		FIGURE NO.: 4-1

5.0 SUMMARY

This study, as a supplemental project to the 2006 Charlie (referred to in this report as Polaris Point), Sierra and SRF Wharf Sediment Characterization Study (Weston Solutions and Belt Collins 2006) was conducted to facilitate selection of an appropriate site for construction of a new deep water wharf in Apra Harbor, Guam. Both studies were performed consistent with guidance outlined in the OTM (USEPA and USACE 1991). The results of this study, when compared to other recent Tier III dredged material evaluations in Apra Harbor (Weston Solutions and Belt Collins 2007) indicate that although some ER-L exceedances were observed for various trace metals and trace organics and ER-M exceedances were observed for one chlorinated pesticide, it is likely if sediments from the proposed Polaris Point or SRF Wharf dredge footprints were evaluated according to guidance outlined in the OTM (USEPA and USACE 1991) and/or Inland Testing Manual (USEPA and USACE 1998) they would be deemed suitable for ocean disposal or upland placement, assuming a practicable beneficial use option was not available.

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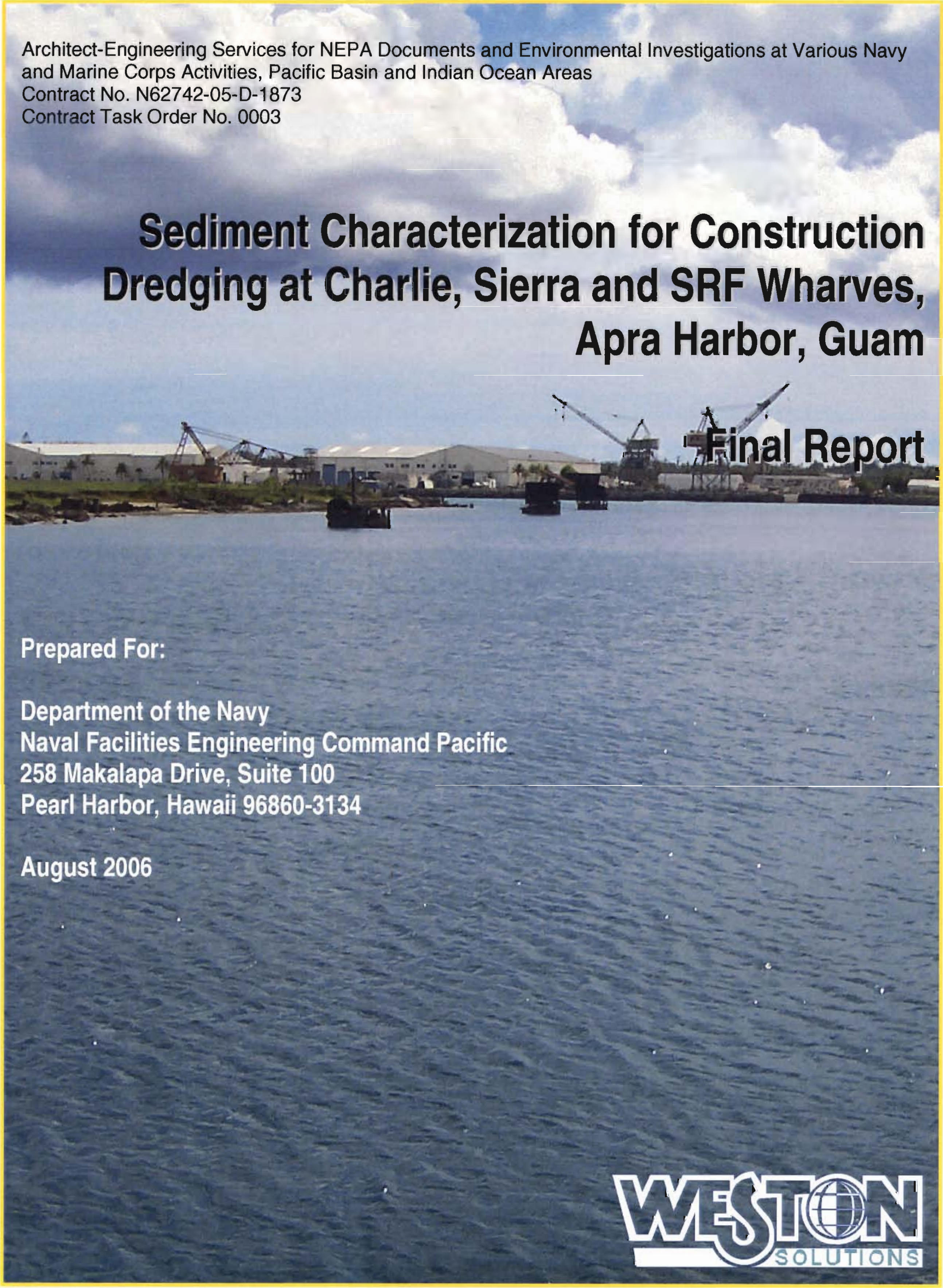
Appendix A
Field Notes and Core Logs

Appendix B
Core Photographs

Appendix C
Sediment Chemistry Results



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Sediment Characterization for Construction Dredging at Charlie, Sierra and SRF Wharves, Apra Harbor, Guam

Final Report

Prepared For:

Department of the Navy
Naval Facilities Engineering Command Pacific
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Pearl Harbor, Hawaii 96860-3134

August 2006

WESTON SOLUTIONS

Sediment Characterization for Construction Dredging Feasibility Study at Charlie, Sierra and SRF Wharves, Apra Harbor, Guam

Final Report

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August 2006

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
COC	Chain of custody
COMNAVMARIANAS	Commander, U.S. Naval Forces Marianas
CVAFS	Cold vapor atomic fluorescence spectrometry
cy	Cubic yard
DDT	Dichlorodiphenyltrichloroethane
DGPS	Differential Global Positioning System
ER-L	Effects Range-Low
ER-M	Effects Range-Median
ER-Mq	ER-M quotient
g	Gram
GC-MS	Gas chromatography/Mass spectrometry
GC-MS SIM	GC-MS selected ion monitoring
ICP-MS	Inductively coupled plasma mass spectrometry
ID	identification
kg	Kilogram
L	Liter
m	Meter
MDL	Method detection limit
mg	Milligrams
mL	Milliliter
MLLW	Mean lower low water
MRL	Method reporting limit
^{o}C	Degrees Celsius
OTM	Ocean Testing Manual
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl
RPD	Relative percent difference
QA	Quality assurance
QC	Quality control
SAP	Sampling and Analysis Plan
SRF	Ship Repair Facility
SOP	Standard Operating Procedure
SVOC	Semivolatile organic compound
TBT	tributyltin
TOC	Total organic carbon
TRPH	Total recoverable petroleum hydrocarbon
TTLC	Total threshold limit concentration
USACE	United States Army Corps of Engineers
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
μg	microgram

EXECUTIVE SUMMARY

Apra Harbor, Guam, is a strategic, forward deployed base for the U.S. Armed Forces and is home to the Commander, U.S. Naval Forces Marianas (COMNAVMARIANAS). Currently, the Apra Harbor Naval Complex provides a base for the Military Sealift Command, Maritime Pre-positioning Ship Squadron 3, Submarine Squadron 15, and the U.S. Navy Public Works Center. The majority of the Apra Harbor Naval Complex's wharves and mission support facilities are located around Inner Apra Harbor.

To maintain its mission and operational preparedness, the Navy requires dredging within the Apra Harbor complex to ensure sufficient water depth for future berthing and ship loading requirements of new classes of vessels transiting through and potentially based at Guam. To accommodate deeper draft vessels, the Navy proposes construction dredging for the development of a deep water wharf at one of three alternative sites within the harbor, and along access fairways to the selected site. The three sites under consideration include the former Charlie Wharf and a site north of the former Navy Ship Repair Facility (SRF), both located within Outer Apra Harbor, and Sierra Wharf, located within the Inner Harbor.

The purpose of this study was to delineate the distribution and magnitude of chemicals of potential concern within material to be dredged from the three alternative sites for the development of a deep water wharf in Apra Harbor, Guam. Material from the turning basins and access fairways for these sites was also evaluated.

A total of 72 sediment cores were collected with a vibracore sampler in May 2006 from nine separate areas within the proposed project footprint. All cores were collected to the target sampling depth with the exception of those areas encountering refusal. Refusal was generally associated with the presence of coral fragments which prevented further recovery. Sediment cores from within each of the nine areas were composited into a single sample and submitted for chemical analyses.

In general, sediment contamination was low throughout all the areas sampled. None of the contaminants exceeded Effects Range-Median (ER-M) values in the nine composite samples. Three of the composite samples did not have any Effects Range-Low (ER-L) exceedances (Area 1, Area 2 and Area 4) and of the remaining six samples, only metals exceeded any of their respective ER-L values, with nickel being the most prevalent to exceed. It should be noted that the ER-L and ER-M values developed for nickel were based on a limited data set (Long, et al. 1995) and are considered highly conservative (i.e., potential adverse ecological effects due to nickel do not occur as frequently as expected based on the ER-M value). It is common for nickel to be found at concentrations greater than the ER-M in material determined to be suitable for ocean disposal. In multiple dredged material evaluations no toxicity was observed in tests of sediment containing elevated nickel concentrations (i.e., greater than the ER-M). Three samples (Area 3, Area 5 and Area 6) only had one exceedance of an ER-L (nickel), two samples (Area 7 and Area 8) had two exceedances of an ER-L (nickel [in both], copper and arsenic, respectively) and one sample (Area 9) had four exceedances of an ER-L (arsenic, chromium, copper and nickel).

With the exception of Aroclor-1260 in Area 2 and tributyltin (TBT) detected in Area 4, polychlorinated biphenyls (PCBs; both individual congeners and aroclors), chlorinated pesticides, organotins, phenols and phthalates were either not detected or were estimated at concentrations below their respective reporting limits in all remaining area composite samples. In all Areas, oil and grease and total recoverable petroleum hydrocarbons (TRPH) were below detection limits. Ammonia ranged from 0.38 mg/kg (wet) in Area 3 to 13.60 mg/kg (wet) in Area 6. Area 2 had the lowest concentration of total sulfides (0.15 mg/kg) whereas Area 7 had the highest concentration (0.89 mg/kg).

Sediments within Inner Apra Harbor and adjacent to Charlie Wharf in Outer Apra Harbor were fine-grained (ranging from 63.91% to 88.83% silts and clays) whereas the sediments in Outer Apra Harbor and the entrance to Inner Apra Harbor were coarser-grained, comprised predominantly of a gravelly sand.

1.0 INTRODUCTION

Apra Harbor, Guam, has been extensively developed into a strategic, forward deployed base for the U.S. Armed Forces since the conclusion of World War II. Centrally located on Guam's west coast, Apra Harbor is home to the Commander, U.S. Naval Forces Marianas (COMNAVMARIANAS). The Apra Harbor Naval Complex provides a base for the Military Sealift Command, Maritime Pre-positioning Ship Squadron 3, Submarine Squadron 15, and the U.S. Navy Public Works Center. The majority of the Apra Harbor Naval Complex's wharves and mission support facilities are located around Inner Apra Harbor.

To maintain its mission and operational preparedness, the Navy requires dredging within the Apra Harbor complex to ensure sufficient water depth for future berthing and ship loading requirements of new classes of vessels transiting through and potentially based at Guam. To accommodate deeper draft vessels, the Navy proposes construction dredging for the development of a deep water wharf at one of three alternative sites within the harbor, and along access fairways to the selected site. The three sites under consideration include the former Charlie Wharf and a site north of the former Navy Ship Repair Facility (SRF), both located within Outer Apra Harbor, and Sierra Wharf, located within the Inner Harbor. The selection of the appropriate site for the berthing of larger vessels will be based on a feasibility study to identify and address engineering, environmental, regulatory, and economic feasibility.

1.1 Purpose

The purpose of this study was to delineate the distribution and magnitude of chemicals of potential concern within material to be dredged from the three alternative sites for the development of a deep water wharf in Apra Harbor, Guam. Material from the turning basins and access fairways for these sites was also evaluated. The distribution and magnitude of chemicals of potential concern within the proposed dredged material are evaluated to facilitate selection of the appropriate site for a deep water wharf and development of an environmentally acceptable management strategy, prior to the commencement of the deep water wharf construction dredging project.

A separate report will be generated that describes the process and provides a recommendation for site selection based on the results contained herein. Similar dredged material evaluations have recently been performed on other scheduled construction dredging projects in Inner and Outer Apra Harbor (Weston 2005a, b, and c), and information developed from these studies will be used for comparative purposes to assist with the selection of appropriate management options (e.g., placement of material in a dewatering facility and eventual beneficial use) for material from the deep water wharf construction project.

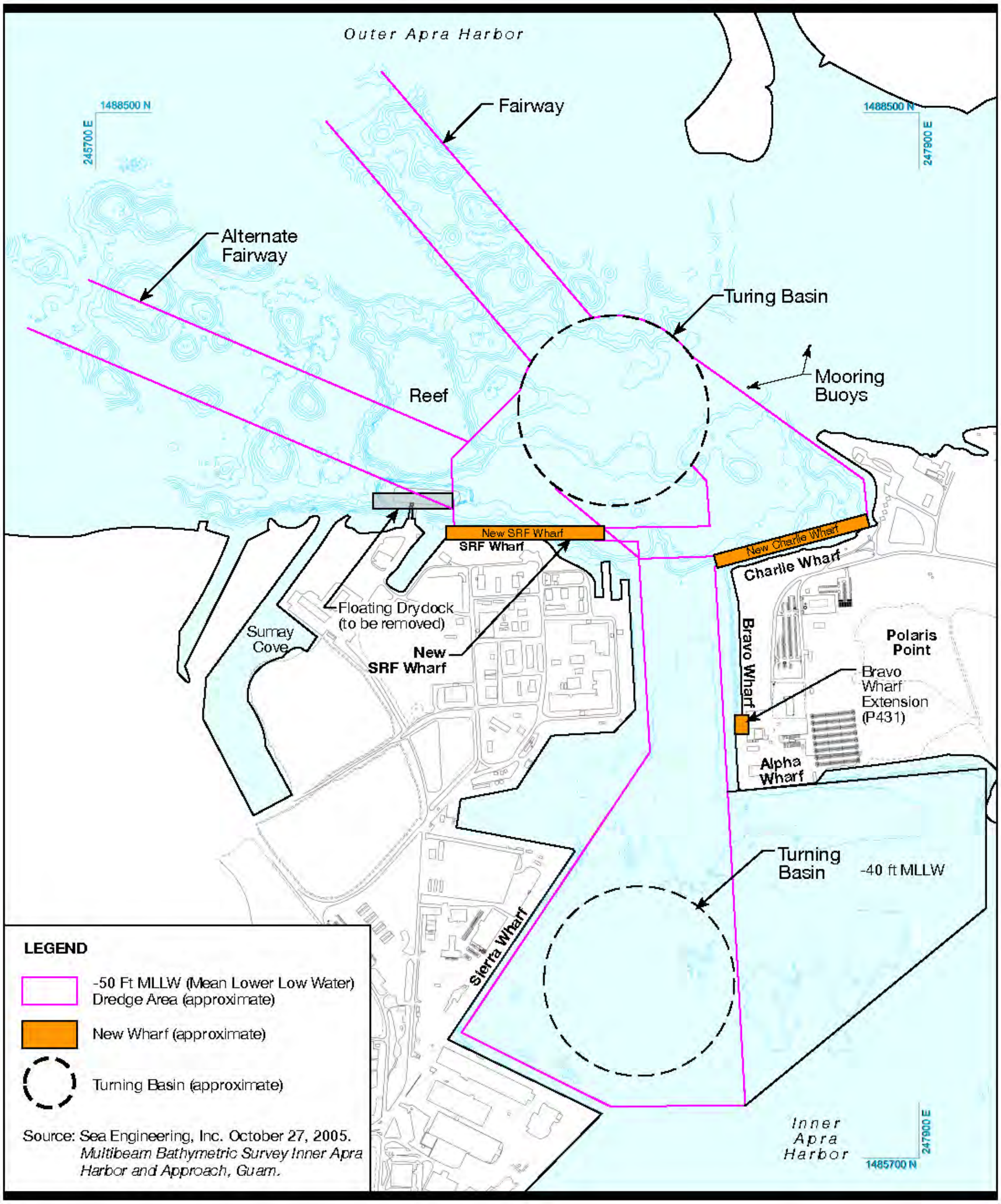
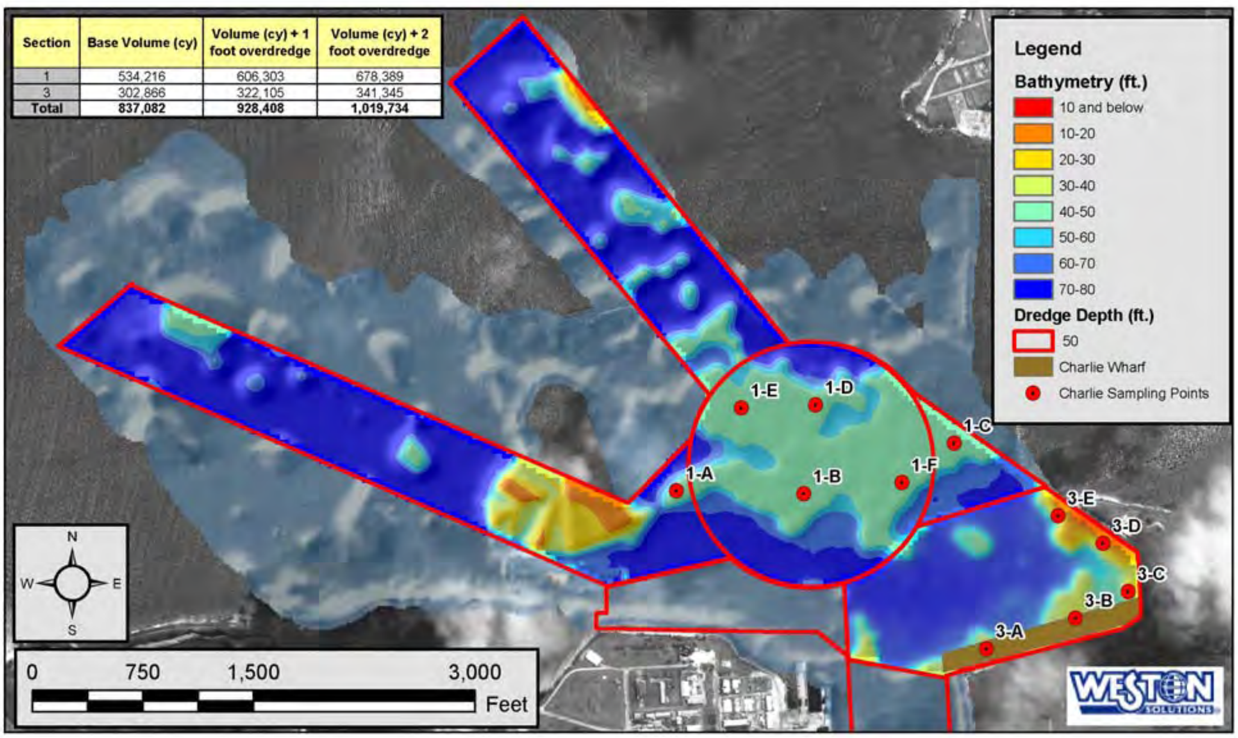


Figure 1-1. Project Area, Proposed Dredge Footprint and New Wharf Construction Sites, Apra Harbor, Guam

1.2 Project Alternatives

Three alternatives, or sites, have been identified for the potential construction of a deep water wharf in Apra Harbor, Guam. These include the former Charlie Wharf, the SRF site and Sierra Wharf. The site of the former Charlie Wharf is located in Outer Apra Harbor at the northern end of Polaris Point in a cove situated east of the Inner Harbor entrance channel. Steel sheet pile caisson foundations from the former wharf lay offshore from this site, and water depths in the area range from -20 to -80 feet mean lower low water (MLLW). The dredge footprint for this potential site includes the area fronting the wharf, a turning basin northeast of the site, and two access fairways trending at different angles to the northwest from the turning basin to Outer Apra Harbor (Figure 1-2). If this site is selected, dredging will occur to -50 feet MLLW in all areas, with removal and management of approximately 341,345 cubic yards (cy) of material from the area fronting the wharf and 678,389 cy of material from the turning basin and access fairways. These volumes are based on recent bathymetry surveys conducted in 2005 (Sea Engineering 2005) and include a 2-foot overdredge.



Section	Base Volume (cy)	Volume (cy) + 1 foot overdredge	Volume (cy) + 2 foot overdredge
1	534,216	606,303	678,389
3	302,866	322,105	341,345
Total	**837,082**	**928,408**	**1,019,734**

Figure 1-2. Charlie Wharf Alternative – Proposed Dredge Footprint, Sample Locations and Estimated Dredged Material Volumes.

The SRF site is located in Outer Apra Harbor, west of the Inner Harbor entrance channel and north of the former Navy SRF complex, which is currently the Guam Shipyard. Water depths in this area range from -20 to -73 feet MLLW, with the exception of a shallow reef that lies immediately north of the site. The dredge footprint for this potential site includes the area fronting the wharf and the same turning basin and access fairways identified for the Charlie Wharf site (Figure 1-3). Like Charlie Wharf, if this site is selected, dredging will occur to -50 feet MLLW, with removal and management of approximately 108,844 cy of material from the area fronting the wharf and 678,389 cy from the turning basin and access fairways. These volumes are based on recent bathymetry surveys conducted in 2005 (Sea Engineering 2005) and include a 2-foot overdredge.

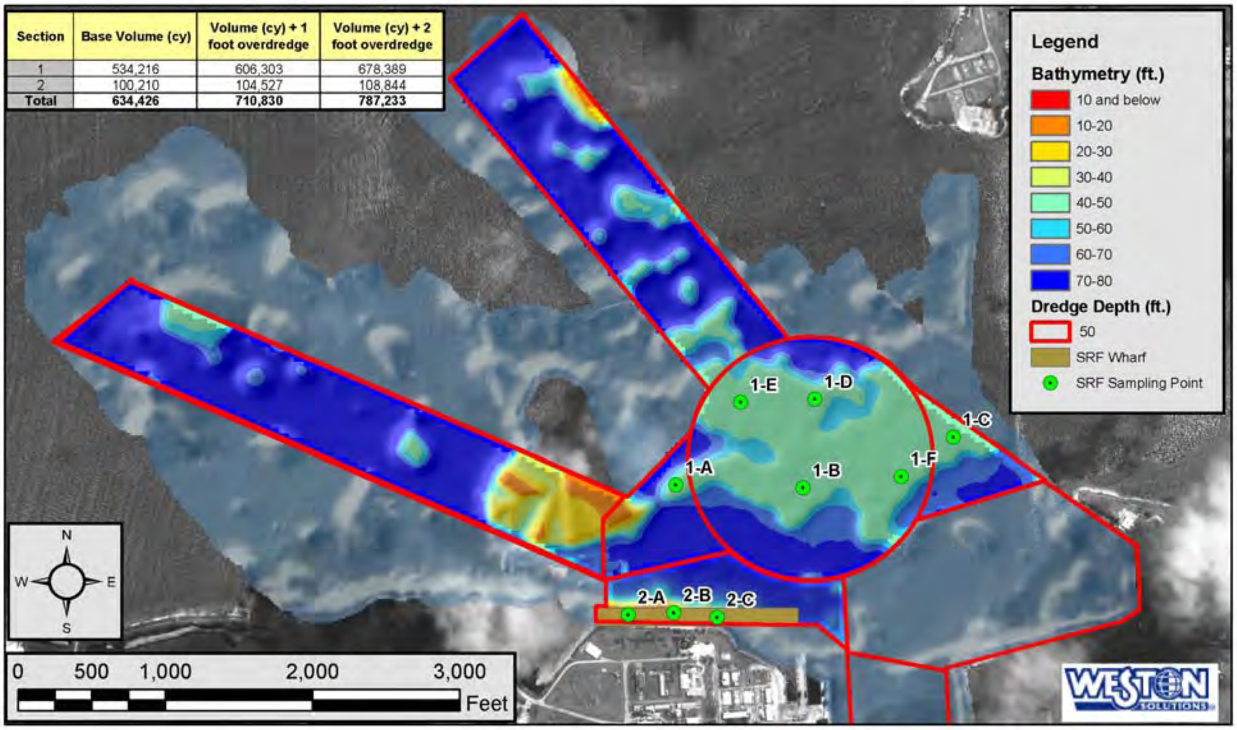
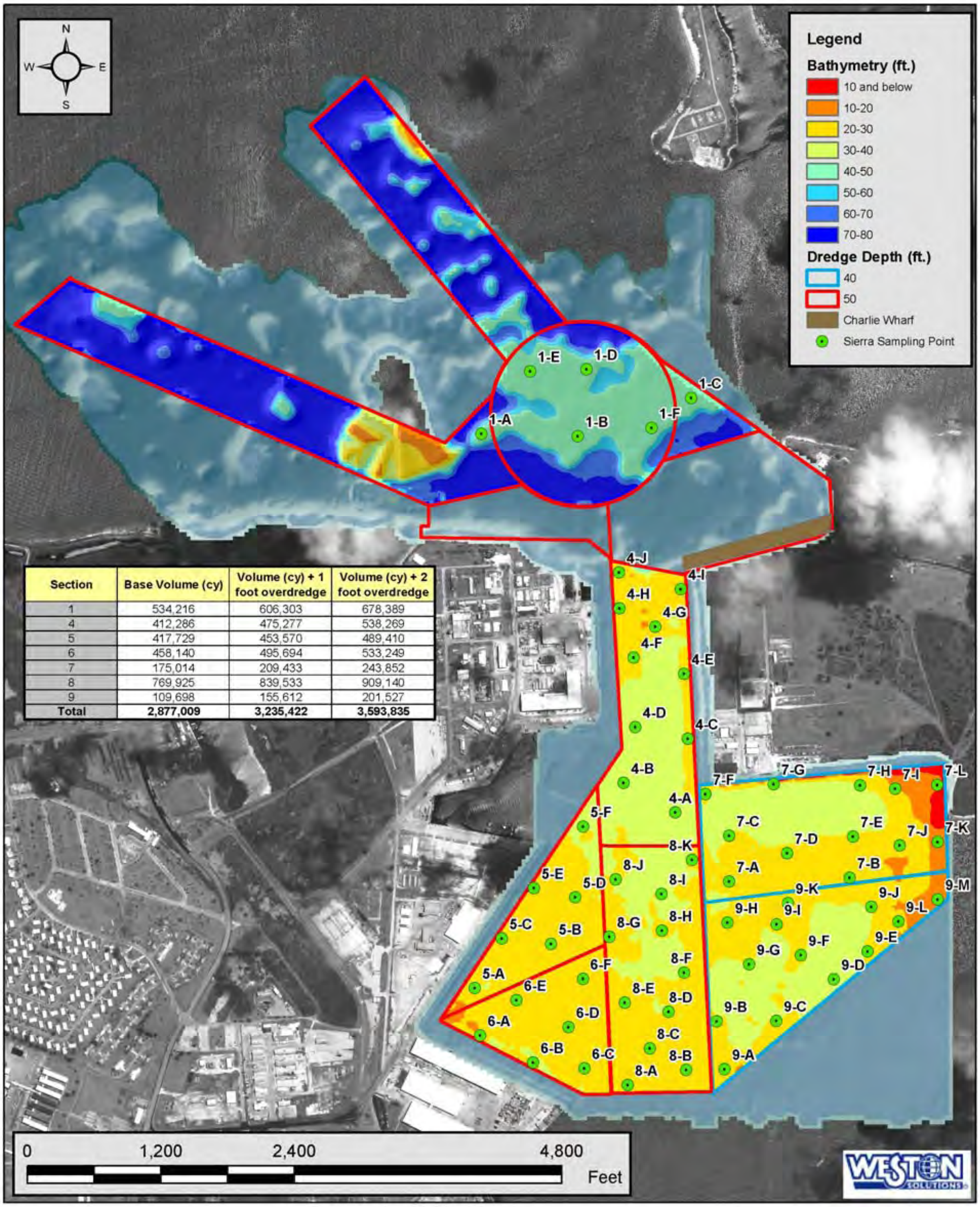


Figure 1-3. SRF Alternative – Proposed Dredge Footprint, Sample Locations and Estimated Dredged Material Volumes.

Sierra Wharf is a 1,986 foot long wharf that serves as a supply and general berthing facility for Military Sealift Command ships, visiting ships, and harbor tugboats at the western edge of Inner Apra Harbor. If this site is chosen for the development of a deep water wharf, sediments from the area fronting the wharf, a turning basin in Inner Apra Harbor, and an access fairway which provides deep water access from Outer Apra Harbor, through the entrance channel, to the Inner Harbor will need to be dredged and managed. Also within Inner Apra Harbor, sediments from an area adjacent to Apra Wharf would need to be dredged to berth vessels currently located along Bravo Wharf (entrance channel). In Outer Apra Harbor, sediments from the two access fairways and a turning basin, as identified in the Charlie Wharf and SRF Site alternatives, will need to be dredged and managed (Figure 1-4). Current depths within this dredge footprint range from approximately -35 feet to -45 feet MLLW in the area fronting the wharf and including the turning basin, and from approximately -35 feet to -80 feet MLLW along the access fairway. A reef at a water depth of approximately -45 feet MLLW spans a large portion of the entrance channel bottom. Material from the Sierra Wharf footprint would be dredged to -50 feet MLLW, with approximately 678,389 cy of material removed from the access fairways and turning basin in Outer Apra Harbor, 538,269 cy of material removed from the access fairway through the entrance to Inner Apra Harbor, and 1,931,799 cy of material removed from the Inner Apra Harbor turning basin and the area fronting Sierra Wharf. Approximately 445,379 cy of material would be dredged to a depth of -40 feet MLLW from an area offshore of Alpha Wharf to berth vessels currently located along the entrance channel at Bravo Wharf. These volumes are based on recent bathymetry surveys conducted in 2005 (Sea Engineering 2005) and include a 2-foot overdredge.



Section	Base Volume (cy)	Volume (cy) + 1 foot overdredge	Volume (cy) + 2 foot overdredge
1	534,216	606,303	678,389
4	412,286	475,277	538,269
5	417,729	453,570	489,410
6	458,140	495,694	533,249
7	175,014	209,433	243,852
8	769,925	839,533	909,140
9	109,698	155,612	201,527
Total	**2,877,009**	**3,235,422**	**3,593,835**

Figure 1-4. Sierra Wharf Alternative - Proposed Dredge Footprint, Sample Locations and Estimated Dredged Material Volumes.

2.0 MATERIALS AND METHODS

2.1 Field Collection Program for Sediment Core Samples

2.1.1 Sampling Locations and Depths

Sediment core samples were collected to the construction depth of -50 feet MLLW plus 2 feet overdredge (i.e., -52 feet MLLW) with the exception of areas directly south of Alpha Wharf, which were sampled to the construction depth of -40 feet MLLW plus 2 feet overdredge. Sediment core samples were collected at 72 locations within the dredging footprints for the three alternative wharf sites (Figure 2-1). The 72 locations were positioned in nine separate composite areas with three to 13 sample locations per area. The sediment cores from each designated area were composited into a single sample for subsequent physical and chemical analysis.

The placement of sample locations was designed to provide high spatial resolution to comprehensively determine the chemical and physical nature of bottom material in the areas to be potentially dredged. However, because the Navy had previously identified coral reef beds in Apra Harbor, sampling activities did not occur in these areas to protect these sensitive habitats. Sample locations were determined using habitat maps created by Navy research divers in March 2006.

The number of cores, core identification (ID), locations, and target lengths are provided in Table 2-1. The target lengths of these cores were based on a bathymetric survey performed in October 2005 and the actual lengths differed based on encountered bathymetry at the time of sample collection.

Sediment cores were collected to -52 feet MLLW at most sampling locations, and -42 feet MLLW in areas directly south of Alpha Wharf, unless refusal was encountered. Refusal was defined as less than 2 inches of penetration per minute. If refusal was encountered, the vessel was moved and a second core attempted. If refusal was encountered again, additional cores were not attempted unless operational problems were suspected.

One core per location was sufficient to ensure an adequate volume of material (~ 4 liter [L]) for all required testing and archival. Stratification was not present in a majority of the cores (i.e., more than half of the cores) to warrant splitting the cores to reflect differences in stratigraphy (e.g., top and bottom) for subsequent compositing and analyses.

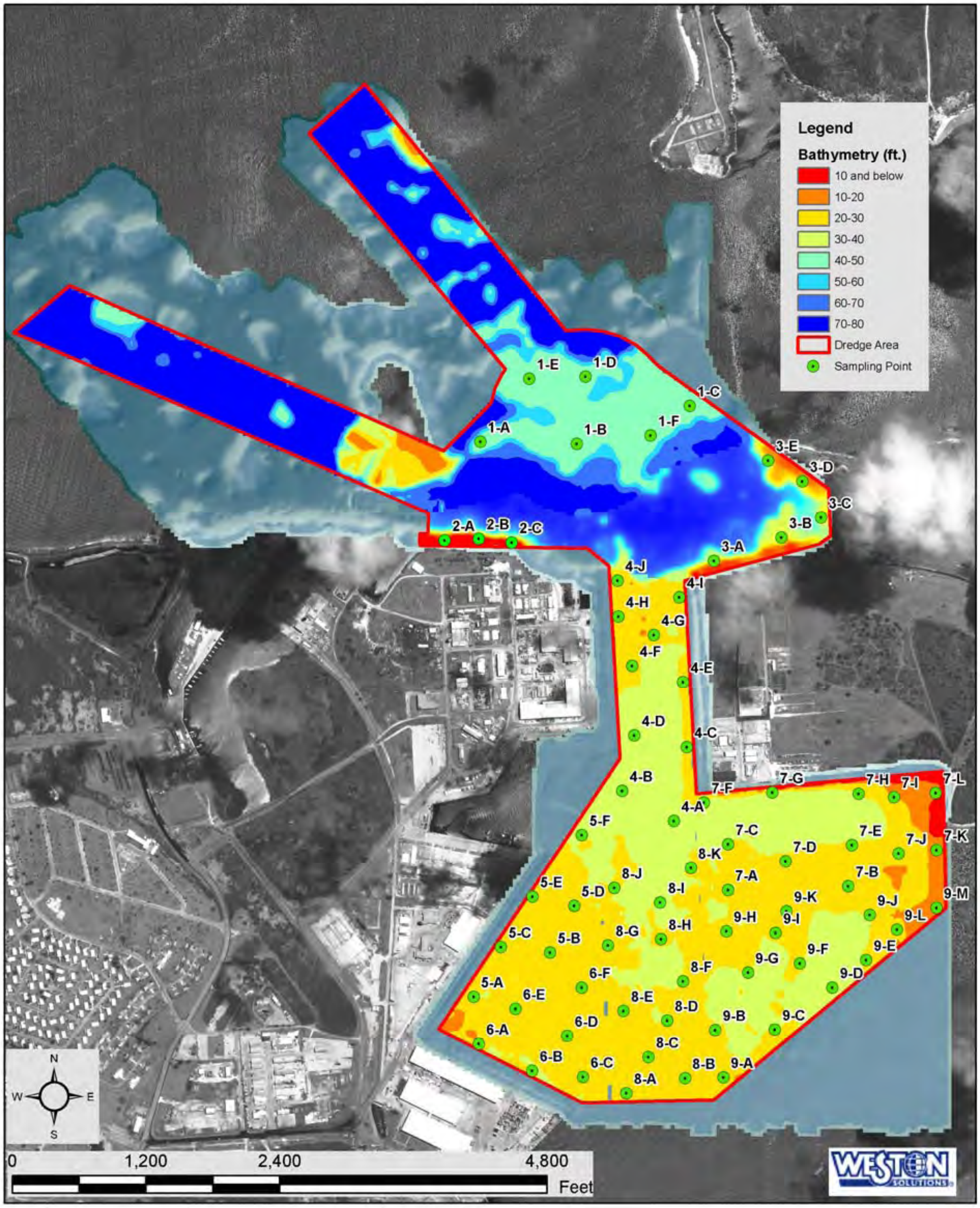


Figure 2-1. Station Locations for Sediment Core Samples at Charlie, SRF and Sierra Wharf Feasibility Study, Apra Harbor, Guam

Table 2-1: Core Locations, Target Lengths, Number of Cores, Composite ID, and Analyses for samples collected during water-based sampling.

Core ID	Longitude – Degrees, Dec. Minutes East (NAD83)	Latitude-Degrees, Dec. Minutes North (NAD83)	Existing Water Depth (feet MLLW)	Project Depth (feet MLLW)	Target Sampling Depth (Project depth + 1' foot MLLW)	Target core Length (feet)	No. of Cores per Location for Required Sample Volume	Composite ID	Composite Analyses
1-A	144° 39.689	13° 26.776	46.8	50	52	5	1	1	Physical, Chemical
1-B	144° 39.836	13° 26.755	48.0	50	52	4	1		
1-C	144° 40.008	13° 26.813	46.0	50	52	6	1		
1-D	144° 39.849	13° 26.855	46.1	50	52	6	1		
1-E	144° 39.764	13° 26.851	47.5	50	52	4	1		
1-F	144° 39.948	13° 26.768	47.4	50	52	5	1		
2-A	144° 39.636	13° 26.609	14.8	50	52	37	1	2	Physical, Chemical
2-B	144° 39.690	13° 26.612	9.3	50	52	43	1		
2-C	144° 39.738	13° 26.607	10.1	50	52	42	1		
3-A	144° 40.044	13° 26.619	31.8	50	52	20	1	3	Physical, Chemical
3-B	144° 40.149	13° 26.619	33.9	50	52	18	1		
3-C	144° 40.209	13° 26.649	29.3	50	52	23	1		
3-D	144° 40.180	13° 26.703	23.6	50	52	28	1		
3-E	144° 40.127	13° 26.733	30.7	50	52	21	1		
4-A	144° 39.990	13° 26.196	45.5	50	52	7	1	4	Physical, Chemical
4-B	144° 39.911	13° 26.24	43.3	50	52	9	1		
4-C	144° 40.009	13° 26.307	38.5	50	52	13	1		
4-D	144° 39.928	13° 26.323	43.9	50	52	8	1		
4-E	144° 40.001	13° 26.403	37.4	50	52	15	1		
4-F	144° 39.924	13° 26.426	37.6	50	52	14	1		
4-G	144° 39.957	13° 26.472	37.0	50	52	15	1		
4-H	144° 39.902	13° 26.499	36.2	50	52	16	1		
4-I	144° 39.994	13° 26.528	37.7	50	52	14	1		
4-J	144° 39.900	13° 26.552	36.6	50	52	15	1		
5-A	144° 39.688	13° 25.932	38.3	50	52	14	1	5	Physical, Chemical
5-B	144° 39.803	13° 25.998	37.5	50	52	15	1		
5-C	144° 39.728	13° 26.006	36.8	50	52	15	1		
5-D	144° 39.840	13° 26.068	38.3	50	52	14	1		
5-E	144° 39.776	13° 26.081	36.9	50	52	15	1		
5-F	144° 39.850	13° 26.174	39.8	50	52	12	1		
6-A	144° 39.697	13° 25.862	35.6	50	52	16	1	6	Physical, Chemical
6-B	144° 39.778	13° 25.822	38.1	50	52	14	1		
6-C	144° 39.855	13° 25.814	36.0	50	52	16	1		
6-D	144° 39.831	13° 25.875	37.2	50	52	15	1		
6-E	144° 39.751	13° 25.914	36.9	50	52	15	1		
6-F	144° 39.852	13° 25.947	36.6	50	52	15	1		
7-A	144° 40.072	13° 26.094	38.8	40	42	3	1	7	Physical, Chemical
7-B	144° 40.255	13° 26.101	36.1	40	42	6	1		

Core ID	Longitude – Degrees, Dec. Minutes East (NAD83)	Latitude-Degrees, Dec. Minutes North (NAD83)	Existing Water Depth (feet MLLW)	Project Depth (feet MLLW)	Target Sampling Depth (Project depth + 1' foot MLLW)	Target core Length (feet)	No. of Cores per Location for Required Sample Volume	Composite ID	Composite Analyses
7-C	144° 40.072	13° 26.162	39.3	40	42	3	1		
7-D	144° 40.160	13° 26.137	37.9	40	42	4	1		
7-E	144° 40.260	13° 26.163	37.2	40	42	5	1		
7-F	144° 40.035	13° 26.224	38.2	40	42	4	1		
7-G	144° 40.139	13° 26.240	37.6	40	42	4	1		
7-H	144° 40.270	13° 26.239	38.9	40	42	3	1		
7-I	144° 40.323	13° 26.234	34.4	40	42	8	1		
7-J	144° 40.331	13° 26.151	35.9	40	42	6	1		
7-K	144° 40.388	13° 26.156	34.1	40	42	8	1		
7-L	144° 40.387	13° 26.241	32.1	40	42	10	1		
8-A	144° 39.921	13° 25.790	37.0	50	52	15	1	8	Physical, Chemical
8-B	144° 40.010	13° 25.813	37.0	50	52	15	1		
8-C	144° 39.954	13° 25.845	36.5	50	52	16	1		
8-D	144° 39.982	13° 25.899	38.6	50	52	13	1		
8-E	144° 39.915	13° 25.912	38.4	50	52	14	1		
8-F	144° 40.006	13° 25.958	38.9	50	52	13	1		
8-G	144° 39.891	13° 26.010	37.7	50	52	14	1		
8-H	144° 39.971	13° 26.020	38.1	50	52	14	1		
8-I	144° 39.970	13° 26.074	39.4	50	52	13	1		
8-J	144° 39.900	13° 26.095	38.6	50	52	13	1		
8-K	144° 40.016	13° 26.126	39.0	50	52	13	1		
9-A	144° 40.068	13° 25.815	35.6	40	42	6	1	9	Physical, Chemical
9-B	144° 40.056	13° 25.886	37.0	40	42	5	1		
9-C	144° 40.146	13° 25.887	39.1	40	42	3	1		
9-D	144° 40.233	13° 25.950	39.7	40	42	2	1		
9-E	144° 40.283	13° 25.992	38.3	40	42	4	1		
9-F	144° 40.183	13° 25.986	37.5	40	42	5	1		
9-G	144° 40.104	13° 25.971	37.8	40	42	4	1		
9-H	144° 40.070	13° 26.033	37.5	40	42	4	1		
9-I	144° 40.145	13° 26.031	38.3	40	42	4	1		
9-J	144° 40.289	13° 26.059	37.1	40	42	5	1		
9-K	144° 40.162	13° 26.063	37.7	40	42	4	1		
9-L	144° 40.330	13° 26.037	35.1	40	42	7	1		
9-M	144° 40.390	13° 26.070	33.5	40	42	9	1		

2.1.2 Core Collection Equipment

Sediment cores were collected using an electric vibracore deployed from the *MV Shamrock*, a transport vessel modified for environmental sampling and owned and operated by Cabras Marine. The vibracore was equipped with a 4-inch outer diameter aluminum barrel and stainless steel cutter head (Figure 2-2). The standard system was capable of collecting cores up to 20 feet long and could have been equipped to handle greater depths, up to an additional 10 feet (more than sufficient to cover the target sampling depths identified for this project [Table 2-1]).

2.1.3 Navigation

For all cores, station locations were pre-plotted (Figure 2-1). Locations were determined using a Garmin Global Positioning System (GPS). The GPS was accurate to ± 14 - 18 feet. There were no failures of the GPS during the course of the sampling event. All final station locations were recorded in the field using positions from the GPS.

Figure 2-2. P-3 Vibracore Sampler in Inner Apra Harbor, Guam.

2.1.4 Sediment Collection

2.1.4.1 Core Handling

Each sample was retrieved, and the dredged material sample was extruded from the core barrel onto polyethylene-lined collection trays on the vessel platform. Following extrusion, each core was examined by a qualified scientist and photographed. The core stratigraphy and other pertinent data and observations were logged (Appendix A). Stratification was not present in the collected core samples, therefore, samples were not split into separate top and bottom portions for subsequent analysis. Sediment for environmental testing was placed into clean, food-grade–quality plastic bags, labeled (project name, date, sample ID and analysis), logged into a field chain-of-custody (COC) form (Appendix B), and placed into a cooler. Cores remained on ice and in the dark until shipped via overnight delivery service to Weston's laboratory in Carlsbad, California for processing.

2.1.4.2 Geologic Description

A qualified scientist evaluated sediment and soil cores according to the Unified Soil Classification System (USCS). The geologic description of each core included the texture, odor, color, approximate grain size distribution, and any evident stratification of the sediment.

2.1.5 Sample Processing and Storage

The sediment cores were stored at 4 degrees Celsius (°C) until processed. First, individual cores were thoroughly homogenized to a uniform consistency at Weston's laboratory using a stainless steel mixing apparatus. A sub-sample of each individual core was then taken for archival and placed into certified clean glass jars with Teflon-lined lids. Next, individual cores representing each of the nine project areas were combined and similarly homogenized to generate nine separate composite samples. From each composite sample, four 500 ml sub-samples were taken for the following purposes: archival, chemical analyses, Atterberg limits and total organic carbon (TOC) analyses, and grain size, specific gravity, and percent solids analyses. The composite samples designated for archival and chemical analyses were placed into certified clean glass jars with Teflon-lined lids. The composite samples designated for Atterberg limits and TOC as well as grain size, specific gravity and percent solids were placed in clean, food-grade quality plastic bags. Sub-samples from each core, as well as the composite used in testing which were designated for archival were preserved (frozen) in the event that further delineation of chemical contamination is required.

2.1.6 Shipping

Samples were placed into re-sealable plastic bags and securely packed inside coolers with ice packs or crushed ice. Prior to shipping, COC forms were completed, inserted into re-sealable plastic bags, and placed inside their respective coolers. All cooler lids were securely taped shut and samples sent to Weston in Carlsbad, California. After processing, samples were delivered to the appropriate analytical laboratories as listed in Table 2-2.

Table 2-2: Analytical Laboratories, Points of Contact, and Shipping Information

Laboratory	Analyses Performed	Point of Contact	Shipping Information
Weston Solutions, Inc. Carlsbad, CA	Grain size, specific gravity, percent solids	Dr. David Moore and Ms. Sheila Holt (760) 931-8081	Weston Solutions, Inc. 2433 Impala Dr. Carlsbad, CA 92010
Applied Marine Sciences	Atterberg Limits, TOC	Mr. Kenneth Davies (281) 554-6356	Applied Marine Sciences. 502 N. Highway 3, Suite B League City, TX, 77573
CRG Marine Laboratories	Sediment chemistry	Mr. Rich Gossett (310) 533-5190	CRG Marine Laboratories 2020 Del Amo Blvd., Suite 200 Torrance, CA 90501

2.1.7 Documentation and Chain-of-Custody

Samples were considered to be in custody if they were (1) in the custodian's possession or view, or (2) retained in a secured place (under lock) with restricted access. The principal documents used to identify samples and to document possession were chain-of-custody (COC) records, field logbooks, and field tracking forms. COC procedures were used for all samples throughout the collection, transport, and analytical process and for all data and data documentation, whether in hard copy or electronic format. A copy of the COC form is provided in Appendix C.

COC procedures were initiated during sample collection. A COC record was provided with each sample or sample group. Each person who had custody of the samples signed the form and ensured that the samples were not left unattended unless properly secured. Documentation of sample handling and custody included the following:

- Sample identifier
- Sample collection date and time
- Any special notations on sample characteristics
- Initials of the person collecting the sample
- Date the sample was sent to the laboratory
- Shipping company and waybill information

The completed COC form was placed in a plastic envelope that traveled inside the ice chest containing the listed samples. The COC form was signed by the person transferring custody of the samples. The condition of the samples was recorded by the receiver. COC records were included in the final analytical report prepared by the laboratory, and were considered an integral part of that report.

2.1.8 Decontamination of Field and Laboratory Equipment

All vibracore equipment was cleaned prior to sampling. Between stations, the core barrel and deck of the vessel were rinsed with site water. Before creating each composite, all stainless steel utensils (stainless steel bowls, spoons, spatulas, mixers, and other utensils) were cleaned with soapy water, rinsed with tap water, and then rinsed three times with deionized water.

2.1.9 Quality Assurance Procedures

Weston's quality control (QC) staff performs periodic audits to ensure that test conditions, data collection, and test procedures are conducted in accordance with Weston's standard operating procedures (SOPs). Weston's SOPs have been audited and approved by an independent USEPA-approved laboratory and placed in the quality assurance (QA) file as well as laboratory files.

2.1.9.1 Field Collection and Sample Handling

All relevant project information and field measurements were recorded on customized water-proof core log data forms. A daily field log was maintained, and formal COC procedures were followed and documented. All sampling equipment was cleaned between sample stations. Samples were double-bagged, and both inner and outer bags labeled. Samples were held on ice until delivery via Federal Express to Weston's laboratory in Carlsbad, California. COC forms were prepared in the field during sediment collection by Weston's personnel. Once samples were composited, a new COC was prepared for the transfer of dredged material for physical and chemical analyses.

2.1.9.2 Chemical and Physical Characteristics of Dredged Materials

Chemical analyses were performed using QC criteria specified in Methods for Chemical Analysis of Water and Wastes (USEPA 1983) and Test Methods for Evaluating Solid Waste (SW-846) (USEPA 1986), in a California state-certified laboratory (California ELAP Certificate #2261). Atterberg Limits and TOC analyses were performed in accordance with EPA (USEPA 2004) and ASTM guidelines (ASTM 2000), the 2006 Department of Defense Quality Systems Manual for Environmental Laboratories (Version 3; DoD 2006) and the 2003 National Environmental Laboratory Accreditation Conference Standard (NELAC 2004) in Texas state-certified and nationally-accredited laboratory (NELAP Certificate #E87956). Grain size analyses performed by Weston were consistent with internal QC criteria. Performance objectives were evaluated via the use of standard reference materials or laboratory control samples, method blanks, surrogates, spiked samples, duplicate samples, and internal QC samples. Precision and accuracy objectives were established for method reporting limits (MRLs), spike recoveries, and duplicate analyses.

2.2 Physical and Chemical Analyses

Physical and chemical analytes measured in this testing program were selected to provide data on potential chemicals of concern in Inner and Outer Apra Harbor dredged material. These data will be used in the determination of a feasible alternative for a deep water wharf in Apra Harbor. The target analytes and associated method detection limits (MDLs) are described in the sampling and analysis plan (SAP) (Weston and Belt Collins 2006). The analytes that were measured for this project are consistent with standard sediment characterization evaluations. Due to time constraints associated with initiating this project and finalizing the SAP only one day before field activities began, several non-standard analytes were included in the SAP that were not analyzed by the analytical laboratory; these included several semivolatile organics (e.g., anilines, dibenzofuran, benzyl alcohol, and pyridine).

2.2.1 Physical Analyses

Physical characteristics of the dredged material included grain size, total solids (TS), specific gravity, and Atterberg limits. Grain size was analyzed to determine the general size classes that make up the sediment (e.g., gravel, sand, silt, and clay). The frequency distribution of the size ranges of the sediment is reported in the final data report. Grain size was conducted using the gravimetric procedure described in Plumb (1981). Specific gravity was measured using ASTM Method 2710F (ASTM 2003). Total solids were also measured to convert concentrations of the chemical parameters from a wet-weight to a dry-weight basis. Total solids were determined by SM 2540G (Clesceri et al. 2000). Sediment physical property analyses (i.e., Atterberg limits) were analyzed by American Society of Testing and Materials (ASTM) Standard D4318-00 (ASTM 2003).

2.2.2 Dredged Material Chemistry

Sediment samples were analyzed for priority pollutants and included organics (semivolatile), metals, organotins, total recoverable petroleum hydrocarbons (TRPH), oil and grease, total sulfides, and TOC. To minimize salt interference, the following analyses were performed as recommended by the Ocean Testing Manual (OTM; USEPA/United States Army Corps of Engineers [USACE] 1991). The analysis for priority pollutant metals (with the exception of mercury) was conducted using an inductively coupled plasma mass spectrometry (ICP-MS), in accordance with USEPA Method 6020m. Mercury analysis was conducted using cold vapor atomic fluorescence spectrophotometry (CVAFS) in accordance with USEPA 245.7m. The analysis for total and dissolved sulfides followed SM 4500 S2-D and the analysis for dissolved ammonia followed SM 4500-NH3. Oil and grease was measured using USEPA 1664 and TRPH was measured by USEPA 418.1.

TOC was determined using the Lloyd Kahn method (USEPA Region II 1988). Sediment was treated with acid to remove the inorganic carbon (carbonates and bicarbonates) prior to TOC analysis using USEPA 9060A protocol.

Semivolatile organics (SVOC) including PAHs, phenols, organochlorine pesticides, and PCBs were analyzed using gas chromatography-mass spectrometry with selected ion monitoring (GC-MS SIM) according to USEPA Method 8270m. This followed serial extraction with methylene chloride and alumina and gel permeation column cleanup procedures. PCBs were identified to the Aroclor level. The analytical method used to determine TBT involved methylene chloride extraction, followed by Grignard derivatization and analysis by GC-MS (Krone et al., 1989). CRG used this method to obtain a detection limit of 1 μg/kg.

3.0 RESULTS

3.1 Dredged Material Sample Collection

Vibracore sampling was conducted between May 10 and May 16, 2006 at three to 10 locations within nine areas located throughout the northern half of Inner Apra Harbor and its entrance channel, and along the former Charlie Wharf and SRF property as well as proposed access fairways and turning basin in Outer Apra Harbor. Cores within each designated area were composited into single samples for subsequent testing and analysis. All 72 stations were successfully sampled with the exception of station 9C which was already at or below project depth and therefore not sampled.

Field coordinates, number of cores per station, depth of penetration relative to the mudline (i.e., the sediment surface), depth of recovery relative to the mudline, and core length retained for each station location are summarized in Table 3-1. Actual locations of the sampling stations are illustrated in Figure 3-1. Samples were visually homogeneous (i.e., no stratification was apparent). Field core logs, core photos, and other associated documentation for the sampling effort are provided in Appendix B.

Table 3-1. Field Coordinates, Sample Depths and Vibracore Recoveries for Samples Collected in the Vicinity of Charlie, SRF and Sierra Wharves.

Station ID	Attempt	Latitude - Degrees Dec. Minutes North (NAD83)	Longitude - Degrees Dec. Minutes East (NAD83)	Water Depth (Feet)	Target Sampling Depth (Feet)	Actual Depth Sampled (Feet)	Penetration (Feet)	Final Core Length (Feet)	Core Length Retained for Analysis (Feet)	Comments
1-A	1	13° 26.757’	144° 39.696’	46.0	52	52.0	6	3.5	3.5	Coral fragments prevent further recovery
1-B	1	13° 26.756’	144° 39.832’	47.0	52	52.0	5	4.5	4.5	Coral fragments prevent further recovery
1-C	1	13° 26.812’	144° 40.007’	46.5	52	52.5	6	5	5	
1-D	1	13° 26.857’	144° 39.849’	45.5	52	52.0	6.5	0	0	Sample lost during retrieval
	2	13° 26.857’	144° 39.849’	46.5	52	52.5	6	5.5	5.5	
1-E	1	13° 26.850’	144° 39.765’	48.2	52	55.2	7	6	3.8	
1-F	1	13° 26.948’	144° 39.768’	47.4	52	55.4	8	7	7	
2-A	1	13° 26.618’	144° 39.637’	39.0	52	54.0	15	14.5	13	
2-B	1	13° 26.621’	144° 39.691’	42.0	52	54.0	12	1	0	Sample lost during retrieval
	2	13° 26.621’	144° 39.691’	42.0	52	51.0	9	8.5	8.5	Refusal encountered at 9.0'
2-C	1	13° 26.739’	144° 39.612’	47.7	52	60.7	13	13	13	Refusal encountered at 13.0'
3-A	1	13° 26.599’	144° 40.049’	47.5	52	55.5	8	8	4.5	Planned sample location deeper than project depth; station moved to shallower location
3-B	1	13° 26.621’	144° 40.149’	36.0	52	52.0	16	10	10	Coral fragments prevent further recovery
	2	13° 26.621’	144° 40.149’	37.7	52	54.2	16.5	10	0	Coral fragments prevent further recovery
3-C	1	13° 26.649’	144° 40.200’	47.5	52	56.5	9	8.5	4.5	Planned sample location inaccessible due to swim buoys; station moved to west

Station ID	Attempt	Latitude - Degrees Dec. Minutes North (NAD83)	Longitude - Degrees Dec. Minutes East (NAD83)	Water Depth (Feet)	Target Sampling Depth (Feet)	Actual Depth Sampled (Feet)	Penetration (Feet)	Final Core Length (Feet)	Core Length Retained for Analysis (Feet)	Comments
3-D	1	13° 26.701'	144° 40.181'	20.5	52	NA	NA	NA	NA	Planned sample location amongst concrete slabs/debris; station moved offshore
	2	13° 26.701'	144° 40.167'	41.5	52	54.5	13	10	10	
3-E	1	13° 26.723'	144° 40.127'	47.1	52	55.1	8	7	4.9	
4-A	1	13° 26.195'	144° 39.990'	46.5	52	56.5	10	10	5.5	
4-B	1	13° 26.240'	144° 39.912'	44.0	52	53.0	9	7	7	
4-C	1	13° 26.309'	144° 40.008'	40.0	52	52.5	12.5	8	8	Coral fragments prevent further recovery
4-D	1	13° 26.323'	144° 39.930'	45.0	52	59.0	14	13.5	7	
4-E	1	13° 26.401'	144° 40.001'	38.0	52	52.0	14	14	14	
4-F	1	13° 26.426'	144° 39.924'	38.5	52	53.5	15	7.5	7.5	Coral fragments prevent further recovery
4-G	1	13° 26.472'	144° 39.959'	38.7	52	53.7	15	13	13	Coral fragments prevent further recovery
4-H	1	13° 26.500'	144° 39.903'	36.6	52	51.6	15	6	0	Coral fragments prevent any recovery; no sample collected
	2	13° 26.499'	144° 39.905'	36.7	52	52.2	15.5	7	7	Coral fragments prevent further recovery
4-I	1	13° 26.528'	144° 39.994'	38.0	52	52.0	14	11	11	
4-J	1	13° 26.552'	144° 39.900'	37.3	52	52.8	15.5	6.5	0	Insufficient recovery
	2	13° 26.553'	144° 39.900'	37.4	52	52.9	15.5	10.5	10.5	
5-A	1	13° 25.932'	144° 39.687'	40.4	52	57.4	17	17	11.6	
5-B	1	13° 26.000'	144° 39.804'	39.0	52	55.0	16	15	13	
5-C	1	13° 26.006'	144° 39.729'	38.1	52	50.1	12	11.5	11.5	Refusal at 12'
5-D	1	13° 26.068'	144° 39.839'	40.0	52	54.0	14	13	12	
5-E	1	13° 26.083'	144° 39.776'	39.0	52	53.0	14	13	13	
5-F	1	13° 26.173'	144° 39.850'	40.3	52	54.3	14	14	12.3	
6-A	1	13° 25.862'	144° 39.697'	37.1	52	52.1	15	12.5	12.5	
6-B	1	13° 25.773'	144° 43.825'	40.7	52	52.7	12	11	11	
6-C	1	13° 25.816'	144° 39.854'	36.6	52	52.6	16	16	15.4	
6-D	1	13° 25.875'	144°39.831'	37.8	52	53.8	16	16	14.2	
6-E	1	13° 25.914'	144° 39.751'	38.0	52	52.5	14.5	13	13	
6-F	1	13° 25.851'	144° 39.947'	38.0	52	52.5	14.5	11	11	
7-A	1	13° 25.895'	144° 40.072'	39.2	42	NA	NA	NA	NA	Sample lost during retrieval
	2	13° 26.095'	144° 40.072'	39.2	42	44.2	5	2	2	
7-B	1	13° 25.257'	144° 40.101'	36.5	42	44.0	7.5	6.3	5.5	
7-C	1	13° 26.159'	144° 40.073'	38.8	42	42.8	4	3.5	3.2	
7-D	1	13° 26.158'	144° 40.113'	39.5	42	43.5	4	3.3	2.5	Planned sample location inaccessible due to berthing of naval vessel; station moved slightly
7-E	1	13° 26.160'	144° 40.260'	36.5	42	42.5	6	3	0	Part of sample lost during retrieval
	2	13° 26.160'	144° 40.260'	36.5	42	42.5	6	0	0	No sample retrieved; station moved slightly
	3	13° 26.143'	144° 40.256'	37.3	42	44.3	7	4.3	4.3	

Station ID	Attempt	Latitude - Degrees Dec. Minutes North (NAD83)	Longitude - Degrees Dec. Minutes East (NAD83)	Water Depth (Feet)	Target Sampling Depth (Feet)	Actual Depth Sampled (Feet)	Penetration (Feet)	Final Core Length (Feet)	Core Length Retained for Analysis (Feet)	Comments
7-F	1	13° 26.216'	144° 40.043'	39.5	42	44.5	5	0	0	Planned sample location inaccessible due to berthing of naval vessel; station moved slightly. Sample lost during retrieval
	2	13° 26.220'	144° 40.034'	38.5	42	43.5	5	3.6	3.5	
7-G	1	13° 26.243'	144° 40.107'	37.4	42	43.4	6	6	4.6	Planned sample location inaccessible due to berthing of naval vessel; station moved slightly
7-H	1	13° 26.268'	144° 40.239'	39.4	42	43.9	4.5	4.2	2.6	Planned sample location deeper than project depth; station moved to shallower location
7-I	1	13° 26.233'	144° 40.321'	36.0	42	43.0	7	4.5	4.5	Loose sandy material at bottom washed out during retrieval
7-J	1	13° 26.151'	144° 40.332'	36.9	42	NA	NA	NA	NA	Sample lost during retrieval
	2	13° 26.151'	144° 40.332'	36.9	42	43.9	7	5.5	5.1	
7-K	1	13° 26.151'	144°40.388'	34.8	42	43.8	9	7.8	7.2	
7-L	1	13° 26.241'	144° 40.387'	33.1	42	41.1	8	7.5	7.5	Refusal encountered at 8.0'
8-A	1	13° 25.790'	144° 39.921'	37.6	52	52.1	14.5	13.8	13.8	
8-B	1	13° 25.814'	144° 40.009'	38.2	52	52.2	14	11	11	
8-C	1	13° 25.845'	144° 39.953'	37.5	52	52.0	14.5	12.5	12.5	
8-D	1	13° 25.899'	144° 39.982'	39.6	52	53.1	13.5	11.7	11.7	
8-E	1	13° 25.814'	144° 39.812'	40.0	52	55.0	15	14.5	12	
8-F	1	13° 25.958'	144° 40.006'	39.8	52	52.8	13	11	11	
8-G	1	13° 25.010'	144° 39.891'	37.7	52	52.2	14.5	11.5	11.5	Coral fragments prevent further recovery
8-H	1	13° 26.020'	144° 39.971'	38.8	52	53.8	15	15	13.2	
8-I	1	13° 26.074'	144° 39.972'	39.7	52	55.7	16	15.8	12.3	
8-J	1	13° 26.095'	144° 39.900'	40.0	52	53.5	13.5	13	12	
8-K	1	13° 26.126'	144° 40.016'	39.5	52	53.5	14	14	12.5	
9-A	1	13° 25.813'	144° 40.069'	36.4	42	38.4	2	2	0	Refusal encountered at 2.0'
	2	13° 25.818'	144° 40.070'	36.2	42	44.2	8	8	5.8	Station location moved slightly due to coral fragments observed in Attempt 1.
9-B	1	13° 25.888'	144° 40.057'	38.0	42	39.0	1	0.5	0	No penetration
	2	13° 25.884'	144° 40.057'	38.0	42	NA	NA	NA	NA	Sample lost during retrieval; winch malfunction
	3	13° 25.888'	144° 40.056'	38.2	42	43.2	5	0	0	Sample lost during retrieval
	4	13° 25.888'	144° 40.056'	38.2	42	44.2	6	3.2	3.2	Coral fragments prevent further recovery
9-C	1	13° 25.888'	144° 40.145'	40.5	42	NA	NA	NA	NA	Planned sample location (and surrounding area) deeper than project depth; no sample collected
9-D	1	13° 25.950'	144° 40.231'	39.6	42	45.6	6	5.5	2.4	
9-E	1	13° 25.992'	144° 40.283'	38.2	42	48.2	10	10	3.8	
9-F	1	13° 25.986'	144° 40.182'	37.9	42	43.9	6	4.5	4.1	
9-G	1	13° 25.970'	144° 40.105'	38.0	42	NA	NA	0	0	Sample lost during retrieval
	2	13° 25.970'	144° 40.105'	38.0	42	45.0	7	6	4	

Station ID	Attempt	Latitude - Degrees Dec. Minutes North (NAD83)	Longitude - Degrees Dec. Minutes East (NAD83)	Water Depth (Feet)	Target Sampling Depth (Feet)	Actual Depth Sampled (Feet)	Penetration (Feet)	Final Core Length (Feet)	Core Length Retained for Analysis (Feet)	Comments
9-H	1	13° 25.071’	144° 40.032’	38.3	42	44.8	6.5	6.5	3.7	
9-I	1	13° 25.030’	144° 40.146’	39.5	42	44.0	4.5	4.5	2.5	
9-J	1	13° 25.290’	144° 40.058’	37.7	42	44.2	6.5	4.5	4.3	
9-K	1	13° 25.161’	144° 40.061’	38.8	42	43.3	4.5	3.8	3.2	
9-L	1	13° 25.331’	144° 40.037’	35.8	42	43.3	7.5	6	6	
9-M	1	13° 25.389’	144° 40.069’	34.2	42	43.2	9	8.5	7.8	

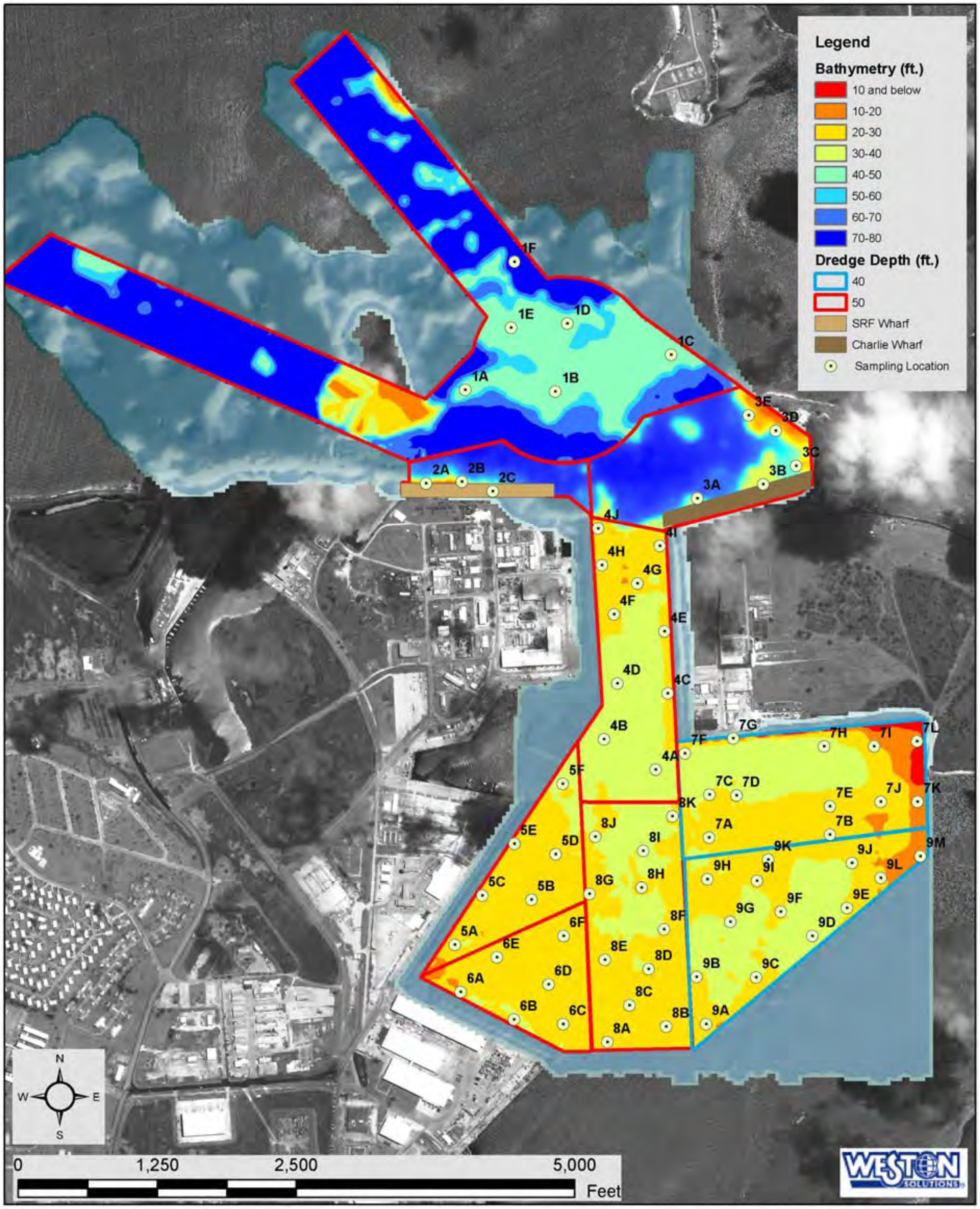


Figure 3-1. Actual Sample Locations for a Dredged Material Characterization for Potential Construction Dredging at Charlie, SRF and Sierra Wharves.

3.2 Analytical Results

3.2.1 Physical and Chemical Characteristics of Dredged Material

Results of physical and chemical analyses for sediments collected within the proposed deep water wharf dredge footprints are discussed below. A summary of these results are presented in Table 3-2. All results are expressed in dry weight unless otherwise indicated. Target detection limits are provided in the SAP (Weston and Belt Collins 2006); actual detection limits and raw data for the analyses are provided in Appendix C.

Results of chemical analyses of project dredged materials were compared to Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values developed by Long et al. (1995), and regulatory levels or total threshold limit concentration (TTLC) values. The effects range values are helpful in assessing the potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analyses. Briefly, these values were developed from a large data set where results of both benthic organism effects (e.g., amphipod toxicity tests) and chemical analysis were available for individual samples. The ER-L was then calculated as the lower 10th percentile of the observed effects concentrations and the ER-M as the 50^{th} percentile of the observed effects concentrations. While these values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. The ER-L and ER-M sediment quality values are included in Table 3-2 for comparative purposes only.

In addition, ER-M values were used to calculate a mean ER-M quotient (ER-Mq). The concentration of each constituent was divided by its ER-M value to produce a quotient, or proportion of the ER-M equivalent to the magnitude by which the ER-M value is exceeded or not exceeded. The mean ER-Mq for each group of constituents and Area was then calculated by summing the ER-Mqs for each constituent and then dividing by the total number of ER-Mqs assessed. The mean ER-Mq represents an assessment for Area of the cumulative sediment chemistry relative to the threshold values.

In the following presentation of analytical results, only arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver and zinc are discussed. These metals are typically identified as constituents [metals] of concern or metals that may cause toxicity, if present at relatively high concentrations. Further, these are the only metals for which ER-L and ER-M values have been determined.

For certain pesticide compounds (i.e., dieldrin) the ER-L (0.02 μg/kg) and ER-M levels (8 μg/kg) are so low as to make it largely impractical to detect them in typical harbor sediments using standard EPA-approved analytical procedures.

Table 3-2. Summary of Physical/Chemical Analysis of Kilo Wharf Project Dredge Materials Including a Comparison to Published ER-L and ER-M Sediment Quality Values.

Analyte	ER-L	ER-M	TTLC	Area 1 Composite	Area 2 Composite	Area 3 Composite	Area 4 Composite	Area 5 Composite	Area 6 Composite	Area 7 Composite	Area 8 Composite	Area 9 Composite
Physical Analyses												
Gravel (%)	-	-	-	12.41	32.37	8.50	26.47	15.95	14.57	6.27	5.33	0.68
Sand (%)	-	-	-	60.85	52.75	27.58	53.57	16.32	16.45	28.55	10.55	10.95
Silt (%)	-	-	-	18.01	7.54	28.66	9.80	29.60	24.95	23.07	31.25	30.17
Clay (%)	-	-	-	8.73	7.34	35.25	10.17	38.13	44.03	42.12	52.88	58.66
Solids, Total (%)	-	-	-	73.80	73.60	61.30	73.50	31.50	28.30	28.70	26.80	26.30
Solids, Volatile (%)	-	-	-	2.90	2.80	7.60	3.10	8.70	9.80	8.90	9.50	10.90
Soil Classification	-	-	-	SW	SW	CH	SW	CH	CH	CH	CH	CH
General Chemistry												
TOC (%)	-	-	-	0.13	0.17	0.5	0.16	0.64	0.66	0.55	0.72	0.75
Specific Gravity	-	-	-	1.92	1.95	1.65	1.91	1.51	1.49	1.43	1.4	1.44
Ammonia (mg/kg Wet Weight)	-	-	-	7.05	0.74	0.38	2.27	2.67	13.60	6.42	1.28	0.96
Sulfide, Dissolved (mg/ kg)	-	-	-	0.11	0.01J	<0.01	0.10	0.01J	0.10	0.13	0.01J	0.01J
Sulfide, Total (mg/kg)	-	-	-	0.23	0.15	0.51	0.22	0.28	0.60	0.89	0.60	0.81
Oil and Grease (% Dry Weight)	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<2
TRPH (% Dry Weight)	-	-	-	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Metals (mg/kg)												
Arsenic (As)	8.2	70	500	3.76	3.76	7.55	4.14	6.80	7.52	7.75	**8.76**	**10.10**
Barium (Ba)	-	-	1000	7.62	9.00	8.32	11.40	8.02	8.14	8.84	7.60	7.81
Beryllium (Be)	-	-	-	<0.025	<0.025	0.08	<0.025	0.10	0.14	0.12	0.15	0.18
Cadmium (Cd)	1.2	9.6	1200	0.27	0.15	0.10	0.08	0.06	0.04J	0.04J	0.03J	0.06
Chromium (Cr)	81.0	370.0	-	11.50	13.30	53.90	15.30	57.30	77.00	65.20	77.10	**98.30**
Cobalt (Co)	-	-	8000	1.13	1.05	5.40	1.13	7.85	11.70	8.67	11.40	13.70
Copper (Cu)	34.0	270.0	2500	4.85	23.60	17.90	12.40	19.60	29.20	**37.10**	33.00	**48.10**
Iron (Fe)	-	-	-	3300.00	3950.00	18400.00	3950.00	21700.00	29100.00	25500.00	30300.00	38600.00
Lead (Pb)	46.7	218.0	1000	4.08	18.60	8.71	9.35	2.57	3.42	11.00	6.20	12.60
Manganese (Mn)	-	-	-	76.80	134.00	220.00	104.00	431.00	583.00	412.00	577.00	556.00
Mercury (Hg)	0.15	0.71	20	0.04	0.12	0.05	0.10	0.02	0.03	0.08	0.05	0.10
Molybdenum (Mo)	-	-	3500	0.36	0.39	1.58	0.46	2.37	2.20	1.74	2.55	1.95
Nickel (Ni)	20.9	51.6	2000	4.91	5.41	**21.50**	5.42	**27.70**	**39.10**	**31.10**	**38.30**	**47.80**
Selenium (Se)	-	-	100	2.99	2.56	1.56	2.47	1.44	0.82	1.05	0.62	0.22
Silver (Ag)	1.0	3.7	500	<0.025	<0.025	<0.025	<0.025	0.03J	0.04J	0.06	0.05	0.06
Strontium (Sr)	-	-	-	6060.00	5390.00	4140.00	5680.00	4090.00	3180.00	3560.00	3070.00	2300.00
Thallium (Tl)	-	-	700	<0.025	<0.025	0.030J	<0.025	0.04J	0.05	0.05	0.05	0.06
Tin (Sn)	-	-	-	0.36	1.70	0.74	0.59	0.52	0.55	1.16	0.81	1.26
Titanium (Ti)	-	-	-	98.50	108.00	622.00	118.00	697.00	872.00	798.00	932.00	1140.00
Vanadium (V)	-	-	-	8.72	9.79	47.80	9.95	51.10	69.80	62.40	71.90	94.10
Zinc (Zn)	150.0	410.0	5000	6.96	24.80	26.80	16.20	20.20	26.80	39.20	32.30	50.80

Analyte	ER-L	ER-M	TTLC	Area 1 Composite	Area 2 Composite	Area 3 Composite	Area 4 Composite	Area 5 Composite	Area 6 Composite	Area 7 Composite	Area 8 Composite	Area 9 Composite
PCBs (μg/kg)												
PCB018	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB028	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB031	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB033	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB037	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB044	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB049	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB052	-	-	-	<1	1J	<1	<1	<1	<1	<1	<1	<1
PCB066	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB070	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB074	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB077	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB081	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB087	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB095	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB097	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB099	-	-	-	<1	1.20J	<1	<1	<1	<1	<1	<1	<1
PCB101	-	-	-	<1	1.5J	<1	<1	<1	<1	<1	<1	<1
PCB105	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB110	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB114	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB118	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB119	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB123	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB126	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB128+167	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB138	-	-	-	<1	4.40J	<1	2.40J	2.5J	3.60J	<1	<1	<1
PCB141	-	-	-	<1	1.10J	<1	<1	<1	<1	<1	<1	<1
PCB149	-	-	-	<1	3.20J	<1	1.5J	2J	2.30J	<1	<1	<1
PCB151	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB153	-	-	-	<1	5.2	<1	2.70J	2.60J	3J	1.90J	<1	1J
PCB156	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB157	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB158	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB168+132	-	-	-	<1	<1	<1	<1	<1	1.10J	<1	<1	<1
PCB169	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB170	-	-	-	<1	3.10J	<1	1.5J	1.30J	1.70J	<1	<1	<1
PCB177	-	-	-	<1	1J	<1	<1	<1	<1	<1	<1	<1
PCB180	-	-	-	<1	4.90J	<1	3.20J	2.90J	3.20J	1.5J	<1	<1
PCB183	-	-	-	<1	1.10J	<1	<1	<1	<1	<1	<1	<1
PCB187	-	-	-	<1	2.30J	<1	1.30J	<1	1.70J	1J	<1	<1
PCB189	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB194	-	-	-	<1	2.80J	<1	<1	<1	<1	<1	<1	<1

Analyte	ER-L	ER-M	TTLC	Area 1 Composite	Area 2 Composite	Area 3 Composite	Area 4 Composite	Area 5 Composite	Area 6 Composite	Area 7 Composite	Area 8 Composite	Area 9 Composite
PCB200	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB201	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB206	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PCB	22.7	180	50000	0.00	32.80	0.00	12.60	11.30	16.60	4.40	0.00	1.00
Aroclors (µg/kg)												
Aroclor-1016	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor-1221	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor-1232	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor-1242	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor-1248	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor-1254	-	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor-1260	-	-	-	<10	22.2	<10	<10	<10	<10	<10	<10	<10
Pesticides (µg/kg)												
2,4'-DDD	-	-	1000	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4'-DDE	-	-	1000	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4'-DDT	-	-	1000	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4'-DDD	2.00	20.00	1000	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4'-DDE	2.20	27.00	1000	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4'-DDT	1.00	7.00	1000	<1	<1	<1	<1	<1	<1	<1	<1	<1
Aldrin	-	-	1400	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-alpha	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-beta	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-delta	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-gamma	-	-	4000	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane-alpha	-	-	2500	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane-gamma	-	-	2500	<1	<1	<1	<1	<1	<1	<1	<1	<1
cis-Nonachlor	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dieldrin	0.02	8.00	8000	**<1**	**<1**	**<1**	**<1**	**<1**	**<1**	**<1**	**<1**	**<1**
Endosulfan Sulfate	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan I	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan II	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	-	-	200	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin Aldehyde	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin Ketone	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor	-	-	4700	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	-	-	100000	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mirex	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Oxychlordane	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Chlordane	0.5	6	2500	0	0	0	0	0	0	0	0	0
Total Detectable DDTs	1.60	46.10		0	0	0	0	0	0	0	0	0
Toxaphene	-	-	5000	<10	<10	<10	<10	<10	<10	<10	<10	<10
trans-Nonachlor	-	-	4700	<1	<1	<1	<1	<1	<1	<1	<1	<1

Analyte	ER-L	ER-M	TTLC	Area 1 Composite	Area 2 Composite	Area 3 Composite	Area 4 Composite	Area 5 Composite	Area 6 Composite	Area 7 Composite	Area 8 Composite	Area 9 Composite
Organotins (μg/kg)												
Dibutyltin	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tetrabutyltin	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tributyltin	-	-	-	<1	<1	<1	34.01	<1	<1	<1	<1	<1
PAHs (μg/kg)												
1-Methylnaphthalene	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
1-Methylphenanthrene	-	-	-	<1	5.00	<1	1.30J	<1	<1	<1	<1	<1
2,3,5-Trimethylnaphthalene	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,6-Dimethylnaphthalene	-	-	-	<1	1.20J	<1	1J	<1	<1	1.90J	1.70J	1.30J
2-Methylnaphthalene	70	670	-	<1	<1	<1	<1	1J	<1	<1	<1	<1
Acenaphthene	16	500	-	<1	1.10J	<1	<1	<1	<1	<1	<1	<1
Acenaphthylene	44	640	-	<1	3.10J	2.90J	1.80J	<1	1.30J	5.50	1.40J	<1
Anthracene	85	1100	-	3.60J	11.70	4.60J	4.70J	1.90J	2.50J	12.80	2.70J	2.20J
Benz[a]anthracene	261	1600	-	2.30J	98.70	6.90	14.50	<1	4J	8.80	1.90J	2.70J
Benzo[a]pyrene	430	1600	-	3.80J	98.50	17.70	27.70	4.5J	8.60	31.80	5.90	4.90J
Benzo[b]fluoranthene	-	-	-	4.10J	88.60	16.00	25.10	4.80J	9.50	35.40	5.50	5.60
Benzo[e]pyrene	-	-	-	3.20J	74.10	11.50	19.30	<1	6.10	18.70	4.60J	4.60J
Benzo[g,h,i]perylene	-	-	-	3.80J	67.20	12.30	21.80	3.20J	5.70	18.60	5.30	4.10J
Benzo[k]fluoranthene	-	-	-	4.30J	102.00	17.70	28.80	4.70J	11.10	35.60	5.90	4.40J
Biphenyl	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chrysene	384	2800	-	3J	99.80	12.40	17.60	1.90J	6.20	14.00	4.30J	3.40J
Dibenz[a,h]anthracene	63	260	-	<1	17.30	3.90J	6.10	<1	2J	6.30	2.20J	<1
Dibenzothiophene	-	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1
Fluoranthene	600	5100	-	<1	159.00	3.10J	21.10	1.10J	3.70J	11.90	4J	3.40J
Fluorene	19	540	-	<1	1.10J	<1	<1	<1	<1	<1	<1	<1
Indeno[1,2,3-c,d]pyrene	-	-	-	3.80J	69.10	11.90	20.80	3.10J	6.10	20.00	4.40J	3.20J
Naphthalene	160	2100	-	<1	<1	<1	<1	<1	1.20J	1.60J	1.30J	1.30J
Perylene	-	-	-	<1	26.90	4.10J	7.80	<1	<1	8.80	2.30J	<1
Phenanthrene	240	1500	-	<1	36.70	1J	4.60J	1.5J	<1	3J	<1	1.70J
Pyrene	665	2600	-	2.10J	154.00	3.30J	23.90	1.70J	5.70	30.20	4.30J	3.40J
Total HMW PAHs	1700	9600	-	0.00	602.90	30.80	102.50	0.00	18.00	89.90	0.00	0.00
Total LMW PAHs	552	3160	-	0.00	48.40	0.00	0.00	0.00	0.00	18.30	0.00	0.00
Total PAHs	4022	44792	-	34.00	1115.10	129.30	247.90	29.40	73.80	264.90	57.70	46.20
Phenols (μg/kg)												
2,4,6-Trichlorophenol	-	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
2,4-Dichlorophenol	-	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
2,4-Dimethylphenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
2,4-Dinitrophenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
2-Chlorophenol	-	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50
4,6-Dinitro-2-Methylphenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
2-Nitrophenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
4-Chloro-3-Methylphenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
4-Nitrophenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
Pentachlorophenol	-	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50

Analyte	ER-L	ER-M	TTLC	Area 1 Composite	Area 2 Composite	Area 3 Composite	Area 4 Composite	Area 5 Composite	Area 6 Composite	Area 7 Composite	Area 8 Composite	Area 9 Composite
Phenol	-	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100
Phthalates (μg/kg)												
bis(2-Ethylhexyl) Phthalate	-	-	-	35.90B	39.10B	55.5B	80.80B	53.90B	60.90B	136B	54.70B	62.20B
Butylbenzyl Phthalate	-	-	-	6.80J	9.80J	10.80B	9.20J	15.90B	12.20B	16.40B	8J,B	<5
Diethyl Phthalate	-	-	-	99.70B	65.60B	158B	153B	145B	112B	79.40B	13.5B	50.10B
Dimethyl Phthalate	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Di-n-butyl Phthalate	-	-	-	530B	237B	1160B	2000B	643B	896B	3970B	308B	992B
Di-n-octyl Phthalate	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5
Mean ER-M Qs												
Metals	-	-	-	0.03	0.06	0.09	0.05	0.09	0.13	0.12	0.13	0.17
PCBs	-	-	-	0.13	0.18	0.00	0.07	0.06	0.09	0.02	0.00	0.01
Pesticides	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PAHs	-	-	-	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean Overall ER-M Q	-	-	-	0.05	0.07	0.03	0.04	0.05	0.07	0.05	0.04	0.06

All values in dry weight except where noted
BOLD = The measured concentration exeeds the analyte's respective ER-L value.
< = Below the method detection limit indicated
J Analyte was detected at a concentration below the reporting limit and above the laboratory method detection limit. Reported value is estimated.
B Analyte was detected in the associated method blank.

3.2.2 Area 1

The composite sample representing Area 1, the area comprising the access fairways and turning basin in Outer Apra Harbor, was classified as well-sorted sand (SW) demonstrating predominantly coarse-grained material (73.26%) comprised of 60.85% sand and 12.41% gravel. The remaining fine-grained fraction consisted of 18.01% silt and 8.73% clay. Total solids were 73.8%, TOC was measured at 0.13% and specific gravity was 1.92. Ammonia was detected at 7.05 mg/kg (wet weight) and total sulfides at 0.23 mg/kg. Oil and grease and TRPH were not detected. None of the metals analyzed had measured concentrations greater than their respective ER-L values. Silver was not detected in the composite sample and the remaining metals of concern ranged in concentration from 0.04 mg/kg (mercury) to 11.50 mg/kg (chromium). Cadmium in Area 1 had the highest concentration (0.27 mg/kg) as compared to other Area composite samples. The mean ER-Mq for metals was 0.03. None of the PCBs (individual congeners or aroclors), chlorinated pesticides or organotins were detected in the composite sample. Concentrations of individual PAHs were either below detection limits or were estimated at concentrations below the reporting limit. Phenols were also not detected in the sample. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.3 Area 2

The composite sample representing Area 2, the area fronting the SRF in Outer Apra Harbor, was classified as well-sorted sand (SW) and was comprised of 85.12% coarse-grained (32.37% gravel and 52.75% sand) and 14.88% fine-grained (7.54% silt and 7.34% clay) material. Total solids were 73.6%, TOC was low with a concentration of 0.17% and specific gravity was 1.95. Ammonia was detected at low levels with a concentration of 0.74 mg/kg (wet) and total sulfides had a concentration of 0.15 mg/kg. Oil and grease and TRPH were not detected. None of the metals analyzed had measured concentrations greater than their respective ER-L values. Silver was not detected in the composite sample and the remaining metals of concern ranged in concentration from 0.12 mg/kg for mercury to 24.80 mg/kg for zinc. The Area 2 composite sample had the highest concentrations of lead (18.60 mg/kg) and mercury (0.12 mg/kg) compared to the other Area composite samples. The mean ER-Mq for metals was 0.06. Individual PCB congeners were either below detection limits or estimated at concentrations below the reporting limit with the exception of PCB153 which had a concentration of 5.2 µg/kg. Aroclor PCBs, chlorinated pesticides and organotins were below detection limits. All detectable PAHs were below ER-L values. Total PAHs were measured at 1115.1 µg/kg, the highest measured Total PAH value compared to all the other Area composite samples. Phenols were not detected in the sample. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.4 Area 3

The composite sample from Area 3, the area fronting Charlie Wharf, was classified as a clay (CH) with predominantly fine-grained (63.91%) material comprised of 28.66% silt and 35.25% clay. The remaining coarse-grained fraction consisted of 8.50% gravel and 27.58% sand. Total solids were measured at 61.3%, TOC was measured at 0.5% and specific gravity was 1.65. Ammonia was detected at its lowest level compared to the other Area composite samples with a concentration of 0.38 mg/kg (wet). Total sulfides was measured at 0.51 mg/kg. Oil and grease and TRPH were not detected. Of the metals analyzed, only nickel (21.50 mg/kg) was detected at concentrations above the ER-L (20.9 mg/kg). Silver was not detected in the composite sample and the remaining metals of concern ranged in concentration from 0.05 mg/kg for mercury to 53.90 mg/kg for chromium. The mean ER-Mq for metals was 0.09. None of the PCBs (individual congeners or aroclors), chlorinated pesticides, organotins or phenols was detected in the composite sample. All detectable PAHs were below ER-L values. Total PAHs were measured at 129.3 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.5 Area 4

The composite sample from Area 4, the area comprising the entrance channel to Inner Apra Harbor, was classified as a well-sorted sand (SW) and was predominantly (80.04%) coarse-grained (26.47% gravel and 53.57% sand). The remaining fine-grained material consisted of 9.80% silt and 10.17% clay. Total solids were measured at 73.5%, TOC was measured at 0.16% and specific gravity was 1.91. Ammonia concentrations were measured at 2.27 mg/kg (wet) and total sulfide concentrations were measured at 0.22 mg/kg. Oil and grease and TRPH were not detected. None of the metals analyzed had measured concentrations greater than their respective ER-L values. Silver was not detected in the composite sample and the remaining metals of concern ranged in concentration from 0.08 mg/kg (cadmium) to 16.20 mg/kg (zinc). The mean ER-Mq for metals was 0.05. Individual PCB congeners were either below detection limits or estimated at concentrations below the reporting limit. Aroclor PCBs, chlorinated pesticides and phenols were below detection limits. TBT was detected at a concentration of 34.01 µg/kg. All detectable PAHs were below ER-L values. Total PAHs were measured at 247.9 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.6 Area 5

The composite sample from Area 5, the area fronting Sierra Wharf in the western portion of Inner Apra Harbor, was classified as a clay (CH) with predominantly fine-grained (67.73%) material consisting of 29.6% silt and 38.13% clay. The remaining coarse-grained (32.27%) material was comprised of 15.95% gravel and 16.32% sand. Total solids were measured at 31.5%, TOC was measured at 0.64% and specific gravity was 1.51. Ammonia was measured at

2.67 mg/kg (wet) and total sulfide concentrations were measured at 0.28 mg/kg. Oil and grease and TRPH were not detected. Of the metals analyzed, only nickel (27.70 mg/kg) was detected at concentrations above the ER-L (20.9 mg/kg). Silver was estimated at 0.03 mg/kg (below the reporting limit) and the remaining metals of concern ranged from 0.02 mg/kg for mercury to 57.30 mg/kg for chromium. The mean ER-Mq for metals was 0.09. Individual PCB congeners were either below detection limits or estimated at concentrations below the reporting limit. Aroclor PCBs, chlorinated pesticides, organotins and phenols were below detection limits. All detectable PAHs were below ER-L values. Total PAHs were estimated at 29.40 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.7 Area 6

The composite sample from Area 6, the area fronting Tango Wharf in the western portion of Inner Apra Harbor, was classified as clay (CH) and had predominantly (68.98%) fine-grained material (24.95% silt and 44.03% clay). The remaining material (31.04%) was coarse-grained (14.57% gravel and 16.45% sand). Total solids comprised 28.3% of the composite sample, TOC comprised 0.66% of the sample and specific gravity was 1.49. The highest concentration of ammonia was measured in Area 6, with an ammonia concentration of 13.60 mg/kg (wet). The concentration of total sulfides was 0.60 mg/kg. Oil and grease and TRPH were not detected. Of the metals analyzed, only nickel (39.10 mg/kg) was detected at concentrations above the ER-L (20.9 mg/kg). Both cadmium and silver were estimated at 0.04 mg/kg (below the reporting limit) and the remaining metals of concern ranged from 0.03 mg/kg for mercury to 29.20 mg/kg for copper. The mean ER-Mq for metals was 0.13. Individual PCB congeners were either below detection limits or estimated at concentrations below the reporting limit. Aroclor PCBs, chlorinated pesticides, organotins and phenols were below detection limits. All detectable PAHs were below ER-L values. Total PAHs were measured at 73.80 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.8 Area 7

The composite sample from Area 7, the area fronting and directly south of Alpha Wharf in Inner Apra Harbor, was classified as a clay (CH) and was comprised of predominantly (65.19%) fine-grained material (23.07% silt and 42.12% clay) with the remaining 34.82% material being coarse-grained (6.27% gravel and 28.55% sand). Total solids was measured at 28.7%, TOC was measured at 0.55% and specific gravity was 1.43. Ammonia had a concentration of 6.42 mg/kg (wet) and total sulfides had a concentration of 0.89 mg/kg. Oil and grease and TRPH were not detected. Of the metals analyzed, only copper (37.10 mg/kg) and nickel (31.10 mg/kg) were detected at concentrations above their ER-Ls (34.0 and 20.9 mg/kg, respectively). Cadmium was estimated at 0.04 mg/kg (below its reporting limit) and the remaining metals of concern ranged from 0.05 mg/kg for silver to 65.20 mg/kg for chromium. The mean ER-Mq for metals was

0.12. Individual PCB congeners were either below detection limits or estimated at concentrations below the reporting limit. Aroclor PCBs, chlorinated pesticides, organotins and phenols were below detection limits. All detectable PAHs were below ER-L values.. Total PAHs were measured at 264.90 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.9 Area 8

The composite sample from Area 8, an area in the south-central part of the project area and directly south of the entrance channel, was classified as a clay (CH) with predominantly fine-grained (84.13%) material consisting of 31.25% silt and 52.88% clay. The remaining coarse-grained (15.88%) material was comprised of 5.33% gravel and 10.55% sand. Total solids was measured at 26.8%, TOC was measured at 0.72% and specific gravity was 1.40. Ammonia was measured at a low concentration of 1.28 mg/kg (wet) and total sulfides was measured at 0.60 mg/kg. Oil and grease and TRPH were not detected. Of the metals analyzed, only arsenic (8.76 mg/kg) and nickel (38.30 mg/kg) were detected at concentrations above their ER-Ls (8.2 and 20.9 mg/kg, respectively). Cadmium was estimated at 0.03 mg/kg (below its reporting limit) and the remaining metals of concern ranged from 0.06 mg/kg for mercury and silver to 77.10 mg/kg for chromium. The mean ER-Mq for metals was 0.13. None of the PCBs (individual congeners or aroclors), chlorinated pesticides, organotins, or phenols were detected in the composite sample. All detectable PAHs were below ER-L values. Total PAHs were measured at 57.70 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.10 Area 9

The composite sample from Area 9, the area in the southeast portion of the project area, was classified as a clay (CH) and was comprised of 88.83% fine-grained (30.17% silt and 58.66% clay) and only 11.63% coarse-grained (0.68% gravel and 10.95% sand) material. Total solids was measured at 26.3%, TOC was measured at 0.75%, the highest concentration of TOC compared to all other Area composite samples and specific gravity was 1.44 Ammonia was measured at 0.96 mg/kg (wet) and total sulfides was measured at 0.81 mg/kg. Oil and grease and TRPH were not detected. Four metals were detected at concentrations above their respective ER-Ls, including arsenic (10.10 mg/kg), chromium (98.30 mg/kg), copper (48.10 mg/kg) and nickel (47.80 mg/kg). Further, the Area 9 composite sample had the highest measured concentration of these four metals as well as of zinc (50.80 mg/kg). The mean ER-Mq for metals was 0.17. None of the PCBs (individual congeners or aroclors), chlorinated pesticides, organotins, or phenols were detected in the composite sample. All detectable PAHs were below ER-L values. Total PAHs were measured at 46.20 µg/kg. Phthalates were either below detection limits or were detected at low levels with associated detections in the method blank. Other SVOCs, including benzenes, toluenes, ethers, methylamines, hexachlorobutadiene, hexachlorocyclopentadiene, and hexachloroethane, were not detected in dredged material from this project area (Appendix C).

3.2.11 Quality Assurance/Quality Control Results

3.2.11.1 Physical Analysis of Sediments

All physical analyses met QA/QC criteria specified by ASTM or USEPA guidelines for the measurement of grain size, specific gravity, total solids, TOC, and Atterberg limits.

3.2.11.2 Chemical Analysis of Sediments

MRLs for target analytes were greater than or equal to MDLs and above instrument detection limits as described by USEPA SW-846 protocol. MRLs are listed in Appendix C for the sediment analyses.

All chemical analyses met QA/QC criteria with the exception of dissolved sulfides, total sulfides, three phthalate analytes, and two PAHs. Laboratory contamination was controlled through the analysis of procedural blanks on a minimum frequency of 1 per batch and procedural blanks were 10 times below the MDL. Accuracy of the project data was indicated by analysis of matrix spikes, surrogate spikes, certified reference materials, and/or laboratory control materials on a minimum frequency of one per batch. For 95% of the target compounds greater than 10 times the MDL, measured concentrations were within the specified acceptance limits. Precision of the project data was determined by analysis of duplicate matrix spikes, blank spikes, and/or duplicate test sample analysis on a minimum frequency of one per batch. All laboratory control sample analyses met the percent recovery criteria established for the appropriate methods. All duplicate analyses met or were within the relative percent difference (RPD) criteria established for the appropriate methods unless otherwise noted below.

For dissolved sulfides, the spike or surrogate compound recovery was out of control due to matrix interference. The associated method blank spike or surrogate compound was in control and therefore the sample data was reported without further clarification. For total sulfides, the spike recovery and RPD control limits do not apply because the analyte concentrations in the sample exceeded the spike concentration. The procedural blanks demonstrated detectable concentrations of phthalates including bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, and diethyl phthalate, likely due to contamination resulting from analytical processes or equipment, a problem frequently observed with phthalate analyses. As a result, the RPD criteria were not met for di-n-butyl phthalate, and diethyl phthalate. For the PAHs benzo(k)fluoranthene and indeno(1,2,3-c,d)pyrene, the RPD criteria were slightly above recommended levels by 23% and 16%, respectively. In addition, the percent recovery of benzo(k)fluoranthene was slightly above (10%) the recommended levels. Based on QA/QC results, the actual detectable concentrations of the three phthalates (bis (2-ethylhexyl)phthalate, di-n-butyl phthalate, and diethyl phthalate) and two PAHs (benzo(k)fluoranthene and indeno(1,2,3-c,d)pyrene) should be interpreted with caution.

4.0 SUMMARY

Sediment sampling within Outer and Inner Apra Harbor was successfully completed in May 2006. All cores were collected to the target sampling depth with the exception of those areas encountering refusal. Refusal was generally associated with the presence of coral fragments which prevented further recovery.

With the exception of Area 3, adjacent to Charlie Wharf, the sediment in Outer Apra Harbor (Areas 1 and 2) and the entrance to Inner Apra Harbor (Area 4) were coarser-grained, comprised predominantly of a gravelly sand. In Area 3 and all the Inner Apra Harbor Areas, material was predominantly comprised of a finer-grained, silty clay material. With the exception of cadmium, lead and mercury, TOC and most metal concentrations were typically highest within the Areas having a finer-grained substrate (i.e., from 63.91% fine-grained material at Area 3 to 88.83% fine-grained material at Area 9). Cadmium tends to be associated with sandy materials; its highest concentration was measured in the Area 1 composite sample which was predominantly sand (60.85%). Lead and mercury concentrations were highest in Area 2.

In general, sediment contamination was low throughout all the areas sampled. None of the contaminants exceeded ER-M values in the nine composite samples. Three of the composite samples did not have any ER-L exceedances, Area 1, Area 2 and Area 4. Three of the composite samples (Area 3, Area 5 and Area 6) only had one contaminant (nickel) exceed its ER-L value. Two of the remaining three composite samples (Area 7 and Area 8) each had two contaminants exceed their ER-L values; nickel exceeded in both with copper exceeding in Area 7 and arsenic exceeding in Area 8. The Area 9 composite sample typically had the highest metals concentrations; four metals (arsenic, chromium, copper and nickel) exceeded their ER-L values.

It should be noted that the ER-L and ER-M values developed for nickel were based on a limited data set (Long, et al. 1995) and are considered highly conservative (i.e., potential adverse ecological effects due to nickel do not occur as frequently as expected based on the ER-M value). It is common for nickel to be found at concentrations greater than the ER-M in material determined to be suitable for ocean disposal. In multiple dredged material evaluations no toxicity was observed in tests of sediment containing elevated nickel concentrations (i.e., greater than the ER-M). Furthermore, the nickel ER-L and ER-M values are within the range nickel occurs naturally (19 mg/kg to 100 mg/kg) based on crustal abundance estimates summarized in Rudnick and Gao (2003).

Total PAHs were highest in Area 2 and the only Aroclor PCB detection occurred in this area as well. With the exception of Aroclor-1260 in Area 2 and tributyltin detected in Area 4, PCBs (both individual congeners and aroclors), chlorinated pesticides, organotins, phenols and phthalates were either not detected or were estimated at concentrations below their respective reporting limits in all remaining area composite samples. In all Areas, oil and grease and TRPH were below detection limits. Ammonia ranged from 0.38 mg/kg (wet) in Area 3 to 13.60 mg/kg (wet) in Area 6. Area 2 had the lowest concentration of total sulfides (0.15 mg/kg) whereas Area 7 had the highest concentration (0.89 mg/kg).

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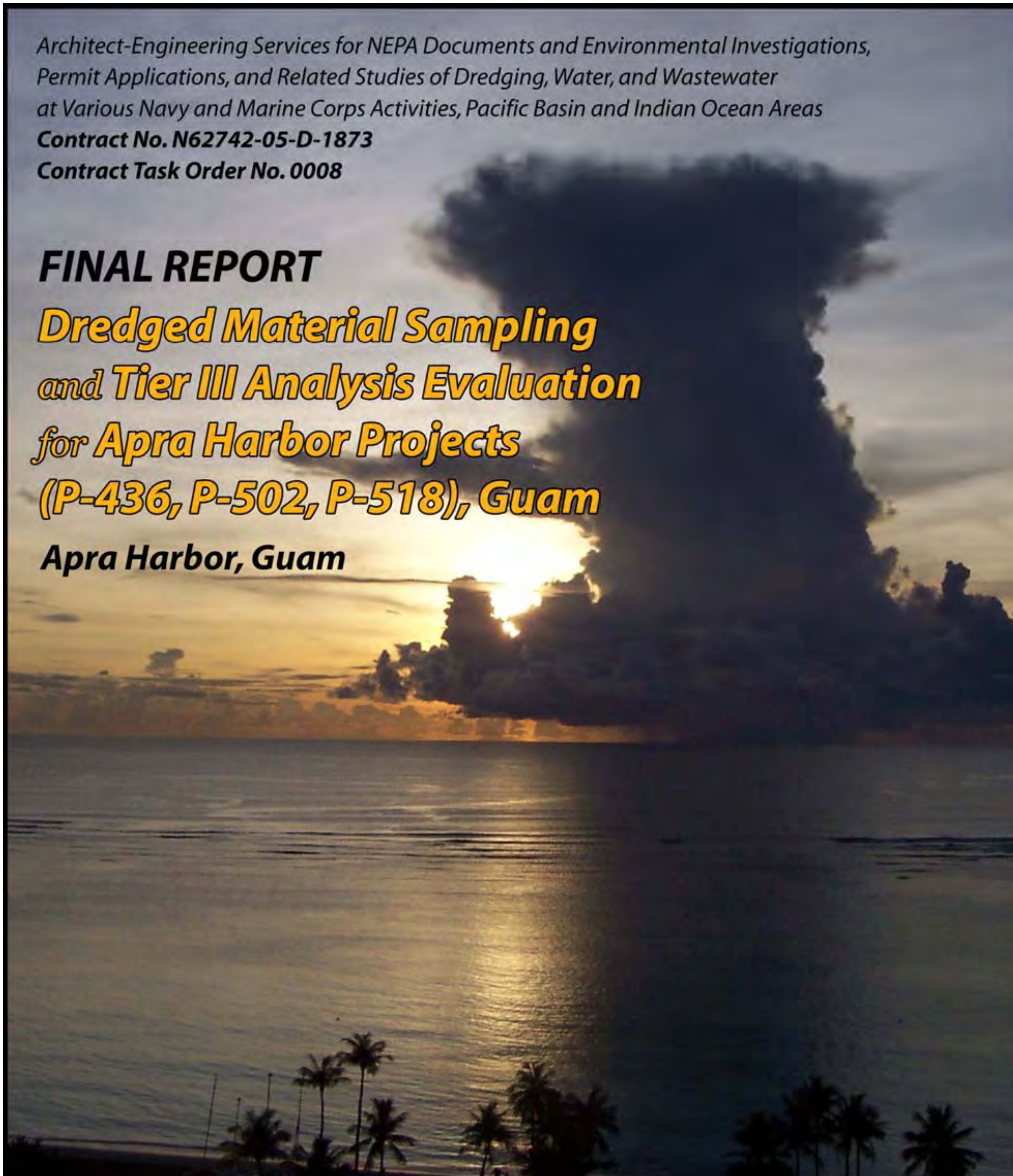
FINAL REPORT

Dredged Material Sampling and Tier III Analysis Evaluation for Apra Harbor Projects (P-436, P-502, P-518), Guam

Apra Harbor, Guam



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EXECUTIVE SUMMARY

Project Description

In order to support new classes of vessels having deeper drafts and larger vessels transiting through Guam, the Navy has scheduled three construction dredging projects within the Apra Harbor Naval Complex. Within Inner Apra Harbor, the P-436 project encompasses the area adjacent to Romeo, Sierra, and Tango Wharves where approximately 222,100 cubic yards (cy) of material will be dredged to the construction depth of -38 feet (ft) mean lower low water (MLLW). Also within Inner Harbor, approximately 131,700 cy of material will be dredged to a depth of -35 ft MLLW in the area fronting X-Ray Wharf for the P-518 project. In Outer Apra Harbor, the P-502 project requires construction dredging of approximately 92,800 cy of material to a depth of -45 ft MLLW from an area fronting the existing Kilo Wharf and its planned wharf extension to the west. These three construction projects will ensure sufficient water depth to meet the Navy's operational requirements for future berthing and ship loading activities in these areas.

Current plans are for all material from these three construction dredging projects to be ocean disposed at the future site of a U.S. Environmental Protection Agency's (USEPA) designated ocean dredged material disposal site offshore from Guam. Prior to dredging and disposal activities, this material must be evaluated for suitability for ocean disposal, in accordance with national testing manuals (USEPA and US Army Corps of Engineers [USACE] 1991 and 1998). Thus, the objective of this study was to evaluate sediment to be dredged in the P-436, P-518 and P-502 construction project areas for its suitability for ocean disposal.

Methods

Sampling and analysis of proposed dredge material under consideration for ocean disposal was conducted in accordance with the Dredged Material Sampling and Analysis Plan (SAP; Weston and Belt Collins Hawaii 2006). Sediment sampling using a vibracore sampling apparatus was conducted in the P-436, P-518 and P-502 proposed dredge footprints on July 14-25, 2006. Sediment sampling was also conducted at the USEPA selected reference site, Asan Beach, on July 22, 2006. Sediment from mulitiple stations within each test area of the three proposed construction dredging projects was collected and composited for sediment characterization tests. Physical, chemical and biological analyses were performed on composited samples from nine composite areas: five composite areas were located in the P-436 dredge footprint (P-436A, P-436B, P-436C, P-436D and P-436E), three areas in the P-518 footprint (P-518A, P-518B and P-518C), and one area at Kilo Wharf in the P-502 dredge footprint (P-502A). An additional six cores, segmented vertically, were collected in P-436B near Oscar Wharf and analyzed for chemicals to further delineate an area of elevated chemical concentrations identified during previous investigations and to provide supporting evidence that portions of Area P-436B be assessed separately for their suitability for ocean disposal.

Results of Physical and Chemical Analyses

Results of Physical Analyses

<u>Area P-436.</u> Sediment ranged from 42.5 to 87.1% fine-grained materials throughout the entire P-436 project area and the soil classification for this sediment was CH.

<u>Area P-518.</u> Sediment ranged from 35.6 to 93.2% fine-grained materials in sediments collected in the P-518 project area and and the soil classification for this sediment was CH.

Area P-502. Sediment from P-502 was predominantly coarse-grained (95.1%) and the soil classification for this sediment was CH.

Results of General Chemistry
Area P-436. Total organic carbon (TOC) was low in all project area test sediments, ranging from 0.52 to 0.87%. Ammonia ranged from 23.4 to 52.2 mg/kg; dissolved sulfides ranged from 0.56 to 58.6 mg/kg; and total sulfides ranged from 1.50 to 57.0 mg/kg. Oil and grease was not detected and total recoverable petroleum hydrocarbons (TRPH) was measured below the method reporting limit (MRL) in only one sample.

Area P-518. TOC was low in all P-518 test sediments, with a maximum value of 0.86%. Ammonia ranged from 16.7 to 27.9 mg/kg. Dissolved and total sulfides were measured at low concentrations in all samples (maximum 1.94 mg/kg and 8.47 mg/kg, respectively). Oil and grease and TRPH were not detetected.

Area P-502. TOC was very low in P-502 test sediment (0.07%). Ammonia was 73.6 mg/kg and dissolved and total sulfides were 5.75 and 0.26 mg/kg, respectively. Oil and grease and TRPH were not detetected.

Results of Chemical Analyses
Results of chemical analyses of proposed dredged material were compared to Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values developed by Long et al. (1995), values that were helpful in screening potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analyses.

Area P-436. Concentrations of target metals were relatively low in composite samples from all areas except P-436B. Cadmium concentrations were below ER-L values in all areas. Chromium concentrations were below ER-L values in all areas except P-436B, in which chromium exceeded the ER-L but not ER-M value. Arsenic and lead exceeded ER-L values in three test areas (P-436A, P-436B, P436E for arsenic and P-436B, P-436C, and P-436E for lead), but were well below ER-M values in all areas. Zinc concentrations were below ER-L values in all areas except P-436B, in which zinc exceeded the ER-M value. Mercury concentrations exceeded the ER-L value in areas P-436A, P-436B, P-436C, and P-436E, but was below the ER-M values in all areas except P-436B. Nickel concentrations exceeded the ER-L value in areas P-436A, P-436B, and P-436E, but was below the ER-M values in all areas except P-436B. Several individual polychlorinated biphenyl (PCB) congeners were detected in all P-436 test samples, with three areas having a total detectable PCB concentration greater than the ER-L value and one area having a total detectable PCB concentration greater than the ER-M value. Dichlorodiphenyltrichloroethane (DDT) derivatives were detected in two test areas, P-436C and P-436E, exceeding their ER-L and ER-M values, respectively. Total detectable polycyclic aromatic hydrocarbons (PAHs) were above the ER-L value in two test areas, but were well below the ER-M value. Tributyltin (TBT) was detected in three of the five P-436 composite samples at extremely low concentrations, and well below concentrations shown to cause toxicity to aquatic organisms. Phenols were not detected in any of the samples.

Area P-518. Concentrations of target metals were relatively low in composite samples from all areas. Zinc and cadmium concentrations were below ER-L values in all areas. Chromium concentrations were below ER-L values in all areas except P-518B, in which chromium was above the ER-L but below the ER-M value. Arsenic and nickel concentrations exceeded the ER-L values in two areas (P-518A and P-518B), but were below ER-M values. Mercury concentrations exceeded the ER-L value in two areas (P-

518B and P-518C) but were below the ER-M value. Copper concentrations were above the ER-L value in all areas, but were below the ER-M value. Several PCB congeners were detected in each of the three composite samples with total detectable PCB concentrations exceeding ER-L values, but were below ER-M values, in two samples. Total detectable PAHs were detected at concentrations below the ER-L value in each sample. TBT was detected above the method detection limit (MDL), but below the MRL, in one sample. Aroclor PCBs, chlorinated pesticides and phenols were not detected in any of the P-518 test areas.

Area P-502. Target metal concentrations were relatively low in Area P-502. Concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc were below their corresponding ER-L values and mercury was not detected. Several individual PAH compounds were also detected, but the total detectable PAH concentration was below its ER-L value. PCBs (both individual congeners and Aroclors), chlorinated pesticides, organotins and phenols were not detected.

Results of Toxicity Tests

Suspended Particulate Phase (SPP) Tests

Area P-436. The SPP tests conducted with *Dendraster excentricus*, *Mysidopsis bahia* and *Menidia beryllina* on all P-436 project sediments resulted in median lethal concentration (LC_{50}) values greater than 100%, indicating a lack of toxicity to echinoderm larvae, mysid shrimp and marine fish, respectively.

Area P-518. The SPP tests conducted with *D. excentricus*, *M. bahia* and *M. beryllina* on all P-518 project sediment resulted in LC_{50} values greater than 100%, indicating a lack of toxicity to echinoderm larvae, mysid shrimp and marine fish, respectively.

Area P-502. The SPP tests conducted with *D. excentricus*, *M. bahia* and *M. beryllina* on P-502 project sediment resulted in LC_{50} values greater than 100%, indicating a lack of toxicity to echinoderm larvae, mysid shrimp and marine fish, respectively.

Solid Phase (SP) Tests

Area P-436. The SP tests conducted with *Ampelisca abdita* and *Neanthes arenaceodentata* on all P-436 project sediments resulted in acceptable survival rates with the exception of *A. abdita* survivorship in Areas P-436B and P-436C. Amphipod survival in the reference sediment was only 53% (likely due to a high percentage of coarse-grained material and low TOC content in the sample); therefore, amphipod survival was compared to control survival (91%). *A. abdita* survivorship was 84% in organisms exposed to Area P-436A sediment, 91% in Area P-436D, and 79% in Area P-436E, resulting in acceptable survival rates. Sediment from Areas P-436A, P-436D and P-436E met the limiting permissible concentration (LPC) requirements.

A. abdita survival in Area P-436C sediment was 70% and was more than 20% lower than survival in the control sediment; however, it should be noted that Area P-436C was only slightly (1%) below the test criteria. There was no survivorship (0% survival) in organisms exposed to Area P-436B sediment. Survivorship of *A. abdita* in tests on Areas P-436B was also more than 20% lower than survival in the control sediment. In organisms exposed to P-436B and P-436C sediment, both these areas showed significantly lower survival compared to organism survival in control sediments. Sediment from Areas P-436B and P-436C does not meet LPC requirements.

N. arenaceodentata survivorship ranged from 96 to 100% in all P-436 area test sediments. Each test area was within 20% of the reference survival (98%). Sediment from all P-436A, P-436B, P-436C, P-436D and P-436E met the LPC requirements.

Area P-518. Survival of the amphipod, *A. abdita*, was 77%, 86% and 84% for P-518A, P-518B and P-518C project sediments, respectively. Similar to the Area P-436 evaluations, amphipod survival was compared to control sediment due to the low survivorship in reference sediment. Survival rates were within 20% of the control survival (91%). Sediment from Areas P-518A, P-518B and P-518C met the LPC requirements.

N. arenaceodentata survivorship ranged from 96 to 100% in all P-518 area test sediments. Each test area was within 20% of the reference survival (98%). Sediment from Areas P-518A, P-518B and P-518C met the LPC requirements.

Area P-502. Survival of *Eohaustorius estuarius* and *N. arenaceodentata* was 96% and 100%, respectively, in Area P-502 project sediments. Each was within 20% of the reference survival (93% for *E. estuaries* and 98% for *N. arenaceodentata*). Sediment from Area P-502A met the LPC requirements.

Bioaccumulation Potential Tests

Area P-436. In *Nereis virens* tissue samples exposed to P-436 project sediments, several metals (copper, lead and nickel), PCB congeners and PAH compounds were significantly elevated when compared to tissue samples exposed to reference sediment. In *Macoma nasuta* tissue samples exposed to P-436 project sediments, one metal and three individual PAH compounds, as well as total detectable PAHs, were significantly elevated when compared to tissue samples exposed to reference sediment. However, a comparison to residue-effects information obtained through the Environmental Residual –Effects Database (ERED) indicated that the mean chemical concentrations in tissues from *N. virens* and *M. nasuta* exposed to P-436A, P-436C, P-436D or P-436E project sediment were below any published relevant effect levels for chemicals identified as elevated in marine polychaetes, bivalves or other marine invertebrates. Moreover, none of the chemicals, except the PCB congeners, in the P-436 project area that exceeded the reference sediment-exposed tissue concentrations have a tendency to biomagnify in marine food webs.

Area P-518. In *N. virens* tissue samples exposed to P-518 project sediments, cadmium, lead, nickel and zinc were the only analytes which were significantly elevated when compared to tissue samples exposed to reference sediment. In *M. nasuta* tissue samples exposed to P-518 project sediments, nickel was the only analyte which was significantly elevated when compared to tissue samples exposed to reference sediment. A comparison to residue-effects information obtained through the ERED indicated that the mean chemical concentrations in tissues from *N. virens* and *M. nasuta* exposed to P-518 project sediment were below any published relevant effect levels for all of the chemicals identified as elevated in marine polychaetes, bivalves or other marine invertebrates. Moreover, none of the chemicals in the P-518 project area that exceeded the reference sediment-exposed tissue concentrations have a tendency to biomagnify in marine food webs.

Area P-502. None of the *N. virens* or *M. nasuta* tissue samples exposed to P-502 project sediment had significantly elevated chemical concentrations relative to tissue samples exposed to reference sediment.

Conclusions

Area P-436

- Proposed dredged material from the P-436A, P-436D and P-436E areas is suitable for ocean disposal.

- Proposed dredged material from Area P-436C does not meet the LPC requirements for ocean disposal; however, this determination was based on the slight toxicity observed in only one amphipod SP test. Based on the high survival of all test organisms in SPP tests, *N. arenceodentata* high survival in SP tests, relatively low contaminant concentrations, tissue concentrations below published relavent effects levels and low total PCB tissue concentrations (<20 µg/kg), the proposed dredged material from the P-436C area should be considered for ocean disposal despite the slightly reduced survivorship observed in the amphipod SP test.

- Proposed dredged material from Area P-436B does not meet the LPC requirements for ocean disposal. This determination was based on multiple ER-M exceedances and significant amphipod toxicity. However, further spatial delineation of the hot spot identified offshore of Oscar Wharf may result in a portion of P-436B being identified as suitable for ocean disposal.

Area P-518

- Proposed dredged material from the entire P-518 area is suitable for ocean disposal.

Area P-502

- Proposed dredged material from the entire P-502 area is suitable for ocean disposal.

2. MATERIALS AND METHODS

2.1 FIELD COLLECTION PROGRAM FOR SEDIMENT CORE SAMPLES

The three proposed construction dredging projects are located in Inner Apra Harbor adjacent to November through Tango Wharves (P-436) and near X-Ray Wharf (P-518) and in Outer Apra Harbor at Kilo Wharf (P-502). For the purposes of sampling and analysis activities, these three project areas were subdivided into nine composite areas (Figure 1-2 and Figure 1-3): five composite areas were located in the P-436 dredge footprint, three areas in the P-518 footprint, and one area at Kilo Wharf in the P-502 dredge footprint. The P-436 area will be dredged to a construction depth of -38 ft MLLW, P-518 to -35 ft MLLW, and P-502 to -45 ft MLLW in the area fronting Kilo Wharf and -56 ft MLLW in the wharf extension area to the west of the existing wharf. The total volume of dredged material, based on the project depth and on the projected bathymetry in each area, is approximately 446,600 cy (Table 2-1). With an additional two-foot overdredge allowance, the total potential dredge material volume to be managed is 765,100 cy (Sea Engineering, Inc. 2005).

Table 2-1. Proposed Volume Dredged Material to be Removed from the Nine Composite Areas within the Three Construction Dredge Projects, P-436, P-518 and P-502.

Area	Volume to be Removed (to project depth) (cy)	Volume to be Removed (to project depth + 2 feet) (cy)
P-436A	8,200	24,200
P-436B	38,700	66,400
P-436C	62,600	110,900
P-436D	57,500	142,800
P-436E	55,100	91,700
Subtotal P-436	**222,100**	**436,000**
P-518A	7,300	42,500
P-518B	64,600	118,600
P-518C	59,800	69,700
Subtotal P-518	**131,700**	**230,800**
P-502A	92,800	98,300
Subtotal P-502	**92,800**	**98,300**
Project Total	**446,600**	**765,100**

This dredged material sampling and Tier III analysis program included collection of continuous sediment cores at three to seven locations within each of nine composite, or test, areas for a total of 41 project core locations (Figure 1-2 and Figure 1-3). Sediment core samples were collected with a vibracore to the project depth plus two feet at each of the 41 sample locations. Surface sediment was collected using a VanVeen grab sampler to supplement core samples collected at one station, 06P502A. Existing depths at the designated sampling locations were confirmed using a lead line or fathometer and compared to bathymetric depth calculations.

Test sediment, reference sediment from Asan Beach, and where appropriate, control sediment (e.g., either sampled from the point of collection for selected test species or historical laboratory control sediment) were analyzed following USEPA and USACE guidelines for ocean disposal (USEPA and USACE 1991). Currently, Guam does not have a designated ocean disposal site and associated reference location. Consequently, Asan Beach was chosen as an interim reference location. Since the beach material is predominantly coarse sand, Asan Beach material is believed to provide a highly conservative point of comparison for establishing suitability of ocean disposal in Guam. Chemical analysis of the test and reference material for each area included metals, organotins, pesticides, PCBs, PAHs and phenols. Conventional chemical analyses included total and water-soluble sulfides, oil and grease, ammonia, total recoverable petroleum hydrocarbon (TRPH), TOC, and percent solids. Physical analyses included Atterberg Limits, specific gravity, and grain size. Biological evaluation of the dredged material proposed for ocean disposal included three suspended particular phase (SPP) bioassays (enchinoderm larvae, fish, and shrimp), two solid phase (SP) bioassays (amphipod and polychaete worm), and two bioaccumulation potential (BP) tests (bivalve and polychaete worm). Tissue chemistry for bioaccumulation tests included metals, organotins, pesticides, PCBs and SVOCs. However, based on the results of the sediment chemistry, a reduced list of analytes for tissue samples was negotiated with the USEPA and USACE (i.e., not all tissue samples were analyzed for all the analytes proposed in the sampling and analysis plan [SAP; Ross 2006]; where sediment chemistry showed the absence of a group of analytes, these analytes were not measured in bioaccumulation test tissue samples).

2.1.1 Equipment

Cores were collected using an electric vibracore (Figure 2-1). Surface sediment was collected using a VanVeen grab sampler to supplement core samples collected at one station. The sampling equipment was deployed from the *M/V Shamrock*, a crew boat modified for environmental sampling. The vibracore was equipped with a 4-inch outer diameter aluminum barrel and stainless steel cutter head. The standard system was capable of collecting cores up to 20 ft long, which was more than sufficient to cover the target sampling depths identified for this project (Table 2-2). The VanVeen grab sampler was capable of collecting surface sediment from a 1 ft^2 area to a depth of 8 inches.

2.1.2 Navigation

All station locations were pre-plotted using the coordinates listed in Table 2-2 and Table 2-3. Locations were determined using a Garmin E-trex Global Positioning System (GPS). The system was accurate to ±15 ft. During the sampling activities, there were no documented GPS failures. All final station locations were recorded in the field using positions from the GPS.

2.1.3 Sampling Locations and Depths

Sediment samples from the nine areas were comprised of composited material from three to seven sample locations within each of the areas (Figure 1-2). Each of the nine composited samples was analyzed for biological and chemical constituents. The planned number of cores, core identification (ID) numbers, locations, and target lengths are provided in Table 2-2. The target lengths of these cores were based on bathymetric surveys conducted in October 2004 and April 2006 for the P-436 area, October 2004 for the P-518 area, and May 2005 for the P-502 area.

Table 2-2: Core Locations, Target Lengths, Number of Cores, Composite ID and Proposed Analyses for Samples

Station ID	Latitude (WGS84)	Longitude (WGS84)	Existing Water Depth (feet MLLW)	Project Depth (feet MLLW)	Target Sampling Depth (Project depth + 2') (feet MLLW)	Target core Length (feet)	No. of Cores per Location for Required Sample Volume[a]	Composite ID	Composite Analyses
P-436 Romeo, Sierra, Tango Wharves Area									
06P436A1	13° 26.296	144° 39.797	36.5	38	40	3.5	6	06P436A	Chemical, Physical, and Biological
06P436A2	13° 26.230	144° 39.780	36.9	38	40	3.1	6		
06P436A3	13° 26.195	144° 39.812	37.7	38	40	2.3	6		
06P436B1	13° 26.243	144° 39.727	35.0	38	40	5.0	2	06P436B	Chemical, Physical, and Biological
06P436B2	13° 26.201	144° 39.653	32.5	38	40	7.5	2		
06P436B3	13° 26.185	144° 39.702	35.9	38	40	4.1	2		
06P436B4	13° 26.222	144° 39.690	30.6	38	40	9.4	2		
06P436B5	13° 26.278	144° 39.748	37.6	38	40	2.4	2		
06P436C1	13° 25.460	144° 40.300	37.3	38	40	2.7	2	06P436C	Chemical, Physical, and Biological
06P436C2	13° 26.081	144° 39.775	37.0	38	40	3.0	2		
06P436C3	13° 26.033	144° 39.746	37.8	38	40	2.2	2		
06P436C4	13° 25.997	144° 39.723	36.0	38	40	4.0	2		
06P436C5	13° 25.904	144° 39.668	32.5	38	40	7.5	2		
06P436C6	13° 25.966	144° 39.694	36.9	38	40	3.1	2		
06P436C7	13° 26.149	144° 39.817	36.6	38	40	3.4	2		
06P436D1	13° 26.056	144° 39.816	37.2	38	40	2.8	3	06P436D	Chemical, Physical, and Biological
06P436D2	13° 25.978	144° 39.793	36.9	38	40	3.1	3		
06P436D3	13° 25.914	144° 39.750	37.6	38	40	2.4	3		
06P436D4	13° 25.881	144° 39.806	36.2	38	40	3.8	3		
06P436D5	13° 25.929	144° 39.817	36.6	38	40	3.4	3		
06P436D6	13° 26.097	144° 39.833	36.6	38	40	3.4	3		
06P436E1	13° 25.862	144° 39.696	35.8	38	40	4.2	3	06P436E	Chemical, Physical, and Biological
06P436E2	13° 25.830	144° 39.723	34.9	38	40	5.1	3		
06P436E3	13° 25.810	144° 39.768	36.5	38	40	3.5	3		
06P436E4	13° 25.808	144° 39.810	35.7	38	40	4.3	3		
P-518 X-Ray Wharf Area									
06P518A3	13° 25.736	144° 40.153	34.4	35	37	2.6	6	06P518A	Chemical, Physical, and Biological
06P518A1	13° 25.687	144° 40.111	34.7	35	37	2.3	6		
06P518A2	13° 25.620	144° 40.060	34.5	35	37	2.5	6		
06P518B1	13° 25.262	144° 40.092	33.6	35	37	3.4	3	06P518B	Chemical, Physical, and Biological
06P518B2	13° 25.348	144° 40.138	33.9	35	37	3.1	3		
06P518B3	13° 25.297	144° 40.133	32.5	35	37	4.5	3		
06P518B4	13° 25.262	144° 40.175	32.8	35	37	4.2	3		
06P518B5	13° 25.233	144° 40.136	33.0	35	37	4.0	3		
06P518C1	13° 25.461	144° 40.298	25.6	35	37	11.4	2	06P518C	Chemical, Physical, and Biological
06P518C2	13° 25.346	144° 40.232	21.2	35	37	15.8	2		
06P518C3	13° 25.509	144° 40.333	30.9	35	37	6.1	2		
06P518C4	13° 25.419	144° 40.273	32.6	35	37	4.4	2		

Station ID	Latitude (WGS84)	Longitude (WGS84)	Existing Water Depth (feet MLLW)	Project Depth (feet MLLW)	Target Sampling Depth (Project depth + 2') (feet MLLW)	Target core Length (feet)	No. of Cores per Location for Required Sample Volume[a]	Composite ID	Composite Analyses
P-502 Kilo Wharf Area									
06P502A1	13° 26.787	144° 37.785	43.8	45	47	3.2	4	06P502A	Chemical, Physical, and Biological
06P502A2	13° 26.774	144° 37.800	43.8	45	47	3.2	4		
06P502A7	13° 26.725	144° 37.878	45.1	45	47	1.9	4		
06P502A3	13° 26.796	144° 37.768	43.5	45	47	3.5	4		

[a] Projected number of cores is based on a four-inch outer diameter core tube (2.45 L/linear foot) and potential loss of material during compositing. Required sample composite volume for proposed Tier III analysis is approximately 90 L.

Six additional cores for high resolution analysis were positioned at and around Station 06P436B1. Five of these sample sites were "planned" prior to field operations commencing. The sixth sample site was opportunistic based on conditions observed in the field during sampling activities. Each of these six samples was analyzed for chemical constituents. The planned number of cores, core ID numbers, locations, and target lengths for high resolution analyses are provided in Table 2-3. The locations of these cores were selected to resolve the horizontal and vertical distribution of elevated contaminant levels in the vicinity of Oscar Wharf. It should be noted that the target core length for the high resolution cores did not include any overdredge depth in order to determine if the area of elevated contaminant levels were associated solely with project sediments.

Table 2-3. Core Locations, Target Lengths, Number of Cores, and Proposed Analyses for Samples Collected for High Resolution Chemistry.

Station ID	Latitude (WGS84)	Longitude (WGS84)	Existing Water Depth (feet MLLW)	Project and Target Sampling Depth (MLLW)	Target core Length (feet)	Composite Analyses
06P436B1/HR1	13° 26.243	144° 39.727	35	38	3.4	Surface and subsurface, PAH, PCB, and Metals
06P436HR3	13° 26.236	144° 39.737	36.6	38	3.1	
06P436HR2	13° 26.231	144° 39.713	32.3	38	4.5	
06P436HR4	13° 26.254	144° 39.744	37.1	38	4.2	
06P436HR5	13° 26.265	144° 39.736	36.8	38	4.0	
06P436RQ1	Unplanned/Opportunistic		32.7	38	5.3	

All sediment cores were collected to the project depth plus 2 ft unless refusal was encountered. Refusal was defined as less than 2 inches of penetration per minute. If refusal was encountered, the vessel was moved and a second core attempted. If refusal was encountered again, additional cores were not attempted unless operational problems were suspected. More than one core per station location was required to ensure that there was sufficient material (≈ 90 liter [L]) for all required testing and archival (Table 2-2).

In addition to the project sediment, reference sediment was collected from the Asan Beach intertidal area (Figure 1-1) on the northwest side of Guam, east of Apra Harbor. Reference sediment was collected with a stainless steel scoop. Control sediment was provided with the bioassay test organisms where appropriate (i.e., SPP tests do not use a control sediment). A sample of site water (approximately 100 L) was also collected from the Apra Harbor area and used in the preparation of the 100% elutriate concentrations for the SPP tests.

2.1.4 Core Collection and Handling

As each core was collected, a qualified scientist examined and classified the sediment. A representative core from each sample location was photographed. The core stratigraphy and other pertinent data and observations were logged (see Appendix A). Stratification was not present; therefore the cores were not split into multiple vertical segments (e.g., top and bottome). However, the high resolution cores were split into top and bottom segments. The high resolution cores were vertically segmented at the mid-point of each core.

Sediment for environmental testing was placed into clean, food-grade-quality plastic bags, labeled (project name, date, sampler ID, analysis, and preservative where applicable), logged into a field chain-of-custody (COC) form, and placed into a cooler. Samples remained on ice and in the dark until shipped via overnight delivery service to Weston's laboratory in Port Gamble, Washington for processing. Sediment samples were then thoroughly homogenized and subsamples were distributed to the appropriate laboratories for analysis (Refer to Sections 2.1.5 and 2.1.6)

2.1.5 Shipping

Prior to shipping, sample containers were placed in sealable plastic bags and securely packed inside the cooler with ice packs or crushed ice. COC forms were filled out (see Section 2.1.7), and the original, signed COC forms were placed in a sealable plastic bag and placed inside the cooler. The cooler lids were securely taped shut.

Samples were delivered to several analytical laboratories for analysis. Table 2-4 lists the laboratories, the particular analyses performed by each, and the point of contact and pertinent shipping information for each laboratory.

Table 2-4: Analytical Laboratories, Points of Contact, and Shipping Information

Laboratory	Analyses Performed	Point of Contact	Shipping Information
Weston Solutions, Inc. Carlsbad, CA	Grain size, specific gravity, SPP, and SP testing	Dr. David Moore and Mr. Chris Osuch (760) 931-8081	Weston Solutions, Inc. 2433 Impala Dr. Carlsbad, CA 92010
Weston Solutions, Inc. Port Gamble, WA	Bioaccumulation testing	Dr. David Moore and Dr. Jack Word (360) 297-6903	Weston Solutions, Inc. 4729 NE View Dr. Port Gamble, WA 98364
CRG Marine Laboratories	Sediment and bioaccumulation tissue chemistry	Mr. Rich Gossett (310) 533-5190	CRG Marine Laboratories 2020 Del Amo Blvd., Suite 200 Torrance, CA 90501
Applied Marine Sciences	TOC and Atterberg analysis	Mr. Ken Davis (281) 554-7272	Applied Marine Sciences 502 N. Hwy 3, Suite B League City, TX 77573

2.1.6 Sample Processing and Storage

The sediment cores were stored at 4 degrees Celsius (°C) until processed. Each core sample was homogenized to a uniform consistency at the laboratory using a stainless steel mixing apparatus. Nine composite samples were generated from the areas by homogenizing sediment from each core location within each given area. The composite sample for each area was then placed into certified clean glass jars with Teflon®-lined lids for chemical and physical analysis. A sub-sample from each core, as well as the composite used in testing, was archived frozen in the event that further delineation of chemical contamination is required. The remainder of the composite sample was analyzed for toxicity.

2.1.7 Documentation and Chain-of-Custody

Samples were considered to be in custody if they were: (1) in the custodian's possession or view, (2) retained in a secured place (under lock) with restricted access, or (3) placed in a secured container. The principal documents used to identify samples and to document possession were COC records, field log books, and field tracking forms. COC procedures were used for all samples throughout the collection, transport, and analytical process, and for all data and data documentation, whether in hard copy or electronic format.

COC procedures were initiated during sample collection. A COC record was provided with each sample or sample group (completed COCs were included with the analytical results and are presented in Appendix B). Each person who had custody of the samples signed the form and ensured that the samples were not left unattended unless properly secured. Minimum documentation of sample handling and custody included the following:

- Sample identification
- Sample collection date and time
- Any special notations on sample characteristics
- Initials of the person collecting the sample
- Date the sample was sent to the laboratory
- Shipping company and waybill information

The completed COC form was placed in a sealable plastic envelope that traveled inside the ice chest containing the listed samples. The COC form was signed by the person transferring custody of the samples. The condition of the samples was recorded by the receiver. COC records were included in the final analytical report prepared by the laboratory, and were considered an integral part of that report.

2.2 PHYSICAL AND CHEMICAL ANALYSES

Physical and chemical parameters to be measured in this testing program were selected to provide data on potential chemicals of concern in the dredged material from the project area sampling locations, in accordance with the OTM (USEPA and USACE 1991) and regional guidance. Current USEPA SW-846 analytical methods were used in chemical analysis (USEPA 2001). The specific sediment analyses and target detection limits are specified in the SAP developed for this project (Weston and Belt Collins Hawaii 2006).

2.2.1 Physical Analyses

To characterize the physical properties of the sediment, tests were performed to predict the behavior of sediment after disposal and to compare to reference and test sediment. Physical analyses of the sediment included grain size, specific gravity, TOC, and total solids. Grain size was analyzed to determine the general size classes that make up the sediment (e.g., gravel, sand, silt, and clay) using the gravimetric procedure described in Plumb (1981). The frequency distribution of the size ranges of the sediment was presented in the final data report. TOC was determined using the Lloyd Kahn method (USEPA Region II

1988). Sediment was treated with acid to remove the inorganic carbon (carbonates and bicarbonates) prior to TOC analysis using the USEPA 9060A protocol. Specific gravity was measured using Standard Method (SM) 2710F. Total solids was measured to convert concentrations of the chemical parameters from a wet-weight to a dry-weight basis. Total solids was determined by SM 2540G (Clesceri et al. 2000). In order to classify sediment, dredged material physical analyses included Atterberg limits evaluated by ASTM D4318 (ASTM 2005a).

2.2.2 Sediment Chemistry

Project and reference sediment were analyzed for the contaminants listed in Table 6 of the SAP (Weston and Belt Collins Hawaii 2006). The target detection limits (sediment – dry weight) are also presented in the SAP. All analytical methods used to obtain physical measurements or contaminant concentrations followed USEPA, Standard Methods (SM) and American Society of Testing and Materials (ASTM) procedures, with the exception of grain size which followed procedures developed by Plumb (1981).

The analysis for priority pollutant metals (except mercury) was conducted using an inductively coupled plasma emissions spectrometer equipped with a mass detector (ICP-MS), in accordance with USEPA 6020m. Mercury analysis was conducted using cold vapor atomic fluorescence spectrophotometry (CVAFS) in accordance with USEPA 245.7m. The analysis for total and dissolved sulfides followed SM 4500-S2-D while the analysis for dissolved ammonia followed SM 4500-NH_3. Oil and grease was measured using USEPA 1664A and TRPH were measured by USEPA 418.1. Total volatile solids were analyzed using USEPA 160.4. Acid extractable compounds and SVOCs including PAHs, phenols, chlorinated pesticides, and PCBs, were analyzed using gas chromatography-mass spectrometry with selected ion monitoring (GC/MS SIM) according to USEPA Method 8270m. This method followed serial extraction with methylene chloride and alumina and gel permeation column cleanup procedures. PCBs were measured as Aroclors and individual congeners, separately. Tributyltin (TBT) and its derivatives were analyzed by GC/MS according to Krone et al. (1989), following a cleanup procedure involving methylene chloride extraction and Grignard derivatization.

2.2.3 Analysis of Sediment Contaminants and Comparison to ER-L and ER-M Values

Results of chemical analyses of project dredged materials were compared to ER-L and ER-M values developed by Long et al. (1995). The effects range values are helpful in assessing the potential significance of elevated sediment-associated contaminants of concern, in conjunction with biological analyses. Briefly, these values were developed from a large data set where results of both benthic organism effects (e.g., toxicity tests, benthic assessments) and chemical concentrations were available for individual samples. To derive these guidelines, the chemical values for paired data demonstrating benthic impairment were sorted in according to ascending chemical concentration. The 10th percentile of this rank order distribution was identified as the ER-L and the 50th percentile as the ER-M. While these values are useful for identifying elevated sediment-associated contaminants, they should not be used to infer causality because of the inherent variability and uncertainty of the approach. The ER-L and ER-M sediment quality values are used in conjunction with bioassay testing and are included for comparative purposes only.

In addition, ER-M values were used to calculate a mean ER-M quotient (ER-Mq). The concentration of each constituent was divided by its ER-M value to produce a quotient, or proportion of the ER-M equivalent to the magnitude by which the ER-M value is exceeded or not exceeded. The mean ER-Mq for each group of constituents in a sample was then calculated by summing the ER-Mqs for each constituent and then dividing by the total number of ER-Mqs assessed. The mean ER-Mq represents an assessment of the cumulative sediment chemistry in a sample relative to the threshold values.

3. RESULTS

3.1 SEDIMENT SAMPLE COLLECTION AND HANDLING

Vibracore sampling was conducted July 14-25, 2006. Sampling was conducted under partly cloudy skies with occasional rain showers. The seas were generally calm and winds were light to moderate out of the East.

Field coordinates, number of cores per station, depth of penetration relative to the mudline (i.e. the sediment surface), depth of recover relative to the mudline and core length retained for each station location are summarized in Table 3-1. Actual lengths of cores differed from the target core length at some stations due to differences in the actual (observed) bathymetry and bathymetry from historical surveys used to calculate the target core lengths. Samples were collected by vibracore, with the exception of supplemental sampling conducted with a VanVeen grab sampler at one station. Samples were visually homogeneous (i.e., no stratification was apparent). Field core logs, core photos, and other associated documentation for the sampling effort are provided in Appendix A.

Figure 3-1 and Figure 3-2 show the final station locations as determined in the field for the P-436 and P-518, and P-502 dredge footprints, respectively.

3.1.1 High Resolution Cores

Table 3-1 also presents the field coordinates, number of cores per station, depth of penetration relative to the mudline, depth of recover relative to the mudline and core length retained for each additional high resolution core sampling location. All five planned core locations were successfully sampled. In addition, a sixth core location (06P436RQ1) was sampled. This station was located in the corner of Romeo and Quebec Wharves where a dry dock is typically located (Figure 3-3). The dry dock structure was removed from this location, so the field team collected an opportunistic sample to supplement the high resolution sampling program.

3.2 RESULTS OF PHYSICAL AND CHEMICAL ANALYSES

3.2.1 Chemical and Physical Characteristics of Sediment Collected from Apra Harbor, Guam

Results of physical and chemical analyses for P-436, P-518 and P-502 project sediment samples are presented in Table 3-2. All results are expressed in dry weight unless otherwise indicated. Target detection limits are provided in the SAP (Weston and Belt Collins 2006). The actual detection limits and raw data for the analyses are provided in Appendix C. The ER-L and ER-M sediment quality values are included in Table 3-2 for comparative purposes, only.

Table 3-1. Field Coordinates, Penetration and Sample Depths for Sediment Cores.

Core ID	Attempt	Latitude (WGS84) Degrees, Dec. Minutes	Longitude (WGS84) Degrees, Dec. Minutes	MLLW (ft) = Water Depth - Tide	Penetration (ft)	Target Sampling Depth (ft MLLW)	Actual Sampling Depth (ft MLLW)	Final Core Length (ft)	Core Length Retained for Processing and Analysis (ft)	Comments
06P436A1	1 of 6	13º 26.296'	144º 39.796'	37.1	5.0	40.0	42.1	4.9	2.9	
06P436A1	2 of 6	13º 26.296'	144º 39.796'	37.1	4.0	40.0	41.1	3.0	2.9	
06P436A1	3 of 6	13º 26.296'	144º 39.796'	37.1	4.5	40.0	41.6	3.9	2.9	
06P436A1	4 of 6	13º 26.296'	144º 39.796'	37.1	4.5	40.0	41.6	4.0	2.9	
06P436A1	5 of 6	13º 26.296'	144º 39.796'	37.1	4.0	40.0	41.1	3.0	2.9	
06P436A1	6 of 6	13º 26.296'	144º 39.796'	37.1	4.5	40.0	41.6	4.0	2.9	
06P436A2	1 of 8	13º 26.230'	144º 39.779'	36.7	4.0	40.0	40.7	2.0	0.0	Low recovery - sample discarded
06P436A2	2 of 8	13º 26.230'	144º 39.780'	37.0	4.5	40.0	41.5	1.5	0.0	Large coral piece prevented further recovery. Some sample washed out. Low recovery - sample discarded
06P436A2	3 of 8	13º 26.231'	144º 39.778'	37.0	5.0	40.0	42.0	2.5	2.5	1.5 ft. lost upon recovery.
06P436A2	4 of 8	13º 26.231'	144º 39.778'	37.0	6.0	40.0	43.0	6.0	3.0	
06P436A2	5 of 8	13º 26.231'	144º 39.778'	37.0	5.0	40.0	42.0	4.5	3.0	
06P436A2	6 of 8	13º 26.231'	144º 39.778'	37.0	5.0	40.0	42.0	5.0	3.0	
06P436A2	7 of 8	13º 26.231'	144º 39.778'	37.0	4.0	40.0	41.0	3.0	3.0	
06P436A2	8 of 8	13º 26.231'	144º 39.778'	37.0	4.0	40.0	41.0	3.0	3.0	
06P436A3	1 of 6	13º 26.195'	144º 39.812'	37.5	3.5	40.0	41.0	2.8	2.5	
06P436A3	2 of 6	13º 26.195'	144º 39.812'	37.5	3.5	40.0	41.0	3.0	2.5	
06P436A3	3 of 6	13º 26.195'	144º 39.812'	37.5	3.5	40.0	41.0	2.4	2.4	
06P436A3	4 of 6	13º 26.195'	144º 39.812'	37.5	3.5	40.0	41.0	3.5	2.5	
06P436A3	5 of 6	13º 26.195'	144º 39.812'	37.5	3.5	40.0	41.0	2.8	2.5	
06P436A3	6 of 6	13º 26.195'	144º 39.812'	37.5	3.5	40.0	41.0	2.5	2.5	
06P436B1	1 of 2	13º 26.243'	144º 39.727'	35.0	6.5	40.0	41.5	6.5	5.0	
06P436B1	2 of 2	13º 26.243'	144º 39.727'	35.0	6.0	40.0	41.0	5.0	5.0	
06P436B2	1 of 3	13º 26.201'	144º 39.653'	33.5	N/A	40.0	N/A	N/A	0.0	Core tube broke. Lost sample.
06P436B2	2 of 3	13º 26.204'	144º 39.656'	32.5	8.5	40.0	41.0	7.0	7.0	
06P436B2	3 of 3	13º 26.204'	144º 39.656'	32.5	9.0	40.0	41.5	7.5	7.5	
06P436B3	1 of 2	13º 26.185'	144º 39.702'	37.3	4.0	40.0	41.3	3.0	2.7	
06P436B3	2 of 2	13º 26.185'	144º 39.702'	37.3	5.0	40.0	42.3	4.5	2.7	
06P436B4	1 of 5	13º 26.222'	144º 39.690'	33.9	0.0	40.0	33.9	N/A	0.0	Vibracore did not start.
06P436B4	2 of 5	13º 26.222'	144º 39.690'	33.9	6.5	40.0	40.4	6.0	6.0	
06P436B4	3 of 5	13º 26.222'	144º 39.690'	33.9	0.0	40.0	33.9	N/A	0.0	Vibracore did not start.
06P436B4	4 of 5	13º 26.222'	144º 39.690'	33.9	1.0	40.0	34.9	1.0	0.0	Used boxcore. Low recovery - sample discarded.
06P436B4	5 of 5	13º 26.222'	144º 39.690'	33.9	6.5	40.0	40.4	6.0	6.0	
06P436B5	1 of 2	13º 26.276'	144º 39.749'	36.8	3.5	40.0	40.3	3.2	3.2	
06P436B5	2 of 2	13º 26.276'	144º 39.749'	36.8	3.5	40.0	40.3	3.0	3.2	
06P436C1	1 of 2	13º 26.151'	144º 39.787'	36.8	4.0	40.0	40.8	2.8	2.8	Large coral piece in catcher prevented further recovery.
06P436C1	2 of 2	13º 26.151'	144º 39.787'	36.8	4.5	40.0	41.3	3.0	3.0	Large coral piece in catcher prevented further recovery.
06P436C2	1 of 4	13º 26.080'	144º 39.772'	37.2	4.5	40.0	41.7	2.0	0.0	Coral pieces in catcher prevented further recovery. Sample discarded.
06P436C2	2 of 4	13º 26.080'	144º 39.772'	37.2	4.5	40.0	41.7	0.0	0.0	Coral piece in catcher prevented recovery.
06P436C2	3 of 4	13º 26.104'	144º 39.769'	36.6	5.5	40.0	42.1	5.0	3.4	
06P436C2	4 of 4	13º 26.104'	144º 39.769'	36.6	5.0	40.0	41.6	3.0	3.0	Coral piece in catcher prevented further recovery.
06P436C3	1 of 2	13º 26.032'	144º 39.743'	37.5	4.5	40.0	42.0	4.0	2.5	
06P436C3	2 of 2	13º 26.032'	144º 39.743'	37.5	5.0	40.0	42.5	5.0	2.5	
06P436C4	1 of 4	13º 25.997'	144º 39.721'	35.8	5.0	40.0	40.8	2.0	0.0	Coral in catcher prevented further recovery. Sample discarded.
06P436C4	2 of 4	13º 25.995'	144º 39.715'	35.7	5.0	40.0	40.7	2.0	0.0	Coral in catcher prevented further recovery. Sample discarded.
06P436C4	3 of 4	13º 26.000'	144º 39.720'	35.9	6.0	40.0	41.9	4.5	4.1	
06P436C4	4 of 4	13º 26.000'	144º 39.720'	35.9	6.0	40.0	41.9	5.0	4.1	
06P436C5	1 of 2	13º 25.904'	144º 39.668'	32.2	9.0	40.0	41.2	7.5	7.5	
06P436C5	2 of 2	13º 25.904'	144º 39.668'	32.2	8.5	40.0	40.7	7.5	7.5	
06P436C6	1 of 5	13º 25.966'	144º 39.694'	36.9	5.0	40.0	41.9	0.0	0.0	Coral piece in catcher prevented recovery.
06P436C6	2 of 5	13º 25.962'	144º 39.695'	36.9	5.0	40.0	41.9	0.0	0.0	Coral piece in catcher prevented recovery.
06P436C6	3 of 5	13º 25.967'	144º 39.695'	37.0	5.0	40.0	42.0	3.0	3.0	
06P436C6	4 of 5	13º 25.967'	144º 39.695'	37.0	5.0	40.0	42.0	2.0	0.0	Coral in catcher prevented further recovery. Sample discarded.
06P436C6	5 of 5	13º 25.967'	144º 39.695'	37.0	5.0	40.0	42.0	3.0	3.0	
06P436C7	1 of 3	13º 26.149'	144º 39.817'	36.6	4.5	40.0	41.1	3.2	3.2	Coral piece in catcher prevented further recovery.
06P436C7	2 of 3	13º 26.149'	144º 39.817'	36.6	4.5	40.0	41.1	0.0	0.0	Coral piece in catcher prevented recovery.
06P436C7	3 of 3	13º 26.149'	144º 39.817'	36.6	5.0	40.0	41.6	4.0	3.4	

Core ID	Attempt	Latitude (WGS84) Degrees, Dec. Minutes	Longitude (WGS84) Degrees, Dec. Minutes	MLLW (ft) = Water Depth - Tide	Penetration (ft)	Target Sampling Depth (ft MLLW)	Actual Sampling Depth (ft MLLW)	Final Core Length (ft)	Core Length Retained for Processing and Analysis (ft)	Comments
06P436D1	1 of 3	13º 26.056'	144º 39.816'	37.5	3.5	40.0	41.0	3.5	2.5	
06P436D1	2 of 3	13º 26.056'	144º 39.816'	37.5	5.0	40.0	42.5	4.5	2.5	
06P436D1	3 of 3	13º 26.056'	144º 39.816'	37.5	4.5	40.0	42.0	4.0	2.5	
06P436D2	1 of 3	13º 25.987'	144º 39.794'	37.5	4.0	40.0	41.5	3.1	2.5	
06P436D2	2 of 3	13º 25.987'	144º 39.794'	37.5	6.0	40.0	43.5	3.1	2.5	
06P436D2	3 of 3	13º 25.987'	144º 39.794'	37.5	3.5	40.0	41.0	2.5	2.5	
06P436D3	N/A	13º 25.914'	144º 39.750'	37.9	N/A	40.0	N/A	N/A	N/A	No Attempt. Moved to shallower location.
06P436D3	1 of 3	13º 25.920'	144º 39.743'	36.9	5.5	40.0	42.4	5.5	3.1	
06P436D3	2 of 3	13º 25.920'	144º 39.743'	36.9	5.0	40.0	41.9	4.2	3.1	
06P436D3	3 of 3	13º 25.920'	144º 39.743'	36.9	5.0	40.0	41.9	5.0	3.1	
06P436D4	1 of 3	13º 25.880'	144º 39.806'	36.5	5.0	40.0	41.5	4.5	3.5	
06P436D4	2 of 3	13º 25.880'	144º 39.806'	36.5	4.0	40.0	40.5	3.2	3.2	
06P436D4	3 of 3	13º 25.880'	144º 39.806'	36.5	5.0	40.0	41.5	4.3	3.5	
06P436D5	1 of 4	13º 25.929'	144º 39.817'	36.9	4.5	40.0	41.4	2.0	0.0	Some sample lost upon recovery. Sample discarded.
06P436D5	2 of 4	13º 25.929'	144º 39.817'	36.9	4.5	40.0	41.4	2.7	2.7	
06P436D5	3 of 4	13º 25.929'	144º 39.817'	36.9	5.0	40.0	41.9	3.6	3.1	
06P436D5	4 of 4	13º 25.929'	144º 39.817'	36.9	4.5	40.0	41.4	2.9	2.9	
06P436D6	1 of 6	13º 26.097'	144º 39.833'	37.3	4.5	40.0	41.8	0.0	0.0	Large rocks in catcher prevented further recovery. Sample washed out.
06P436D6	2 of 6	13º 26.097'	144º 39.833'	37.3	4.5	40.0	41.8	2.7	2.7	
06P436D6	3 of 6	13º 26.097'	144º 39.833'	37.3	5.0	40.0	42.3	0.0	0.0	Sample washed out.
06P436D6	4 of 6	13º 26.097'	144º 39.833'	37.3	5.0	40.0	42.3	0.0	0.0	Large rocks in catcher prevented further recovery. Sample washed out.
06P436D6	5 of 6	13º 26.097'	144º 39.833'	37.3	5.0	40.0	42.3	3.0	2.7	
06P436D6	6 of 6	13º 26.097'	144º 39.833'	37.3	5.0	40.0	42.3	2.5	2.5	
06P436E1	1 of 3	13º 25.863'	144º 39.694'	35.4	5.5	40.0	40.9	4.5	4.5	
06P436E1	2 of 3	13º 25.863'	144º 39.694'	35.4	6.0	40.0	41.4	4.9	4.6	
06P436E1	3 of 3	13º 25.863'	144º 39.694'	35.4	7.5	40.0	42.9	4.5	4.5	
06P436E2	N/A	13º 25.830'	144º 39.723'	38.9	N/A	40.0	N/A	N/A	N/A	No Attempt. Already at project depth.
06P436E2	N/A	13º 25.827'	144º 39.722'	38.7	N/A	40.0	N/A	N/A	N/A	No Attempt. Already at project depth.
06P436E2	1 of 3	13º 25.835'	144º 39.697'	36.2	4.5	40.0	40.7	3.7	3.7	
06P436E2	2 of 3	13º 25.835'	144º 39.697'	36.2	5.0	40.0	41.2	5.0	3.8	
06P436E2	3 of 3	13º 25.835'	144º 39.697'	36.2	5.0	40.0	41.2	5.0	3.8	
06P436E3	1 of 4	13º 25.809'	144º 39.767'	36.6	5.5	40.0	42.1	5.5	3.4	
06P436E3	2 of 4	13º 25.809'	144º 39.767'	36.6	4.0	40.0	40.6	3.4	3.4	
06P436E3	3 of 4	13º 25.809'	144º 39.767'	36.6	2.0	40.0	38.6	2.0	0.0	Vibracore hit debris and fell over. Low recovery - sample discarded.
06P436E3	4 of 4	13º 25.809'	144º 39.767'	36.6	6.5	40.0	43.1	4.4	3.4	
06P436E4	N/A	13º 25.808'	144º 39.810'	38.9	N/A	40.0	N/A	N/A	N/A	No Attempt. Already at project depth.
06P436E4	1 of 3	13º 25.784'	144º 39.800'	37.4	3.5	40.0	40.9	2.9	2.6	
06P436E4	2 of 3	13º 25.784'	144º 39.800'	37.4	3.5	40.0	40.9	3.2	2.6	
06P436E4	3 of 3	13º 25.784'	144º 39.800'	37.4	3.5	40.0	40.9	2.6	2.6	
06P518A1	1 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	2.9	2.2	
06P518A1	2 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	3.0	2.2	
06P518A1	3 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	2.5	2.2	
06P518A1	4 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	0.0	0.0	Sample washed out.
06P518A1	5 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	3.5	2.2	
06P518A1	6 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	3.0	2.2	
06P518A1	7 of 7	13º 25.686'	144º 40.111'	34.8	3.5	37.0	38.3	2.8	2.2	
06P518A2	1 of 6	13º 25.620'	144º 40.060'	34.3	4.0	37.0	38.3	3.0	2.7	
06P518A2	2 of 6	13º 25.620'	144º 40.060'	34.3	3.5	37.0	37.8	2.5	2.5	
06P518A2	3 of 6	13º 25.620'	144º 40.060'	34.3	4.0	37.0	38.3	3.5	2.7	
06P518A2	4 of 6	13º 25.620'	144º 40.060'	34.3	4.0	37.0	38.3	3.7	2.7	
06P518A2	5 of 6	13º 25.620'	144º 40.060'	34.3	4.5	37.0	38.8	4.0	2.7	
06P518A2	6 of 6	13º 25.620'	144º 40.060'	34.3	4.0	37.0	38.3	3.5	2.7	
06P518A3	1 of 7	13º 25.736'	144º 40.153'	34.8	4.0	37.0	38.8	3.5	2.2	
06P518A3	2 of 7	13º 25.736'	144º 40.153'	34.8	4.0	37.0	38.8	0.0	0.0	Sample washed out.
06P518A3	3 of 7	13º 25.736'	144º 40.153'	34.8	4.0	37.0	38.8	2.5	2.2	
06P518A3	4 of 7	13º 25.736'	144º 40.153'	34.8	3.5	37.0	38.3	2.2	2.2	
06P518A3	5 of 7	13º 25.736'	144º 40.153'	34.8	5.0	37.0	39.8	4.7	2.2	
06P518A3	6 of 7	13º 25.736'	144º 40.153'	34.8	4.0	37.0	38.8	3.5	2.2	

Core ID	Attempt	Latitude (WGS84) Degrees, Dec. Minutes	Longitude (WGS84) Degrees, Dec. Minutes	MLLW (ft) = Water Depth - Tide	Penetration (ft)	Target Sampling Depth (ft MLLW)	Actual Sampling Depth (ft MLLW)	Final Core Length (ft)	Core Length Retained for Processing and Analysis (ft)	Comments
06P518A3	7 of 7	13º 25.736'	144º 40.153'	34.8	4.0	37.0	38.8	4.0	2.2	
06P518B1	1 of 4	13º 25.262'	144º 40.092'	33.8	unknown	37.0	N/A	1.0	0.0	Vibracore fell over and some sample washed out. Remaining sample discarded.
06P518B1	2 of 4	13º 25.262'	144º 40.092'	33.8	5.0	37.0	38.8	5.0	3.2	
06P518B1	3 of 4	13º 25.262'	144º 40.092'	33.8	4.5	37.0	38.3	4.5	3.2	
06P518B1	4 of 4	13º 25.262'	144º 40.092'	33.8	5.0	37.0	38.8	5.0	3.2	
06P518B2	1 of 3	13º 25.348'	144º 40.138'	34.7	4.0	37.0	38.7	4.0	2.3	
06P518B2	2 of 3	13º 25.348'	144º 40.138'	34.7	4.0	37.0	38.7	4.0	2.3	
06P518B2	3 of 3	13º 25.348'	144º 40.138'	34.7	5.0	37.0	39.7	5.0	2.3	
06P518B3	1 of 4	13º 25.297'	144º 40.133'	32.9	5.5	37.0	38.4	5.5	4.1	
06P518B3	2 of 4	13º 25.297'	144º 40.133'	32.9	5.0	37.0	37.9	5.0	4.1	
06P518B3	3 of 4	13º 25.297'	144º 40.133'	32.9	5.0	37.0	37.9	0.0	0.0	Sample washed out.
06P518B3	4 of 4	13º 25.297'	144º 40.133'	32.9	5.0	37.0	37.9	5.0	4.1	
06P518B4	1 of 3	13º 25.262'	144º 40.175'	32.6	5.5	37.0	38.1	5.5	4.4	
06P518B4	2 of 3	13º 25.262'	144º 40.175'	32.6	5.0	37.0	37.6	5.0	4.4	
06P518B4	3 of 3	13º 25.262'	144º 40.175'	32.6	5.5	37.0	38.1	5.5	4.4	
06P518B5	1 of 4	13º 25.233'	144º 40.136'	33.0	5.5	37.0	38.5	5.5	4.0	
06P518B5	2 of 4	13º 25.233'	144º 40.136'	33.0	6.0	37.0	39.0	6.0	4.0	
06P518B5	3 of 4	13º 25.233'	144º 40.136'	33.0	6.0	37.0	39.0	2.0	0.0	Some sample washed out. Remaining sample discarded.
06P518B5	4 of 4	13º 25.233'	144º 40.136'	33.0	6.0	37.0	39.0	6.0	4.0	
06P518C1	1 of 5	13º 25.464'	144º 40.305'	33.1	5.0	37.0	38.1	1.0	0.0	Original coordinates already at project depth. Coral piece in catcher prevented recovery of entire sample. Remaining sample discarded.
06P518C1	2 of 5	13º 25.464'	144º 40.305'	33.1	5.0	37.0	38.1	1.0	0.0	Coral piece in catcher prevented recovery of entire sample. Remaining sample discarded.
06P518C1	3 of 5	13º 25.469'	144º 40.312'	32.2	5.5	37.0	37.7	5.0	4.8	
06P518C1	4 of 5	13º 25.469'	144º 40.312'	32.2	5.5	37.0	37.7	5.5	4.8	
06P518C1	5 of 5	13º 25.469'	144º 40.312'	32.2	5.5	37.0	37.7	4.8	4.8	
06P518C2	N/A	13º 25.346'	144º 40.232'	36.1	N/A	37.0	N/A	N/A	N/A	No attempt. Already at project depth.
06P518C2	1 of 4	13º 25.344'	144º 40.247'	31.6	4.5	37.0	36.1	0.0	0.0	Refusal at 4.5 ft. Sample washed out. Moved to slightly new location.
06P518C2	2 of 4	13º 25.334'	144º 40.241'	31.1	5.5	37.0	36.6	5.3	5.3	Refusal at 5.5 ft.
06P518C2	3 of 4	13º 25.334'	144º 40.242'	31.1	6.0	37.0	37.1	6.0	5.9	
06P518C2	4 of 4	13º 25.334'	144º 40.242'	31.1	6.5	37.0	37.6	6.3	5.9	
06P518C3	1 of 4	13º 25.512'	144º 40.331'	31.0	6.0	37.0	37.0	4.5	4.5	Large coral piece in catcher prevented further recovery.
06P518C3	2 of 4	13º 25.512'	144º 40.331'	31.0	6.5	37.0	37.5	6.0	6.0	
06P518C3	3 of 4	13º 25.512'	144º 40.331'	31.0	6.5	37.0	37.5	0.0	0.0	Sample washed out.
06P518C3	4 of 4	13º 25.512'	144º 40.331'	31.0	6.5	37.0	37.5	6.0	6.0	
06P518C4	N/A	13º 25.420'	144º 40.271'	36.7	N/A	37.0	N/A	N/A	N/A	No attempt. Already at project depth.
06P518C4	N/A	13º 25.417'	144º 40.277'	33.7	N/A	37.0	N/A	N/A	N/A	No attempt. Generator not working.
06P518C4	1 of 5	13º 25.417'	144º 40.278'	33.6	4.0	37.0	37.6	3.2	3.2	
06P518C4	2 of 5	13º 25.417'	144º 40.278'	33.6	4.5	37.0	38.1	2.4	0.0	Some sample lost upon recovery. Remaining sample discarded.
06P518C4	3 of 5	13º 25.417'	144º 40.278'	33.6	4.5	37.0	38.1	1.5	0.0	Large coral pieces prevented further recovery. Remaining sample discarded. Moved location slightly.
06P518C4	4 of 5	13º 25.404'	144º 40.274'	32.4	6.5	37.0	38.9	6.5	4.6	
06P518C4	5 of 5	13º 25.404'	144º 40.274'	32.4	6.0	37.0	38.4	5.5	4.6	
06P502A1	1 of 10	13º 26.785'	144º 37.789'	43.3	2.0	47.0	45.3	0.0	0.0	Refusal at 2 ft. Sample washed out.
06P502A1	2 of 10	13º 26.785'	144º 37.787'	44.8	2.5	47.0	47.3	2.2	2.2	
06P502A1	3 of 10	13º 26.785'	144º 37.787'	44.8	2.5	47.0	47.3	1.7	1.7	
06P502A1	4 of 10	13º 26.785'	144º 37.787'	44.8	2.5	47.0	47.3	1.0	1.0	Some wash out of sample. Remaining sample kept.
06P502A1	5 of 10	13º 26.785'	144º 37.787'	44.8	2.5	47.0	47.3	0.0	0.0	Sample washed out.
06P502A1	6 of 10	13º 26.785'	144º 37.787'	44.8	2.5	47.0	47.3	0.0	0.0	Sample washed out.
06P502A1	7 of 10	13º 26.786'	144º 37.787'	44.8	2.5	47.0	47.3	0.0	0.0	Sample washed out.
06P502A1	8 of 10	13º 26.786'	144º 37.787'	44.8	2.5	47.0	47.3	0.0	0.0	Sample washed out. Van Veen will be used to collect top material to 1.5 ft.
06P502A1	9 of 10	13º 26.785'	144º 37.787'	44.8	1.5	47.0	46.3	1.5	1.5	Van Veen used to collect sample.
06P502A1	10 of 10	13º 26.785'	144º 37.787'	44.8	1.5	47.0	46.3	1.5	1.5	Van Veen used to collect sample.
06P502A2	1 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	3.7	3.5	
06P502A2	2 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	3.2	3.2	
06P502A2	3 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out.
06P502A2	4 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out.
06P502A2	5 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out.
06P502A2	6 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out.
06P502A2	7 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out.
06P502A2	8 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out.

Core ID	Attempt	Latitude (WGS84) Degrees, Dec. Minutes	Longitude (WGS84) Degrees, Dec. Minutes	MLLW (ft) = Water Depth - Tide	Penetration (ft)	Target Sampling Depth (ft MLLW)	Actual Sampling Depth (ft MLLW)	Final Core Length (ft)	Core Length Retained for Processing and Analysis (ft)	Comments
06P502A2	9 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	2.8	2.8	
06P502A2	10 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	3.5	3.5	
06P502A2	11 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	0.0	0.0	Sample washed out
06P502A2	12 of 12	13º 26.774'	144º 37.802'	43.5	4.0	47.0	47.5	3.8	3.5	
06P502A3	N/A	13º 26.796'	144º 37.772'	46.6	N/A	47.0	N/A	N/A	N/A	No Attempt. Already at project depth. Location moved slightly.
06P502A3	1 of 6	13º 26.790'	144º 37.769'	44.2	3.0	47.0	47.2	1.0	1.0	Some wash out of sample. Remaining sample kept.
06P502A3	2 of 6	13º 26.790'	144º 37.769'	44.2	3.0	47.0	47.2	3.0	2.8	
06P502A3	3 of 6	13º 26.790'	144º 37.769'	44.2	3.0	47.0	47.2	2.5	2.5	
06P502A3	4 of 6	13º 26.790'	144º 37.769'	44.2	3.0	47.0	47.2	2.8	2.8	
06P502A3	5 of 6	13º 26.790'	144º 37.769'	44.2	3.0	47.0	47.2	0.0	0.0	Sample washed out.
06P502A3	6 of 6	13º 26.790'	144º 37.769'	44.2	3.0	47.0	47.2	2.8	2.8	
06P502A7	N/A	13º 26.725'	144º 37.878'	47.0	N/A	47.0	N/A	N/A	N/A	No Attempt. Already at project depth. Location moved slightly.
06P502A7	1 of 6	13º 26.727'	144º 37.874'	44.0	1.0	47.0	45.0	0.0	0.0	Refusal at 1 ft. Sample washed out.
06P502A7	2 of 6	13º 26.725'	144º 37.884'	44.0	3.5	47.0	47.5	3.0	3.0	
06P502A7	3 of 6	13º 26.725'	144º 37.884'	44.0	3.5	47.0	47.5	2.0	2.0	
06P502A7	4 of 6	13º 26.725'	144º 37.884'	44.0	3.5	47.0	47.5	2.0	2.0	
06P502A7	5 of 6	13º 26.725'	144º 37.884'	44.0	3.5	47.0	47.5	2.2	2.2	
06P502A7	6 of 6	13º 26.725'	144º 37.884'	44.0	3.5	47.0	47.5	2.0	2.0	
06P436B1/HR1	1 of 1	13º 26.243'	144º 39.727'	35.0	4.5	38.0	39.5	4.0	3.0	
06P436HR2	1 of 1	13º 26.231'	144º 39.713'	33.6	5.0	38.0	38.6	5.0	4.4	
06P436HR3	1 of 2	13º 26.227'	144º 39.731'	35.7	4.0	38.0	39.7	0.0	0.0	Large piece of plastic caught in catcher prevented recovery.
06P436HR3	2 of 2	13º 26.227'	144º 39.731'	35.7	4.5	38.0	40.2	4.5	2.3	
06P436HR4	1 of 2	13º 26.254'	144º 39.744'	35.6	2.5	38.0	38.1	1.5	0.0	Some wash out of sample. Remaining sample discarded.
06P436HR4	2 of 2	13º 26.254'	144º 39.744'	35.6	5.0	38.0	40.6	5.0	2.4	
06P436HR5	1 of 1	13º 26.265'	144º 39.735'	35.0	3.5	38.0	38.5	3.0	3.0	
06P436RQ1	1 of 1	13º 26.222'	144º 39.646'	32.7	5.5	38.0	38.2	5.0	5.0	

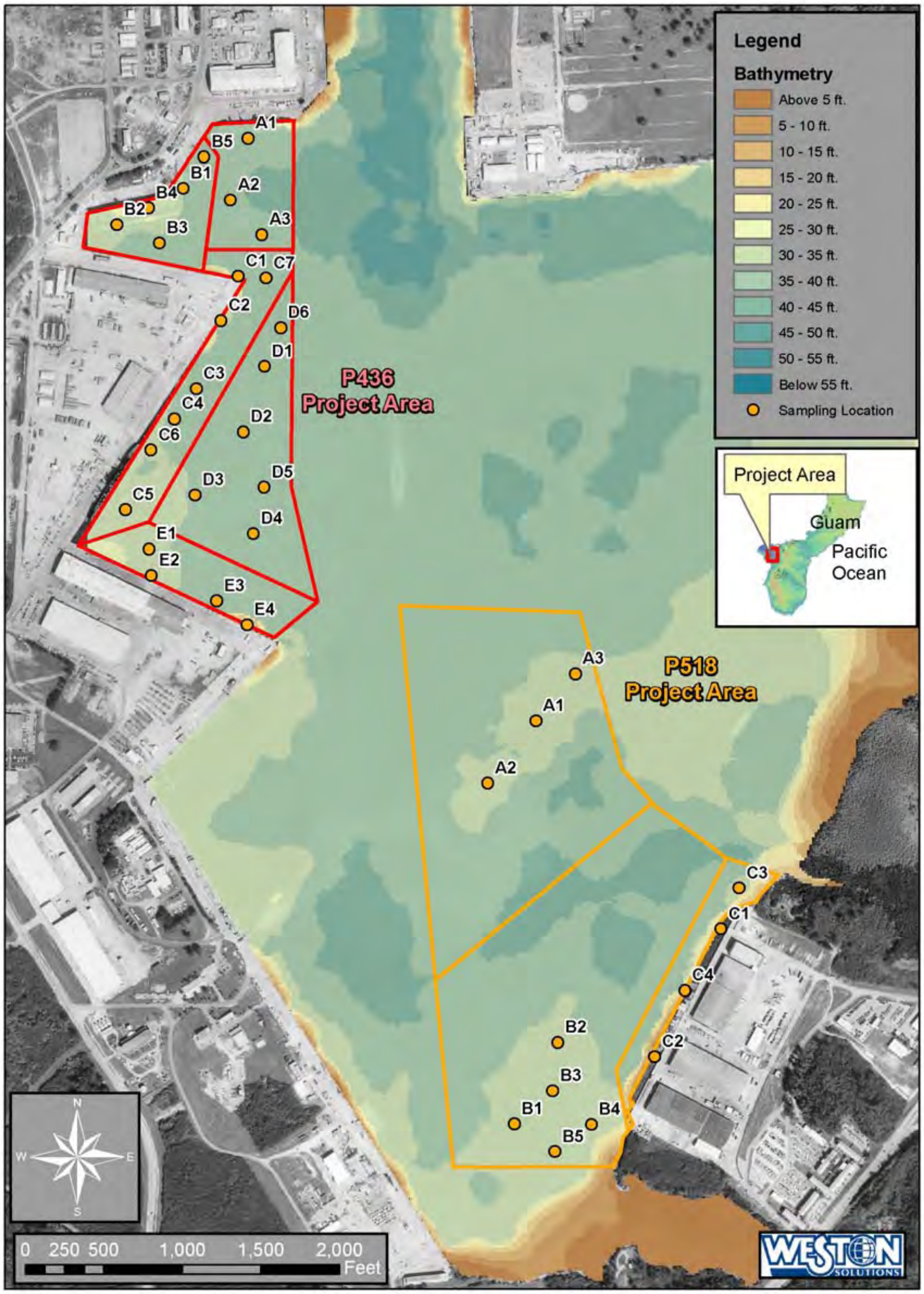

Figure 3-1. Final Sampling Locations for Sediment Cores in the P-436 and P-518 Dredge Footprints in Inner Apra Harbor, Guam.

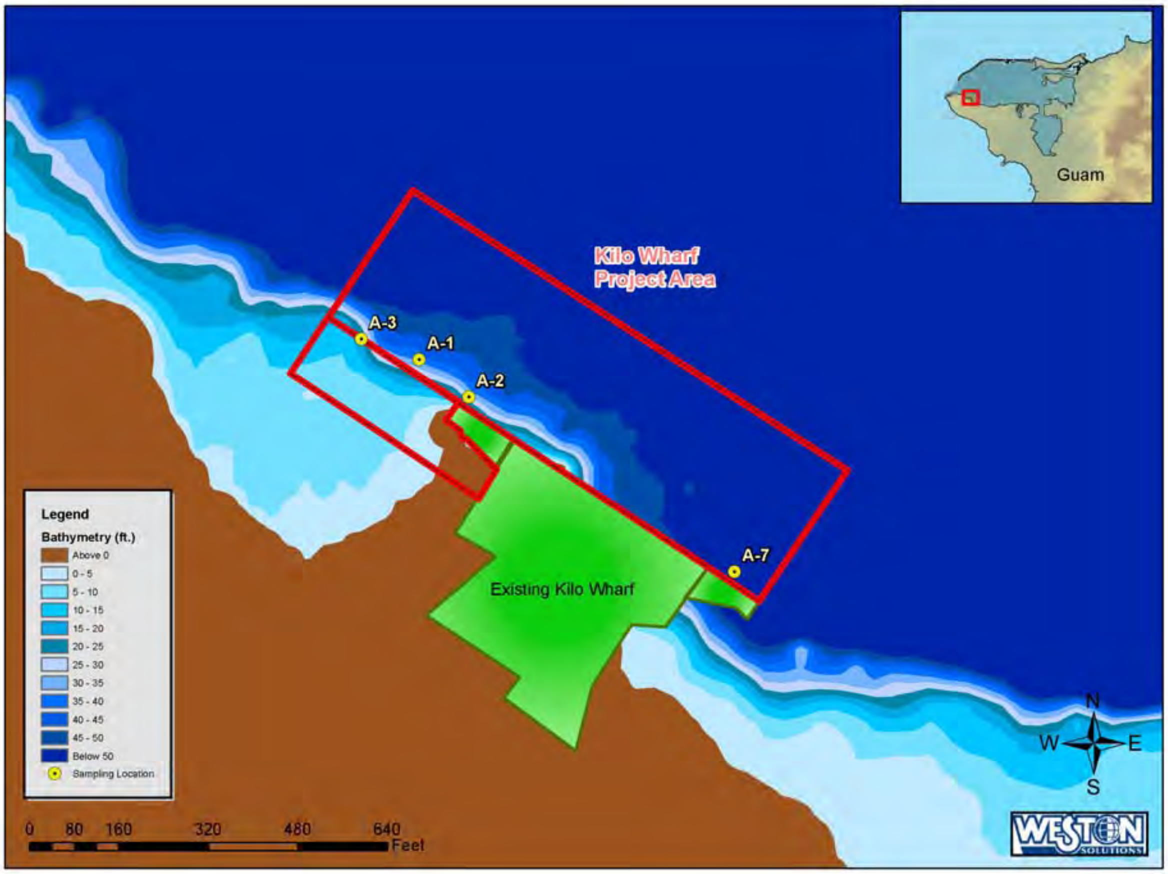

Figure 3-2. Final Sampling Locations for Sediment Cores in the P-502 Dredge Footprint in Outer Apra Harbor, Guam.

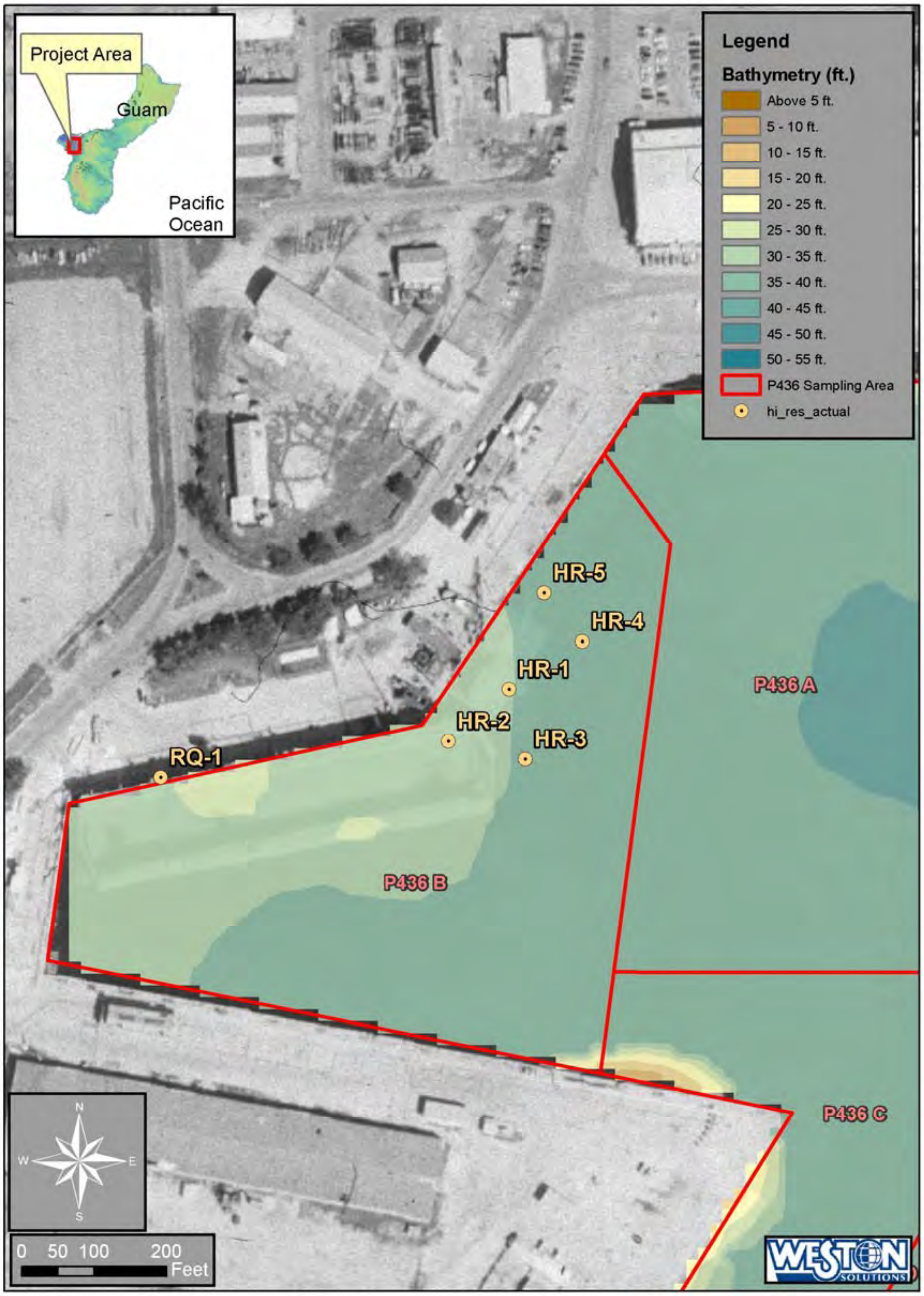

Figure 3-3. Final Sampling Locations for High Resolution Sediment Chemistry Cores to Delineate Area with Elevated Contaminant Concentrations.

Table 3-2. Summary of Chemistry Analytical Results and Physical Measurements of P-436, P-518 and P-502 Project Sediments, Apra Harbor, Guam with a Comparison to Reference Sediment and ER-L and ER-M Sediment Quality Values.

Analyte	ER-L	ER-M	06P436A Composite	06P436B Composite	06P436C Composite	06P436D Composite	06P436E Composite	06P502A Composite	06P518A Composite	06P518B Composite	06P518C Composite	Reference
Physical Analyses												
Atterberg Limits												
Liquid Limit (LL)	-	-	77	61	71	77	67	98	99	101	61	--
Plastic Limit (PL)	-	-	28	25	28	30	26	32	35	30	25	NP
Plasticity Index (PI)	-	-	49	36	43	47	41	66	64	71	36	--
Soil Classification	-	-	CH	CH	CH	CH	CH	CH	CH	CH	CH	--
Gravel (%)	-	-	1.50	4.04	9.15	6.53	10.18	20.97	3.25	0.91	5.37	8.85
Sand (%)	-	-	11.41	53.52	31.45	26.44	37.96	74.11	13.08	5.95	59.05	90.22
Silt (%)	-	-	37.76	19.77	26.28	26.67	21.08	2.56	23.83	26.50	11.83	0.49
Clay (%)	-	-	49.34	22.68	33.13	40.36	30.77	2.36	59.84	66.65	23.76	0.45
Solids, Total (%)	-	-	51.1	64.5	59.1	55.1	62.9	69.1	42.9	44.9	58.8	85.8
Specific Gravity	-	-	1.40	1.60	1.52	1.55	1.57	1.70	1.33	1.30	1.47	1.80
General Chemistry												
TOC (%)	-	-	0.65	0.87	0.64	0.6	0.52	0.07	0.7	0.86	0.44	0.05
Ammonia-N (mg/wet kg)	-	-	23.4	41.8	52.2	25.9	37.8	73.6	16.7	27.9	24.7	373
Dissolved Sulfides (mg/wet kg)	-	-	2.0	58.6	0.96	0.56	5.6	5.75	0.42	1.26	1.94	<0.01
Total Sulfides (mg/wet kg)	-	-	3.82	57.0	9.61	1.50	3.41	0.26	3.11	8.47	4.54	<0.05
Oil & Grease (mg/kg)	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
TRPH (mg/kg)	-	-	<0.1	0.2J	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Solids, Total Volatile (%)	-	-	2.08	2.02	2.10	2.21	2.63	1.32	2.20	2.34	2.31	0.89
Metals (mg/kg)												
Arsenic (As)	8.2	70	8.8	25.0	7.9	7.7	8.5	0.9	10.7	10.8	7.4	1.0
Cadmium (Cd)	1.2	9.6	0.4	0.6	0.3	0.2	0.4	0.1	0.1	0.2	0.3	0.1
Chromium (Cr)	81	370	66.8	359.4	48.1	42.6	92.7	4.5	78.9	88.0	61.4	3.0
Copper (Cu)	34	270	78.7	146.6	59.5	27.9	37.6	2.5	43.6	51.1	38.0	0.9
Lead (Pb)	46.7	218	27.3	129.8	91.0	9.2	91.0	3.4	11.4	21.6	85.1	2.1
Mercury (Hg)	0.15	0.71	0.32	0.81	0.25	0.08	0.25	<0.01	0.12	0.21	0.17	<0.01
Nickel (Ni)	20.9	51.6	28.3	243.9	18.6	19.2	23.7	1.2	37.0	37.1	28.0	1.5
Zinc (Zn)	150	410	72.5	524.7	69.0	25.5	144.4	6.0	46.3	70.1	93.4	3.5
PCBs (ug/kg)												
PCB018	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB028	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB031	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB033	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB037	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB044	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB049	-	-	3.5J	<1	2.5J	1.1J	<1	<1	<1	<1	2.6J	<1
PCB052	-	-	2.9J	12.0	6.7	<1	6.2	<1	<1	<1	1.4J	<1
PCB066	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB070	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB074	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB077	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB081	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB087	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB095	-	-	2.8J	6.4	9.2	<1	6.1	<1	<1	1.8J	2.1J	<1
PCB097	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB099	-	-	<1	<1	3.2J	<1	3.8J	<1	<1	<1	<1	<1
PCB101	-	-	5.0	7.3	12.3	<1	10.2	<1	<1	<1	<1	<1

Analyte	ER-L	ER-M	06P436A Composite	06P436B Composite	06P436C Composite	06P436D Composite	06P436E Composite	06P502A Composite	06P518A Composite	06P518B Composite	06P518C Composite	Reference
PCB105	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB110	-	-	2.6J	3.7J	4.5J	<1	4.1J	<1	<1	<1	<1	<1
PCB114	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB118	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB119	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB123	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB126	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB128+167	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB138	-	-	4.1J	11.6	32.8	2.3J	15.7	<1	2.6J	3.3J	5.2	<1
PCB141	-	-	<1	<1	7.4	<1	4.1J	<1	<1	<1	<1	<1
PCB149	-	-	4.4J	9.1	32.1	1.4J	18.2	<1	1J	4.3J	3.4J	<1
PCB151	-	-	1.2J	<1	10.4	<1	6.3	<1	<1	<1	1J	<1
PCB153	-	-	7.2	18.0	38.3	2.8J	25.8	<1	2J	6.2	5.4	<1
PCB156	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB157	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB158	-	-	1J	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB168+132	-	-	<1	4.6J	<1	<1	<1	<1	<1	<1	<1	<1
PCB169	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB170	-	-	<1	<1	20.0	<1	9.8	<1	<1	3J	1.6J	<1
PCB177	-	-	<1	<1	8.9	<1	4.3J	<1	<1	1.1J	<1	<1
PCB180	-	-	4.7J	15.0	36.7	2.4J	19.6	<1	<1	4.9J	3.9J	<1
PCB183	-	-	<1	3.7J	9.4	<1	5.1	<1	<1	1J	<1	<1
PCB187	-	-	1.8J	7.3	19.8	1.3J	10.1	<1	1.2J	2.90J	2.1J	<1
PCB189	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB194	-	-	<1	12.6	9.6	<1	6.1	<1	<1	<1	<1	<1
PCB200	-	-	<1	<1	1J	<1	<1	<1	<1	<1	<1	<1
PCB201	-	-	<1	<1	9.0	<1	<1	<1	<1	<1	<1	<1
PCB206	-	-	<1	3.2J	2.3J	<1	<1	<1	<1	<1	<1	<1
Total Detectable PCBs	22.7	180	41.2	114.5	276.1	11.3	155.5	0.0	6.8	28.5	28.7	0.0
Aroclor (ug/kg)												
Aroclor 1016	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor 1221	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor 1232	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor 1242	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor 1248	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Aroclor 1254	-	-	20.8	30.5	36.9	<10	33.5	<10	<10	<10	<10	<10
Aroclor 1260	-	-	<10	100.0	76.6	<10	49.0	<10	<10	<10	<10	<10
Pesticides (ug/kg)												
2,4'-DDD	-	-	<1	<1	<1	<1	54.0	<1	<1	<1	<1	1.1J
2,4'-DDE	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,4'-DDT	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
4,4'-DDD	2	20	<1	<1	<1	<1	125.0	<1	<1	<1	<1	3.8J
4,4'-DDE	2.2	27	<1	<1	5.0	<1	58.8	<1	<1	<1	<1	10.7
4,4'-DDT	1	7	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.5J
Aldrin	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-alpha	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-beta	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-delta	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
BHC-gamma	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane-alpha	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chlordane-gamma	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Analyte	ER-L	ER-M	06P436A Composite	06P436B Composite	06P436C Composite	06P436D Composite	06P436E Composite	06P502A Composite	06P518A Composite	06P518B Composite	06P518C Composite	Reference
Chlordane, Total	0.5	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dieldrin	0.02	8	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan Sulfate	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan-I	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endosulfan-II	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin Aldehyde	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Endrin Ketone	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Heptachlor Epoxide	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Methoxychlor	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total Detectable DDTs	1.58	46.1	0.0	0.0	5.0	0.0	183.8	0.0	0.0	0.0	0.0	17.0
Toxaphene	-	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
trans-Nonachlor	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Organotins (ug/kg)												
Monobutyltin	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dibutyltin	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tributyltin	-	-	<1	<1	7.2	3.5	11.2	<1	<1	<1	2.4J	<1
Tetrabutyltin	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PAHs (ug/kg)												
Acenaphthene	16	500	2.61J	15.6	1.58J	<1	3.67J	<1	<1	1.8J	11.0	<1
Acenaphthylene	44	640	7.9	21.3	9.4	2.45J	43.8	<1	1.7J	3.75J	4.2J	<1
Anthracene	85.3	1100	17.2	78.1	20.1	5.8	72.9	2.0J	4.3J	9.7	33.1	<1
Benz[a]anthracene	261	1600	119.3	437.0	24.8	11.4	208.0	19.9	9.1	32.3	155.5	1.9J
Benzo[a]pyrene	430	1600	247.2	725.2	159.2	22.0	1050.6	17.8	12.7	48.3	188.6	2.9J
Benzo[b]fluoranthene	-	-	226.9	702.9	148.0	21.4	983.0	20.4	13.9	39.6	161.8	2.4J
Benzo[e]pyrene	-	-	154.5	455.0	79.6	16.3	566.2	17.9	11.4	29.0	119.5	3.4J
Benzo[g,h,i]perylene	-	-	132.3	444.4	79.8	19.3	465.6	11.3	13.0	34.8	116.6	6.0
Benzo[k]fluoranthene	-	-	194.5	647.2	156.0	21.1	925.7	21.3	16.2	41.9	169.2	2.1J
Chrysene	384	2800	82.6	411.4	35.2	18.0	390.3	18.3	11.6	45.3	139.5	2.75J
Dibenz[a,h]anthracene	63.4	260	41.8	141.4	20.6	6.1	146.3	2.3J	<1	8.5	31.8	<1
Fluoranthene	600	5100	72.4	551.0	18.9	11.8	106.6	17.5	9.0	38.3	217.0	2.5J
Fluorene	19	540	<1	19.0	<1	<1	3.2J	<1	<1	<1	7.9	<1
Indeno[1,2,3-c,d]pyrene	-	-	166.6	579.0	107.5	24.1	655.2	13.4	10.4	38.7	134.6	<1
Naphthalene	160	2100	<1	<1	3.2J	<1	<1	<1	<1	<1	<1	<1
Phenanthrene	240	1500	9.9	49.0	6.8	2.6J	13.6	2.0J	4.1J	16.6	105.7	<1
Pyrene	665	2600	102.3	781.0	69.4	14.5	317.6	17.2	9.8	37.5	196.7	<1
Total Detectable PAHs	4022	44792	1640.4	6417.5	984.4	202.4	6171.5	186.1	130.2	436.8	1862.6	29.2
Phenols (ug/kg)												
2,4,6-Trichlorophenol	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
2,4-Dichlorophenol	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
2,4-Dimethylphenol	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
2,4-Dinitrophenol	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
2-Chlorophenol	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
2-Nitrophenol	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
4-Nitrophenol	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Pentachlorophenol	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Phenol	-	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100

3.2.1.1 Reference Sample

The reference sample from Asan Beach was primarily coarse-grained material having 8.9% gravel and 90.2% sand (Table 3-2). The sample contained less than 1% fine-grained material. Atterberg limits (i.e., liquid limit, plastic limit, and plasticity index) demonstrated that the sediment was non-plastic (NP). Total solids were measured at 85.8% and specific gravity was 1.80.

TOC in the sample was 0.05%. Ammonia was measured at a concentration of 373 milligram per kilogram (mg/kg; wet weight). Dissolved and total sulfides, oil and grease, and TRPH were not detected in the reference sample. Total volatile solids were measured at 0.89%.

Metals were measured at low concentrations ranging from non-detect (<0.01 mg/kg) for mercury to 3.5 mg/kg for zinc, and were well below ER-L values. Most PAH compounds were either below detection limits or were estimated at concentrations below the MRL. Only one PAH compound, benzo[g,h,i]perylene was detected above the MRL at a concentration of 6.0 microgram per kilogram (µg/kg). Total detectable PAHs were calculated at a concentration of 29.2 µg/kg. Total dichlorodiphenyltrichlorethanes (DDTs) and the DDT derivative, dichlorodiphenyldichloroethylene (DDE) were the only organochlorine pesticides detected in the reference sample above their respective ER-L values. The concentration of 4,4'-DDE was measured at 10.7 µg/kg, above its ER-L value of 2.2 µg/kg but below its ER-M value of 27 µg/kg. Total detectable DDT was calculated at a concentration of 17.0 µg/kg, above its ER-L value of 1.58 µg/kg, but well below the ER-M value (46.1 µg/kg). All phenols, PCBs (both individual congeners and Aroclors) and organotins were not detected in the reference sample.

3.2.1.2 P-436 Test Samples

Area P-436A

The composite sample from Area P-436A consisted primarily of fine-grained material (37.8% silt and 49.3% clay; Table 3-2). Gravelly sand (1.5% gravel and 11.4% sand) comprised the remainder of the sample. Atterberg limits were 77, 28 and 49 for the liquid limit (LL), plastic limit (PL) and plasticity index (PI), respectively. The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 51.1% and specific gravity was 1.40.

TOC in the sample was 0.65%. The concentration of ammonia was 23.4 mg/kg (wet weight). Dissolved sulfides and total sulfides were measured to be 2.0 mg/kg (wet weight) and 3.82 mg/kg (wet weight), respectively. Oil and grease, and TRPH were not detected in the sample. Total volatile solids were measured at 2.08%.

The only metals exceeding an ER-L value were Arsenic (8.8 mg/kg), copper, mercury and nickel (28.3 mg/kg) were the only metals which slightly exceeded their respective ER-L values; no metals exceeded an ER-M value. Metals ranged in concentration from 0.32 mg/kg for mercury to 78.7 mg/kg for copper. Fluorene and naphthalene were the only PAH compounds not detected in the P-436A sample. No PAHs exceeded ER-L values. Detectable PAH concentrations ranged from 2.61 µg/kg for acenaphthene (estimated below the MRL) to 247.2 µg/kg for benzo[a]pyrene. Total detectable PAHs were calculated at a concentration of 1640.4 µg/kg, a concentration well below the ER-L value of 4,022 µg/kg. Twelve individual PCB congeners were detected but all were at estimated concentrations, or those below MRLs. Aroclor 1254 was the only PCB Aroclor to be detected in the sample with a concentration of 20.8 µg/kg. Total detectable PCBs were calculated at a concentration of 41.2 µg/kg, which exceeds its ER-L value of 22.7 µg/kg but is well below the ER-M value of 180 µg/kg. Phenols, pesticides and organotins were not detected in the P-436A composite sample.

Area P-436B

The composite sample from Area P-436B consisted of 57.5% coarse-grained material (4.0% gravel and 53.5% sand; Table 3-2). The remaining 42.5% fine-grained material was comprised of 19.8% silt and 22.7 clay. The liquid limit (LL), plastic limit (PL) and plasticity index (PI) were 61, 25 and 36, respectively. The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 64.5% and specific gravity was 1.60.

The sample contained 0.87% TOC. Ammonia in the sample was measured to be 41.8 mg/kg (wet weight). Dissolved and total sulfide concentrations were 58.6 mg/kg (wet weight) and 57.0 mg/kg (wet weight), respectively. Oil and grease was not detected in the sample; TRPH was estimated below the MRL at a concentration of 0.2 mg/kg. Total volatile sulfides were measured at 2.02%.

Only four metals, including arsenic (25.0 mg/kg), chromium (359.4 mg/kg), copper (146.6 mg/kg) and lead (129.8 mg/kg) were detected above their respective ER-L values of 8.2 mg/kg, 81 mg/kg, 34 mg/kg and 46.7 mg/kg but were below their respective ER-M values. Three metals, mercury (0.81 mg/kg), nickel (243.9 mg/kg) and zinc (524.7 mg/kg), exceeded their respective ER-M values (0.71 mg/kg, 51.6 mg/kg and 410 mg/kg, respectively). Six individual PAH compounds were detected at concentrations above their ER-L values but were below their ER-M values. These included benzo[a]anthracene (437.0 µg/kg), benzo[a]pyrene (725.2 µg/kg), chrysene (411.4 µg/kg), dibenz[a,h]anthracene (141.4 µg/kg), fluorene (19.0 µg/kg) and pyrene (781.0 µg/kg). Total detectable PAHs was calculated at a concentration of 6,417.5 µg/kg, a concentration above the ER-L value of 4,022 µg/kg but well below its ER-M value of 44,792 µg/kg. Phenols, pesticides and organotins were not detected in the P-436B composite sample. Thirteen individual PCB congeners were detected and Aroclor 1254 and Aroclor 1260 were the only PCB Aroclors to be detected in the sample with a concentration of 30.5 µg/kg and 100.0 µg/kg, respectively. Total detectable PCBs was calculated at a concentration of 114.5 µg/kg, a concentration above the ER-L value of 22.7 µg/kg but below the ER-M value of 180 µg/kg.

Area P-436C

The Area P-436C composite sample was predominantly fine-grained material consisting of 26.3% silt and 33.1% clay (Table 3-2). The coarse-grained fraction consisted of 9.2% gravel and 31.5% sand. Atterberg limits, including liquid limit (LL), plastic limit (PL) and plasticity index (PI), were 71, 28 and 43, respectively. The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 59.1% and specific gravity was 1.52.

The sample contained 0.64% TOC. The concentration of ammonia was 52.2 mg/kg (wet weight). Dissolved and total sulfides were measured to be 0.96 mg/kg (wet weight) and 9.61 mg/kg (wet weight), respectively. Oil and grease and TRPH were not detected in the sample. Total volatile solids were measured at 2.10%.

Only three metals were detected at concentrations slightly above their ER-L values, including copper (measured concentration of 59.5 mg/kg, with an ER-L of 34 mg/kg), lead (measured concentration of 91.0 mg/kg, with and ER-L of 46.7 mg/kg) and mercury (measured concentration of 0.25 mg/kg, with and ER-L of 0.15 mg/kg). All remaining metals were detected below ER-L values, with concentrations ranging from 0.3 mg/kg for cadmium to 69.0 mg/kg for zinc. All individual PAHs were measured at concentrations below their ER-L values. Total detectable PAHs were calculated at a concentration of 984.4 µg/kg, well below its ER-L value of 4,022 µg/kg. Only one chlorinated pesticide was detected; 4,4'-DDE was measured at a concentration of 5.0 µg/kg which was above its ER-L value of 2.2 µg/kg but well below its ER-M value of 27 µg/kg. Twenty-one individual PCB congeners were detected. Total PCBs (276.1 µg/kg) was calculated at a concentration above its ER-M (180 µg/kg). Aroclor 1254 and Aroclor 1260 had concentrations of 36.9 µg/kg and 76.6 µg/kg, respectively. TBT was measured at a concentration of 7.2 µg/kg (no sediment quality guidelines). Phenols were not detected in the P-436C composite sample.

Area P-436D

The composite sample from Area P-436D was comprised predominantly of fine-grained material (67.1%) with 26.7% silt and 40.4% clay (Table 3-2). The remaining 32.9% coarse-grained material consisted of 6.5% gravel and 26.4% sand. The liquid limit (LL), plastic limit (PL) and plasticity index (PI) were 77, 30 and 47, respectively. The sediment was classified as an inorganic fat clay (CH). Total solids was measured at 55.1% and specific gravity was 1.55.

TOC in the sample was 0.60%. The concentration of ammonia was 25.9 mg/kg (wet weight). The concentration of dissolved sulfides was 0.56 mg/kg (wet weight) and total sulfides was 1.50 mg/kg (wet weight). Oil and grease and TRPH were not detected in the sample. Total volatile sulfides were measured at 2.21%.

None of the metals' concentrations were above their respective ER-L values. Concentrations of metals ranged from 0.08 mg/kg for mercury to 42.6 mg/kg for chromium. Several PAHs were measured, but all were at concentrations below their respective ER-L values. Total detectable PAHs were below the ER-L value (4,022 µg/kg) with a concentration of 202.4 µg/kg. Six individual PCB congeners were measured, but were at concentrations below the MRL and total detectable PCBs were calculated at a concentration of 11.3 µg/kg, below its ER-L value of 22.7 µg/kg. The concentration of TBT was determined to be 3.5 µg/kg. Phenols, chlorinated pesticides and Aroclor PCBs were not detected in the P-436D composite sample.

Area P-436E

The Area P-436E composite sample consisted 51.9% fine-grained and 48.2% coarse-grained material. The fine-grained fraction consisted of 21.1% silt and 30.8% clay; the coarse-grained fraction consisted of 10.2% gravel and 38.0% sand (Table 3-2). Atterberg limits, including liquid limit (LL), plastic limit (PL) and plasticity index (PI), were 67, 26 and 41, respectively. The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 62.9% and specific gravity was 1.57.

The sample contained 0.52% TOC. The concentration of ammonia was 37.8 mg/kg (wet weight). The concentration of dissolved and total sulfides was 5.6 mg/kg (wet weight) and 3.41 mg/kg (wet weight), respectively. Oil and grease and TRPH were not detected in the sample. Total volatile solids were measured at 2.63%.

Cadmium (0.4 mg/kg) and zinc (144.4 mg/kg) were detected at low concentrations below their respective ER-L values. All remaining metals were detected at concentrations slightly above their respective ER-L values; no metals were detected above their respective ER-M values. The PAHs, benzo[a]pyrene, chrysene and dibenz[a,h]anthracene were detected above their ER-L values with concentrations of 1,050.6 µg/kg, 390.3 µg/kg and 146.3 µg/kg, respectively. Total detectable PAHs were also calculated above the ER-L value with a concentration of 6,171.5 µg/kg. The DDT derivatives, 4,4'-DDE and 4,4'-DDD were detected above their ER-M values at concenctrations of 58.8 µg/kg and 125.0 µg/kg, respectively. Total detectable DDTs, therefore, were also above the ER-M value (46.1 µg/kg) with a concentration of 183.8 µg/kg. Sixteen individual PCB congeners were detected and two Aroclors

(Aroclor 1254 [33.5 µg/kg] and Aroclor 1260 [49.0 µg/kg]) were detected. Total detectable PCBs was calculated at a concentration of 155.5 µg/kg, above the ER-L value of 22.7 µg/kg but below the ER-M value of 180 µg/kg. TBT was the only organotin detected, having a concentration of 11.2 µg/kg. Phenols were not detected in the P-436E composite sample.

3.2.1.3 P-518 Test Samples

Area P-518A

The composite sample from Area P-518A was predominantly fine-grained (83.6%) having 23.8% silt and 59.8% clay (Table 3-2). The remaining 16.4% coarse-grained material consisted of 3.3% gravel and 13.1% sand. Atterberg limits were 99 for the liquid limit (LL), 35 for the plastic limit (PL) and 64 for the plasticity index (PI). The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 42.9% and specific gravity was 1.33.

The sample contained 0.70% TOC. Ammonia in the sample was measured to be 16.7 mg/kg (wet weight). Dissolved and total sulfides concentrations were 0.42 mg/kg (wet weight) and 3.11 mg/kg (wet weight), respectively. Oil and grease, and TRPH were not detected in the sample. Total volatile sulfides were measured at 2.20%.

The concentrations of three metals, arsenic (10.7 mg/kg), copper (43.6 mg/kg) and nickel (37.0 mg/kg), were slightly above their ER-L values (8.2 mg/kg, 34 mg/kg and 20.9 mg/kg, respectively), but well below their ER-M values (70 mg/kg, 270 mg/kg and 51.6 mg/kg, respectively). Metals concentrations ranged from 0.1 mg/kg for cadmium to 78.9 mg/kg for chromium. No metals exceeded ER-M values. Several individual PAHs were measured, but all were below their respective ER-L values. The total detectable PAH concentration was 130.2 µg/kg, which was also below the ER-L value (4,022 µg/kg). Only four individual PCB congeners were detected in the sediment sample and total detectable PCBs were calculated at a concentration of 6.8 µg/kg, well below the ER-L value of 22.7 µg/kg. Phenols, pesticides, Aroclor PCBs and organotins were not detected in the P-518A composite sample.

Area P-518B

The composite sample from Area P-518B was comprised of 93.2% fine-grained material (26.5% silt and 66.7% clay; Table 3-2). Gravelly sand (0.9% gravel and 6.0% sand) comprised the remaining 6.9% coarse-grained material. The liquid limit (LL), plastic limit (PL), and plasticity index (PI) were 101, 30 and 71, respectively. The sediment was classified as an inorganic fat clay (CH). Total solids was measured at 44.9% and specific gravity was 1.30.

TOC in the sample was 0.86%. The concentration of ammonia was 27.9 mg/kg (wet weight). The concentration of dissolved sulfides was 1.26 mg/kg (wet weight) and total sulfides was 8.47 mg/kg (wet weight). Oil and grease and TRPH were not detected n the sample. Total volatile sulfides were measured at 2.34%.

Five of the metals detected had concentrations greater than their respective ER-L values; none of the metals had concentrations greater than their ER-M values. Arsenic (10.8 mg/kg), chromium, copper (51.1 mg/kg), mercury (0.21 mg/kg) and nickel (37.1 mg/kg), exceeded their ER-L values of 8.2 mg/kg, 81 mg/kg, 34 mg/kg, 0.15 mg/kg and 20.9 mg/kg, respectively; however, all metal were below their respective ER-M values. Concentrations of metals ranged from 0.2 mg/kg for cadmium to 88.0 mg/kg for chromium. Most PAHs were detected but were below their ER-L values. Similarly, total detectable PAHs were calculated at a concentration of 436.8 µg/kg, well below the ER-L value of 4,022 µg/kg. Nine individual PCB congeners were detected; and total detectable PCBs was calculated at a concentration of 28.5 µg/kg, slightly above its ER-L value of 22.7 µg/kg, but well below the ER-M value of 180 µg/kg. Phenols, chlorinated pesticides, Aroclor PCBs and organotins were not detected in the P-518B composite sample.

Area P-518C

The Area P-518C composite sample consisted predominantly of coarse-grained material (5.4% gravel and 59.1% sand; Table 3-2). Silt (11.8%) and clay (23.8%) comprised the remaining portion of the sample. Atterberg limits, including liquid limit (LL), plastic limit (PL) and plasticity index (PI), were 61, 25 and 36, respectively. The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 58.8% and specific gravity was 1.47.

The sample contained 0.44% TOC. The concentration of ammonia was 24.7 mg/kg (wet weight). The concentration of dissolved and total sulfides was 1.94 mg/kg (wet weight) and 4.54 mg/kg (wet weight), respectively. Oil and grease and TRPH were not detected in the sample. Total volatile solids were measured at 2.31%.

The only metals that exceeded their respective ER-L values were copper (38.0 mg/kg), lead (85.1 mg/kg), mercury (0.17 mg/kg) and nickel (28.0 mg/kg). None of the metals exceeded their ER-M values. Most PAHs were detected at concentrations below their respective ER-L values. Total detectable PAHs were calculated at a concentration of 1862.6 µg/kg, which was also below its ER-L value of 4,022 µg/kg. Ten individual PCB congeners were detected and total detectable PCBs (28.7 µg/kg) were slightly greater than the ER-L value (22.7 µg/kg), but far below the ER-M value (180 µg/kg). TBT was estimated at a concentration of 2.4 µg/kg. Phenols, chlorinated pestides and Arcolor PCBs were not detected in the P-518C composite sample.

3.2.1.4 P-502 Test Samples

Area P-502A

The composite sample from Area P-502A was predominantly coarse-grained material (95.1%) having 21.0% gravel and 74.1% sand fractions (Table 3-2). The remaining 5.0% fine-grained material consisted of 2.6% silt and 2.4% clay. Atterberg limits were 98, 32 and 66 for the liquid limit (LL), plastic limit (PL) and plasticity index (PI), respectively. The sediment was classified as an inorganic fat clay (CH). Total solids were measured at 69.1% and specific gravity was 1.70.

TOC in the sample was 0.07%. The concentration of ammonia was 73.6 mg/kg (wet weight). Dissolved sulfides and total sulfides were measured to be 5.75 mg/kg (wet weight) and 0.26 mg/kg (wet weight), respectively. Oil and grease, and TRPH were not detected in the sample. Total volatile solids were measured at 1.32%.

Metal concentrations ranged from non-detect (mercury) to only 6.0 mg/kg (zinc). None of the detected metals had concentrations greater than their ER-L values. Several PAHs were detected but were at concentrations below ER-L values. Total detectable PAHs was calculated at a concentration of 186.1 µg/kg, well below its ER-L value of 4,022 µg/kg. Phenols, chlorinated pesticides, PCBs (both individual congeners and Aroclors) and organotins were not detected in the P-502A composite sample.

3.2.1.5 High Resolution Cores

High Resolution Core 1 (06P436HR1)

High Resolution Core 1 (06P436HR1) was co-located with core location P-436B1. This core was split vertically into two 1.5-ft segments. The upper segment of the core contained 61.4% fine-grained material (32.63% silt and 28.80% clay) and 38.6% coarse-grained material (4.06% gravel and 34.51% sand; (Table 3-3) Metals concentrations in the upper 1.5 ft were elevated relative to ER-L and ER-M values, with the exception of cadmium. Arsenic (45.0 mg/kg) and chromium (198.8 mg/kg) were greater than their ER-L values. The remaining metals, including copper (482.7 mg/kg), lead (245.7 mg/kg), mercury (7.2 mg/kg), nickel (59.0 mg/kg) and zinc (624.6 mg/kg), were above their respective ER-M values. Only one PAH compound, dibenz[a,h]anthracene, was above its ER-L value with a concentration of 67.5 µg/kg; total detectable PAHs was 2,619.5 µg/kg, and were also below the ER-L value. Fourteen individual PCB congeners were detected. Total detectable PCBs were calculated at a concentration of 147.9 µg/kg, above the ER-L value but below the ER-M value for PCBs.

The lower segment of High Resolution Core 1 was comprised of similar material as the upper portion and contained 57.7% fine-grained material (24.81% silt and 32.89% clay) and 42.3% coarse-grained material (4.33% gravel and 37.97% sand; Table 3-3). All of the metals in the lower segment were greater than their ER-L or ER-M values. Arsenic (12.5 mg/kg), cadmium (3.9 mg/kg), copper (139.6 mg/kg) and nickel (26.1 mg/kg) exceeded their ER-L values. The remaining metals exceeded ER-M values. These included chromium (487.1 mg/kg), lead (376.9 mg/kg), mercury (2.8 mg/kg) and zinc (1692.9 mg/kg). Two individual PAH compounds, benzo[a]pyrene and dibenz[a,h]anthracene, were detected above their ER-L values. All remaining PAH compounds were detected at levels below their ER-L values. The total detectable PAH concentration was calculated to be 3,072.1 µg/kg, a concentration below the ER-L value (4,022 µg/kg). Sixteen individual PCB congeners were detected. Total detectable PCBs were calculated at a concentration of 246.4 µg/kg, above the ER-M value for total PCBs.

High Resolution Core 2 (06P436HR2)

High Resolution Core 2 (06P436HR2) was split vertically into two 2.2-ft sections. The upper segment of the core contained 35.8% fine-grained material (14.9% silt and 20.9% clay) and 64.2% coarse-grained material (3.6% gravel and 60.6% sand; Table 3-3). Metals concentrations in the upper 2.2 ft were elevated relative to ER-L and ER-M values, with the exception of cadmium. Arsenic (38.6 mg/kg), chromium (328.4 mg/kg), copper (249.6 mg/kg), lead (127.9 mg/kg), mercury (0.5 mg/kg) and zinc (355.5 mg/kg) exceeded ER-L values. Nickel was the only metal to exceed its ER-M value with a concentration of 139.3 mg/kg. Benzo[a]pyrene and dibenz[a,h]anthracene were the only PAH compounds to exceed their ER-L values with concentrations of 541.7 µg/kg and 96.6 µg/kg, respectively. Total PAHs were calculated at a concentration of 3,838.2 µg/kg. Fifteen individual PCB congeners were detected. Total detectable PCBs were calculated at a concentration of 127.1 µg/kg, above its ER-L value, but below the ER-M value.

The lower segment of High Resolution Core 2 was comprised of similar material as the upper portion and contained 32.9% fine-grained material (16.2% silt and 16.7% clay) and 67.1% coarse-grained material (4.1% gravel and 63.00% sand; Table 3-3). All of the metals in the lower segment were greater than their ER-L or ER-M values. Arsenic (8.3 mg/kg), cadmium (3.7 mg/kg), chromium (126.0 mg/kg), copper (220.8 mg/kg) and nickel (34.6 mg/kg) all exceeded ER-L values. Lead (483.8 mg/kg), mercury (1.8 mg/kg) and zinc (1,600.9 mg/kg) each exceeded their respective ER-M values. Total PAHs exceeded the ER-L value with a calculated concentration of 7,591.0 µg/kg. Four individual PAH compounds also exceeded their ER-L values but were below ER-M values; these included anthracene, benz[a]anthracene, benzo[a]pyrene and dibenz[a,h]anthracene. Sixteen individual PCB congeners were detected contributing to the total PCB concentration of 347.7 µg/kg, above the ER-M value for this group.

Table 3-3. Summary of Chemistry Analytical Results and Physical Measurements of High Resolution Sediment Cores in the Vicinity of Oscar Whar, Apra Harbor, Guam with a Comparison to ER-L and ER-M Sediment Quality Values.

Analyte	Units	ERL	ERM	High Resolution Core 1 06P436B1/HR1		High Resolution Core 2 06P436HR2		High Resolution Core 3 06P436HR3		High Resolution Core 4 06P436HR4		High Resolution Core 5 06P436HR5		High Resolution Core 6 06P436RQ1	
				Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Physical Analyses															
Gravel (%)	-	-	-	4.33	4.06	4.14	3.62	2.81	3.51	0.06	0.33	10.35	9.34	45.90	9.09
Sand (%)	-	-	-	37.97	34.51	63.00	60.63	17.83	18.53	4.66	10.09	57.39	66.26	39.20	52.03
Silt (%)	-	-	-	24.81	32.63	16.15	14.85	37.18	33.91	33.90	37.64	13.65	12.46	6.29	18.51
Clay (%)	-	-	-	32.89	28.80	16.71	20.91	42.19	44.05	61.38	51.94	18.62	11.95	8.61	20.37
Metals (mg/kg)															
Arsenic (As)	µg/dry g	8.2	70	12.5	45.0	8.3	38.6	32.2	21.3	13.2	50.4	73.3	530.6	9.4	22.5
Cadmium (Cd)	µg/dry g	1.2	9.6	3.9	0.7	3.7	0.3	2.1	1.0	1.0	1.8	1.9	1.7	0.7	0.6
Chromium (Cr)	µg/dry g	81	370	487.1	198.8	126.0	328.4	231.0	142.6	150.7	222.1	495.2	1020.2	68.4	188.2
Copper (Cu)	µg/dry g	34	270	139.6	482.7	220.8	249.6	296.7	249.2	164.8	588.9	473.0	1615.0	97.6	204.2
Lead (Pb)	µg/dry g	46.7	218	376.9	245.7	483.8	127.9	220.6	145.1	154.9	414.8	642.1	680.2	109.4	97.8
Mercury (Hg)	µg/dry g	0.15	0.71	2.8	7.2	1.8	0.5	0.9	0.9	1.6	2.3	4.8	0.9	0.4	0.5
Nickel (Ni)	µg/dry g	20.9	51.6	26.1	59.0	34.6	139.3	87.5	51.6	43.9	62.7	121.7	648.4	32.2	105.3
Zinc (Zn)	µg/dry g	150	410	1692.9	624.6	1600.9	355.5	403.5	423.8	409.3	807.2	2523.9	1995.9	269.6	687.9
PAHs (µg/kg)															
Acenaphthene	ng/dry g	16	500	6.2	3.6J	15.3	5.4	2.1J	2.92J	<1	4.6J	2.6J	6.2	6.4	3.5J
Acenaphthylene	ng/dry g	44	640	15.2	22.6	39.1	14.6	15.0	31.5	25.1	42.8	45.9	17.8	13.8	15.5
Anthracene	ng/dry g	85.3	1100	60.3	60.6	152.6	49.8	54.3	109.1	90.9	128.4	144.2	69.0	64.3	53.5
Benz[a]anthracene	ng/dry g	261	1600	144.3	103.0	305.6	157.3	64.2	176.9	224.8	391.2	291.8	161.8	219.7	70.6
Benzo[a]pyrene	ng/dry g	430	1600	460.5	402.4	1194.6	541.7	456.2	766.6	618.6	899.9	1604.7	464.9	497.2	356.0
Benzo[b]fluoranthene	ng/dry g	-	-	492.3	426.3	1257.3	600.3	508.4	848.9	695.9	987.5	1703.0	539.8	559.3	437.8
Benzo[e]pyrene	ng/dry g	-	-	167.9	128.7	770.7	297.4	279.2	436.8	490.8	555.1	888.1	301.2	356.7	218.4
Benzo[g,h,i]perylene	ng/dry g	-	-	231.4	217.5	566.0	304.1	246.9	403.7	341.0	487.1	840.1	209.6	261.5	171.6
Benzo[k]fluoranthene	ng/dry g	-	-	487.4	426.9	1220.8	546.6	481.8	789.4	613.4	865.6	1525.5	577.0	542.2	381.2
Chrysene	ng/dry g	384	2800	170.2	138.8	373.5	255.4	77.4	215.3	289.0	815.8	614.5	766.2	252.0	69.8
Dibenz[a,h]anthracene	ng/dry g	63.4	260	73.4	67.5	223.3	96.6	78.0	148.5	115.2	161.5	290.8	68.7	76.4	64.1
Fluoranthene	ng/dry g	600	5100	152.0	121.4	239.0	146.1	42.8	126.0	247.8	363.6	141.1	217.0	146.8	68.3
Fluorene	ng/dry g	19	540	5.0J	2.5J	10.4	3.6J	3.1J	5.1	<1	11.2	4.1J	6.8	6.8	3.7J
Indeno[1,2,3-c,d]pyrene	ng/dry g	-	-	270.0	253.1	729.0	365.8	297.7	517.9	400.0	619.0	1023.8	269.8	313.5	220.1
Naphthalene	ng/dry g	160	2100	4.4J	9.9	5.7	129.8	3.26J	4.70J	7.1	5.5	11.1	6.8	3.4J	20.0
Phenanthrene	ng/dry g	240	1500	46.9	36.9	37.1	33.3	11.9	20.4	34.8	64.5	20.4	94.0	22.4	22.3
Pyrene	ng/dry g	665	2600	205.3	136.8	213.2	168.9	90.4	564.0	648.0	906.1	140.7	235.3	625.7	151.3
Total Detectable PAHs	ng/dry g	4022	44792	3072.1	2619.5	7591.0	3838.2	2781.4	5283.7	4973.8	7495.2	9492.4	4115.6	4086.2	2406.4
PCBs (mg/kg)															
PCB018	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	8.5	<1	<1	<1
PCB028	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB031	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB033	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB037	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB044	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	9.6	<1	<1	<1
PCB049	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	18.6	<1	<1	<1
PCB052	ng/dry g	-	-	<1	<1	<1	8.9	<1	<1	<1	<1	51.8	<1	<1	<1
PCB066	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB070	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB074	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB077	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Analyte	Units	ERL	ERM	High Resolution Core 1 06P436B1/HR1		High Resolution Core 2 06P436HR2		High Resolution Core 3 06P436HR3		High Resolution Core 4 06P436HR4		High Resolution Core 5 06P436HR5		High Resolution Core 6 06P436RQ1	
				Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
PCB081	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB087	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB095	ng/dry g	-	-	8.0	8.2	21.1	5.4	8.0	10.9	8.4	9.9	35.4	4.6J	<1	2.7J
PCB097	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB099	ng/dry g	-	-	<1	2.2J	<1	<1	<1	<1	<1	<1	16.3	<1	<1	<1
PCB101	ng/dry g	-	-	13.7	7.3	28.4	8.3	14.8	14.6	8.8	18.0	42.8	5.5	<1	<1
PCB105	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB110	ng/dry g	-	-	<1	<1	13.7	<1	<1	<1	<1	<1	28.9	5.4	<1	<1
PCB114	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB118	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	17.9	3.7J	<1	<1
PCB119	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB123	ng/dry g	-	-	<1	<1	<1	<1	7.6	<1	<1	<1	<1	<1	<1	<1
PCB126	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	6.4	<1	<1	<1	<1
PCB128+167	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB138	ng/dry g	-	-	26.3	21.8	40.4	15.4	28.5	33.6	34.1	44.2	40.2	9.7	<1	<1
PCB141	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB149	ng/dry g	-	-	24.0	16.7	35.9	9.5	31.4	27.5	26.6	36.1	36.0	7.2	<1	9.8
PCB151	ng/dry g	-	-	8.7	5.6	7.1	4.4J	12.3	10.7	15.0	18.5	10.9	2.8J	<1	4.3J
PCB153	ng/dry g	-	-	24.1	18.4	33.7	10.5	33.4	34.9	30.9	46.2	34.8	9.2	<1	7.9
PCB156	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB157	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB158	ng/dry g	-	-	<1	4.8J	<1	<1	<1	<1	<1	<1	<1	3.4J	<1	<1
PCB168+132	ng/dry g	-	-	13.8	8.3	14.1	<1	13.7	22.6	16.4	11.6	11.0	3.5J	<1	7.2
PCB169	ng/dry g	-	-	26.6	<1	<1	<1	<1	<1	<1	<1	<1	11.6	<1	<1
PCB170	ng/dry g	-	-	16.7	<1	21.5	<1	16.6	18.5	30.7	<1	7.0	5.3	<1	<1
PCB177	ng/dry g	-	-	5.6	7.8	6.0	4.9J	10.3	10.3	<1	<1	9.1	4J	<1	5.4
PCB180	ng/dry g	-	-	24.3	21.0	36.9	13.3	31.9	35.0	38.0	47.4	27.4	7.0	<1	11.3
PCB183	ng/dry g	-	-	8.1	<1	10.3	4.7J	9.2	13.4	11.6	17.7	7.1	<1	<1	<1
PCB187	ng/dry g	-	-	14.6	<1	20.5	10.0	15.7	18.4	21.3	27.6	16.3	<1	<1	<1
PCB189	ng/dry g	-	-	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
PCB194	ng/dry g	-	-	14.6	9.8	22.6	6.9	11.5	14.6	24.4	23.5	8.2	4.2J	<1	<1
PCB200	ng/dry g	-	-	<1	<1	<1	2.8J	<1	<1	<1	<1	<1	<1	<1	<1
PCB201	ng/dry g	-	-	8.9	9.3	19.5	14.0	14.2	12.4	12.9	23.6	7.5	<1	<1	<1
PCB206	ng/dry g	-	-	8.4	6.7	16.0	8.1	7.0	15.1	24.8	24.9	<1	<1	<1	<1
Total Detectable PCBs	ng/dry g	22.7	180	246.4	147.9	347.7	127.1	266.1	292.5	303.9	355.6	445.3	87.1	0.0	48.6

High Resolution Core 3 (06P436HR3)

High Resolution Core 3 (06P436HR3) was split vertically into an upper 1.1-ft section and a lower 1.2-ft section. The upper segment of the core contained 78.0% fine-grained material (33.91% silt and 44.05% clay) and 22.0% coarse-grained material (3.51% gravel and 18.53% sand; Table 3-3). Similar to High Resolution Cores 1 and 2, all metals except cadmium exceeded their ER-L values. Arsenic (21.3 mg/kg), chromium (142.6 mg/kg), copper (249.2 mg/kg), lead (145.1 mg/kg) and nickel (51.6 mg/kg) exceeded their ER-L values, but were below ER-M values. Mercury and zinc exceeded their ER-M values with concentrations of 0.9 mg/kg and 423.8 mg/kg, respectively. Only three PAH compounds, anthracene, benzo[a]pyrene and dibenz[a,h]anthracene, were above their ER-L values with concentrations of 109.1 µg/kg, 766.6 µg/kg and 148.5 µg/kg, respectively. Total detectable PAHs were 5,283.7 µg/kg, also above its ER-L value. Fifteen individual PCB congeners were detected and total detectable PCBs were above its ER-M value with a concentration of 292.5 µg/kg.

The lower segment of High Resolution Core 3 was comprised of similar material as the upper portion and contained 79.4% fine-grained material (37.18% silt and 42.19% clay) and 20.6% coarse-grained material (2.81% gravel and 17.83% sand; Table 3-3). All of the metals in the lower section had metals concentrations greater than ER-L or ER-M values. Arsenic (32.2 mg/kg), cadmium (2.1 mg/kg), chromium (231.0 mg/kg) and zinc (403.5 mg/kg) had concentrations greater than their respective ER-L values. Copper (296.7 mg/kg), lead (220.6 mg/kg), mercury (0.9 mg/kg) and nickel (87.5 mg/kg) had concentrations greater than their respective ER-M values. All PAHs were below their respective ER-L values except benzo[a]pyrene (456.2 µg/kg) and dibenz[a,h]anthracene (78.0 µg/kg), whose concentrations were above their respective ER-L values, but below ER-M values. Total detectable PAHs were calculated at a concentration of 2,781.4 µg/kg. Sixteen individual PCB congeners were detected in the sample. Total detectable PCBs were detected above its ER-M value with a concentration of 266.1 µg/kg.

High Resolution Core 4 (06P436HR4)

High Resolution Core 4 (06P436HR4) was split vertically into two 1.2-ft sections. The upper segment of the core contained 89.5% fine-grained material (37.6% silt and 51.9% clay) and 10.4% coarse-grained material (0.3% gravel and 10.1% sand; Table 3-3). All metals, including cadmium, exceeded their ER-L or ER-M values in the upper section. Arsenic (50.4 mg/kg), cadmium (1.8 mg/kg) and chromium (222.1 mg/kg) exceeded their ER-L values. Copper (588.9 mg/kg), lead (414.8 mg/kg), mercury (2.3 mg/kg), nickel (62.7 mg/kg) and zinc (807.2 mg/kg) exceeded ER-M values. Six individual PAH compounds were detected above their ER-L values, including anthracene, benz[a]anthracene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene and pyrene; however, concentrations of these PAHs were below ER-M values. Total detectable PAHs were calculated above its ER-L at a concentration of 7,495.2 µg/kg, but was below the ER-M value. Fourteen individual PCB congeners were detected and total detectable PCBs were calculated at a concentration of 355.6 µg/kg, above the ER-L value for this group.

The lower segment of High Resolution Core 4 was comprised of similar material as the upper portion and contained 95.3% fine-grained material (33.9% silt and 61.4% clay) and 4.8% coarse-grained material (0.1% gravel and 4.7% sand; Table 3-3). The lower section also had elevated metals concentrations relative to ER-L and ER-M values. Cadmium did not exceed its ER-L value, but arsenic (13.2 mg/kg), chromium (150.7 mg/kg), copper (164.8 mg/kg), lead (154.9 mg/kg), nickel (43.9 mg/kg) and zinc (409.3 mg/kg) did have concentrations greater than their ER-L values. Only one metal, mercury (1.6 mg/kg), had a concentration greater than its ER-M value. Three PAH compounds, anthracene, benzo[a]pyrene and dibenz[a,h]anthracene, were detected at levels above their ER-L values. Total detectable PAHs were above their ER-L value with a concentration of 4,973.8 µg/kg. Fourteen individual PCB congeners were detected and total detectable PCBs were calculated at a concentration of 303.9 µg/kg, above the ER-L value for this group.

High Resolution Core 5 (06P436HR5)

High Resolution Core 5 (06P436HR5) was split vertically into two 1.5 foot sections. The upper segment of the core contained 24.5% fine-grained material (12.5% silt and 12.0% clay) and 75.6% coarse-grained material (9.3% gravel and 66.3% sand; Table 3-3). In the upper section, two metals (arsenic and chromium) not only exceeded their ER-M values, but also exceeded total threshold limit concentrations (TTLCs; federal criteria for identifying material as hazardous waste), with concentrations of 530.6 mg/kg and 1,020.2 mg/kg, respectively. Six of the remaining seven metals also exceeded their ER-M values, including copper (1,615.0 mg/kg), lead (680.2 mg/kg), mercury (0.9 mg/kg), nickel (648.4 mg/kg) and zinc (1,995.9 mg/kg). Cadmium, measured at a concentration of 1.7 mg/kg, was above its ER-L value but did not exceed its ER-M value (9.6 mg/kg). Three individual PAH compounds, benzo[a]pyrene, chrysene and dibenz[a,h]anthracene, were detected above ER-L values, but were below ER-M values. Total detectable PAHs were calculated above its ER-L value with a concentration of 4,115.6 µg/kg. Fifteen individual PCB congeners were detected and total detectable PCBs were calculated at a concentration of 87.1 µg/kg, above the ER-L value, but well below the ER-M value, for this group of analytes.

The lower segment of High Resolution Core 5 was comprised of similar material as the upper portion and contained 32.3% fine-grained material (13.7% silt and 18.6% clay) and 67.8% coarse-grained material (10.4% gravel and 57.4% sand; Table 3-3). In the lower section, all metals exceeded their ER-M values with the exception of cadmium which only exceeded its ER-L value. Four individual PAH compounds were detected above their ER-L values, including acenaphthylene, anthracene, benz[a]anthracene and chrysene, and two PAH compounds, benzo[a]pyrene and dibenz[a,h]anthracene, were detected above their ER-M values. Total detectable PAHs were calculated above the ER-L at a concentration of 9,492.4 µg/kg, but did not exceed the ER-M value. Twenty-one individual PCB congeners were detected and total detectable PCBs were calculated at a concentration of 445.3 µg/kg, above the ER-M value for this group of analytes.

High Resolution Core 6 (06P436RQ1)

High Resolution Core 6 (06P436RQ1) was located in the corner of Papa and Quebec Wharves where a dry dock is typically located. The dry dock structure was removed from this location, so the field team collected an opportunistic sample to supplement the high resolution sampling program. This core was split vertically into two 2.5-ft sections. The upper segment of the core contained 38.9% fine-grained material (18.5% silt and 20.4% clay) and 61.1% coarse-grained material (9.1% gravel and 52.0% sand; Table 3-3). In the upper section, arsenic (22.5 mg/kg), chromium (188.2 mg/kg), copper (204.2 mg/kg), lead (97.8 mg/kg) and mercury (0.5 mg/kg) exceeded their respective ER-L values. Two metals, nickel (105.3 mg/kg) and zinc (687.9 mg/kg) exceeded their ER-M values. Cadmium was detected below its ER-L value. Only one PAH compound, dibenz[a,h]anthracene, was detected above its ER-L value. Total detectable PAHs were calculated at a concentration of 2,406.4 µg/kg. Only seven individual PCB congeners were detected and total detectable PCBs were calculated at a concentration above its ER-L value (48.6 µg/kg).

The lower segment of High Resolution Core 6 was comprised of a coarser-grained material than the upper portion and contained only 14.9% fine-grained material (6.3% silt and 8.6% clay) and 85.1% coarse-grained material (45.9% gravel and 39.2% sand; Table 3-3). In the lower section, all metals, with the exception of cadmium and chromium were detected above their ER-L values, but did not exceed their respective ER-M values. Only two PAH compounds, benzo[a]pyrene and dibenz[a,h]anthracene were detected above their ER-L values. Total detectable PAHs were calculated at a concentration of 4,086.2

µg/kg, slightly above its ER-L value of 4,022 µg/kg. No PCBs were detected in the lower section of High Resolution Core 6.

3.3 RESULTS OF TOXICITY TESTING

3.3.1 Suspended Particulate Phase Testing

3.3.1.1 Dendraster excentricus Test Results.

Area P-436

Water quality parameters were within appropriate limits for the 72-hour SPP bioassay test using *D. excentricus* with the exception of temperaute and salinity (Table 3-4). For P-436 project sediment, temperature slightly exceeded the test limit (15 ± 1 °C) with a maximum recorded temperature of 16.6°C on the initial day in the 100% concentration test of P-436E sediment. Salinity slightly exceeded the test limit (30-32 ± 1 ppt) with a maximum recorded value of 33.7 ppt on the last day in the 100% concentration test of P-436D sediment. These deviations did not affect test performance. The LC_{50} value for survival was greater than 100% for sediment elutriates from project Areas P-436A, P-436B, P-436C, P-436D and P-436E (Table 3-5). Detailed test results are presented in Appendix D.

Area P-518

Water quality parameters were within appropriate limits for the 72-hour SPP bioassay test using *D. excentricus* with the exception of salinity (Table 3-4). For P-518 project sediment, salinity slightly exceeded the test limit (30-32 ± 1 ppt) with a maximum recorded value of 33.7 ppt on the last day in the 100% concentration test of P-518B sediment and a maximum recorded value of 33.5 ppt on the last day in the 100% concentration test of P-518C sediment. These deviations did not affect test performance. The LC_{50} value for survival was greater than 100% for sediment elutriates from project Areas P-518A, P-518B and P-518C (Table 3-5). Detailed test results are presented in Appendix D.

Area P-502

Water quality parameters were within appropriate limits for the 72-hour SPP bioassay test using *D. excentricus* (Table 3-4). The LC_{50} value for survival was greater than 100% for sediment elutriates from project Area P-502A (Table 3-5). Detailed test results are presented in Appendix D.

Control and Reference Toxicants

Mean control survival of *D. excentricus* was 100% (Table 3-5) and met the minimum acceptable control survival criterion of ≥90%. Detailed test results for the control and reference toxicant tests using *D. excentricus* are presented in Appendix D.

The copper sulfate reference toxicant test resulted in a LC_{50} of >60 µg Cu^{2+}/L and an EC_{50} (indicative of % normal development) of 20.3 µg Cu^{2+}/L using concentrations of 0, 3.75, 7.5, 15, 30 and 60 µg Cu^{2+}/L (Table 3-5). A control chart was not available to compare the LC_{50} calculated in the copper sulfate reference toxicant test to a laboratory mean LC_{50} because the 72-hour echinoderm development test is not the standard development SPP test performed as part of dredged matrial evaluations at Weston. Specifically, the echinoderm development test was selected based on the lack of reproductively active bivalves and sea urchins typically used in this SPP test (See Section 2.3.1).

The ammonium chloride reference toxicant test resulted in LC_{50} values of 12.85 mg total NH_3/L and 0.588 mg un-ionized NH_3/L using measured total ammonia concentrations 0, 1.25, 2.5, 5, 10 and 20 mg total NH_3/L and calculated un-ionized ammonia concentrations of 0, 0.063, 0.14, 0.287, 0.466 and 0.88

4. DISCUSSION

4.1 CHEMICAL AND PHYSICAL ANALYSIS OF TEST SEDIMENTS

4.1.1 Reference

The reference sample was predominantly coarse-grained material (>90% sand). All metals, except mercury, were detected at low concentrations below their respective ER-L values. Mercury was not detected in the reference sample. No PCBs (both individual congeners or Aroclors) were detected. DDT and its derivatives were detected in the reference sample with a total detectable DDT concentration of 17.0 µg/kg. The reference sample had a measured total detectable PAH concentration of 29.2 µg/kg. No organotins or phenols were detected.

4.1.2 Area P-436

There was no predominant grain-size characteristic in sediments collected from Area P-436. Sediment ranged from 42.5 to 87.1% fine-grained materials throughout the entire P-436 project area. In four of the five test areas within Area P-436, three or more metals exceeded their ER-L values but at concentrations which were below ER-M values. Only mercury, nickel and zinc exceeded the ER-M in Area P-436B. Area P-436D did not have any metals exceeding their respective ER-L values. Three of the five test areas within Area P-436 had total detectable PCB concentrations greater than ER-L and less than ER-M values; only total detectable PCBs in Area P-436B exceeded the ER-M value. Area P-436D did not have PCB concentrations greater than its respective ER-L value. The heavier Aroclors (1254 and 1260) were the only aroclors detected suggesting historical contamination as these are the Aroclors most persistent in environment. DDT derivatives were detected in Area P-436C and P-436E sediment samples, exceeding their ER-L and ER-M values, respectively. Total detectable PAHs slightly exceeded ER-L values, and were well below the ER-M values, in Area P-436B and P-436E sediment samples. TBT was detected in three of the five Area P-436 composite samples. Phenols were not detected.

4.1.3 Area P-518

Grain size ranged from 35.6 to 93.2% fine-grained materials in sediments collected from Area P-518. Several metals exceeded ER-L values in each of the three P-518 composite samples; no metals exceeded an ER-M value in P-518 sediment samples. Several PCB congeners were also detected in the each of the three P-518 samples with total detectable PCB concentrations exceeding ER-L values, but less than ER-M values, in Areas P-518B and P-518C. Total detectable PAHs were detected at concentrations below its ER-L value in each sample. TBT was detected below the MRL in the Area P-518C composite sample. Aroclors, chlorinated pesticides and phenols were not detected in any of the P-518 project areas.

4.1.4 Area P-502

Area P-502 sediment was predominantly coarse-grained material (95.1%). All detectable analytes were found at low concentrations (i.e., below the ER-L values). PCBs (both individual congeners and Aroclors), chlorinated pesticides, organotins and phenols were not detected.

4.1.5 Comparison between Physical/Chemical Characteristics of Sediment Sampled in 2005 vs. 2006

It should be noted that it is difficult to make direct comparisons between sediment physical and chemical data collected in the present study and those collected in previous studies (Weston 2005b; Weston and Belt Collins 2005). Specifically, some of the stations (in Areas P-436C, D, and E) sampled during the maintenance dredging project in 2005, had been dredged to the maintenance dredge depth (but not construction dredge depth) prior to this sampling effort (July 2006). Consequently, stations sampled in 2005, which consisted of material above the maintenance dredge depth, could not be resampled in 2006 (i.e., station locations in these areas were moved to new locations in 2006). In addition, in areas that had not yet been dredged to the maintenance dredge depth, station locations were kept from previous studies and sampling events; however, because the target construction depth was increased from 2005 to 2006, there was a greater volume of material to be dredged than initially anticipated. As a result, additional stations were added in 2006 for Areas P-518, P-436, and P-502 to represent that additional volume of material, and thus composites from 2006 are comprised of a more cores than those in 2005. These differences should be considered when reviewing the following sections.

4.1.5.1 Area P-436

In general, sediment sampled in Area P-436 in 2005 demonstrated similar physical characteristics to that sampled in 2006, demonstrating a mixture of clay, sand, and silt. For example, the percent clay in the Area P-436A sediment composite was 56.9% in 2005 and 49.3% in 2006. Chemicals measured in subareas within Area P-436 were also similar in 2005 vs. 2006. In both years, concentrations of metals were relatively low in Area P-436D with only one ER-L exceedance in 2005 and no ER-L exceedances in 2006. Other areas demonstrated ER-L and some ER-M exceedances (P-436B in both years and P-436C and P-436E in 2005 only) for metals including arsenic, chromium, copper, lead, mercury, nickel and zinc. However, different metals exceeded ER-M values in 2005 than in 2006 in Area P-436B. Total PCB concentrations were within the same order of magnitude in 2005 and 2006 with ER-L and one ER-M exceedance in both years; however, actual concentrations measured varied among subareas with the highest concentration in 2005 detected in P-436B, and the highest concentration in 2006 detected in P-436C. Total PAH concentrations were also similar between different sampling events. In 2005, total PAHs were below ER-L values in all areas except P-436B, which was below the ER-M value. In 2006, total PAHs were below ER-L values in all areas except P-436B and P-436E, whose concentrations were below ER-M values. All other chemicals except total DDTs demonstrated low concentrations in 2005 and 2006. DDTs were not detected in 2005; however, in 2006, total DDTs exceeded the ER-L value in Area P-436B and exceeded the ER-M value in Area P-436E. For Area P-436, all other chemicals analyzed demonstrated similarly low or non-detect concentrations in 2005 and 2006.

4.1.5.2 Area P-518

Sediment sampled in Areas P-518A and P-518B in 2005 demonstrated similar physical characteristics to that sampled in 2006, demonstrating a mixture of clay, sand, and silt. For example, the percent clay in the Area P-518A sediment composite was 60.1% in 2005 and 59.8% in 2006. However, for Area P-518C, there were substantial differences in grain size between 2005 and 2006, with a higher concentration of clay in 2005 (44.7%) than in 2006 (23.8%). Chemicals measured in subareas within Area P-518 were also similar in 2005 vs. 2006. In both years, concentrations of metals were relatively low in Area P-518 with ER-L exceedances in both years; however, in 2005 nickel slightly exceeded the ER-M value in Areas P-518A and P-518C, while in 2006 there were no ER-M exceedances. PCB concentrations were within the same order of magnitude in 2005 and 2006 with slight ER-L exceedances in Area P-518C and in Areas P-518B and P-518C, respectively. Total PAH concentrations were also similar between different sampling events for Areas P-518A and P-518B, demonstrating concentrations below ER-L values in both years. However, in Area P-518C, concentrations of total PAHs exceeded ER-L values in 2005, but were below ER-L values in 2006. For Area P-518, all other chemicals analyzed demonstrated similarly low or non-detect concentrations in 2005 and 2006.

4.1.5.3 Area P-502

Sediment sampled in Area P-502A in 2005 demonstrated similar physical characteristics to that sampled in 2006, demonstrating primarily coarse-grained material. The percent sand in the Area P-502A sediment composite was 81.0% in 2005 and 74.1% in 2006. Chemicals measured in subareas within P-502A were also similar in 2005 vs. 2006. In both years, concentrations of metals were low in Area P-502A and all metals were below the ER-L values in both years. Total PAH concentrations were also similar between different sampling events for Area P-502A, demonstrating concentrations below ER-L values in both years. For Area P-502A, all other chemicals analyzed demonstrated similarly low or non-detect concentrations in 2005 and 2006.

4.1.6 High Resolution Cores

Additional sediment cores were analyzed for specific chemical constituents in the vicinity of station P-436B1. A previous sediment evaluation (Weston 2005b) found elevated levels of metals, PCBs and PAHs in the area. In order to determine the spatial magnitude, both horizontally and vertically, of the area of elevated contaminates, five sediment cores were collected and analyzed near P-436B1 and a sixth sediment core (RQ1) was collected opportunistically and analyzed near the intersection of Papa and Quebec wharves. High Resolution Core RQ1 was located in an area historically occupied by a floating dry dock.

Table 4-1 compares the distribution of contaminants within this area. The upper and lower segments of each high resolution core are compared to the P-436B composite described in Section 3.2.1.2. It should be noted that station location P-436B1, which was included in the P-436B composite sample, is co-located with High Resolution Core HR1. Vertically, there was no apparent trend in chemical concentrations. Also, horizontally, there was no apparent trend in chemical concentrations with the exception that station RQ1, furthest removed from P-436B1, consistently had chemical concentrations below the concentrations measured in the P-436B composite sample.

A mean ER-M quotient (ER-Mq) was used to compare metals concentrations between stations (See Section 2.2.3 for a discussion on ER-Mq values). The upper and lower sections of HR5 had the greatest number of metals exceeding ER-M values (consistent with the site's high ER-Mq values of 4.8 and 2.8 in the upper and lower core segments, respectively). High Resolution Core 3 (HR3) and High Resolution Core 6 (RQ1) each had an ER-Mq below 1 in both their upper and lower sections.

Throughout all the high resolution cores, benzo[a]pyrene and dibenz[a,h]anthracene were consistently elevated with respect to ER-L or ER-M values, with the exception of benzo[a]pyrene in the upper segments of High Resolution Core HR1 and High Resolution Core RQ1 (Table 3-3). Other PAHs which occasionally were elevated with respect to ER-L values included acenaphthylene, anthracene, benz[a]anthracene, chrysene and pyrene.

Although no discernable trends in the chemical concentrations around station P-436B1 were identified, the comparison of the high resolution cores to the Area P-436B composite core suggests the elevated chemical concentrations are limited to the area fronting Oscar Wharf and not widespread throughout Area P-436B. Wilcoxon Signed Rank and Chen tests were performed to determine if the chemical concentrations in sediments collected from the five high resolution cores in the area fronting Oscar Wharf were significantly greater than the P-436B composite sample. With the exception of nickel, the mean concentration of all the metals analyzed in the high resolution cores was significantly greater than the area composite sample. Also, total PCBs were significantly greater in the high resolution cores samples compared to the P-436B composite sample. The tests were inconclusive regarding the difference in total detectable PAH concentrations.

Using similar statistical analysis methods, arsenic, copper, lead and nickel were the only analytes to have significantly greater sediment concentrations in the upper segments of the cores compared to the sediment concentrations in the lower segments.

Table 4-1. Comparison of High Spatial Resolution Sediment Cores to the P-436B Composite Sample.

Analyte	ER-L	ER-M	Core Segment	P436B1/ HR1	HR2	HR3	HR4	HR5	RQ1	P-436B Composite
Metals (mg/kg)										
Metals ER-Mq	-	-	Upper	2.1	0.9	0.7	1.5	4.8	0.8	1.2
			Lower	1.6	1.4	0.9	0.8	2.8	0.4	
PCBs (ug/kg)										
Total Detectable PCBs	22.7	180	Upper	147.9	127.1	**292.5**	**355.6**	87.1	48.6	114.5
			Lower	**246.4**	**347.7**	**266.1**	**303.9**	**445.3**	0.0	
PAHs (ug/kg)										
Total Detectable PAHs	4022	44792	Upper	2619.5	3838.2	5283.7	7495.2	4115.6	2406.4	6417.1
			Lower	3072.1	7591.0	2781.4	4973.8	9492.4	4086.2	

38.6	Underlined values are greater than the ER-L
483.8	Bolded values are greater than the ER-M
	Highlighted values are greater than the Area P-436B composite sample

4.2 BIOLOGICAL TESTING

4.2.1 Suspended Particulate Phase Tests

4.2.1.1 Area P-436

The SPP tests conducted with *D. excentricus*, *M. bahia* and *M. beryllina* on all P-436 project sediment resulted in LC50 values greater than 100%, indicating a lack of toxicity to echinoderm larvae, mysid shrimp and marine fish, respectively. Based on these three SPP tests, sediment from P-436 is suitable for ocean disposal.

4.2.1.2 Area P-518

The SPP tests conducted with *D. excentricus*, *M. bahia* and *M. beryllina* on all P-518 project sediment resulted in LC50 values greater than 100%, indicating a lack of toxicity to echinoderm larvae, mysid shrimp and marine fish, respectively. Based on these three SPP tests, sediment from P-518 is suitable for ocean disposal.

4.2.1.3 Area P-502

The SPP tests conducted with *D. excentricus*, *M. bahia* and *M. beryllina* on P-502 project sediment resulted in LC50 values greater than 100%, indicating a lack of toxicity to echinoderm larvae, mysid shrimp and marine fish, respectively. Based on these three SPP tests, sediment from P-502 is suitable for ocean disposal.

4.2.2 Solid Phase Bioassays

4.2.2.1 Area P-436

The SP tests conducted with *A. abdita* and *N. arenaceodentata* on all P-436 project sediment resulted in acceptable survival rates with the exception of *A. abdita* survivorship in Areas P-436B and P-436C. Amphipod survival in the reference sediment was only 53% (likely due to a high percentage of coarse-grained material and low TOC content in the sample); therefore, amphipod survival was compared to control survival (91%). *A. abdita* survivorship was 84% in organisms exposed to Area P-436A sediment, 91% in Area P-436D and 79% in Area P-436E, resulting in acceptable survival rates. Sediment from Areas P-436A, P-436D and P-436E met the LPC requirements.

Survival of A. abdita exposed to P-436B and P-436C sediments showed significantly lower survival compared to control and had more than a 20% reduction from control; therefore, it does not meet the LPC requirements. *A. abdita* survival in Area P-436C sediment was 70%. Survivorship of *A. abdita* in Area

5. CONCLUSIONS

P-436

- Chemistry analyses of project sediments from Areas P-436A, P-436B, P-436C, P-436D and P-436E indicate relatively low concentrations of all analytes measured with a few exceptions. In Area P-436B, mercury, nickel, zinc and total PCBs were detected at concentrations above the ER-M value. In Area P-436E, DDT and its derivatives were detected at concentrations above the ER-M value.

- SPP toxicity tests were conducted on elutriate samples derived from Areas P-436A, P-436B, P-436C, P-436D and P-436E project sediment and site water. Results from these tests showed no toxic effect to test organisms. Based on the results of these bioassay tests, the proposed dredged material is recommended as suitable for ocean disposal.

- SP toxicity tests were conducted on project sediments from Areas P-436A, P-436B, P-436C, P-436D and P-436E. Results from these tests showed no toxic effect to test organisms exposed to P-436A, P-436D or P-436E sediment. Toxic effects were observed in amphipods (*A. abdita*), but not marine polychaetes (*N. arenaceodentata*), exposed to P-436B and P-436C sediment. Based on the results of these bioassay tests, proposed dredged material from Areas P-436A, P-436D and P-436E is recommended as suitable for ocean disposal. Proposed dredged material from Area P-436C is technically not suitable for ocean disposal based on criteria outlined in the OTM (USEPA and USACE 1991). However, this material should be considered for ocean disposal because it only failed to meet the LPC requirements by one percentage point in one SP test (i.e., survival of amphipods was 70% and was 21% lower than survival in control sediment, 91%. Proposed dredged material from Area P-436B is not recommended as suitable for ocean disposal.

- BP tests were conducted on tissues from organisms exposed to Area P-436 project sediments. Elevated tissue concentrations in Areas P-436A, P-436B, P-436D and P-436E were compared to ERED and CBR data. All comparisons to contaminant concentrations in tissues from organisms exposed to P-436 project sediments were below published relevant effect levels. In addition, none of the chemicals in the P-436 project area that were measured above concentrations in tissues from reference test organisms have a tendency to biomagnify in marine food webs, with the exception of PCBs in Areas P-436C and P-436E. Based on the results of the BP tests on tissues from organisms exposed to project sediments from Areas P-436A, P-436B, P-436C, P-436D and P-436E, the proposed dredged material is recommended as suitable for ocean disposal.

- *Proposed dredged material from the P-436A, P-436D and P-436E areas is suitable for ocean disposal.*

- *Area P-436C sediment is not suitable for ocean disposal. This determination is based on the slight toxicity in one amphipod SP test. However, survival of all test organisms in SPP tests, N. arenceodentata survival in SP tests, relatively low contaminant concentrations, tissue concentrations below published relavent effects levels and low total PCB tissue concentrations (<20 µg/kg), the proposed dredged material from the P-436C area should be considered for ocean disposal despite the slightly reduced survivorship observed in the amphipod SP test.*

- *Based on multiple ER-M exceedances and significant amphipod toxicity, proposed dredged material from the P-436B area is not suitable for ocean disposal. However, further spatial delineation of the hot spot identified offshore of Oscar Wharf may result in a portion of P-436B being identified as suitable for ocean disposal.*

P-518

- Chemistry analyses of project sediments from Areas P-518A, P-518B and P-518C indicate relatively low concentrations of all analytes measured. None of the analytes were detected at concentrations greater than ER-M values. Based on the results of the chemical analysis of project sediments from Area P-518A, P-518B and P-518C, the proposed dredged material is recommended as suitable for ocean disposal.

- SPP toxicity tests were conducted on elutriate samples derived from Areas P-518A, P-518B and P-518C project sediment and site water. Results from these tests showed no toxic effect to test organisms. Based on the results of these bioassay tests, the proposed dredged material is recommended as suitable for ocean disposal.

- SP toxicity tests were conducted on project sediments from Areas P-518A, P-518B and P-518C. Results from these tests showed no toxic effect to test organisms. Based on the results of these bioassay tests, the proposed dredged material is recommended as suitable for ocean disposal.

- BP tests were conducted on tissues from organisms exposed to Areas P-518A, P-518B and P-518C project sediments. Based on information obtained from the ERED, all contaminant concentrations in tissues from organisms exposed to P-518 project sediments were below published relevant effect levels. In addition, none of the chemicals in the P-518 project area that were measured above concentrations in tissues from organisms exposed to reference sediment have a tendency to biomagnify in marine food webs. Based on the results of the BP tests on tissues from organisms exposed to project sediments from Areas P-518A, P-518B and P-518C, the proposed dredged material is recommended as suitable for ocean disposal.

- *Proposed dredged material from the entire P-518 area is suitable for ocean disposal.*

P-502

- Chemistry analyses of project sediments from Area P-502A indicate relatively low concentrations of all analytes measured. None of the analytes were detected at concentrations greater than ER-L values. Based on the results of the chemical analysis of project sediments from Area P-502A, the proposed dredged material is recommended as suitable for ocean disposal.

- SPP toxicity tests were conducted on elutriate samples derived from Area P-502A project sediment and site water. Results from these tests showed no toxic effect to test organisms. Based on the results of these bioassay tests, the proposed dredged material is recommended as suitable for ocean disposal.

- SP toxicity tests were conducted on project sediments from Area P-502A. Results from these tests showed no toxic effect to test organisms. Based on the results of these bioassay tests, the proposed dredged material is recommended as suitable for ocean disposal.

- BP tests were conducted on tissues from organisms exposed to Area P-502A project sediments. Results of from these tests showed no difference in tissue uptake as compared to tissues from organisms exposed to reference sediment. Based on the results of the BP tests on tissues from organisms exposed to project sediments from Area P-502A, the proposed dredged material is recommended as suitable for ocean disposal.

- *Proposed dredged material from the entire P-502 area is suitable for ocean disposal.*

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Appendix K - Noise

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FINAL

Wyle Report

WR 08-01

Aircraft Noise Study for Andersen Air Force Base, Guam

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1.0 Introduction

The Naval Facilities Engineering Command (NAVFACENGCOM) conducts aircraft surveys at various Naval and Marine Corps facilities throughout the United States and overseas. The noise exposure contours developed during these studies are incorporated into Air Installations Compatible Use Zones (AICUZ), Range Air Installation Compatible Use Zones (RAICUZ) or other environmental documents such as Environmental Impact Statements (EIS). These documents are used to promote the compatibility of Navy and Marine Corps activities with neighboring land uses.

This noise analysis was conducted in conjunction with the Joint Guam Program Office EIS for proposed activity at Andersen Air Force Base (AFB) including the Guam Joint Military Master Plan (GJMMP). The data are based on a 2003 noise study by the Air Force Center for Engineering and the Environment[1] (AFCEE) initially intended to provide input to an AICUZ update for the installation; however, no AICUZ study was ever produced or released using the data. Data for the analysis herein was also based on Alternative A of the 2006 EIS for the establishment of a intelligence, surveillance, reconnaissance and strike capability (ISR/Strike EIS) and interviews with Andersen AFB personnel (AFCEE, 2003; DAF, 2006; Andersen AFB, 2007b; Andersen AFB 2007c). The current noise study includes analyses of a Baseline scenario, defined as Calendar Year (CY) 2006 tempo of operations; a No Action scenario, defined as CY2014 projected tempo of operations; and a Proposed Action scenario based on proposed operations for CY2014.

The No Action Scenario includes CY2006 operations plus the following changes:

- Transfer of ISR/Strike-related operations for transient B-1, B-2, B-52, F-15, F-22, KC-135R, and RQ-4 Global Hawk aircraft;
- Increased use of Andersen AFB for special exercises, resulting in up to four-fold operations increase of transient F-15A, F-16C, KC-10, KC-135 aircraft;
- Increase in Air Mobility Command (AMC) deployment-related cargo and air carrier service;
- One-for-one replacement of all aircraft carrier (CVN) airwing EA-6B “Prowler” operations with EA-18G “Growler” operations; and
- One-for-one replacement of Multimission Maritime Aircraft (MMA) P-3A operations with P-8A operations.

[1] Formerly known as Air Force Center for Environmental Excellence

The Prospective scenario includes a range of potential actions the Navy could take in addition to the actions listed above. For Andersen AFB in particular, the Navy anticipates the following changes:

- Transfer of four CH-53E, six AH-1Z, and three UH-1N aircraft in support of the USMC relocation to Guam;;
- Transfer of a Marine F/A-18D squadron in support of the USMC relocation to Guam;
- Addition of a new based MV-22 squadron; and
- Increased visits by CVN airwings to Andersen AFB, resulting in a four-fold increase of transient CVN F/A-18C, F/A-18F, SH-60B/F, EA-18G, and E-2C airfield operations.

This report has six sections followed by four appendices. Section 2.0 describes the noise metrics and technical tools used to conduct the analyses. Section 3 describes Andersen AFB. The CY2006 operations data and noise exposure are presented in Section 4. Section 5 presents the modeled operations data and noise exposure of the CY2014 No Action scenario. Section 6 presents the modeled operations data and noise exposure of the CY2014 Proposed Scenario.

Appendix A provides an in-depth discussion of noise, noise metrics, and the effect of noise on communities and the environment. Appendix B contains tables of runway and flight track utilization for all modeled aircraft. Appendix C includes representative flight profiles modeled for proposed based aircraft: CH-53, AH-1, UH-1, MV-22, and F/A-18D. Appendix D lists the maintenance run-up profiles for all modeled aircraft.

2.0 Noise Metrics, Zones and Analysis Tools

2.1 Noise Metrics

As used in environmental noise analyses, a noise metric refers to the unit that quantitatively measures the effect of noise on the environment. Although the primary noise metric for this study is a cumulative daily metric, it is built upon single-event noise metrics. Pertinent single-event and cumulative metrics and their uses are described below and in greater detail in Appendix A.

2.1.1 Maximum Sound Level (L_{max})

The highest A-weighted[2] integrated sound level measured during a single event in which the sound level changes value with time (e.g., an aircraft overflight) is called the maximum A-weighted sound level or maximum sound level (L_{max}). L_{max} is given in units of A-weighted decibels (dBA).

During an aircraft overflight, the noise level starts at the ambient or background noise level, rises to the maximum level as the aircraft flies closest to the observer, and returns to the background level as the aircraft recedes into the distance. L_{max} indicates the maximum sound level occurring for a fraction of a second. For aircraft noise, the "fraction of a second" over which the maximum level occurs is one-eighth second (ANSI, 1988). The maximum sound level is important in judging the interference caused by a noise event with conversation, TV or radio listening, sleep, or other common activities. Although it provides some measure of the intrusiveness of the event, it does not completely describe the total event because it does not account for the length of time that the sound is heard.

2.1.2 Sound Exposure Level (SEL)

SEL is a composite metric that represents both the intensity of a sound and its duration. Individual time-varying noise events (e.g., aircraft overflights) have two main characteristics: a sound level that changes throughout the event and a period of time over which the event is heard. SEL provides a measure of the net impact of the entire acoustic event, but it does not directly represent the sound level heard at any given instant. During an aircraft flyover, SEL would include both the maximum noise level and the lower noise levels produced during onset and recess periods of the overflight.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the A-weighted sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound from aircraft overflights, which typically last more than one second, the SEL is usually greater than the L_{max} because an individual overflight takes seconds and the L_{max} occurs instantaneously. SEL is considered the best metric to compare noise levels from overflights.

[2] A-weighting refers to adjustments made to the measured or computed sound pressure level at different frequencies in order to approximate the frequency response of the human ear.

2.1.3 Day-Night Average Sound Level (DNL)

Day-Night Average Sound Level is the noise measure used for federal assessment of aircraft noise exposures in communities in the vicinity of airfields/airports. Day-Night Average Sound Level is abbreviated DNL or L_{dn} and is given in dBA. DNL is an average A-weighted sound level generated by all aviation-related operations during an average or busy 24-hour period, with sound levels of nighttime noise events emphasized by adding an additional 10 dB to their measured levels. Nighttime is defined as the period from 10 p.m. (2200) to 7:00 a.m. (0700) the following morning. The 10 dB weighting accounts for the generally lower background sound levels and greater community sensitivity to noise during nighttime hours. As explained in Appendix A, DNL has been found to provide the best measure of long-term community reaction to transportation noises, especially aircraft noise.

For consistency with Air Force standard practice, DNL was based on annual average flying day (AFD) operations. The number of AFD operations is calculated for each aircraft type by dividing the annual number of operations of that aircraft type by the number of days in the year that that aircraft was active.

2.2 Clear Zones and Accident Potential Zones

Inhabited areas around airports are exposed to the possibility of aircraft accidents even with well-maintained aircraft and highly trained crews. Despite stringent maintenance requirements and countless hours of training, past history makes it clear that accidents will occur. The risk of people on the ground being injured or killed by aircraft accidents is small. However, an aircraft accident is a high consequence event and when a crash does occur, the results are often catastrophic. Because of this, the Air Force does not attempt to base its safety standards on accident probabilities. Instead, the Air Force approaches this safety issue from a planning perspective.

In support of the Air Installation Compatible Use Zone (AICUZ) program, the Air Force completed a study in 1973 that analyzed accidents that occurred within 10 nautical miles of military airfields. The study found that accidents clustered around the extended runway centerline. Three zones were based on the crash distribution: the Clear Zone (CZ), Accident Potential Zone (APZ) I, and Accident Potential Zone II. All zones are 3,000 feet wide and centered on the runway centerline. The Clear Zone has the highest accident potential of the three zones. It begins at the end of the runway and extents 3,000 feet. No structures except navigational aids and airfield lighting are allowed in the Clear Zone. APZ I is an area of reduced accident potential beginning at the end of the clear zone and extending 5,000 feet. Various industrial, manufacturing, and agricultural land uses are acceptable within APZ I. APZ II extends from the end of APZ I an additional 7,000 feet. The accident potential in APZ II is low enough that low-density housing and commercial uses are compatible with flight operations. (US Air Force, 1999)

2.3 Analysis Tools

This section describes the analysis tools used to calculate the noise levels in this report: the NOISEMAP and Rotorcraft Noise Model (RNM) computer programs.

The programs described below are most accurate and useful for comparing "before-and-after" noise levels that would result from alternative scenarios when calculations are made in a consistent manner. The programs allow noise exposure prediction of such proposed actions without actual implementation or noise monitoring of those actions. The programs also have the capability of calculating sound levels at specified points on the ground, allowing the analysis of noise-sensitive receptors.

2.3.1 NOISEMAP and RNM

Analyses of aircraft noise exposure and compatible land uses around DoD facilities are normally accomplished using a group of computer-based programs, collectively called NOISEMAP (Czech and Plotkin, 1998; Wasmer Consulting, 2006a; Page, et. al., 2007; Wasmer Consulting, 2006b). The NOISEMAP suite of computer programs was primarily developed by the Air Force, which serves as the lead DoD agency for aircraft noise modeling. The NOISEMAP suite of computer programs includes BaseOps, OMEGA10, OMEGA11, NOISEMAP, RNM and NMPlot. The suite also includes the NOISEFILE and NCFiles databases.

The BaseOps program allows entry of runway coordinates, airfield information, flight tracks, flight profiles (engine thrust settings, altitudes, and speeds) along each flight track for each aircraft, numbers of daily flight operations, run-up coordinates, run-up profiles, and run-up operations. At this stage, closed-pattern operations, which are counted by Air Traffic Control (ATC) as two operations (one departure and one arrival), are entered in the program as one noise event (one departure followed by one arrival with the aircraft remaining in the vicinity of the airfield). The OMEGA10 program then calculates the SEL for each model of aircraft from the NOISEFILE database, taking into consideration the specified speeds, engine thrust settings, and environmental conditions appropriate to each type of flight operation. The OMEGA11 program calculates maximum A-weighted sound levels from the NOISEFILE database for each model of aircraft taking into consideration the engine thrust settings and environmental conditions appropriate to run-up operations. The core NMAP program incorporates the number of daytime and nighttime flight and run-up events, the flight paths, and flight/run-up profiles of each aircraft and calculates the resulting sound level at points on the ground in the facility's vicinity. NMPlot calculates contours of equal sound level, and is used to visualize and output the modeling results. In this study, NOISEMAP Version 7.2 was used to analyze fixed-wing aircraft operations.

RNM is a computer program developed by Wyle Laboratories, Inc. for the National Aeronautics and Space Administration (NASA)-Langley Research Center (LaRC). RNM, as part of LaRC's Tilt Rotor Aeroacoustic Code (TRAC) suite of computer programs, is aimed at the prediction of far-field sound levels from tilt rotor aircraft and helicopters. DoD and the North Atlantic Treaty Organization (NATO) have adopted RNM for the environmental impact assessment of rotorcraft noise (NATO, 2000).

RNM simulates vehicle flight along a prescribed flight track, and the sound is analytically propagated through the atmosphere to specified receiver locations. RNM accounts for spherical spreading, atmospheric absorption, ground reflection and attenuation, Doppler shifts, the difference in phase between direct and reflected rays, varying terrain and ground impedance between the vehicle and the receiver. Although not utilized for this study, RNM has the ability to account for horizontally stratified atmospheres with winds and curved ray paths. RNM's acoustic algorithms are more robust than NOISEMAP's algorithms, partially due to RNM's more detailed noise database (NCFiles), consisting of one-third octave band sound hemispheres for each vehicle in its inventory. In addition to altitude and speed, RNM accounts for roll, pitch, yaw, and nacelle angles, if applicable, along each flight track for each aircraft. In this report, RNM Version 7 was used to analyze most rotary-wing aircraft/operations.

2.3.2 Topography and Noise Contours

NOISEMAP Version 7.2 and RNM Version 7 have been expanded to include atmospheric sound propagation effects over varying terrain, including hills and mountainous regions, as well as regions of varying acoustical impedance—for example, water around coastal regions. Even for flat terrain, the terrain propagation algorithms are more robust than for excluding terrain. This feature was used for computing the noise levels presented in this analysis. Elevation grid files with a grid point spacing of 500 feet were created from the National Elevation Dataset (NED) one arcsecond data (USGS, 2008). Impedance grid files were created from geographic information systems (GIS) data provided by Andersen AFB (Andersen AFB, 2007a). Because the majority of the off-base land is undeveloped jungle, the island of Guam was modeled as acoustically "soft" with a flow resistivity of 200 cgs-rayls.

Each of the noise computation programs can incorporate the number of day and night operations, flight paths, and profiles of the aircraft to calculate DNL at many points on the ground around the facility. This process results in a "grid" file containing noise levels at different points of a user specified rectangular area. The grid point spacing used to compute the noise grids for this study was 500 feet. The NMPlot program uses the grid file to draw contours of equal DNL for overlay onto maps. The NMPlot program is also capable of adding multiple grid files logarithmically and arithmetically subtracting grids.

Each program can also compute DNL for specific points of interest, e.g., noise-sensitive receptors and determine the primary contributors to the overall DNL at each point. No points of interest were modeled in this study.

3.0 Andersen Air Force Base

The following sections discuss the history, region, and vicinity of Andersen AFB, as well as the aviation users, climatic conditions, data collection efforts and historical flight operations.

3.1 Regional and Local Setting

As shown in Figure 3-1, Andersen AFB is located on the north end of the island of Guam. Guam is one of the Mariana Islands and lies approximately 3,800 statute miles southwest of Hawaii and 1,500 miles east of the Philippines. The land use on Guam is 36 percent agricultural and 47 percent undeveloped forest. (UN, 2007) The largest metropolitan area, Hagatna, is located approximately 20 miles southwest of the base.

Andersen AFB is approximately 150 miles south of the Farallon de Medinilla Island naval bombing range. In addition, nearby Air Traffic Control Assigned Airspaces provide numerous training opportunities. Northwest Field, an unlit auxiliary airfield, is approximately five miles northwest of the center of the Andersen airfield. The only other major aviation use on the island is A.B. Won Pat International Airport (Guam International Airport.)

The Andersen airfield has two parallel runways. Runway 06L/24R is 11,185 feet long and 200 feet wide. Runway 06R/24L is 10,558 feet long and 200 feet wide. Based helicopters generally depart and arrive on Pad N1 or Pad N19 on the north side of the airfield, but perform closed patterns on the runways. Field elevation is 627 feet above Mean Sea Level (MSL) (DAFIF, 2003), and the magnetic declination is 1.5 degrees East (NGA, 2006). All maps in this report depict a north arrow pointing to true north.

3.2 Historical Context

Andersen Air Force Base opened as North Field in 1944, part of an Army Air Forces plan to prevent the need for a full-scale invasion of Japan. It was primarily used as a B-29 staging base in the Pacific during WWII, when daily bombing missions over Japan were launched from North Field. When the Air Force became a separate branch of service in 1947, North Field was renamed North Guam AFB. In 1949, it was renamed Andersen AFB in honor of Brigadier General James Roy Andersen.

During the years between World War II and the Korean War, Guam was a consolidation and disposal point for surplus war materials that had accumulated in the Pacific Theater. During the Korean War, Andersen served in an administrative and logistical capacity, operating ammunition dumps and providing maintenance services to transient aircraft. After the war, Andersen began supporting bomber and aerial refueling units on rotational deployments from the United States.

Figure 3-1.
Regional Map of Guam

Andersen's role in the Vietnam conflict is legendary. In 1964, KC-135 Stratotankers assigned to the Andersen Tanker Task Force were used for the first time to support combat operations. From early 1972, Andersen AFB was the site of one of the most massive buildups of air power in history. Over 150 B-52s used all available space on the flight line, and the influx of bombers, crews, and support personnel pushed Andersen's military population past 15,000.

In 1989, control of Andersen AFB passed from Strategic Air Command to Pacific Air Forces. The 633rd Air Base Wing, a Pacific Air Forces organization aligned under Thirteenth Air Force, was activated on Andersen AFB and became the host unit, providing support services for various transient and tenant organizations. The base continues to support strategic operations in the region and serves as a staging base for activities in Asia and the South Pacific, as well as providing forward support to bomber crews deploying overseas in Europe, Southwest Asia and in the Pacific. (Andersen AFB, 2008a)

3.3 Aviation Users

Andersen AFB is an important forward-based logistics support center for contingency forces deploying in the Pacific and Indian oceans. Andersen is home to the 36th Wing, Air Mobility Command's 734th Air Mobility Support Squadron, naval unit Helicopter Sea Combat Squadron Twenty Five (HSC-25) and several other tenant organizations. The 36th Wing of the Pacific Air Forces is host unit to USAF Active, Reserve, National Guard and US Naval forces, and provides peacetime and wartime support to project global power and reach from its strategic location in the Pacific. Andersen's clear flying conditions, relatively unlimited airspace, nearby air-to-ground range, and unlit auxiliary fields make this an ideal and active training area for the U.S. military and militaries of nearby countries.

Based aircraft include the MH-60S of the Navy HSC-25 Squadron. The MH-60S Knighthawk is a four-bladed single rotor helicopter that combines the fuselage of the US Army Blackhawk with the engine, rotor system, and dynamic components of the Navy SH-60 Seahawk. MH-60S aircraft perform aerial resupply of seaborne vessels, evacuation, day/night amphibious search and rescue, and airborne mine countermeasures services.

As described in Section 4, the balance of the airfield's flight operations is by transient units. Transient fixed-wing aircraft types include B-1, B-2, and B-52 bombers, KC-135 tankers, and F-15, F-16, and F-18 fighters, among others. Regular transit and cargo aircraft include C-5, C-17, and KC-10, as well as civilian-type B747.

3.4 Climate

Guam has a tropical marine climate with high humidity and nearly constant warm temperatures. There is little seasonal or daily variation in temperature or humidity. Rain falls throughout the year, with approximately 5 inches of precipitation per month during the dry season (January to June) and frequent squalls totaling 15 inches per month in the rainy season (July through December). The island experiences moderate northeast trade winds, and infrequent typhoon activity occurs during the rainy season.

Because weather is an important factor in the propagation of noise, the computer model requires input of the average daily temperatures in degrees Fahrenheit (°F), percent relative humidity (% RH) and station pressure in inches of mercury (inHg) for each month of a year. NOISEMAP's BaseOps program computes absorption coefficients for each month and selects the median coefficient to use in the noise exposure modeling (US Air Force, 1992). Monthly average climatic data was provided by Andersen AFB. Average monthly temperature and relative humidity are plotted in Figure 3-2. Temperatures for summer months (May to September) and winter months (October to April) averaged 85 °F and 83 °F, respectively. Relative humidity for the same periods averaged 76 percent during summer months and 75 percent during winter months. The station pressure averaged 29.22 inHg. The modeled conditions selected by the BaseOps program correspond to the month of November with a temperature of 84 °F and a relative humidity of 78 percent.

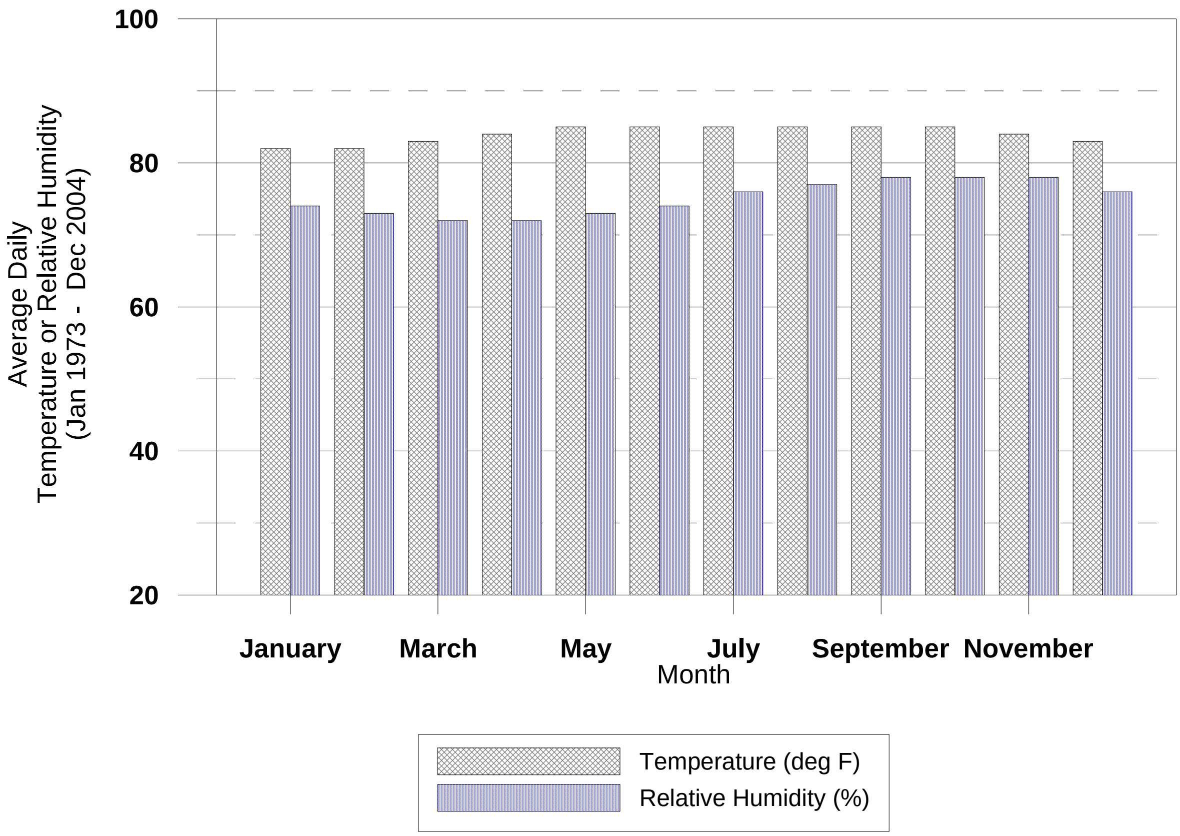

Figure 3-2. Average Daily Temperature and Relative Humidity at Andersen AFB

3.5 Noise Study Data Collection

The primary purpose of this noise study is to support the Guam Joint Military Master Plan and to estimate noise exposure due to the relocation of Marine aircraft to Andersen AFB. In May of 2007, Wyle began the data collection phase and prepared a set of data collection packages based on previous modeling of Andersen AFB. Wyle supplied the data package in electronic format to Andersen AFB and Navy personnel. These packages were used to gather and/or confirm airfield information (weather data, geographic coordinates of navigational aids, runways, etc.), points of interest and noise-sensitive receptors, numbers of existing flight operations, flight tracks, runway and flight track utilization, run-up and operations.

In June of 2007, Wyle personnel traveled to Andersen AFB to review the contents of the data packages. Wyle engineers met with the contacts listed in Table 3-1 (Andersen AFB, 2007b).

Table 3-1. Contacts for Andersen AFB GJMMP Aircraft Noise Study

Name	Title/Function	Organization	Phone	E-Mail
Bob Henderson	Program Manager	NAVFAC Southwest	619-532-1622	robert.k.henderson @navy.mil
Fang Yang	Project Manager	Earth Tech	212-778-8605	fang.yang @earthtech.com
Rachel Romond	Acoustical Engineer	Wyle Labs	310-322-1763	rachel.romond @wyle.com
Geral Long	Project Manager Alternate	Wyle Labs	703-415-4550	geral.long @wyle.com
Jun H. Abaya	Architect/Planner	36 CES	671-366-2075	jun.abaya @andersen.af.mil
LCDR Jonathan Kline	Maint. Officer	HSC-25	671-366-2218	jonathan.kline @hsc25.navy.mil
SMSgt Fred Erolin	Chief Controller	36 OSS/OSAT (ATC/Tower)	671-366-3416	fred.erolin @andersen.af.mil
TSgt Danielle Gresser	TERPS	36 OSS/OSAT (ATC)	671-366-4306	danielle.gresser @andersen.af.mil
Pat Larson	Air Terminal Manager	734 AMS/TR (AMC)	671-366-7220	patrick.larson @andersen.af.mil
CMsgt Al Irwin	AMC Maintenance Superintendent	734 AMS/MX (AMC)	671-366-7346	alvin.irwin @andersen.af.mil
Capt. Allen Neyland	36 MSX OpsO	36 MSX (Maint. Sqn)	671-366-6121	allen.neyland @andersen.af.mil
Maj Rob Puckett	36 OSS / ADO	36 OSS (Base Ops)	671-366-1016	robert.puckett @andersen.af.mil
Capt Paul Lee	Weather Flight Commander	36 OSS/OSW (Weather)	671-366-3176	paul.lee @andersen.af.mil
SMSgt Darron Williams	Airfield Manager	36 OSS/OSAM	671-366-1196	darron.williams @andersen.af.mil
Rich Storaci	FAA Airspace	FAA Guam ARTCC	671-473-1234	richard.storaci @FAA.gov
Michael D. Lynn	QAE Transient Alert	36 MXS	671-688-7107	michael.lynn @andersen.af.mil

As a result of the June 2007 site visit, significant changes were made to the flight tracks, aircraft mix, and operations of the previous modeling. After the results of the June site visit were integrated into the model, Wyle prepared data verification packages. The Navy program manager returned to Andersen AFB and confirmed the remainder of information needed to estimate noise exposure (Andersen AFB, 2007c).

3.6 Historical Flight Operations

For the purposes of Air Traffic Control (ATC), a flight operation is defined as a takeoff or landing of one aircraft, with closed patterns counted as two operations. The counts in this and subsequent sections of this report do not include operations at Northwest Field (except for interfacility flights by Andersen based aircraft), Guam International Airport, nor transitions through the airspace above Andersen AFB.

Table 3-2 and Figure 3-3 show historical aircraft operations at Andersen AFB for CY2001 through CY2006 from Air Traffic Activity Reports (ATARs). Over the past six years, operational tempo has been fairly constant. The peak operation was reached during CY2005 with 30,642 aircraft operations, of which 29,102 were by Air Force or other military aircraft. The year with the least amount of activity over the past six years is CY2004 with 29,623 operations, of which 27,998 were Air Force or other military aircraft. As depicted in Table 3-2 and Figure 3-3, military aircraft account for approximately 95 percent of the flight operations.

Table 3-2. Historical Annual Flight Operations from Air Traffic Activity Reports

Annual Operations from ATARs				
		Civil		
Calendar Year	Military	Air Carrier	General Aviation	Total
2006	28,903	623	929	30,455
2005	29,102	605	935	30,642
2004	27,998	620	1,005	29,623
2003	28,705	635	1,000	30,340
2002	28,705	635	1,000	30,340
2001	28,705	635	1,000	30,340

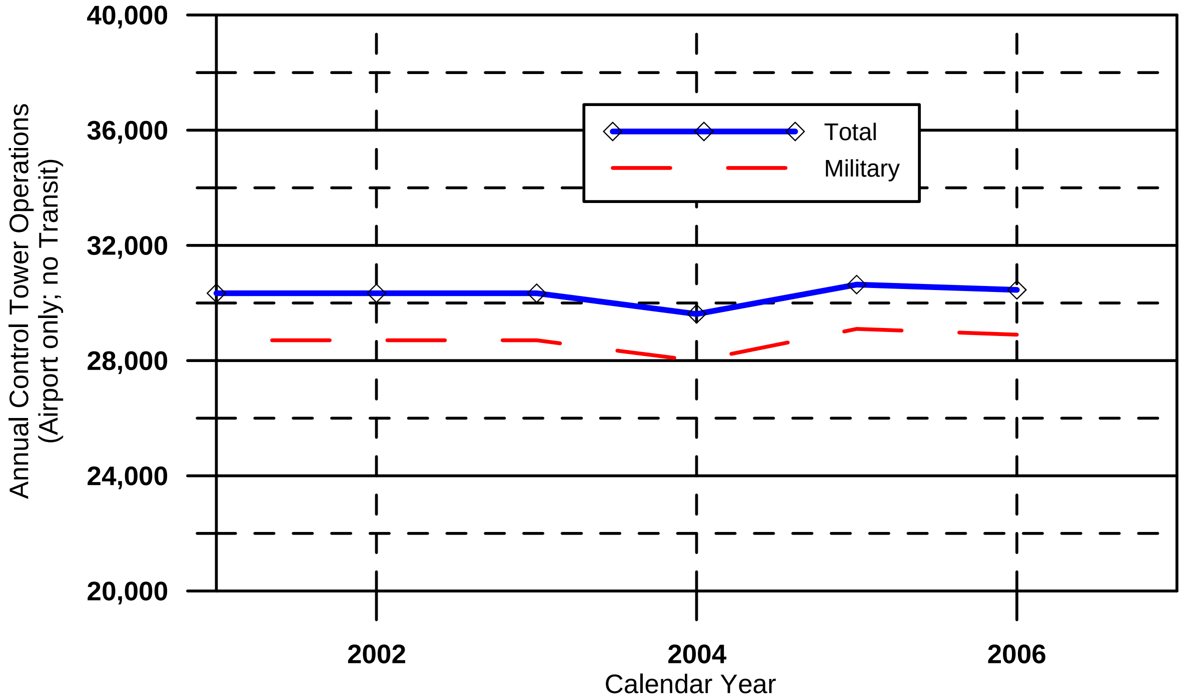

Figure 3-3. Annual Flight Operations at Andersen AFB

3.7 Clear Zones and Accident Potential Zones

Clear Zones and Accident Potential Zones for Andersen AFB are shown in Figure 3-4. They were determined using the standard Air Force geometry described in Section 2.

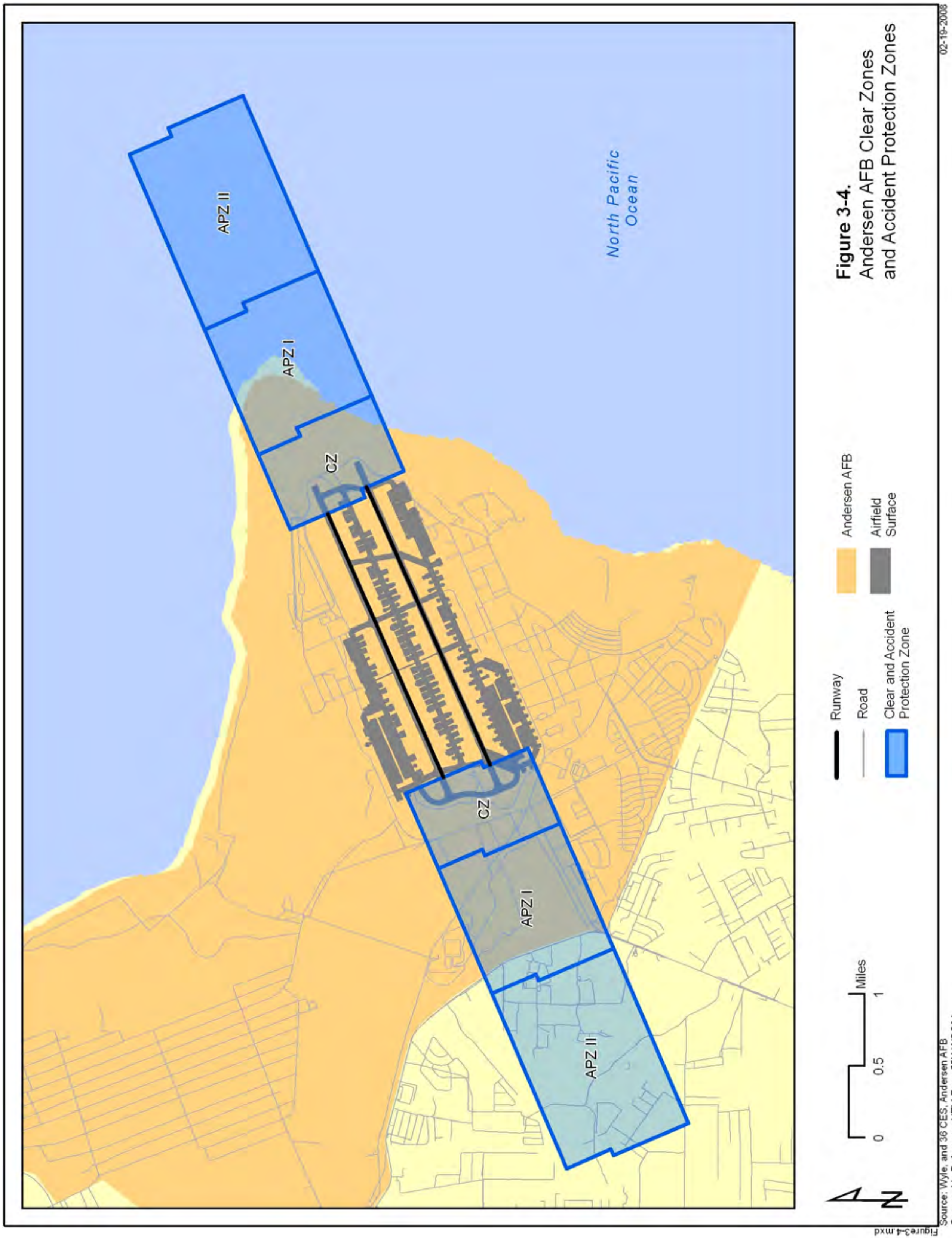

Figure 3-4. Andersen AFB Clear Zones and Accident Protection Zones

4.0 Baseline (CY2006) Scenario

The Baseline scenario for Andersen AFB is defined as airfield operations during CY2006. Northwest Field is considered a separate airfield, and operations other than based aircraft interfacility flights are not included in this analysis. Section 4.1 discusses flight operations by aircraft type. Section 4.2 discusses runway/helipad utilization, flight track utilization, flight profiles and daily operations by aircraft type. Section 4.3 describes maintenance run-up operations, and Section 4.4 discusses the calculated DNL contours.

4.1 Flight Operations

The first step in the noise analysis process is to determine the number of annual flight operations for the year studied. The computer noise model requires input of the annual operations by aircraft type, operation type, and temporal period (acoustical daytime hours of 0700-2200 and nighttime hours of 2200-0700). Upon inspection by Andersen AFB staff, the aircraft mix and flight operations numbers from the 2003 noise study were found to be out of date. As the military ATARs counts were fairly constant from 2001 through 2006, the total number of annual flight operations for the Baseline scenario was based on the 2006 ATAR count. Operations by aircraft type were based on interviews with Andersen AFB staff from Base Operations, Tower, Air Mobility Command (AMC), Maintenance, and HSC-25 (Andersen AFB, 2007b; Andersen AFB, 2007c). The Baseline scenario includes operations by deployed transport and AMC aircraft, Coronet West, Valiant Shield, Cope North and SOCPAC exercises, and visiting CVN airwings.

Table 4-1 shows the resultant numbers of operations by aircraft group, modeled aircraft type, and period of day for the Baseline scenario. Annual based and transient military flight operations and civilian Air Carrier total 29,524, which is two less than what would be derived from Table 3-2 due to rounding. General Aviation (GA) operations were not modeled and their contribution to the overall aircraft noise environment would likely be insignificant relative to the contribution of the military and air carrier aircraft.

Operation types include departures, straight-in (nonbreak) arrivals, overhead break arrivals, touch-and-go patterns, and ground controlled approach (GCA) patterns. According to Andersen AFB Tower personnel, less than seven field carrier landing practice (FCLP) operations were performed at Andersen AFB between January and December 2007, so FCLP operations were not modeled for any aircraft. Due to lack of flight profile input, C-130 and E-2 overhead breaks were modeled as non-breaks and C-130 touch-and-go and GCA Box pattern operations were not modeled.

Because much of Andersen AFB flight activity is by deployed or transient aircraft, the fleet mix for the Baseline scenario includes many aircraft types. The top users of the airfield are the MH-60S Knighthawks in HSC-25 (modeled as SH-60B aircraft in RNM), with 66 percent of the total military operations. Jet tankers (modeled as KC-135R) are the next most frequent users of the airfield, with approximately 10 percent of the total operations. F/A-18E/F and T-45 comprise eight percent of the total operations. The next most frequent users are transient F-15s, with approximately seven percent of the total operations. Based HSC-25 aircraft perform approximately 6 percent of their operations during the acoustical nighttime (10pm – 7am) period, and transient aircraft perform an average of 14 percent of their operations during the same period.

Table 4-1 Baseline (CY2006) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go(1)			GCA Box(1)			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
HSC-25	OM Helo	SH60B	2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Local & Transient	Jet	B-1	80	9	89	80	9	89	-	-	-	322	36	358	161	18	179	643	72	715
	Jet	B-2	49	6	55	49	6	55	-	-	-	198	22	220	99	11	110	395	45	440
	Jet	B-52H	95	10	105	95	10	105	-	-	-	322	36	358	161	18	179	673	74	747
	Jet	C-9A	14	3	17	14	3	17	-	-	-	-	-	-	-	-	-	28	6	34
	Jet	KC-10A(2)	60	50	110	101	9	110	-	-	-	124	14	138	62	7	69	347	80	427
	Jet	C-21A(4)	24	6	30	24	6	30	-	-	-	-	-	-	-	-	-	48	12	60
	Prop	C-130H&N&P(3,5)	43	-	43	22	-	22	22	-	22	172	-	172	86	-	86	345	-	345
	Jet	KC-135R	388	41	429	388	41	429	-	-	-	1,240	138	1,378	620	69	689	2,636	289	2,925
	Jet	F-15A	598	-	598	11	-	11	588	-	588	964	-	964	-	-	-	2,161	-	2,161
	Jet	F-16C	9	-	9	-	-	-	9	-	9	-	-	-	-	-	-	18	-	18
Transient(7)	VM Helo	CH-46E(6)	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
	VM Helo	CH53E	6	16	22	6	16	22	-	-	-	-	-	-	-	-	-	12	32	44
	Jet	C-5A	46	186	232	209	23	232	-	-	-	-	-	-	-	-	-	255	209	464
	Jet	C-17	58	232	290	262	29	291	-	-	-	-	-	-	-	-	-	320	261	581
	Jet	C-20	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-	4	-	4
	Prop	C-12(6)	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
Transient CVN Wing	VM Jet	EA-6B	17	-	17	1	-	1	16	-	16	-	-	-	-	-	-	34	-	34
	VM Jet	F-18A/C	121	-	121	12	-	12	110	-	110	-	-	-	-	-	-	243	-	243
	VM Jet	F-18E/F	146	-	146	14	-	14	131	-	131	-	-	-	-	-	-	291	-	291
	VM Jet	C-21A(4)	17	-	17	17	-	17	-	-	-	-	-	-	-	-	-	34	-	34
	VM Prop	E-2C(5)	26	-	26	3	-	3	23	-	23	-	-	-	-	-	-	52	-	52
	VM Helo	SK70 (UH-60A) BLACKH(6)	37	2	39	37	2	39	-	-	-	-	-	-	-	-	-	74	4	78
Transient MMA	VM Prop	P-3A	78	11	89	78	11	89	-	-	-	-	-	-	-	-	-	156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	104	166	270	104	166	270	-	-	-	-	-	-	-	-	-	208	332	540
	Civilian	B-757-200-RR	33	8	41	33	8	41	-	-	-	-	-	-	-	-	-	66	16	82
Based Total			2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Military Transient Total			1,952	572	2,524	1,463	165	1,628	899	-	899	3,342	246	3,588	1,189	123	1,312	8,845	1,106	9,951
Civilian (Transient) Total			137	174	311	137	174	311	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total			5,055	837	5,892	4,198	798	4,996	899	-	899	15,080	735	15,815	1,774	148	1,922	27,006	2,518	29,524

Day = 0700-2159 local; Night = 2200-0659 Local

Notes: (1) Each Closed Pattern event (Touch and Go, GCA Box) is counted here as 2 operations (1 landing + 1 departure)

(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC-135R

(3) C-130H&N&P Closed Pattern Operations (Touch and go, GCA Box) not modeled

(4) C-21A Local& Transient Operations modeled as C-21A Transient CVN Wing

(5) Overhead Break Arrivals Modeled as Nonbreak Arrivals

(6) Ops from AFCEE's Modeling of Baseline for 2003

(7) Obtained for CVW-5 data from NAVAIR

Source: AAFB (Wyle and NAVFAC site visits)

4.2 Runway and Flight Track Utilization, Flight Profiles, and Average Flying Day Events

The next step in the noise modeling process is assignment of the flight operations to runways via runway utilization percentages for each aircraft type, operation type and DNL time period. This data was extracted directly from the 2003 noise study.

Appendix B presents the runway utilization for the modeled aircraft types. As confirmed by the 2003 noise study and interviews with Andersen AFB Tower and Base Operations personnel, fixed-wing aircraft at Andersen AFB primarily use Runway 06 because of the direction of the prevailing winds. For most aircraft, Runway 24 for used approximately three percent of the operations.

As runway usage can differ during different periods of the day, specific percentages of operations during the DNL time periods of day and night are also shown in the tables. Note the percentages are not percentages of total operations but percentages for each period and operation type – they sum vertically to 100 percent for each operation type. As listed in Appendix B, Based MH-60S (SH-60B) rotary-wing aircraft only use Pad N1 or Pad N19 for departure and arrival operations, but use the main runways for pattern work.

The next step in the noise modeling process is assignment of runway operations to flight tracks via flight track utilization percentages for each aircraft type, operation type, and DNL time period. Figures 4-1 through 4-7 depict the modeled flight tracks. The track IDs generally follow a naming convention of runway/pad ID, operation type (D for departure, U for departure from the runway underrun, A for arrival, T for touch-and-go, G for GCA Box), and sequence number or letter. Tracks for based rotary-wing aircraft follow a slightly different convention: “RW”, operation type (D for departure or A for arrival) and sequence number. The letter P is appended to the ID of tracks in the proposed scenario. The tracks were initially extracted from the 2003 noise study and reviewed by ATC and Andersen AFB Tower personnel. Modifications, additions, and/or deletions were based on squadron input and a second review by ATC and Andersen Tower (Andersen AFB, 2007a; Andersen AFB, 2007b).

Overhead break patterns measure approximately 1.5 nautical miles (NM) abeam and 2.5 NM end to end. The overhead break altitude is 2,100 feet MSL, or 1,473 feet above ground level (AGL). The pattern altitude for fixed-wing touch-and-go flight tracks is 1,600 feet MSL (973 feet AGL). The touch-and-go pattern for most fixed-wing aircraft is approximately 1 NM abeam and 4.5 NM end to end, while the touch-and-go pattern for large fixed-wing aircraft is 3 NM abeam and 7.5 NM long. Rotary-wing and tiltrotor aircraft use a smaller touch-and-go pattern that is approximately 0.25 NM abeam and 1 NM long. The rotary-wing pattern altitude is 1,100 feet MSL (473 feet AGL). Each runway has a single Ground Controlled Approach (GCA) box pattern that is used by all aircraft regardless of type. The GCA box is approximately 6 NM abeam and 17 NM end-to-end. The final approach leg is 10 NM on runway heading. The GCA box altitude is 2,200 feet MSL.

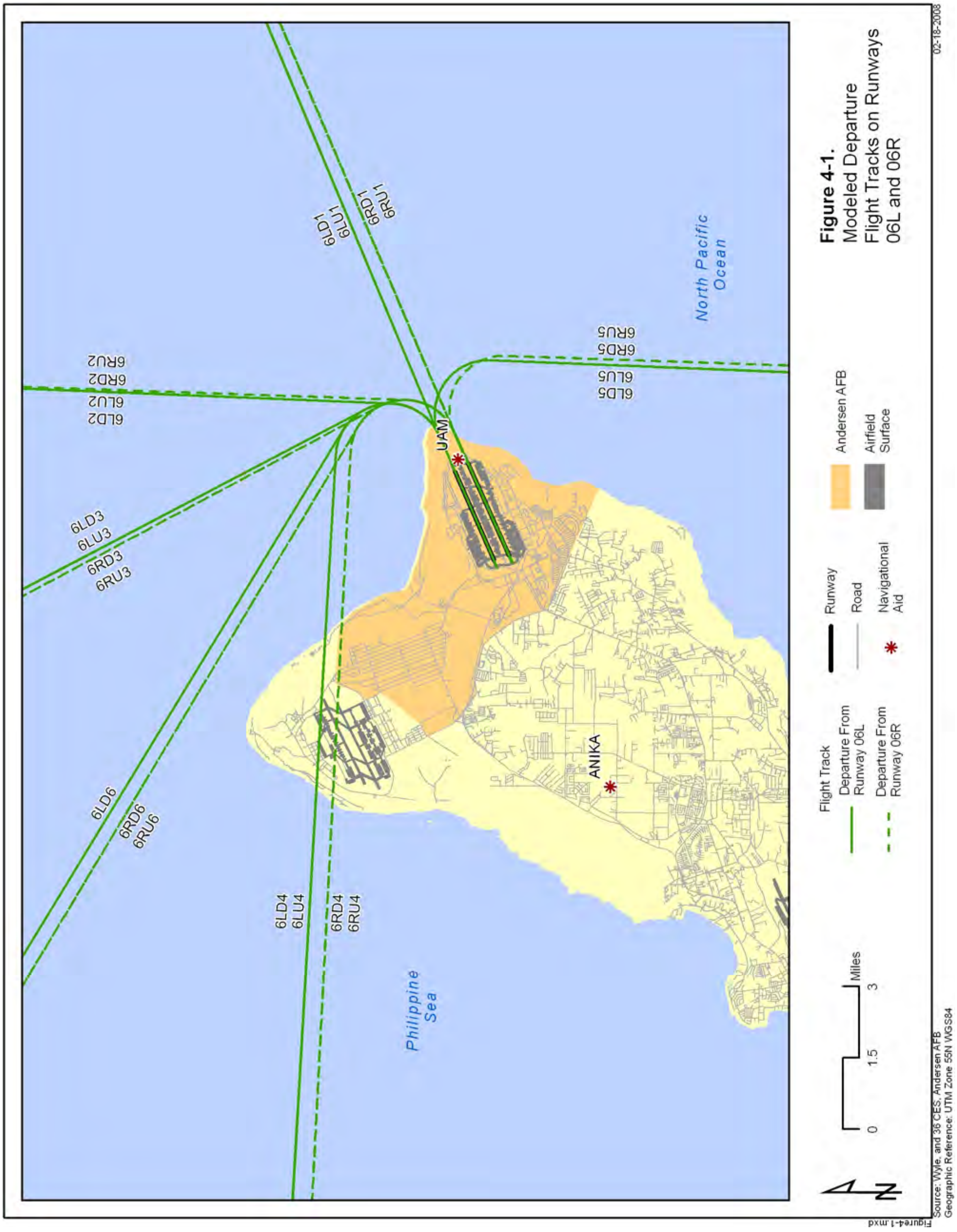

Figure 4-1. Modeled Departure Flight Tracks on Runways 06L and 06R

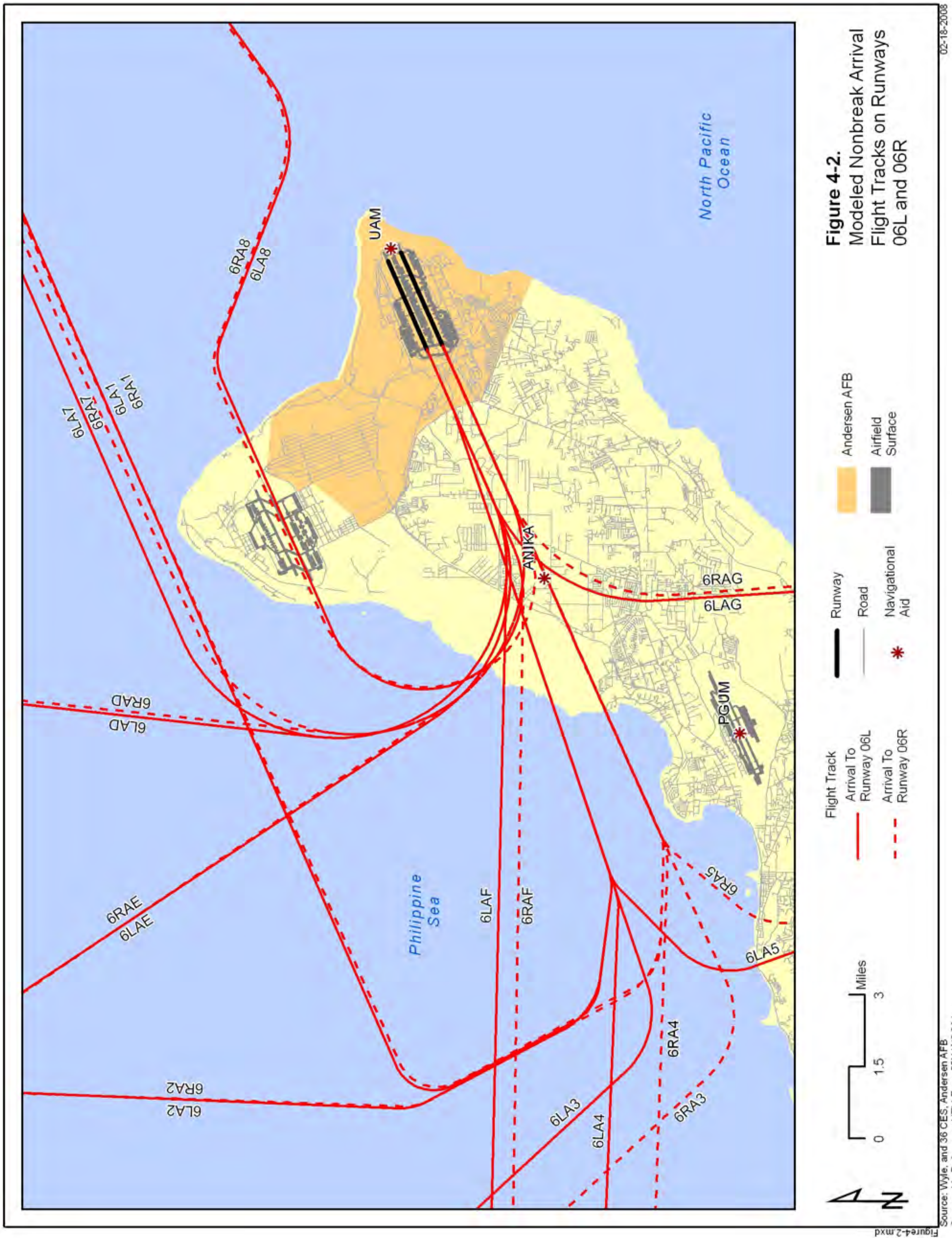

Figure 4-2. Modeled Nonbreak Arrival Flight Tracks on Runways 06L and 06R

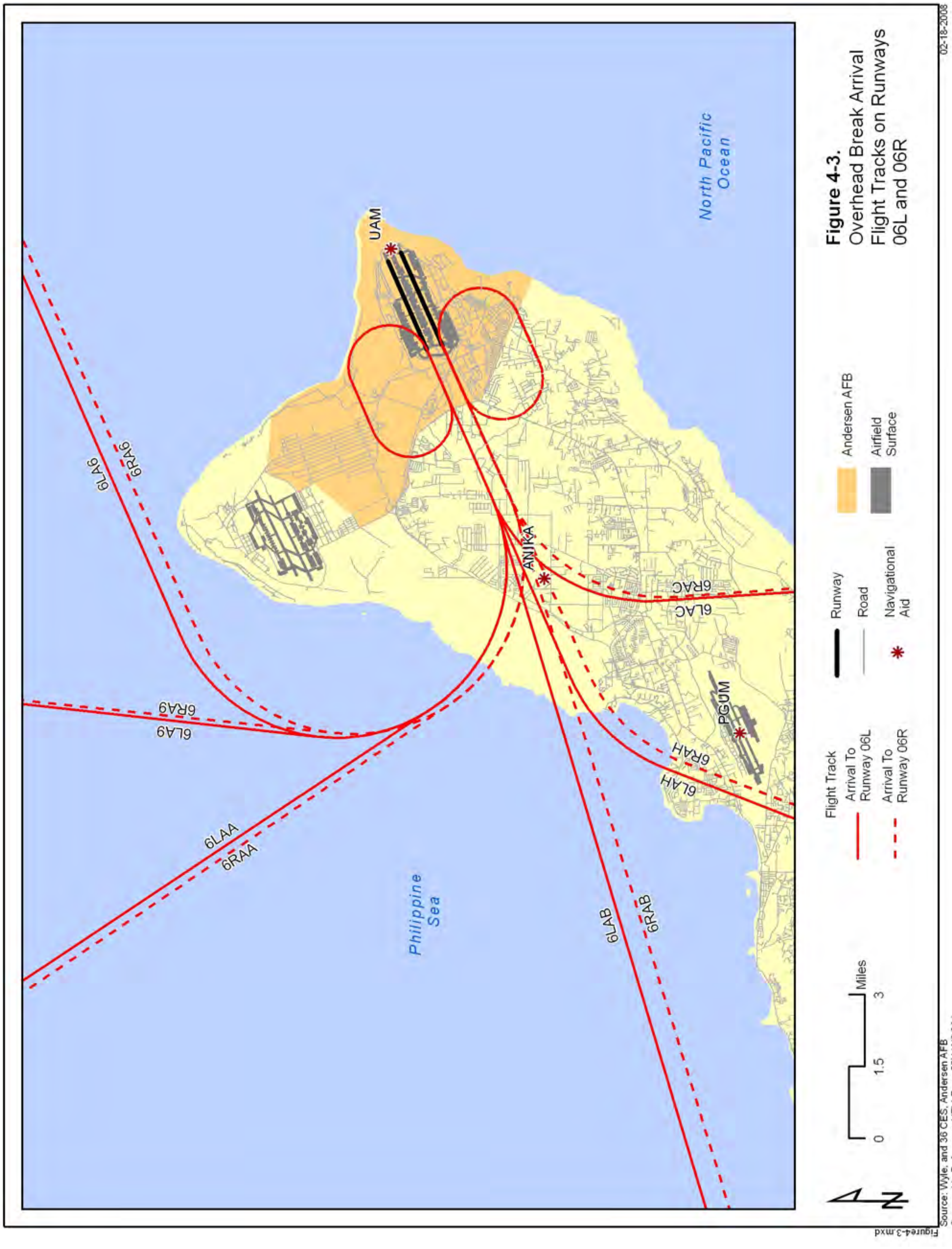

Figure 4-3. Overhead Break Arrival Flight Tracks on Runways 06L and 06R

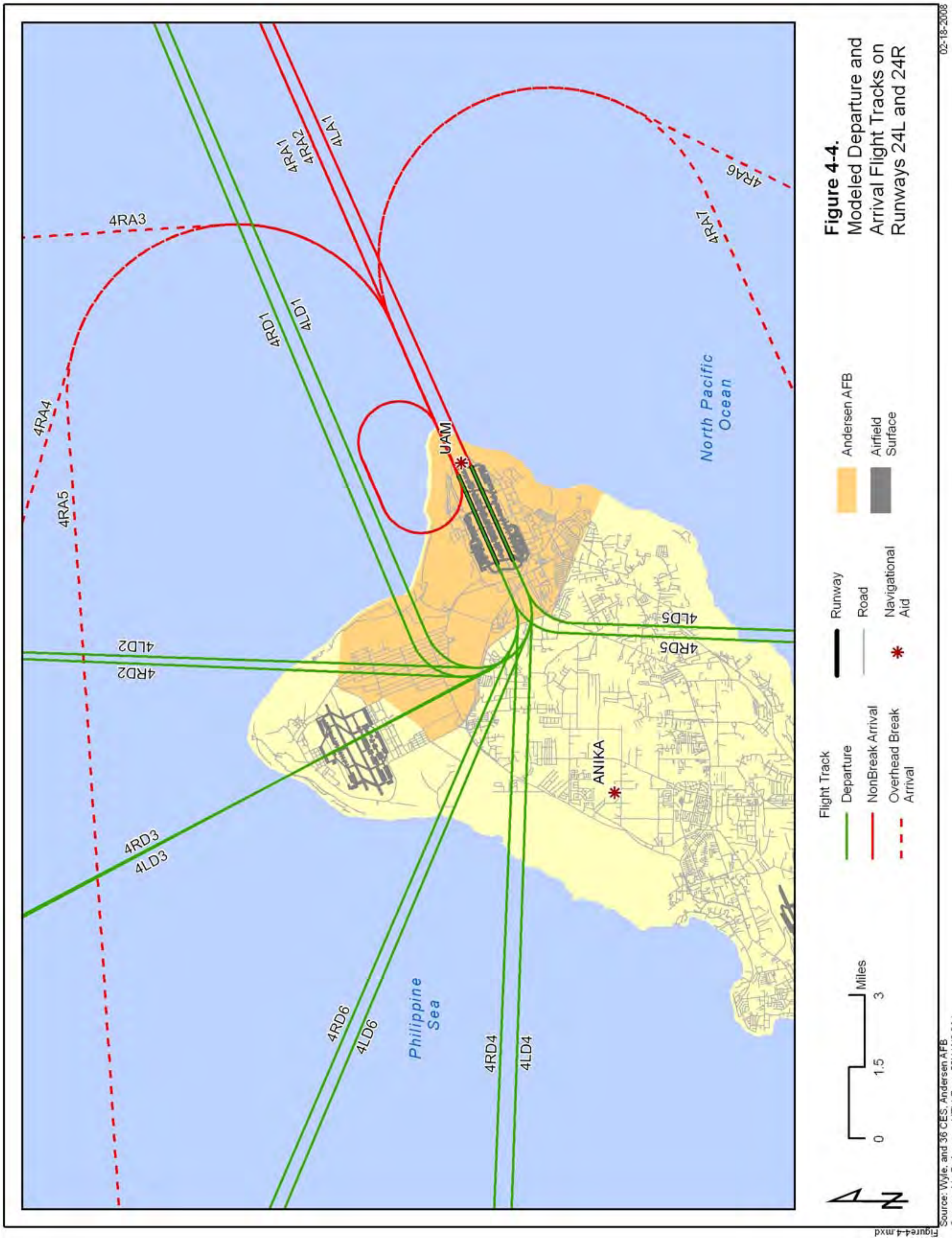

Figure 4-4. Modeled Departure and Arrival Flight Tracks on Runways 24L and 24R

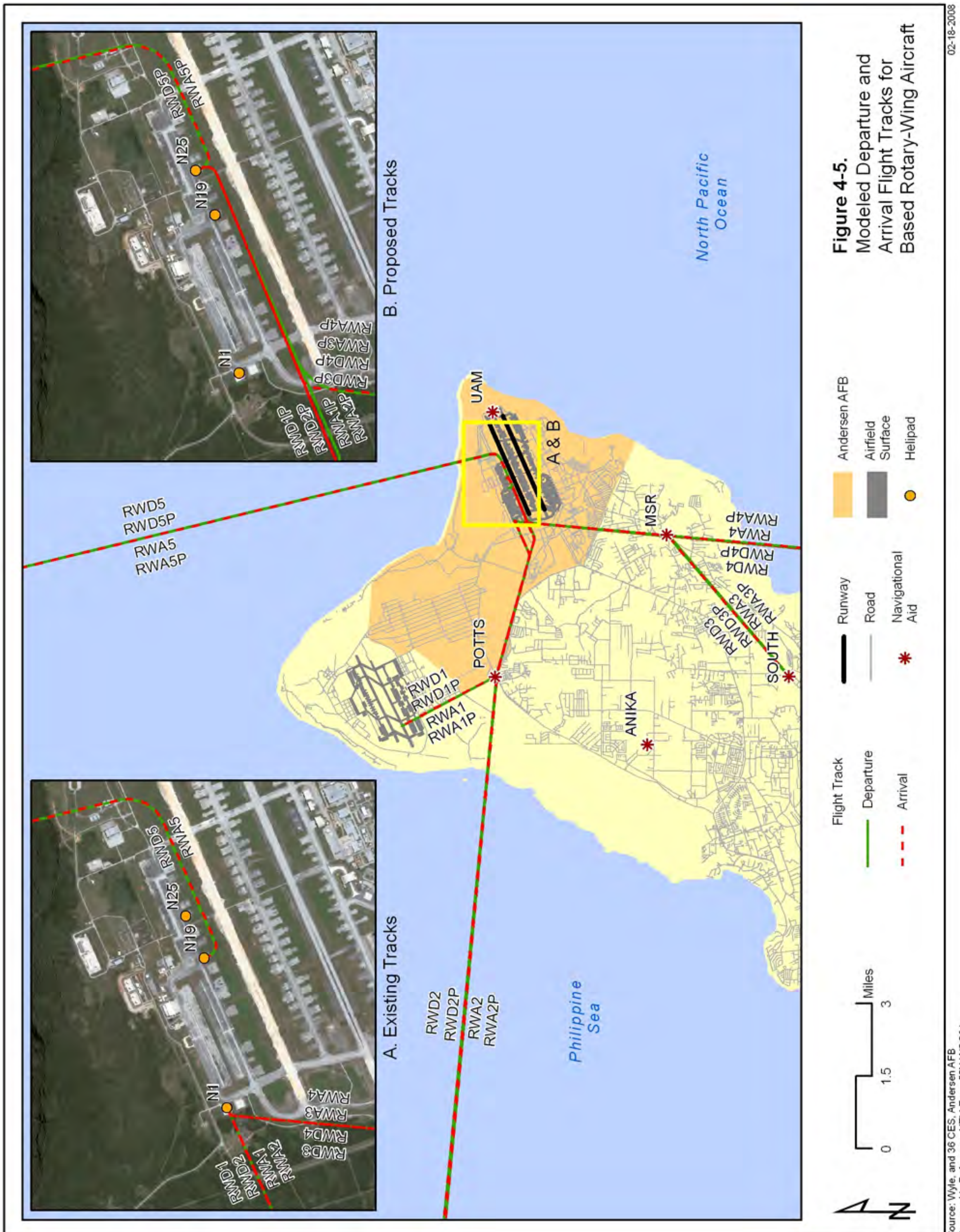

Figure 4-5. Modeled Departure and Arrival Flight Tracks for Based Rotary-Wing Aircraft

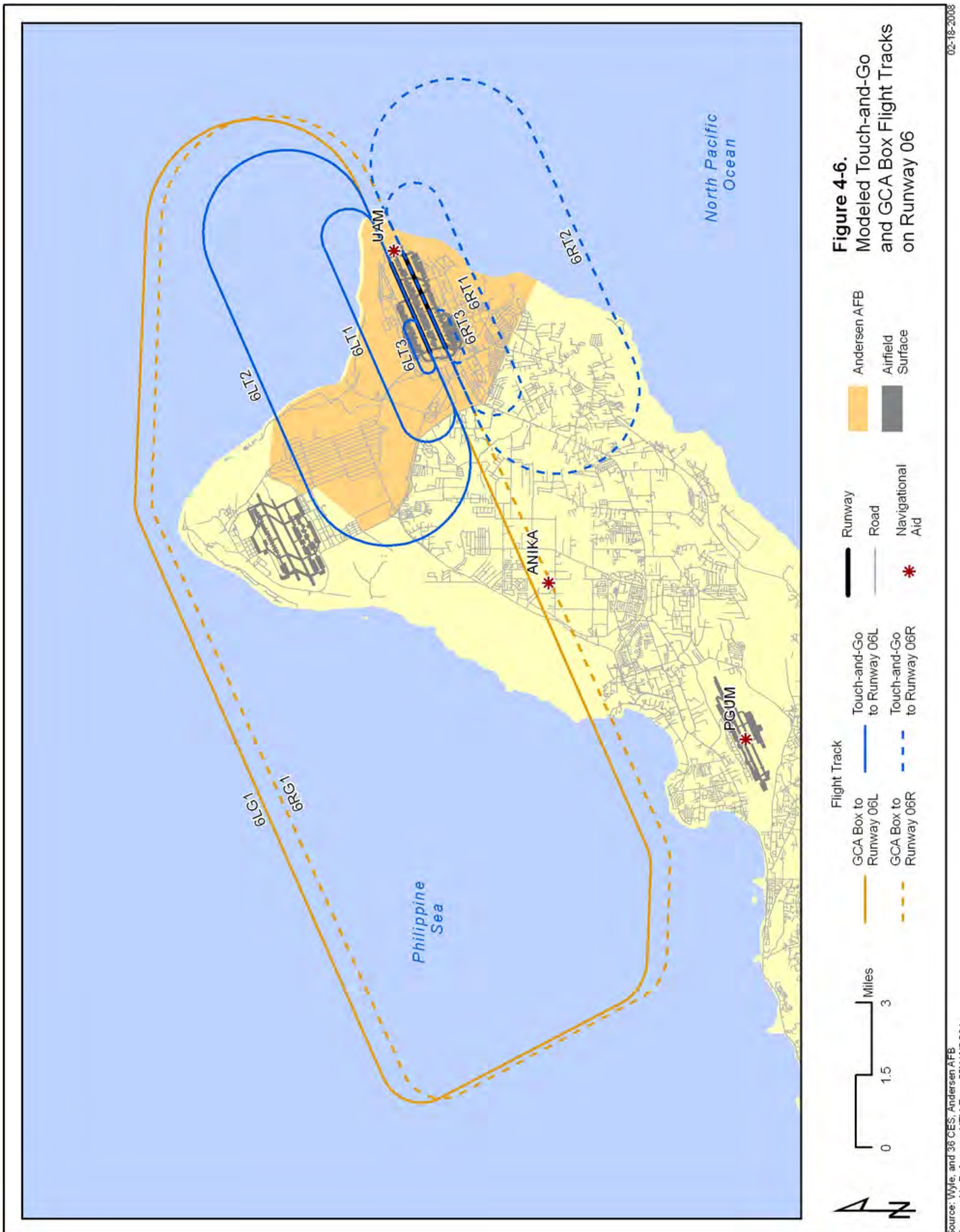

Figure 4-6. Modeled Touch-and-Go and GCA Box Flight Tracks on Runway 06

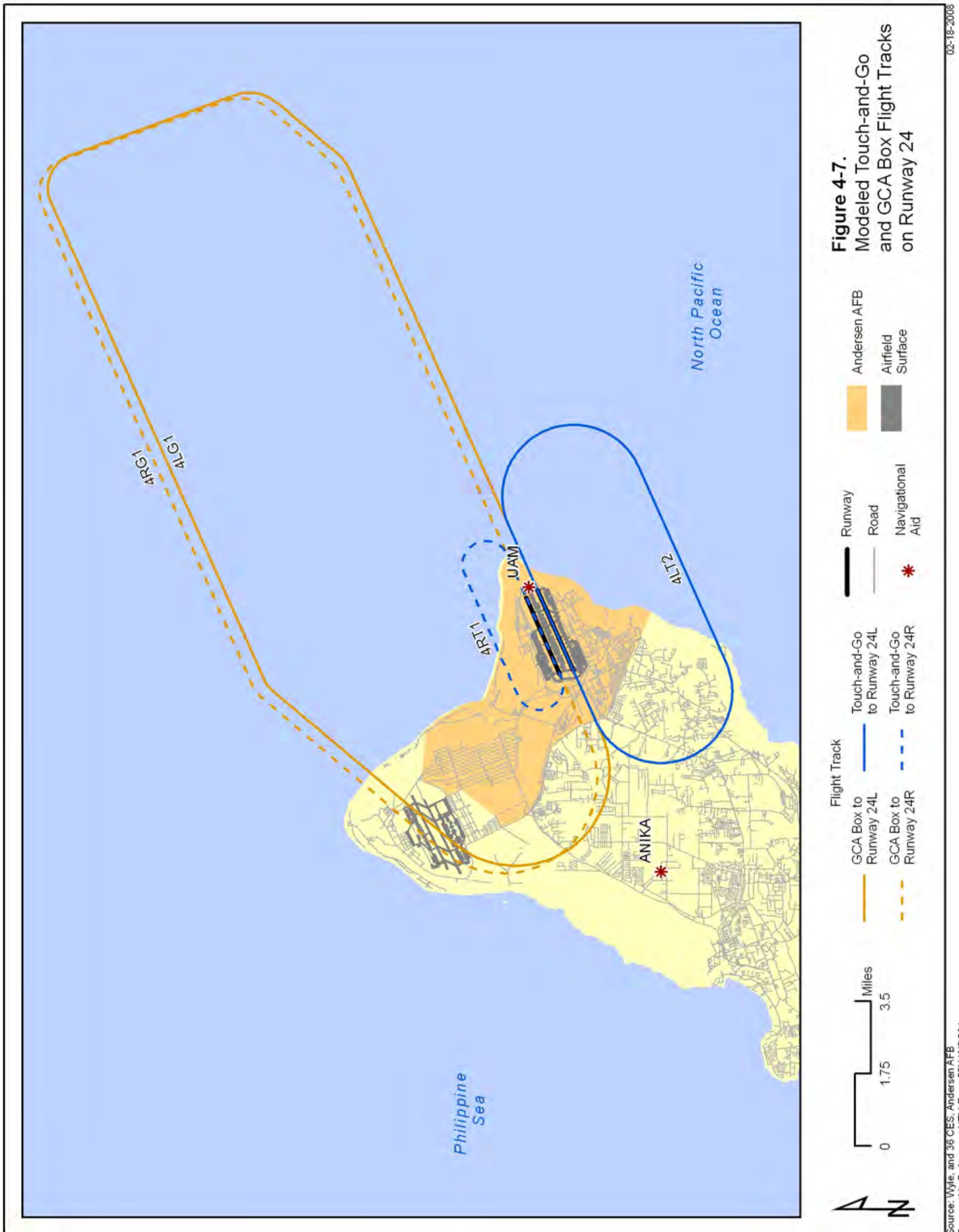

Figure 4-7. Modeled Touch-and-Go and GCA Box Flight Tracks on Runway 24

The tables in Appendix B show the modeled flight track utilization percentages for each modeled aircraft type. This data was extracted directly from the 2003 noise study and modified per changes to flight tracks. Note the percentages for each period sum vertically to 100 for each runway and operation type combination.

Fixed-wing flight profiles consist of power settings, airspeeds and altitudes at a series of points along each modeled flight track. Rotary-wing flight profiles consist of a combination of airspeeds, altitudes and attitude along each modeled flight track. Attitude consists of roll, pitch and yaw angles (and nacelle angle for tilt rotor aircraft). This data defines the vertical profile (altitude) and performance profile (power setting and/or airspeed) and orientation for each modeled aircraft.

Where applicable, flight profiles for this study were initially extracted from the 2003 noise study. Flight personnel from HSC-25 modified the profiles to be modeled for the MH-60S. Representative flight profiles for based HSC-25 aircraft are shown in Appendix C. All other flight profiles were checked for consistency with course rules, resulting in some updates to overhead break and pattern altitudes. Because of the wide array of origins for the modeled aircraft, the other aspects of the flight profiles taken from the 2003 noise study were assumed to be accurate. KC-10 closed patterns were modeled with a KC-135R surrogate due to lack of flight profile input.

Fixed-wing departure profiles can also be automatically modeled with a pre-flight run-up, conducted at the runway threshold prior to brake release. As in the 2003 noise study, nearly all fixed-wing aircraft were modeled with a five-second run-up at the takeoff power setting for that aircraft. The exceptions were B-2As, whose departure profiles included a 15-second pre-flight run-up. If an aircraft's departure profile used afterburner power, then the pre-flight run-up was modeled with afterburner power. Pre-flight run-ups were not modeled for rotary-wing or tiltrotor aircraft.

The next step in the noise modeling process is the computation of the daytime and nighttime events in an annual average flying day (AFD) for each aircraft's flight profile on each modeled track. This is accomplished by dividing the track operations by the number of annual flying days for the given aircraft and dividing closed-pattern operations (e.g., touch-and-go, FCLP and GCA Box) by 2[3]. As in the 2003 noise study, the based MH-60Ss and all transient aircraft were modeled with 356 flying days per year. The resultant daily numbers of events are presented in Table 4-2 There are approximately 56 events per average flying day, 34 of which are based aircraft, 20 are other military transient aircraft, and 2 are civilian transient aircraft.

[3] The closed pattern operations are divided by two for noise modeling purposes only. ATC counts closed patterns as two distinct operations: one departure and one arrival. In NOISEMAP and RNM, the departure and arrival are represented by one event because both operations are connected on a single flight track.

Table 4-2 Baseline (CY2006) Modeled Average Flying Day Flight Events for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
HSC-25	OM Helo	SH60B	8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Local & Transient	Jet	B-1	0.22	0.02	0.24	0.22	0.02	0.24	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.10	0.12	1.22
	Jet	B-2	0.13	0.02	0.15	0.13	0.02	0.15	-	-	-	0.27	0.03	0.30	0.14	0.02	0.15	0.67	0.09	0.75
	Jet	B-52H	0.26	0.03	0.29	0.26	0.03	0.29	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.18	0.14	1.32
	Jet	C-9A	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	-	-	-	-	-	-	0.08	0.02	0.10
	Jet	KC-10A[2]	0.16	0.14	0.30	0.28	0.02	0.30	-	-	-	-	-	-	-	-	-	0.44	0.16	0.60
	Jet	C-21A[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prop	C-130H&N&P[3,5]	0.12	-	0.12	0.12	-	0.12	-	-	-	-	-	-	-	-	-	0.24	-	0.24
	Jet	KC-135R	1.06	0.11	1.17	1.06	0.11	1.17	-	-	-	1.87	0.21	2.08	0.94	0.11	1.04	4.93	0.54	5.46
	Jet	F-15A	1.64	-	1.64	0.03	-	0.03	1.61	-	1.61	1.32	-	1.32	-	-	-	4.60	-	4.60
	Jet	F-16C	0.02	-	0.02	-	-	-	0.02	-	0.02	-	-	-	-	-	-	0.04	-	0.04
Transient	VM Helo	CH-46E[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
	VM Helo	CH53E	0.02	0.04	0.06	0.02	0.04	0.06	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12
	Jet	C-5A	0.13	0.51	0.64	0.57	0.06	0.63	-	-	-	-	-	-	-	-	-	0.70	0.57	1.27
	Jet	C-17	0.16	0.64	0.80	0.72	0.08	0.80	-	-	-	-	-	-	-	-	-	0.88	0.72	1.60
	Jet	C-20	0.01	-	0.01	0.01	-	0.01	-	-	-	-	-	-	-	-	-	0.02	-	0.02
	Prop	C-12[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
Transient CVN Wing[7]	VM Jet	EA-6B	0.05	-	0.05	-	-	-	0.04	-	0.04	-	-	-	-	-	-	0.09	-	0.09
	VM Jet	F-18A/C	0.33	-	0.33	0.03	-	0.03	0.30	-	0.30	-	-	-	-	-	-	0.66	-	0.66
	VM Jet	F-18E/F	0.40	-	0.40	0.04	-	0.04	0.36	-	0.36	-	-	-	-	-	-	0.80	-	0.80
	VM Jet	C-21A[4]	0.11	0.02	0.13	0.11	0.02	0.13	-	-	-	-	-	-	-	-	-	0.22	0.04	0.26
	VM Prop	E-2C[5]	0.07	-	0.07	0.01	-	0.01	0.06	-	0.06	-	-	-	-	-	-	0.14	-	0.14
	VM Helo	SK70 (UH-60A) BLACKH[6]	0.10	0.01	0.11	0.10	0.01	0.11	-	-	-	-	-	-	-	-	-	0.20	0.02	0.22
Transient MMA	VM Prop	P-3A	0.21	0.03	0.24	0.21	0.03	0.24	-	-	-	-	-	-	-	-	-	0.42	0.06	0.48
Civilian (Transient)	Civilian	B-747-SP (N)	0.28	0.45	0.73	0.28	0.45	0.73	-	-	-	-	-	-	-	-	-	0.56	0.90	1.46
	Civilian	B-757-200-RR	0.09	0.02	0.11	0.09	0.02	0.11	-	-	-	-	-	-	-	-	-	0.18	0.04	0.22
Based Total			8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Military Transient Total			5.34	1.58	6.92	4.06	0.45	4.51	2.39	-	2.39	4.34	0.34	4.68	1.51	0.17	1.68	17.64	2.54	20.18
Civilian (Transient) Total			0.37	0.47	0.84	0.37	0.47	0.84	-	-	-	-	-	-	-	-	-	0.74	0.94	1.68
Grand Total			13.84	2.30	16.14	11.55	2.18	13.73	2.39	-	2.39	20.42	1.01	21.43	2.31	0.21	2.52	50.51	5.70	56.21

Day = 0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and go, GCA Box) is counted here as 1 event

(2) KC-10A Closed Pattern Operation (touch and Go, GCA Box) modeled as KC-135R

(3) C-130 H&N&P Closed Pattern Operations (Touch and Go, GCA Box) not modeled

(4) C-21A Local & Transient Operations modeled as C-21A Transient CVN Wing

(5) Overhead Break Arrivals Modeled as Nonbreak Arrivals

(6) Ops from AFCEE's modeling of Baseline for 2003

(7) Obtained for CVW-5 data from NAVAIR

Source: AAFB (Wyle and NAVFAC site visits)

4.3 Maintenance Run-up Operations

Maintenance run-up operations are performed by both based and transient aircraft. Run-up modeling from the 2003 noise study was reviewed by Andersen AFB maintenance personnel for run-up location, aircraft type, and event frequency. Based MH-60S run-up data was verified by HSC-25 maintenance personnel. Because most maintenance is performed on transient aircraft, Andersen Maintenance personnel were not able to verify all run-up power profiles for fixed-wing aircraft. After removing profiles for retired aircraft and verifying the frequency, type, and duration of run-ups, remaining profiles were assumed to be accurate. Figure 4-8 shows the modeled run-up locations. Not all locations in the figure are used for the Baseline scenario. Modeled run-up operations, profiles, and locations for all scenarios are shown in Appendix D.

4.4 Baseline Scenario Noise Exposure

Using the data described in Sections 4.1 through 4.3, NOISEMAP Version 7.2, RNM Version 7.0 were used to calculate and plot the 60 dB through 85 dB DNL contours for the AFD operations for Andersen AFB, as shown in Figure 4-9.

The off-base overland portion of the 60 dB DNL contour extends along runway heading approximately five statute miles southwest of the base boundary. The off-base overland portion of the 65 dB DNL contour extends approximately 2.5 miles southwest of the AFB boundary. The main contributors to off-base overland noise exposure are the approaches to Runway 06R and pattern work on Runway 06R. The highest off-base overland DNL exposure outside Andersen AFB property is between 75 dB and 80 dB DNL evidenced by the 75 dB DNL contour extending approximately 600 feet past the southwest base boundary.

Figure 4-8. Modeled Run-Up Locations

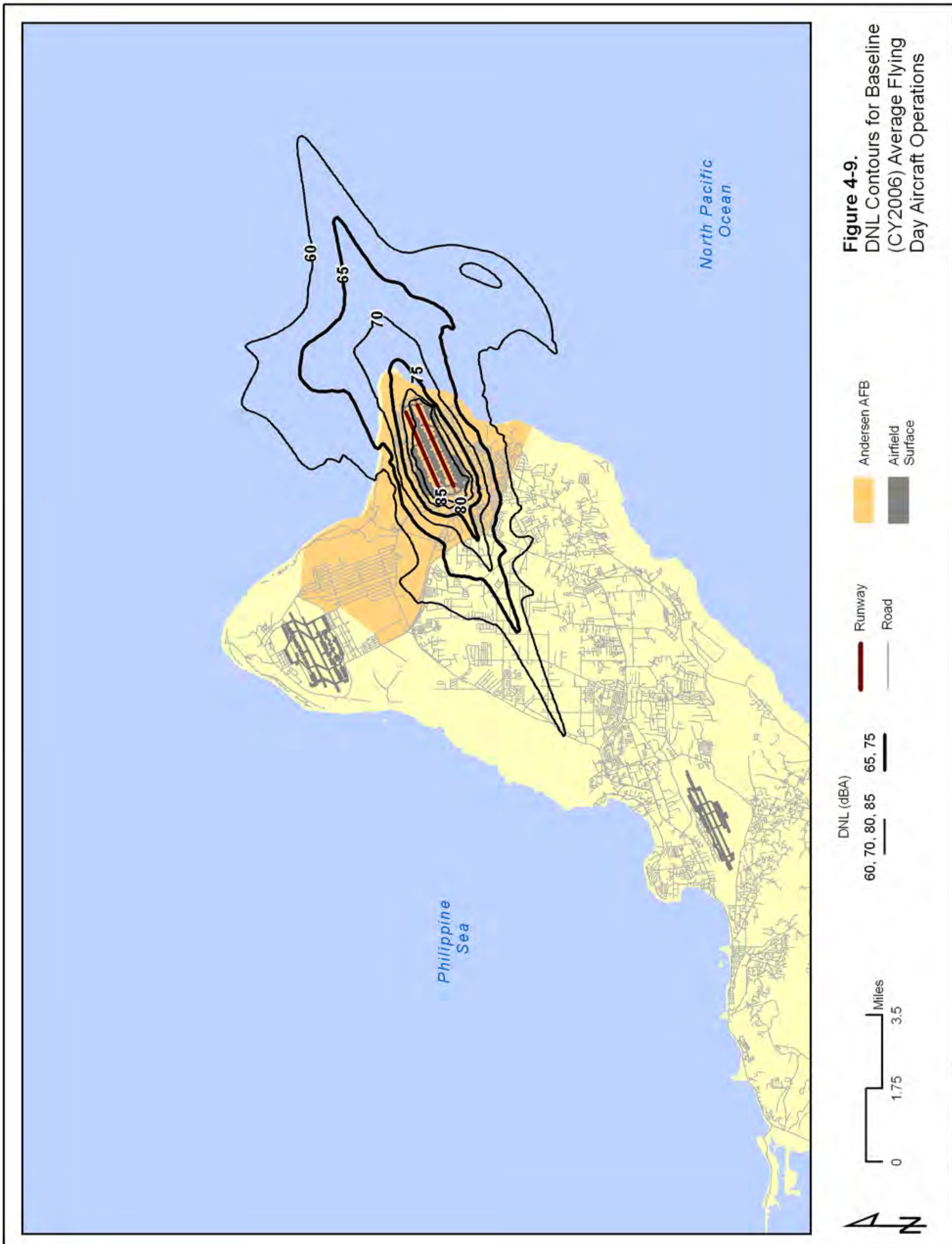

Figure 4-9. DNL Contours for Baseline (CY2006) Average Flying Day Aircraft Operations

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5.0 No Action (CY2014) Scenario

The No Action scenario models projected Andersen AFB airfield operations during CY2014. Northwest Field is considered a separate airfield. Except for based aircraft interfacility flights, operations at Northwest Field are not included in this analysis. Section 5.1 discusses flight operations by aircraft type. Section 5.2 discusses runway/helipad utilization, flight track utilization, flight profiles and daily operations by aircraft type. Section 5.3 describes maintenance run-up operations, and Section 5.4 discusses the calculated DNL contours.

5.1 Flight Operations

Calendar Year 2014 No Action operations are based on the Baseline CY2007 operations, with increases in mission- or exercise-specific aircraft provided by Andersen AFB personnel. These additions include:

- Addition of ISR/Strike-related operations for transient B-1, B-2, B-52, F-15E, F-22, KC-135R, and RQ-4 Global Hawk aircraft. 2014 will be during Phase 1 of ISR/Strike deployment, and the additional operations were calculated by scaling Phase 4 operations by the ratio of Phase 1 and Phase 4 aircraft loading;
- Increased use of Andersen AFB for special exercises, resulting in three times the number of operations for transient heavies (modeled as KC-10A and KC-135R) and four times the number of operations for transient fighters (modeled as F-15A and F-16C);
- Increased Air Mobility Command (AMC) deployment-related cargo and air carrier sorties by MD-11 (modeled as KC-10A) and C-17 aircraft;
- One-for-one replacement of all CVN airwing EA-6B “Prowler” operations with EA-18G “Growler” operations; and
- One-for-one replacement of Multimission Maritime Aircraft (MMA) P-3A operations with P-8A operations.

HSC-25 and civilian transient operations would remain the same as in the Baseline scenario, and no FCLPs are modeled. Table 5-1 shows the resultant numbers of operations by aircraft group, modeled aircraft type, and period of day for the Baseline scenario. Annual based and transient military flight operations would total 67,517. Addition of civilian and air carrier operations would bring the total to 68,139.

The top users of the airfield would still be the MH-60S Knighthawks in HSC-25 (modeled as SH-60B aircraft in RNM), with 28 percent of the total military operations. ISR/Strike F-22s would be the next most frequent users, with 17 percent of the total military operations. KC-135Rs and F-15As would each account for 13 percent of the total airfield operations. The based HSC-25 aircraft would remain at 6 percent nighttime (i.e., between 2200 and 0700) and transient aircraft would reduce their nighttime operations percentage from 14 to 8.

Table 5-1. No Action (CY2014) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based	HSC-25 Sqn	SH60B	2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Transient ISR Strike	Jet	**B-1**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**B-2A**	42	6	48	42	6	48	-	-	-	84	12	96	84	12	96	252	36	288
	Jet	**B-52H**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**F-15E**	341	5	346	102	2	104	239	4	242	1,736	27	1,763	307	5	311	2,724	41	2,765
	Jet	**F-22[7]**	1,362	21	1,383	408	6	414	953	15	968	6,945	106	7,050	1,226	19	1,244	10,892	166	11,058
	Jet	**KC-135R**	835	125	960	835	125	960	-	-	-	2,506	374	2,880	2,506	374	2,880	6,682	998	7,680
	Jet	**Global Hawk (modeled as T-45)**	187	33	220	187	33	220	-	-	-	187	33	220	-	-	-	561	99	660
Local & Transient	Jet	B-1	80	9	89	80	9	89	-	-	-	322	36	358	161	18	179	643	72	715
	Jet	B-2	49	6	55	49	6	55	-	-	-	198	22	220	99	11	110	395	45	440
	Jet	B-52H	95	10	105	95	10	105	-	-	-	322	36	358	161	18	179	673	74	747
	Jet	C-9A	14	3	17	14	3	17	-	-	-	-	-	-	-	-	-	28	6	34
	Jet	**KC-10A[2,7]**	201	235	436	324	112	436	-	-	-	372	42	414	186	21	207	1,083	410	1,493
	Jet	C-21A[4]	24	6	30	24	6	30	-	-	-	-	-	-	-	-	-	48	12	60
	Prop	C-130H&N&P[3,5]	43	-	43	22	-	22	22	-	22	172	-	172	86	-	86	345	-	345
	Jet	KC-135R	1,164	123	1,287	1,164	123	1,287	-	-	-	3,720	414	4,134	1,860	207	2,067	7,908	867	8,775
	Jet	**F-15A**	2,392	-	2,392	44	-	44	2,352	-	2,352	3,856	-	3,856	-	-	-	8,644	-	8,644
	Jet	**F-16C**	36	-	36	-	-	-	36	-	36	-	-	-	-	-	-	72	-	72
Transient	VM Helo	CH-46E[6]	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
	VM Helo	CH-53E	6	16	22	6	16	22	-	-	-	-	-	-	-	-	-	12	32	44
	Jet	C-5A	46	186	232	209	23	232	-	-	-	-	-	-	-	-	-	255	209	464
	Jet	**C-17[7]**	112	238	350	274	77	351	-	-	-	-	-	-	-	-	-	386	315	701
	Jet	C-20	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-	4	-	4
	Prop	C-12[6]	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
Transient CVN Wing[8]	VM Jet	**EA-18G (as F/A-18E/F)**	17	-	17	1	-	1	16	-	16	-	-	-	-	-	-	34	-	34
	VM Jet	F-18A/C	121	-	121	12	-	12	110	-	110	-	-	-	-	-	-	243	-	243
	VM Jet	F-18E/F	146	-	146	14	-	14	131	-	131	-	-	-	-	-	-	291	-	291
	VM Jet	C-21A[4]	17	-	17	17	-	17	-	-	-	-	-	-	-	-	-	34	-	34
	VM Prop	E-2C[5]	26	-	26	3	-	3	23	-	23	-	-	-	-	-	-	52	-	52
	VM Helo	SK70 (UH-60A) BLACKH[6]	37	2	39	37	2	39	-	-	-	-	-	-	-	-	-	74	4	78
Transient MMA	VM Jet	P-8A (modeled as B 737-700)	78	11	89	78	11	89	-	-	-	-	-	-	-	-	-	156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	104	166	270	104	166	270	-	-	-	-	-	-	-	-	-	208	332	540
	Civilian	B-757-200-RR	33	8	41	33	8	41	-	-	-	-	-	-	-	-	-	66	16	82
Based Total			2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Military Transient Total			7,886	1,091	8,977	4,457	626	5,082	3,882	18	3,900	21,172	1,213	22,385	7,427	796	8,223	44,823	3,744	48,566
Civilian (Transient) Total			137	174	311	137	174	311	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total			10,989	1,356	12,345	7,192	1,259	8,450	3,882	18	3,900	32,910	1,702	34,612	8,012	821	8,833	62,984	5,156	68,139

Day = 0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and go, GCA Box) is counted here as 2 operations (1 landing + 1 departure)
(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC-135R
(3)C-130H&N&P Closed Pattern Operations (Touch and go, GGCA Box) not modeled
(4) C-21A Local & Transient Operations Modeled as C-21A Transient CVN Wing
(5) Overhead Break Arrivals Modeled as Nonbreak Arrivals
(6) Ops from AFCEE's modeling of Baseline for 2003
(7) Include add'l Transient ops per AMC & Base Ops
(8) Obtained for CVW-5 data from NAVAIR
(9) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits)

5.2 Runway and Flight Track Utilization, Flight Profiles, and Average Flying Day Events

Runways, flight tracks, runway/flight track utilization and flight profiles for the aircraft present in the Baseline case would remain the same as in the No Action case. Flight profiles and flight track utilization for the ISR/Strike aircraft were taken from the modeling files for the ISR/Strike EIS. EA-18G flight profiles were taken from a 2004 analysis of EA-18Gs at NAS Whidbey Island, modeled with the F/A-18E/F aircraft type. P-8 flight profiles were taken from an MMA study at MCBH Kaneohe Bay and modeled with the civilian-style B737-700 aircraft type. All new flight profiles were checked for consistency with current Andersen AFB course rules. The CVN wing EA-18 would use the same runway and flight track utilization as the Baseline EA-6B, and the P-8A would use the same runway and flight track utilization as the Baseline P-3. Runway and flight track utilization tables for all modeled aircraft are shown in Appendix C.

Average flying day operations were calculated in the same manner as for the Baseline case. The annual operations for each aircraft type and track were divided by the number of flying days for the aircraft. Based and transient aircraft would have 365 flying days per year All ISR/Strike aircraft except the Global Hawk would have 240 flying days per year, and the Global Hawk would have 220 flying days. The resultant AFD events for each aircraft are shown on Table 5-2. There would be approximately 150 events in an average flying day, of which 34 would be based aircraft, 114 would be other military transient aircraft, and 2 would be civilian transient aircraft.

Table 5-2. Modeled Average Flying Day Flight Events for No Action (CY2014) Scenario

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based	HSC-25 Sqn	SH60B	8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Transient ISR Strike	Jet	**B-1**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**B-2A**	0.18	0.03	0.21	0.18	0.03	0.21	-	-	-	0.18	0.03	0.20	0.18	0.03	0.20	0.71	0.11	0.82
	Jet	**B-52H**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**F-15E**	1.42	0.02	1.44	0.43	0.01	0.44	0.99	0.01	1.00	3.62	0.06	3.67	0.64	0.01	0.65	7.10	0.11	7.20
	Jet	**F-22[7]**	5.67	0.09	5.76	1.70	0.03	1.73	3.97	0.06	4.03	14.47	0.22	14.69	2.56	0.04	2.60	28.37	0.44	28.81
	Jet	**KC-135R**	3.48	0.52	4.00	3.48	0.52	4.00	-	-	-	5.22	0.78	6.00	5.22	0.78	6.00	17.40	2.60	20.00
	Jet	**Global Hawk (modeled as T-45)**	0.85	0.15	1.00	0.85	0.15	1.00	-	-	-	0.43	0.08	0.50	-	-	-	2.13	0.38	2.50
Local & Transient	Jet	B-1	0.22	0.02	0.24	0.22	0.02	0.24	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.10	0.12	1.22
	Jet	B-2	0.13	0.02	0.15	0.13	0.02	0.15	-	-	-	0.27	0.03	0.30	0.14	0.02	0.15	0.67	0.09	0.75
	Jet	B-52H	0.26	0.03	0.29	0.26	0.03	0.29	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.18	0.14	1.32
	Jet	C-9A	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	-	-	-	-	-	-	0.08	0.02	0.10
	Jet	**KC-10A[2,7]**	0.55	0.64	1.19	0.89	0.31	1.20	-	-	-	-	-	-	-	-	-	1.44	0.95	2.39
	Jet	C-21A[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prop	C-130H&N&P[3,5]	0.12	-	0.12	0.12	-	0.12	-	-	-	-	-	-	-	-	-	0.24	-	0.24
	Jet	KC-135R	3.19	0.34	3.53	3.19	0.34	3.53	-	-	-	5.61	0.63	6.23	2.81	0.31	3.12	14.79	1.62	16.41
	Jet	**F-15A**	6.55	-	6.55	0.12	-	0.12	6.44	-	6.44	5.28	-	5.28	-	-	-	18.39	-	18.39
	Jet	**F-16C**	0.10	-	0.10	-	-	-	0.10	-	0.10	-	-	-	-	-	-	0.20	-	0.20
Transient	VM Helo	CH-46E[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
	VM Helo	CH-53E	0.02	0.04	0.06	0.02	0.04	0.06	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12
	Jet	C-5A	0.13	0.51	0.64	0.57	0.06	0.63	-	-	-	-	-	-	-	-	-	0.70	0.57	1.27
	Jet	**C-17[7]**	0.31	0.65	0.96	0.75	0.21	0.96	-	-	-	-	-	-	-	-	-	1.06	0.86	1.92
	Jet	C-20	0.01	-	0.01	0.01	-	0.01	-	-	-	-	-	-	-	-	-	0.02	-	0.02
	Prop	C-12[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
Transient CVN Wing[8]	VM Jet	**EA-18G (as F/A-18E/F)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	VM Jet	F-18A/C	0.33	-	0.33	0.03	-	0.03	0.30	-	0.30	-	-	-	-	-	-	0.66	-	0.66
	VM Jet	F-18E/F	0.45	-	0.45	0.04	-	0.04	0.40	-	0.40	-	-	-	-	-	-	0.89	-	0.89
	VM Jet	C-21A[4]	0.11	0.02	0.13	0.11	0.02	0.13	-	-	-	-	-	-	-	-	-	0.22	0.04	0.26
	VM Prop	E-2C[5]	0.07	-	0.07	0.07	-	0.07	-	-	-	-	-	-	-	-	-	0.14	-	0.14
	VM Helo	SK70 (UH-60A) BLACKH[6]	0.10	0.01	0.11	0.10	0.01	0.11	-	-	-	-	-	-	-	-	-	0.20	0.02	0.22
Transient MMA	VM Jet	P-8A (modeled as B-737-700)	0.21	0.03	0.24	0.21	0.03	0.24	-	-	-	-	-	-	-	-	-	0.42	0.06	0.48
Civilian (Transient)	Civilian	B-747-SP (N)	0.28	0.45	0.73	0.28	0.45	0.73	-	-	-	-	-	-	-	-	-	0.56	0.90	1.46
	Civilian	B-757-200-RR	0.09	0.02	0.11	0.09	0.02	0.11	-	-	-	-	-	-	-	-	-	0.18	0.04	0.22
Based Total			8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Military Transient Total			26.16	3.37	29.53	15.18	2.08	17.26	12.20	0.07	12.27	37.51	2.14	39.65	13.54	1.46	15.00	104.59	9.12	113.71
Civilian (Transient) Total			0.37	0.47	0.84	0.37	0.47	0.84	-	-	-	-	-	-	-	-	-	0.74	0.94	1.68
Grand Total			34.66	4.09	38.75	22.67	3.81	26.48	12.20	0.07	12.27	53.59	2.81	56.40	14.34	1.50	15.84	137.46	12.28	149.74

Day = 0700-2159 local; Night = 2200-0659 local

Note: (1) Each Closed Pattern Event (Touch and Go, GCA Box) is counted here as 1 event
(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC135R
(3) C-130H&N&P Closed Pattern Operation (Touch and go, GCA Box) not modeled
(4) C-21A Local & Transient Operations Modeled a C21A Transient CVN Wing
(5) Overhead Break Arrivals modeled as Nonbreak Arrivals
(6) Ops from AFCEE's modeling of Baseline for 2003
(7) Include add'l Transient ops per AMC & Base Ops
(8) Obtained for CVW-5 data from NAVAIR
(9) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits

5.3 Maintenance Run-up Operations

The location, frequency, and profiles of maintenance run-up operations for based and transient aircraft present in the Baseline scenario would be the same in the No Action scenario. Run-up profiles for ISR/Strike F-15E and F-22 were taken from the ISR/Strike EIS and moved from the EIS modeled location to Pad S27 and Pad S35 because the EIS modeled location would not exist. No run-up profiles existed in the source files for the EA-18G or P-8A, so run-ups for those aircraft were omitted from the study. Modeled run-up operations, profiles, and locations for all scenarios are shown in Appendix D.

5.4 No Action Scenario Noise Exposure

Using the data described in Sections 5.1 through 5.3, NOISEMAP Version 7.2, RNM Version 7.0 were used to calculate and plot the 60 dB through 85 dB DNL contours for the AFD operations for the No Action Scenario for Andersen AFB, as shown in Figure 5-1.

The off-base overland portion of the 60 dB DNL contour would extend along runway heading approximately seven statute miles southwest of the base boundary to the western shoreline of the island. The 60 dB DNL contour over the water to the northwest would be due to GCA box operations on 06L/06R. The 60 dB DNL contour would have a 'hook' to the southeast due to large-aircraft touch-and-go operations on Runway 06R/24L.

The off-base overland portion of the 65 dB DNL contour would extend approximately 3.5 miles southwest of the AFB boundary. The main lobes would follow the approach paths to Runways 06L/06R. The highest off-base overland DNL exposure outside Andersen AFB property would be between 75 dB and 80 dB evidenced by the 75 dB DNL contour extending approximately an average of 1,700 feet past the southwest base boundary.

Figure 5-2 compares the No Action DNL contours to the Baseline DNL contours. The influence of the growth in GCA pattern operations and large aircraft touch-and-goes is evident in the 60 DNL No Action contour lobes over water to the northwest and in the 'hook' to the southeast. The increase in overall operations, especially in approaches to Runways 06L/R, would cause the approximately two-mile growth in the 60 and 65 dB DNL contours along the extended centerlines of Runways 06L/R southwest of the AFB.

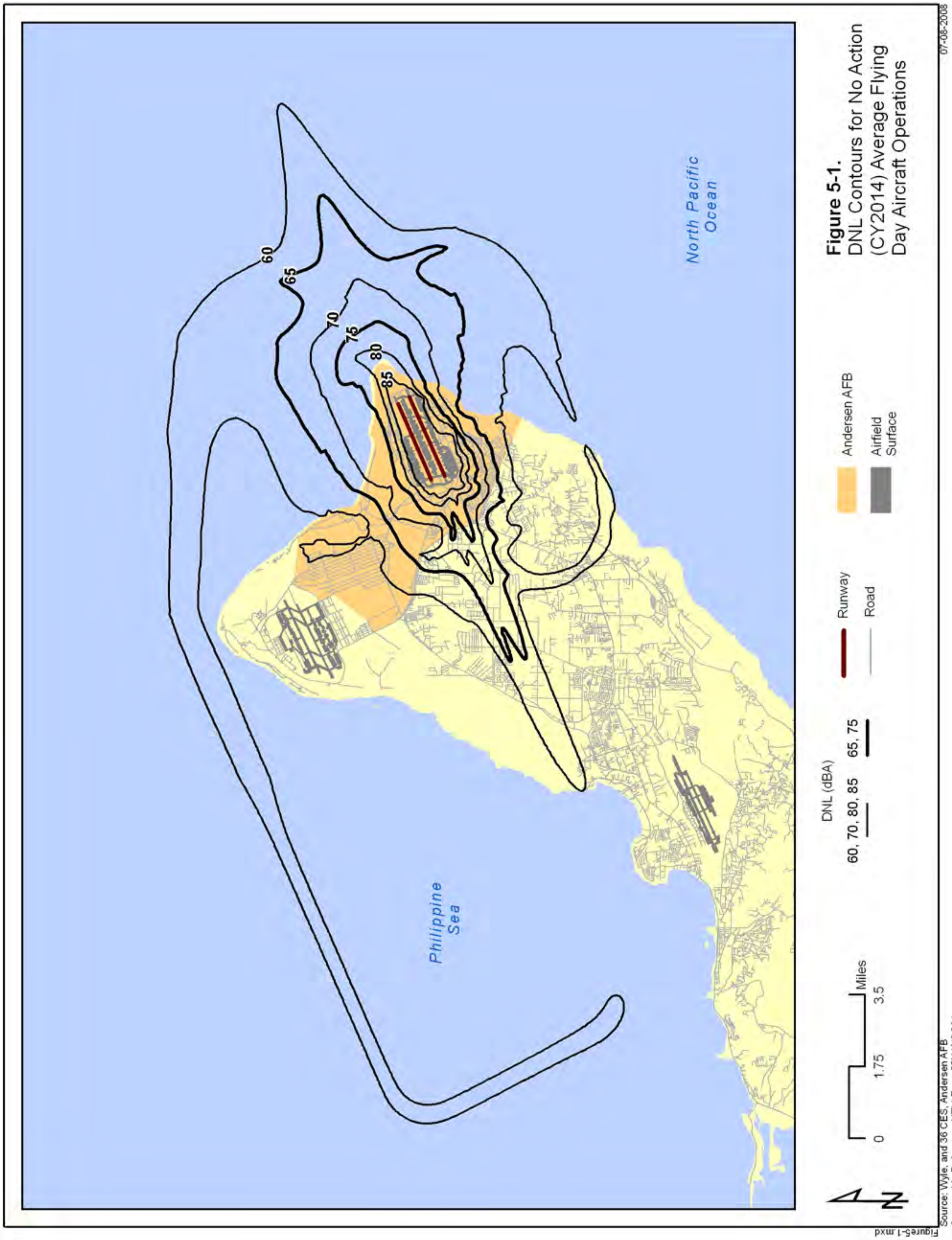

Figure 5-1. DNL Contours for No Action (CY2014) Average Flying Day Aircraft Operations

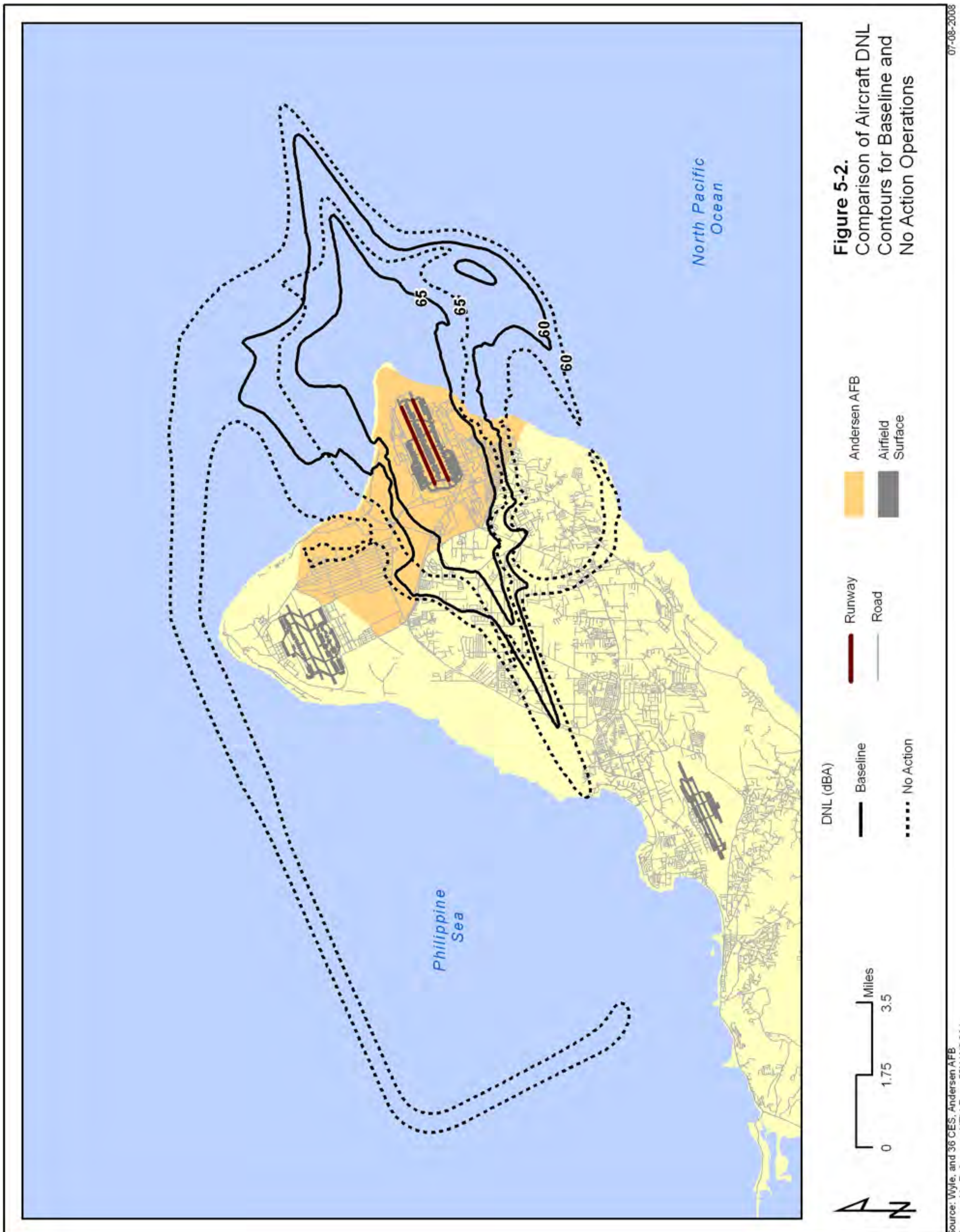

Figure 5-2. Comparison of Aircraft DNL Contours for Baseline and No Action Operations

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6.0 Proposed (CY2014) Scenario

The Proposed scenario models proposed Andersen AFB airfield operations during CY2014. Northwest Field is considered a separate airfield. Except for based aircraft interfacility flights, operations at Northwest Field are not included in this analysis. Section 6.1 discusses flight operations by aircraft type. Section 6.2 discusses runway/helipad utilization, flight track utilization, flight profiles and daily operations by aircraft type. Section 6.3 describes maintenance run-up operations, and Section 6.4 discusses the calculated DNL contours.

6.1 Flight Operations

Calendar Year 2014 Proposed operations are based on the Baseline CY2007 operations with the increases and replacements described in Section 5.1, plus the following changes:

- Transfer of four CH-53E, six AH-1Z, and three UH-1N aircraft in support of the USMC relocation to Guam;
- Transfer of a Marine F/A-18D Squadron in support of the USMC relocation to Guam;
- Transfer of a new based MV-22 squadron; and
- Increased visits of CVN airwings from one per year to four per year, resulting in an increase of transient CVN F/A-18C, F/A-18F, SH-60B/F, EA-18G, and E-2C airfield operations.

HSC-25 and civilian transient operations would remain the same as in the Baseline scenario, and no FCLPs are modeled. Table 6-1 shows the resultant numbers of operations by aircraft group, modeled aircraft type, and period of day for the Proposed scenario. Annual based and transient military flight operations would total 93,037. Addition of civilian and air carrier operations would bring the total to 93,649.

The top users of the airfield would still be the MH-60S Knighthawks in HSC-25 (modeled as SH-60B aircraft in RNM), now with 20 percent of the total military operations. ISR/Strike F-22s would be the next most frequent users, with 12 percent of the total military operations. Based AH-1s, F-15As, Transient ISR Strike KC-135Rs and Local Transient KC-135Rs would each account for 8 to 10 percent of the total airfield operations. Overall, seven percent of the based aircraft operations would be flown at night (i.e., between 2200 and 0700), and nine percent of the transient operations would be flown during the same period.

Table 6-1. Proposed Action (CY2014) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go(1)			GCA Box(1)			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based Additions	VM Helo	**CH-53E(8)**	432	18	450	383	68	451	-	-	-	540	60	600	108	12	120	1,463	158	1,621
	VM Helo	**AH-1N(9)**	2,250	-	2,250	2,250	-	2,250	-	-	-	3,000	-	3,000	1,500	-	1,500	9,000	-	9,000
	VM Helo	**UH-1N(9)**	750	-	750	750	-	750	-	-	-	1,000	-	1,000	500	-	500	3,000	-	3,000
	VM Rotary	**MV-22B(9)**	1,244	735	1,979	124	74	198	1,119	662	1,781	566	-	566	707	-	707	3,760	1,471	5,231
	VM Jet	**F/A-18D**	1,147	23	1,170	168	8	176	985	10	995	1,752	73	1,825	374	24	398	4,426	138	4,564
Based (HSC-25)	OM Helo	SH60B	2,966	91	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610	17,887	1,064	18,951
Transient ISR Strike	Jet	**B-1**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**B-2A**	42	6	48	42	6	48	-	-	-	84	12	96	84	12	96	252	36	288
	Jet	**B-52H**	188	28	216	188	28	216	-	-	-	376	56	432	376	56	432	1,128	168	1,296
	Jet	**F-15E**	341	5	346	102	2	104	239	4	242	1,736	27	1,763	307	5	311	2,724	41	2,765
	Jet	**F-22(7)**	1,362	21	1,383	408	6	414	953	15	968	6,945	106	7,050	1,226	19	1,244	10,892	166	11,058
	Jet	**KC-135R**	835	125	960	835	125	960	-	-	-	2,506	374	2,880	2,506	374	2,880	6,682	998	7,680
	Jet	**Global Hawk (modeled as T-45)**	187	33	220	187	33	220	-	-	-	187	33	220	-	-	-	561	99	660
Local & Transient	Jet	B-1	80	9	89	80	9	89	-	-	-	322	36	358	161	18	179	643	72	715
	Jet	B-2	49	6	55	49	6	55	-	-	-	198	22	220	99	11	110	395	45	440
	Jet	B-52H	95	10	105	95	10	105	-	-	-	322	36	358	161	18	179	673	74	747
	Jet	C-9A	14	3	17	14	3	17	-	-	-	-	-	-	-	-	-	28	6	34
	Jet	**KC-10A(2,7)**	201	235	436	324	112	436	-	-	-	372	42	414	186	21	207	1,083	410	1,493
	Jet	C-21A(4)	24	6	30	24	6	30	-	-	-	-	-	-	-	-	-	48	12	60
	Prop	C-130H&N&P(3,5)	43	-	43	22	-	22	22	-	22	172	-	172	86	-	86	345	-	345
	Jet	KC-135R	1,164	123	1,287	1,164	123	1,287	-	-	-	3,720	414	4,134	1,860	207	2,067	7,908	867	8,775
	Jet	**F-15A**	2,392	-	2,392	44	-	44	2,352	-	2,352	3,856	-	3,856	-	-	-	8,644	-	8,644
	Jet	**F-16C**	36	-	36	-	-	-	36	-	36	-	-	-	-	-	-	72	-	72
Transient	VM Helo	CH-46E(6)	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
	VM Helo	CH-53E	6	16	22	6	16	22	-	-	-	-	-	-	-	-	-	12	32	44
	Jet	C-5A	46	186	232	209	23	232	-	-	-	-	-	-	-	-	-	255	209	464
	Jet	**C-17(7)**	112	238	350	274	77	351	-	-	-	-	-	-	-	-	-	386	315	701
	Jet	C-20	2	-	2	2	-	2	-	-	-	-	-	-	-	-	-	4	-	4
	Prop	C-12(6)	19	-	19	19	-	19	-	-	-	-	-	-	-	-	-	38	-	38
Transient CVN Wing(10)	VM Jet	**EA-18G (as F/A-18E/F)**	68	-	68	4	-	4	64	-	64	-	-	-	-	-	-	136	-	136
	VM Jet	**F-18A/C**	484	-	484	48	-	48	440	-	440	-	-	-	-	-	-	972	-	972
	VM Jet	**F-18E/F**	584	-	584	56	-	56	524	-	524	-	-	-	-	-	-	1,164	-	1,164
	VM Jet	C-21A(4)	17	-	17	17	-	17	-	-	-	-	-	-	-	-	-	34	-	34
	VM Prop	**E-2C(5)**	104	-	104	12	-	12	92	-	92	-	-	-	-	-	-	208	-	208
	VM Helo	**SK70 (UH-60A) BLACKH(6)**	148	8	156	148	8	156	-	-	-	-	-	-	-	-	-	296	16	312
Transient MMA	VM Jet	**P-8A (modeled as B-737-700)**	78	11	89	78	11	89	-	-	-	-	-	-	-	-	-	156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	104	166	270	104	166	270	-	-	-	-	-	-	-	-	-	208	332	540
	Civilian	B-757-200-RR	33	8	41	33	8	41	-	-	-	-	-	-	-	-	-	66	16	82
Based Total			8,789	867	9,656	6,273	609	6,882	2,104	672	2,776	18,596	622	19,218	3,774	61	3,835	39,536	2,831	42,367
Military Transient Total			8,927	1,097	10,024	4,658	632	5,289	4,722	18	4,740	21,172	1,213	22,385	7,427	796	8,223	46,905	3,756	50,660
Civilian (Transient) Total			137	174	311	137	174	311	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total			17,853	2,138	19,991	11,068	1,415	12,482	6,826	690	7,516	39,768	1,835	41,603	11,201	857	12,058	86,715	6,935	93,649

Day=0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and go, GCA Box) is counted here as 2 operations (1 landing + 1 departure)

(2) KC-10A Closed Pattern Operations (Touch and go, GCA box) modeled as KC-135R

(3) C-130H&N&P Closed Pattern Operations (Touch and Go, GCA Box) not modeled

(4) C-21A Local & Transient Operations modeled as C-21A Transient CVN Wing

(5) Overhead Break Arrivals modeled as Nonbreak Ariivals

(6) Ops from AFCEE's modeling of Baseline for 1993

(7) Include add'l transient ops per AMC & Base Ops

(8) Excludes LHA T&G from FRF Camp Schwab

(9) Excludes LHA T&G from FRF Camp Schwab

(10) Obtained for CVW-5 data from NAVAIR

(11) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits)

6.2 Runway and Flight Track Utilization, Flight Profiles, and Average Flying Day Events

With the exception of the based MH-60S, runways, flight tracks, runway/flight track utilization and flight profiles for the aircraft in the No Action case would remain the same for corresponding aircraft in the Proposed case. Flight profiles and flight track utilization for the proposed rotary wing aircraft were taken from a draft noise study for the Futenma Replacement Facility (FRF) at Camp Schwab, Okinawa (Wyle, 2008). Flight profiles for the Marine F/A-18D were extracted from the 2003 noise study. MV-22 flight profiles were taken from the West Coast MV-22 beddown EIS currently in progress. All new flight profiles were checked for consistency with current Andersen AFB course rules. All proposed based rotary wing aircraft would have the same flight track utilization as the existing HSC-25 aircraft, except departure and arrival flight tracks would originate and terminate at pad N25 rather than pads N1 and N19. The MH-60S departure and arrival flight tracks would move to pad N25, and proposed MH-60S flight profiles would be applied to the new tracks. Marine F/A-18D flight track utilization would be the same as modeled in the 2003 noise study, but the runway utilization would be modified to favor Runway 06L because the proposed hangar would be on the north side of the airfield. MV-22 aircraft would use the same flight tracks and pads as HSC-25 aircraft, with additional departures and overhead break arrivals to the main runways. Runway and flight track utilization tables for all modeled aircraft are shown in Appendix C.

Average flying day operations were calculated in the same manner as for the Baseline and No Action cases. The annual operations for each aircraft type and track were divided by the number of flying days for the aircraft. All based and transient (including proposed aircraft) aircraft would have 365 flying days per year All ISR/Strike aircraft except the Global Hawk would have 240 flying days per year, and the Global Hawk would have 220 flying days. The resultant AFD operations for each aircraft are shown on Table 6-2. There would be approximately 206 events in an average flying day, of which 85 would be based aircraft, 119 would be other military transient aircraft, and 2 would be civilian transient aircraft.

Table 6-2. Modeled Average Flying Day Flight Events for Proposed (CY2014) Scenario

Mission Group	Assumed Type	Modeled Aircraft Type	Departure			Nonbreak Arrival			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			Total		
			Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based Additions	VM Helo	**CH-53E[8]**	1.18	0.05	1.23	1.05	0.19	1.24	-	-	-	0.74	0.08	0.82	0.15	0.02	0.17	3.12	0.34	3.46
	VM Helo	**AH-1N[9]**	6.16	-	6.16	6.16	-	6.16	-	-	-	4.11	-	4.11	2.06	-	2.06	18.49	-	18.49
	VM Helo	**UH-1N[9]**	2.05	-	2.05	2.05	-	2.05	-	-	-	1.37	-	1.37	0.69	-	0.69	6.16	-	6.16
	VM Rotary	**MV-22B[9]**	3.41	2.01	5.42	0.34	0.20	0.54	3.07	1.81	4.88	0.78	-	0.78	0.97	-	0.97	8.57	4.02	12.59
	VM Jet	**F/A-18D**	3.14	0.06	3.20	0.46	0.02	0.48	2.70	0.03	2.73	2.40	0.10	2.50	0.51	0.04	0.55	9.21	0.25	9.46
Based (HSC-25)	OM Helo	SH60B	8.13	0.25	8.38	7.12	1.26	8.38	-	-	-	16.08	0.67	16.75	0.80	0.04	0.84	32.13	2.22	34.35
Transient ISR Strike	Jet	**B-1**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**B-2A**	0.18	0.03	0.21	0.18	0.03	0.21	-	-	-	0.18	0.03	0.20	0.18	0.03	0.20	0.71	0.11	0.82
	Jet	**B-52H**	0.78	0.12	0.90	0.78	0.12	0.90	-	-	-	0.79	0.12	0.90	0.79	0.12	0.90	3.13	0.47	3.60
	Jet	**F-15E**	1.42	0.02	1.44	0.43	0.01	0.44	0.99	0.01	1.00	3.62	0.06	3.67	0.64	0.01	0.65	7.10	0.11	7.20
	Jet	**F-22[7]**	5.67	0.09	5.76	1.70	0.03	1.73	3.97	0.06	4.03	14.47	0.22	14.69	2.56	0.04	2.60	28.37	0.44	28.81
	Jet	**KC-135R**	3.48	0.52	4.00	3.48	0.52	4.00	-	-	-	5.22	0.78	6.00	5.22	0.78	6.00	17.40	2.60	20.00
	Jet	**Global Hawk (modeled as T-45)**	0.85	0.15	1.00	0.85	0.15	1.00	-	-	-	0.43	0.08	0.50	-	-	-	2.13	0.38	2.50
Local & Transient	Jet	B-1	0.22	0.02	0.24	0.22	0.02	0.24	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.10	0.12	1.22
	Jet	B-2	0.13	0.02	0.15	0.13	0.02	0.15	-	-	-	0.27	0.03	0.30	0.14	0.02	0.15	0.67	0.09	0.75
	Jet	B-52H	0.26	0.03	0.29	0.26	0.03	0.29	-	-	-	0.44	0.05	0.49	0.22	0.03	0.25	1.18	0.14	1.32
	Jet	C-9A	0.04	0.01	0.05	0.04	0.01	0.05	-	-	-	-	-	-	-	-	-	0.08	0.02	0.10
	Jet	**KC-10A[2,7]**	0.55	0.64	1.19	0.89	0.31	1.20	-	-	-	-	-	-	-	-	-	1.44	0.95	2.39
	Jet	C-21A[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Prop	C-130H&N&P[3,5]	0.12	-	0.12	0.12	-	0.12	-	-	-	-	-	-	-	-	-	0.24	-	0.24
	Jet	KC-135R	3.19	0.34	3.53	3.19	0.34	3.53	-	-	-	5.61	0.63	6.23	2.81	0.31	3.12	14.79	1.62	16.41
	Jet	**F-15A**	6.55	-	6.55	0.12	-	0.12	6.44	-	6.44	5.28	-	5.28	-	-	-	18.39	-	18.39
	Jet	**F-16C**	0.10	-	0.10	-	-	-	0.10	-	0.10	-	-	-	-	-	-	0.20	-	0.20
Transient	VM Helo	CH-46E[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
	VM Helo	CH-53E	0.02	0.04	0.06	0.02	0.04	0.06	-	-	-	-	-	-	-	-	-	0.04	0.08	0.12
	Jet	C-5A	0.13	0.51	0.64	0.57	0.06	0.63	-	-	-	-	-	-	-	-	-	0.70	0.57	1.27
	Jet	**C-17[7]**	0.31	0.65	0.96	0.75	0.21	0.96	-	-	-	-	-	-	-	-	-	1.06	0.86	1.92
	Jet	C-20	0.01	-	0.01	0.01	-	0.01	-	-	-	-	-	-	-	-	-	0.02	-	0.02
	Prop	C-12[6]	0.05	-	0.05	0.05	-	0.05	-	-	-	-	-	-	-	-	-	0.10	-	0.10
Transient CVN Wing[10]	VM Jet	**EA-18G (as F/A-18E/F)**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	VM Jet	**F-18A/C**	1.33	-	1.33	0.13	-	0.13	1.21	-	1.21	-	-	-	-	-	-	2.67	-	2.67
	VM Jet	**F-18E/F**	1.79	-	1.79	0.16	-	0.16	1.61	-	1.61	-	-	-	-	-	-	3.56	-	3.56
	VM Jet	C-21A[4]	0.11	0.02	0.13	0.11	0.02	0.13	-	-	-	-	-	-	-	-	-	0.22	0.04	0.26
	VM Prop	**E-2C[5]**	0.28	-	0.28	0.28	-	0.28	-	-	-	-	-	-	-	-	-	0.56	-	0.56
	VM Helo	**SK70 (UH-60A) BLACKH[6]**	0.41	0.02	0.43	0.41	0.02	0.43	-	-	-	-	-	-	-	-	-	0.82	0.04	0.86
Transient MMA	VM Jet	**P-8A (modeled as B-737-700)**	0.21	0.03	0.24	0.21	0.03	0.24	-	-	-	-	-	-	-	-	-	0.42	0.06	0.48
Civilian (Transient)	Civilian	B-747-SP (N)	0.28	0.45	0.73	0.28	0.45	0.73	-	-	-	-	-	-	-	-	-	0.56	0.90	1.46
	Civilian	B-757-200-RR	0.09	0.02	0.11	0.09	0.02	0.11	-	-	-	-	-	-	-	-	-	0.18	0.04	0.22
Based Total			24.07	2.37	26.44	17.18	1.67	18.85	5.77	1.84	7.61	25.48	0.85	26.33	5.17	0.09	5.26	77.67	6.82	84.48
Military Transient Total			29.02	3.38	32.40	15.92	2.09	18.01	14.32	0.07	14.39	37.51	2.14	39.65	13.54	1.46	15.00	110.31	9.14	119.45
Civilian (Transient) Total			0.37	0.47	0.84	0.37	0.47	0.84	-	-	-	-	-	-	-	-	-	0.74	0.94	1.68
Grand Total			53.46	6.22	59.68	33.47	4.23	37.70	20.09	1.91	22.00	62.99	2.99	65.98	18.71	1.55	20.26	188.72	16.90	205.61

Day = 0700-2159 local; Night = 2200-0659 local

Notes: (1) Each Closed Pattern Event (Touch and Go, GCA Box) is counted here as 1 event
(2) KC-10A Closed Pattern Operations (Touch and Go, GCA Box) modeled as KC-135R
(3) C-130H&N&P Closed Pattern Operation (Touch and Go, GCA Box) not modeled
(4) C-21A Local & Transient Operations modeled as C-21A Transient CVN Wing
(5) Overhead Break Arrivals modeled as Nonbreak Arrivals
(6) Ops from AFCEE's modeling of Baseline for 2003
(7) Include add'l transient ops per AMC & Base Ops
(8) Excludes LHA T&G and CLA T&G from FRF Camp Schwab
(9) Excludes LHA T&G from FRF Camp Schwab
(10) Obtained for CVW-5 data from NAVAIR
(11) **BOLD = changes from Baseline**

Source: AAFB (Wyle and NAVFAC site visits)

6.3 Maintenance Run-up Operations

The location, frequency, and profiles of maintenance run-up operations for based and transient aircraft present in the No Action scenario would be the same in the Proposed scenario. Run-up profiles for ISR/Strike F-15E and F-22 were taken from the ISR/Strike EIS and moved from the EIS modeled location to Pad S27 and Pad S35 because the EIS modeled location would not exist. No run-up profiles existed in the source files for the EA-18G or P-8A, so run-ups for those aircraft were omitted from the study. Run-up profiles for the proposed based rotary wing and MV-22 aircraft were taken from the draft FRF Camp Schwab study, and their operations were scaled by the ratio of aircraft loading at Andersen AFB to the loading at Camp Schwab. Run-up profiles for the proposed Marine F/A-18D aircraft were taken from a draft noise study for NAS Lemoore (Wyle, 2008b), and their operations were scaled by the aircraft loading ratio as well.

Because the facility for the proposed based aircraft would be on the north side of the airfield, all run-up operations that were modeled on pads N19 through N42 in the Baseline scenario would be moved to pads S4 through S45 for the proposed scenario. Maintenance run-ups by proposed rotary-wing aircraft and HSC-25 aircraft would be performed at a dedicated hover check pad at the new facility. See Figure 4-8 for the location of the hover check pad. Maintenance run-ups by proposed fixed-wing aircraft would be performed at Pad N1 or Pad N2. Modeled run-up operations, profiles, and locations for all scenarios are shown in Appendix D.

Although a maintenance test cell or hush house is anticipated, the presence of these capabilities is yet to be determined as aircraft engine production may be supported from site(s) in US or Japan depending on the airframe mix and future logistics practices. For conservative noise exposure computations, all run-ups were modeled to be outdoors.

6.4 Proposed Scenario Noise Exposure

Using the data described in Sections 6.1 through 6.3, NOISEMAP Version 7.2, RNM Version 7.0 were used to calculate and plot the 60 dB through 85 dB DNL contours for the AFD operations for the Proposed CY2014 Scenario at Andersen AFB, as shown in Figure 6-1.

The off-base overland portion of the 60 dB DNL contour would extend along runway heading approximately 7.5 statute miles southwest of the base boundary to the western shoreline of the island. The 60 dB DNL contour over the water to the northwest would be due to GCA box operations on 06L/06R. The 60 dB DNL contour would have a 'hook' to the southeast due to large-aircraft touch-and-go operations on Runway 06R/24L and a 'hook' to Northwest Field due to GCA box operations on Runways 24L/R.

The off-base overland portion of the 65 dB DNL contour would extend approximately four miles southwest of the AFB boundary. The main lobes would follow the approach paths to Runways 06L/06R with an 'offshoot' to the northwest due to GCA Box pattern operations on Runway 24R. The highest off-base overland DNL exposure outside Andersen AFB property would be between 75 dB and 80 dB evidenced by the 75 dB DNL contour extending approximately an average of 4,000 feet past the southwest base boundary.

Figure 6-2 compares the Proposed Action DNL contours to the No Action DNL contours. The primary difference between the two sets of contours is the 60 dB DNL Proposed Action contour 'hook' extending to Northwest Field which would be due to the growth in GCA pattern operations on Runways 24L/R. Minor differences (increases) in the 70 and 75 dB DNL contours in proximity to the AFB are noticeable and would be due to the increase in overall operations that are primarily a result of increased visits of the CVN Wing.

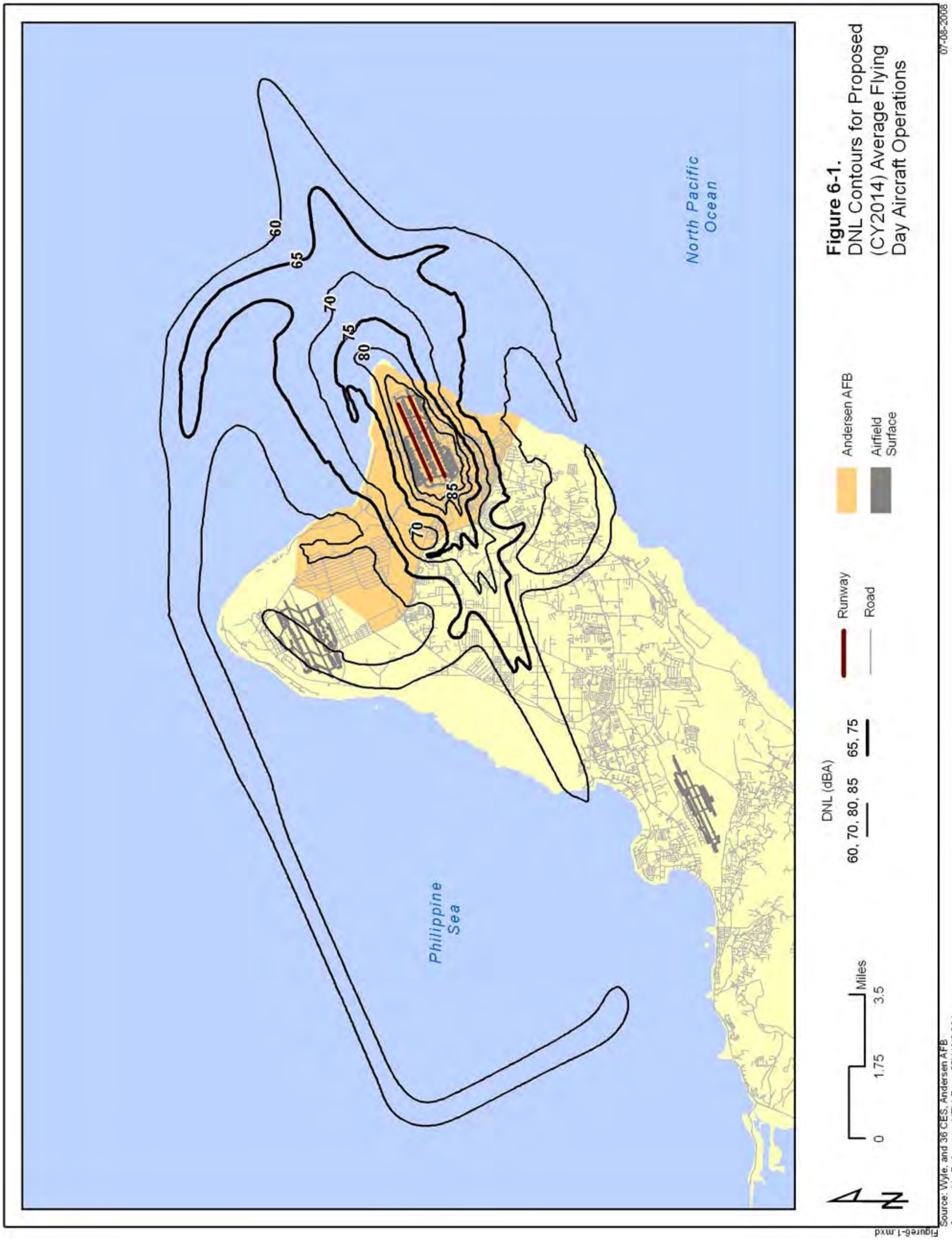

Figure 6-1.
DNL Contours for Proposed (CY2014) Average Flying Day Aircraft Operations

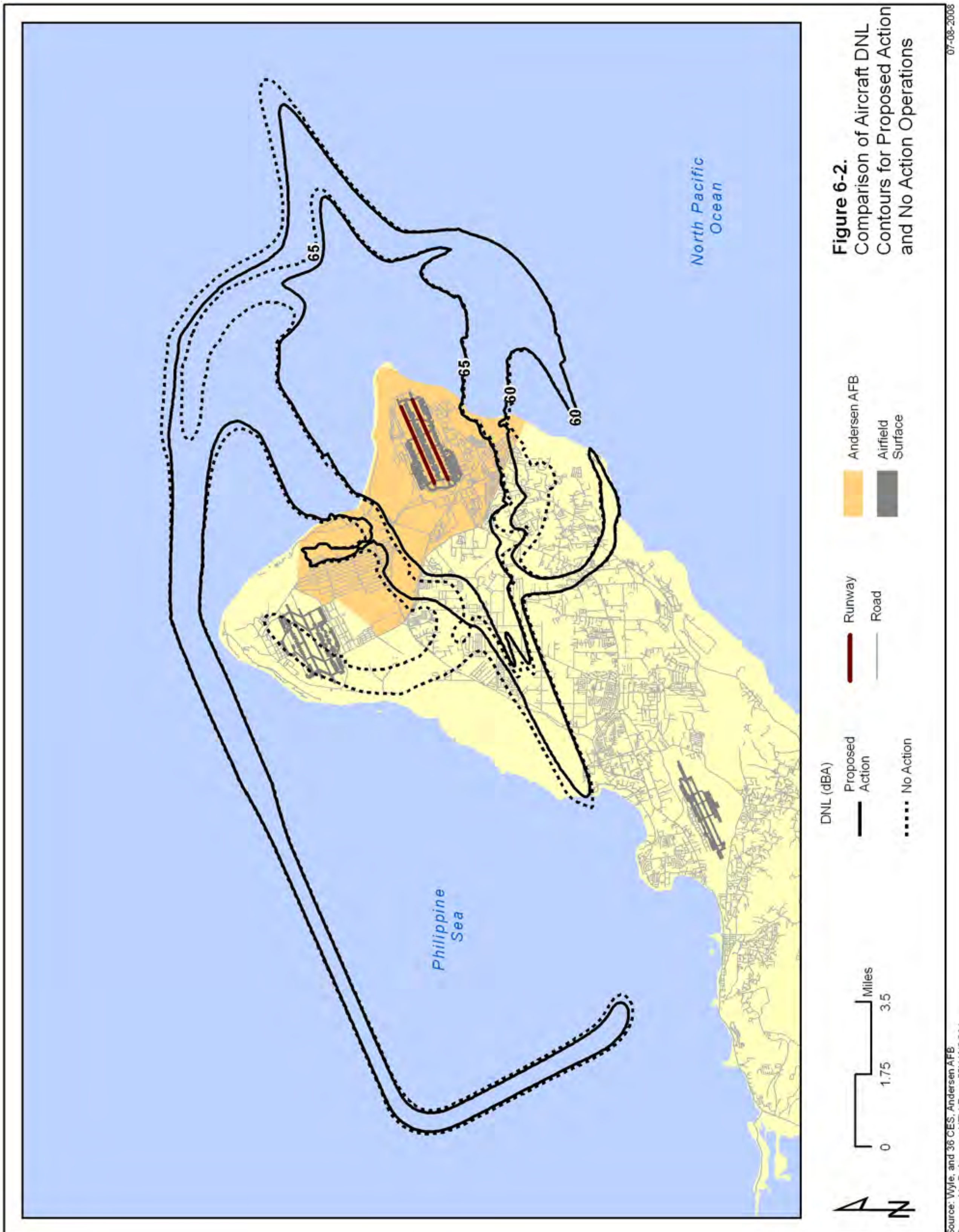

Figure 6-2. Comparison of Aircraft DNL Contours for Proposed Action and No Action Operations

DEPARTMENT OF THE ARMY
US ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND MD 21010-5403

MCHB-TS-EON

26 AUG 2009

MEMORANDUM FOR Navy Facilities Engineering Command, Pacific (Environmental Planning Branch/Mr. Kyle Fujimoto), 258 Makalapa Drive, Suite 100, Pearl Harbor, HI 96860

SUBJECT: Operational Noise Consultation, No. 52-EN-0BVU-09, Operational Noise Contours for Proposed Range Development at Guam and Tinian, August 2009.

1. We are enclosing 2 copies of the consultation.

2. Please contact us if this consultation or any of our services did not meet your needs or expectations.

3. The point of contact is Ms. Kristy Broska, Environmental Protection Specialist or Ms. Catherine Stewart, Program Manager, Operational Noise, USACHPPM, at DSN 584-3829, Commercial (410) 436-3829, or email: kristy.broska@us.army.mil or catherine.stewart@us.army.mil.

FOR THE COMMANDER:

Encl

DONALD F. ARCHIBALD
COL, MS
Director, Environmental Health Engineering

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U.S. Army Center for Health Promotion and Preventive Medicine

USACHPPM

OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
AUGUST 2009

Distribution authorized to U.S. Government agencies only; protection of privileged information evaluating another command; August 09. Other requests for this document shall be referred to Navy Facilities Engineering Command, Pacific (Environmental Planning Branch/Mr. Kyle Fujimoto), 258 Makalapa Drive, Suite 100, Pearl Harbor, HI 96860

Preventive Medicine Survey: 40-5fl

CHPPM FORM 433-E (MCHB-CS-IPD), OCT 03

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EXECUTIVE SUMMARY
OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
AUGUST 2009

1. PURPOSE. To provide the Navy Facilities Engineering Command, Pacific (NAVFAC PAC) noise contours for proposed range development at Guam and Tinian.

2. CONCLUSIONS.

a. Guam Training Ranges.

(1) Northwest Field Weapons. The existing and projected "busy day" C-weighted average sound Day Night Level (CDNL) Noise Zone II (62 decibels (dB) CDNL) and Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen Air Force Base (AFB) boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(2) Andersen South.

(a) Breacher Facility and Hand Grenade Range Alternative 1. Under the Breacher Facility and the Hand Grenade Alternative 1 location, the "busy day" CDNL Noise Zone II (62 dB CDNL) extends into a small portion of the non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image, there appears to be no noise sensitive land uses in this area. The Noise Zone III (70 dB CDNL) contour does not extend beyond the Andersen South boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(b) Breacher Facility and Hand Grenade Range Alternative 2. Under the Breacher Facility and the Hand Grenade Alternative 2 location, multiple residential areas exist within the "busy day" Noise Zone II (62 dB CDNL) contour. The Noise Zone III (70 dB CDNL) contour extends into the non-military land between Andersen South and the Route 15 Land. There may be a small number of residences within the Noise Zone III (70 dB CDNL) contour.

(c) Small Caliber Weapons Activity. The proposed Route 15 Alternatives would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the Andersen South boundary and the Route 15 Land. Under the Route 15 Alternatives, existing residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There may be scattered residences within the Noise Zone III (104 dB PK15[met]) contour.

(d) Grenade Launcher Activity. The proposed grenade launcher activity would be audible at the boundary but unlikely loud enough to generate complaints.

(e) Mitigation Potential. Small Arms Noise Zones are based on peak levels and computed using the loudest weapon fired at each location. Since the .50 caliber is significantly louder than the other rounds used for the assessment, though the contours would remain the same size, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities. Additionally, further modeling could be run to investigate if incorporating barriers into the range designs would lessen the number of noise sensitive receptors within the Noise Zones.

b. Tinian Training Ranges. The proposed small caliber weapon activity alternatives would generate PK15(met) Noise Zone II (87 dB) and Noise Zone III (104 dB) contours that extend beyond the Tinian Training Range boundary. However, there are no noise sensitive land uses within the noise contours.

3. RECOMMENDATIONS.

a. Include the information from this consultation in the appropriate National Environmental Policy Act documentation.

b. Although no Federal Law prohibits the Department of Defense training and testing activities from making noise, the Services have always tried to be good neighbors. To reduce the risk of noise complaints from the proposed activity, the NAVFAC PAC should use the U.S. Army's Operational Noise Management Program guidance in conjunction with the Air Force's Air Installation Compatible Use Zone program to address the impulsive noise events.

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OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
AUGUST 2009

1. REFERENCES. A list of the references used in this consultation is in Appendix A. A glossary of terms and abbreviations used are in Appendix B. Appendix C contains the Noise Zone Descriptions and Land Use Guidelines used in this consultation.

2. AUTHORITY. The Navy Facilities Engineering Command, Pacific (NAVFAC PAC) funded this consultation.

3. PURPOSE. To provide the NAVFAC PAC noise contours for the proposed range development for use in the appropriate Guam and Tinian National Environmental Policy Act (NEPA) documentation.

4. NOISE CONTOURING PROCEDURES.

a. Demolition Activity.

(1) The noise simulation program used to assess the demolition, explosive, and hand grenade noise is the Blast Noise Impact Assessment (BNOISE2) program (U.S. Army 2003a). The BNOISE2 program requires operational data concerning the location of the range, the quantity and type explosives and hand grenades utilized. Due to the limited number of operational days per year, the C-weighted average sound Day Night Level (CDNL) noise contours were developed based upon a "busy day" scenario. The use of a "busy day" scenario is twofold, it provides an up tempo training scenario and ensures the calculated noise levels are not diluted by periods of low or non-existent activity.

(2) To predict the risk of complaints for the demolition and hand grenade operations, PK15(met) contours were developed. The complaint risk contours are based on peak levels rather than a cumulative or average level, therefore the size of the contours will not change if the number of detonations increases or decreases.

b. Small Caliber Activity. The noise simulation program used to assess small caliber weapons (.50 caliber and below) noise is the Small Arms Range Noise Assessment Model (SARNAM) (U.S. Army 2003b). The SARNAM program requires operational data concerning types of weapons and range layout. The contours for small arms operations were created using PK15(met) as prescribed in Army Regulation (AR) 200-1 (U.S. Army 2007). The contours show the predicted peak levels for individual rounds (metric term is PK15(met)). Since the contours are based on peak levels rather than a cumulative or average level, the size of the contours will not change if the number of rounds fired increases.

5. GUAM TRAINING RANGES – NORTHWEST FIELD WEAPONS (NFW).

a. General. The NFW is a field exercise training area located in the northern area of Andersen Air Force Base (AFB). Appendix D shows the location of the Guam Training Ranges.

b. Existing Demolition Activity. Table 1 lists the ammunition expenditure utilized to develop the CDNL noise contours at NFW. The facility is utilized during daytime hours (0700 – 2200) approximately 25 days per year.

TABLE 1. NORTHWEST FIELD WEAPONS – EXISTING DEMOLITION EXPENDITURE.

Explosive Type and Weight	**"Busy Day" Expenditure**	**Annual Expenditure**
	0700 – 2200 hours	0700 – 2200 hours
Ammonium Nitrate (40 pounds)	1	25

(1) Figure 1 contains the CDNL noise contours for the existing activity at the NFW. The Land Use Planning Zone (LUPZ) (57 decibel (dB) CDNL), Zone II (62 dB CDNL) and Zone III (70 dB CDNL) noise contours do not extend beyond the Andersen AFB boundary.

(2) Figure 2 contains the complaint risk noise contours for the NFW demolition activity. The moderate risk of complaint (115 dB PK15[met]) area extends approximately 1,300 meters beyond the Andersen AFB boundary into a residential area. The high risk of complaint (130 dB PK15[met]) area does not extend beyond the boundary.

c. Projected Demolition Activity. Table 2 lists the ammunition expenditure utilized to develop the projected CDNL noise contours at the NFW. The facility is utilized during daytime hours (0700 – 2200). Under the projected operating environment, the number of operational days would vary between 2 – 48 days per year dependant upon the unit and the type of training being conducted.

(1) Figure 3 contains the CDNL noise contours for the existing and projected activity at the NFW. The LUPZ (57 dB CDNL) noise contour extends slightly into the Naval Computer and Telecommunications Station (NCTS) Finegayan. The Zone II (62 dB CDNL) and Zone III (70 dB CDNL) noise contours do not extend beyond the Andersen AFB boundary.

(2) The projected operating environment complaint risk contours are identical to the existing operating environment as the largest explosive charge is the same (Figure 2).

TABLE 2. NORTHWEST FIELD WEAPONS – PROJECTED DEMOLITION EXPENDITURE.

Explosive Type and Weight	"Busy Day" Expenditure 0700 – 2200 hours	Annual Expenditure 0700 – 2200 hours
Ammonium Nitrate (40 pounds) [1]	0	25
Ammonium Nitrate (40 pounds) [2]	3	6
TNT (7 pounds) [3]	6	288
C-4 (0.5 pounds) [4]	6	288
Other (20 pounds TNT equivalent)	2	96

Note: TNT = Trinitrotoluene

[1] Existing cratering charge expenditure (1 per day, 25 days per year). Due to unit specific training, the existing cratering charges would not be conducted on the same day as the proposed cratering charges.

[2] Proposed expenditure (3 per day, 2 days per year).

[3] Estimated TNT charges (less than 20 pounds, average weight of 7 pounds per charge, 48 days per year).

[4] Estimated C-4 charges (0.5 pounds per soldier, 48 days per year).

d. Land Use Compatibility.

(1) Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial images in Appendix D, land use near Andersen AFB is primarily residential.

(2) The "busy day" CDNL Noise Zone II and Noise Zone III contours do not extend beyond the Andersen AFB boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

e. Complaint Risk. The complaint risk guidelines indicate a moderate probability of receiving noise complaints from the NFW demolition activity.

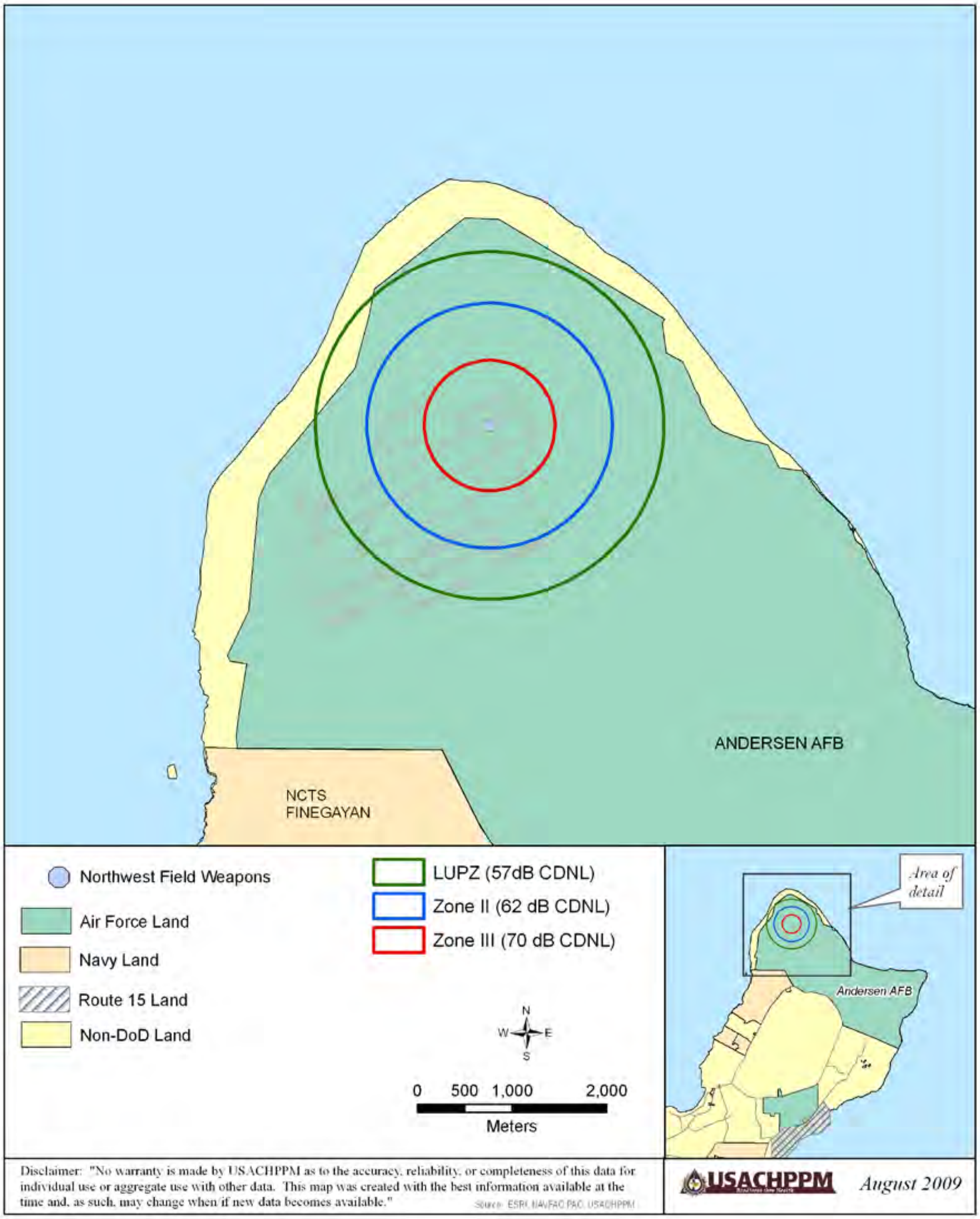

FIGURE 1. GUAM TRAINING RANGE – NORTHWEST FIELD WEAPONS EXISTING DEMOLITION OPERATIONAL NOISE CONTOURS

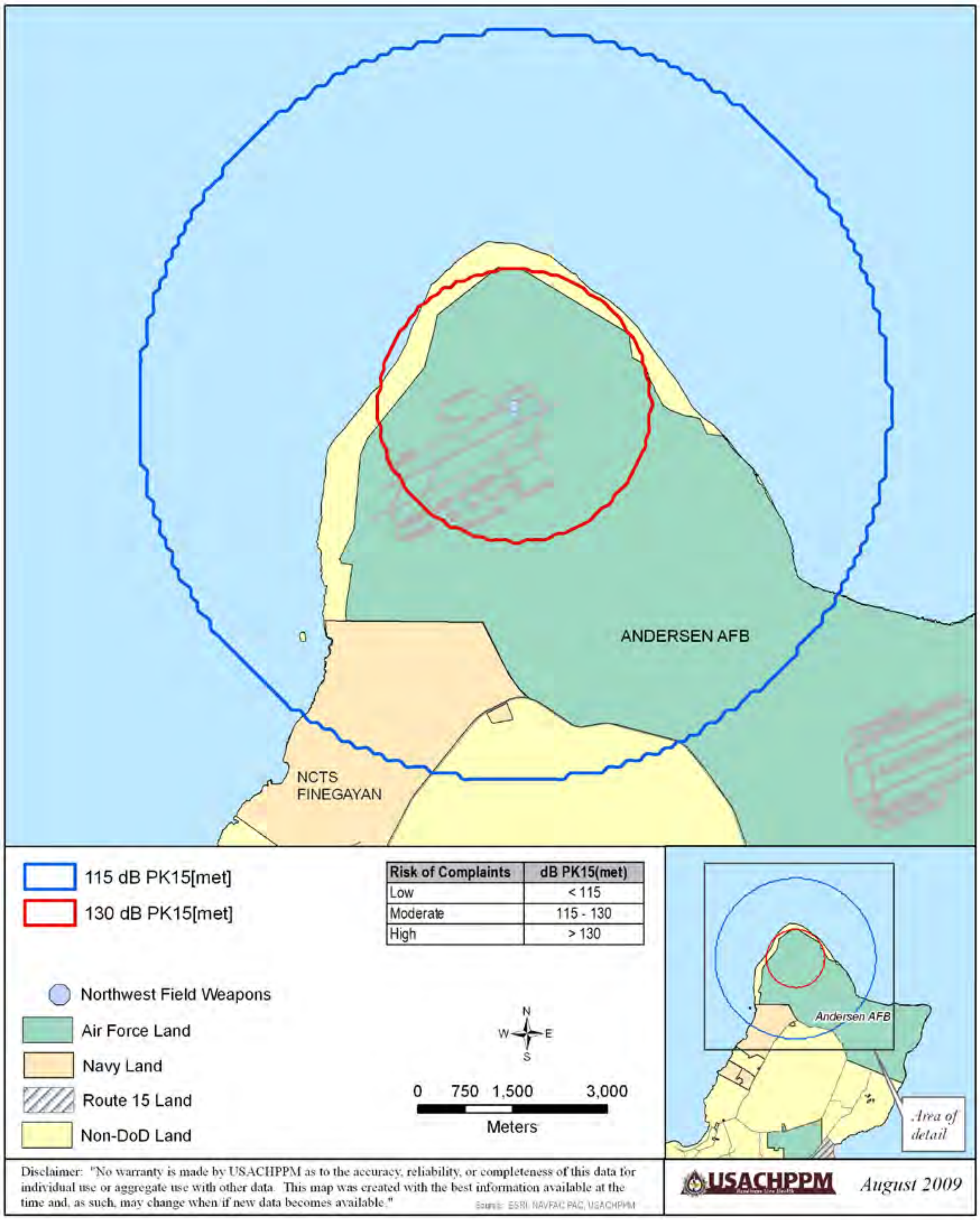

FIGURE 2. GUAM TRAINING RANGE - NORTHWEST FIELD WEAPONS COMPLAINT RISK CONTOURS

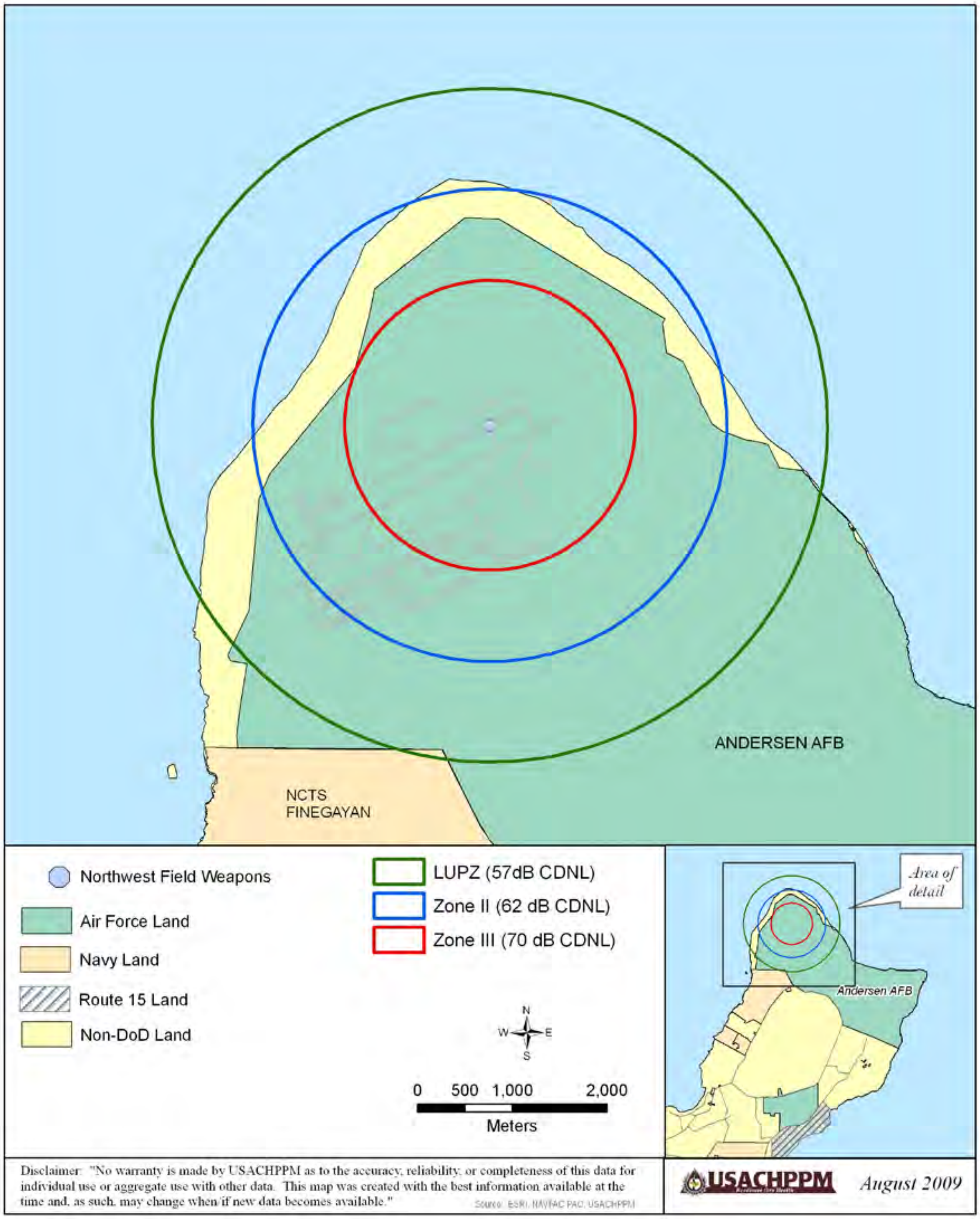

FIGURE 3. GUAM TRAINING RANGE – NORTHWEST FIELD WEAPONS PROJECTED DEMOLITION OPERATIONAL NOISE CONTOURS

6. GUAM TRAINING RANGES – ANDERSEN SOUTH TRAINING AREA.

a. Breacher Facility and Hand Grenade Range Noise Contour Results.

(1) General.

(a) The proposed Breacher Facility would consist of multiple existing structures. These structures would be utilized as a Military Operations in Urbanized Terrain (MOUT) training environment. The proposed activity is estimated at 36 days of utilization per year.

(b) The Hand Grenade Range consists of a hand grenade familiarization range and a hand grenade house with shock absorbing concrete walls. The proposed activity is estimated at 70 days of utilization per year with an average of 80 hand grenades per day.

(c) Table 3 lists the ammunition expenditure utilized to develop the CDNL noise contours. The facilities will be utilized during daytime hours (0700 – 2200).

TABLE 3. ANDERSEN SOUTH PROJECTED BREACHER FACILITY AND HAND GRENADE EXPENDITURE.

Facility	**Weapon**	**"Busy Day" Expenditure**	**Annual Expenditure**
		0700 – 2200 hours	0700 – 2200 hours
Breacher Facility	TNT (0.25 pounds)	2	72
Familiarization Range	Hand Grenade, M67	54	3,780
Grenade House	Hand Grenade, M67	26	1,820

(2) Alternative 1 Layout.

(a) Figure 4 contains the noise contours for the projected activity for the Breacher Facility and the Hand Grenade Range Alternative 1 layout. The LUPZ (57 dB CDNL) noise contour extends beyond the Andersen South boundary in all directions. The Zone II (62 dB CDNL) extends into a small area of non-military land between the Andersen South boundary and the Route 15 Land. The Zone III (70 dB CDNL) noise contour extends into the Route 15 Land.

(b) Figure 5 contains the complaint risk noise contours for the Breacher Facility and the Hand Grenade Range Alternative 1 layout. The moderate risk of complaint (115 dB PK15[met]) area extends beyond the boundary in all directions. Land use within the moderate risk of complaint (115 dB PK15[met]) area varies, containing both undeveloped and residential areas. The high risk of complaint (130 dB PK15[met]) area extends into the Route 15 Land.

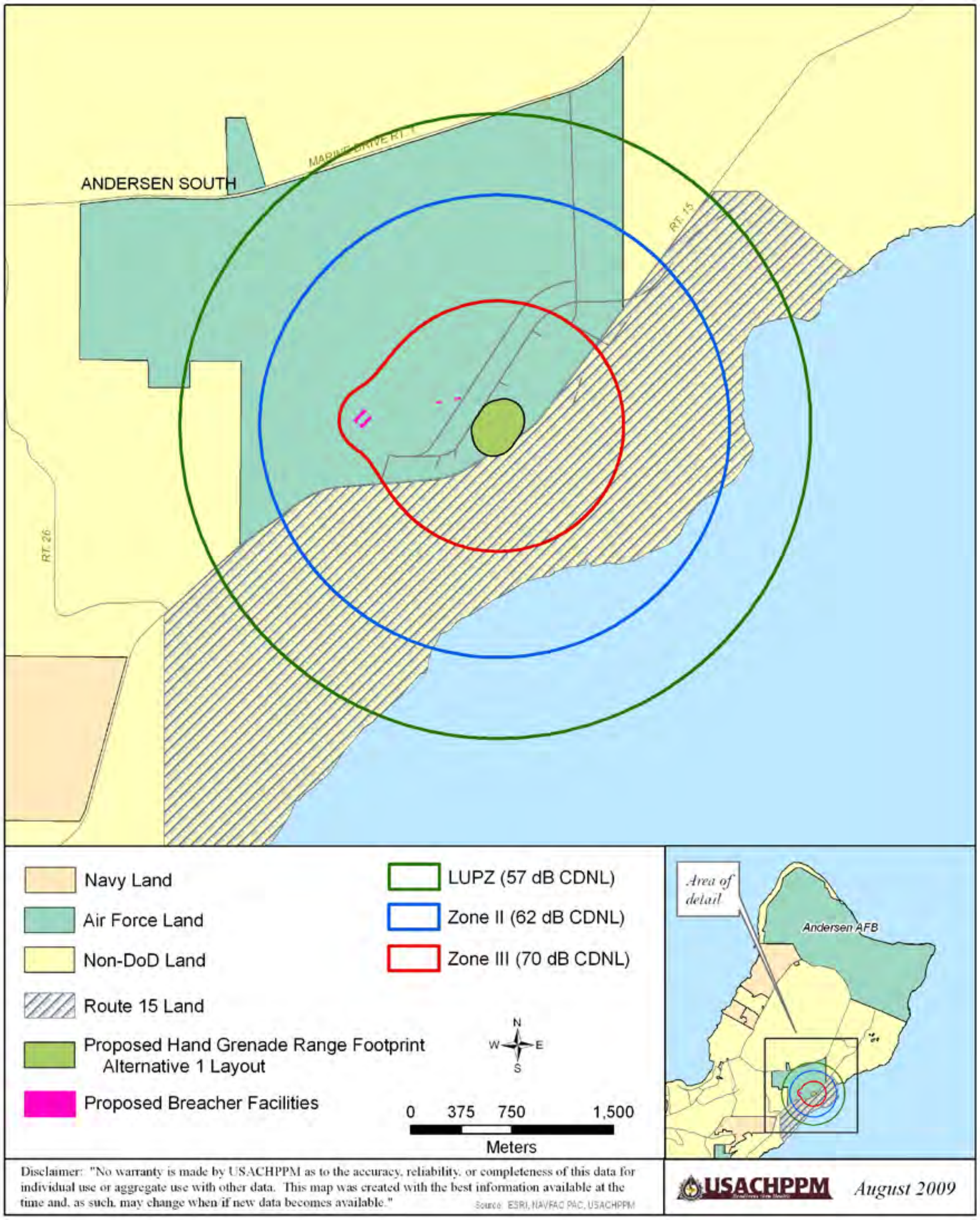

FIGURE 4. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 1 LAYOUT
OPERATIONAL NOISE CONTOURS

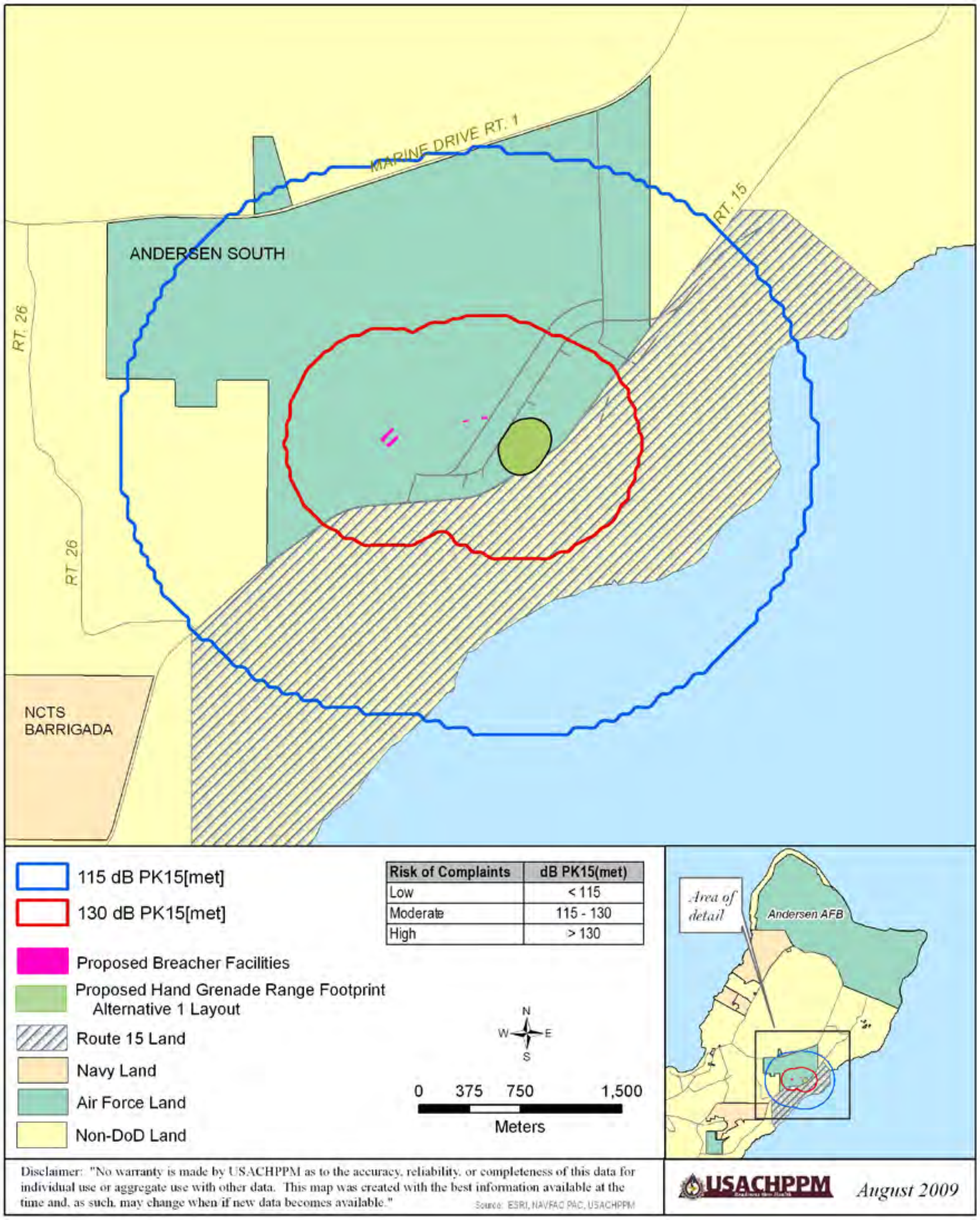

FIGURE 5. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 1 LAYOUT
COMPLAINT RISK CONTOURS

(3) Alternative 2 Layout.

(a) Figure 6 contains the noise contours for the projected activity for the Breacher Facility and the Hand Grenade Range Alternative 2 layout. The LUPZ (57 dB CDNL) noise contour extends beyond the boundary in all directions. The Zone II (62 dB CDNL) noise contour extends approximately 1,000 meters beyond the eastern boundary, crossing Route 15 and less than 600 meters beyond the northern boundary. The Zone III (70 dB CDNL) noise contour extends into the non-military land between Andersen South and the Route 15 Land.

(b) Figure 7 contains the complaint risk noise contours for the Breacher Facility and the Hand Grenade Range Alternative 2 layout. The moderate risk of complaint (115 dB PK15[met]) area extends beyond the boundary in all directions. Land use within the moderate risk of complaint (115 dB PK15[met]) area varies, containing both undeveloped and residential areas. The high risk of complaint (130 dB PK15[met]) area extends into the non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image land use within the high risk of complaint (130 dB PK15[met]) area is undeveloped.

(4) Land Use Compatibility.

(a) Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial image shown in Appendix D, land use surrounding Andersen South area varies from undeveloped to residential.

(b) Under the Breacher Facility and the Hand Grenade Alternative 1 location, the "busy day" CDNL Noise Zone II (62 dB CDNL) extends into a small portion of non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image there appears to be no noise sensitive land uses in this area. The Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen South boundary.

(c) Under the Breacher Facility and the Hand Grenade Alternative 2 location, multiple residential areas exist within the "busy day" Noise Zone II (62 dB CDNL) contour. The Noise Zone III (70 dB CDNL) contour extends into the non-military land between Andersen South and the Route 15 Land. There may be a small number of residences within the Noise Zone III (70 dB CDNL) contour.

(5) Complaint Risk. The complaint risk guidelines indicate a moderate probability of receiving noise complaints from the breacher facility activity. The complaint risk guidelines indicate a moderate probability of receiving noise complaints for the hand grenade activity from the Alternative 1 location. The complaint risk guidelines indicate a moderate to high probability of receiving noise complaints for the hand grenade activity from the Alternative 2 location.

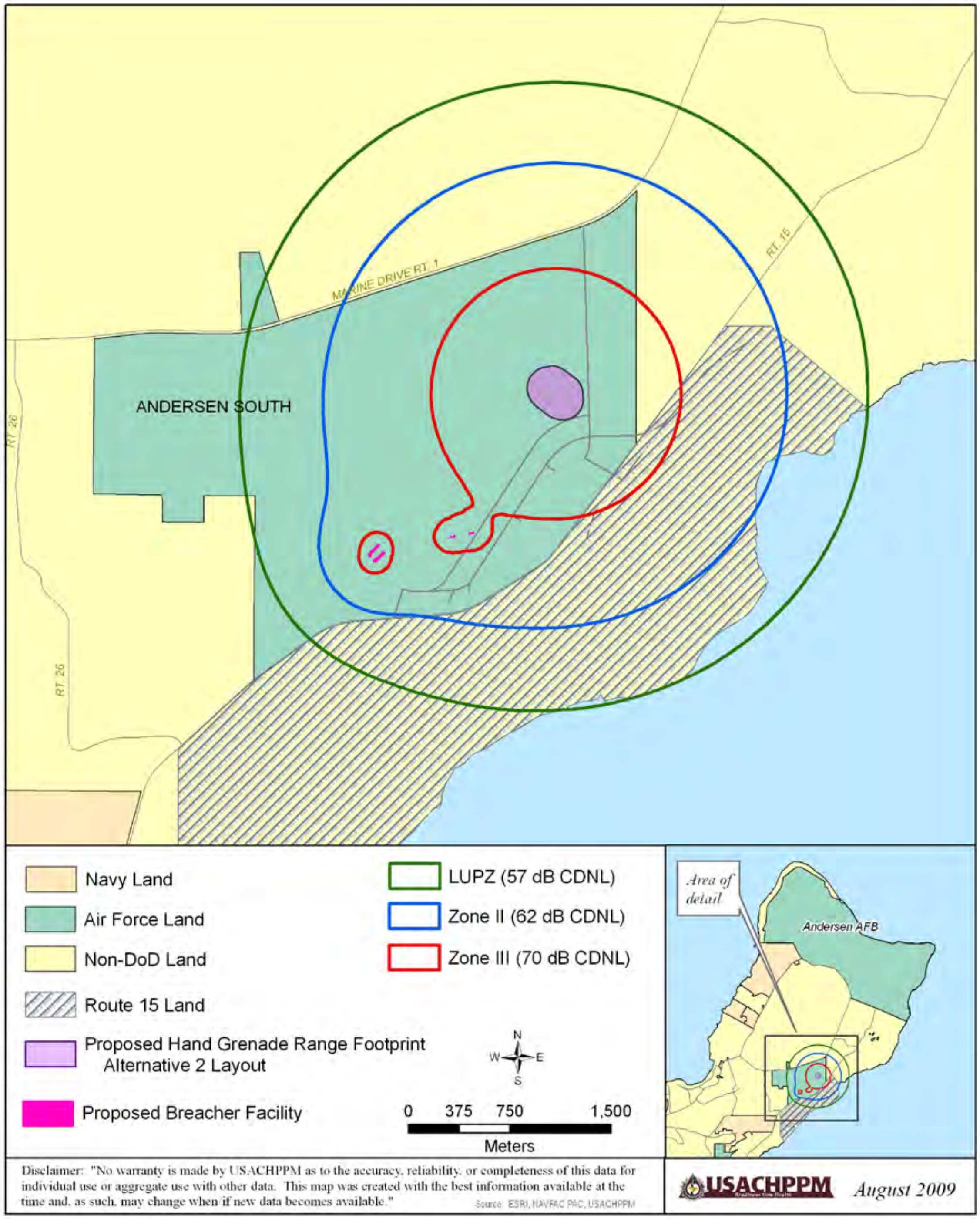

FIGURE 6. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 2 LAYOUT
OPERATIONAL NOISE CONTOURS

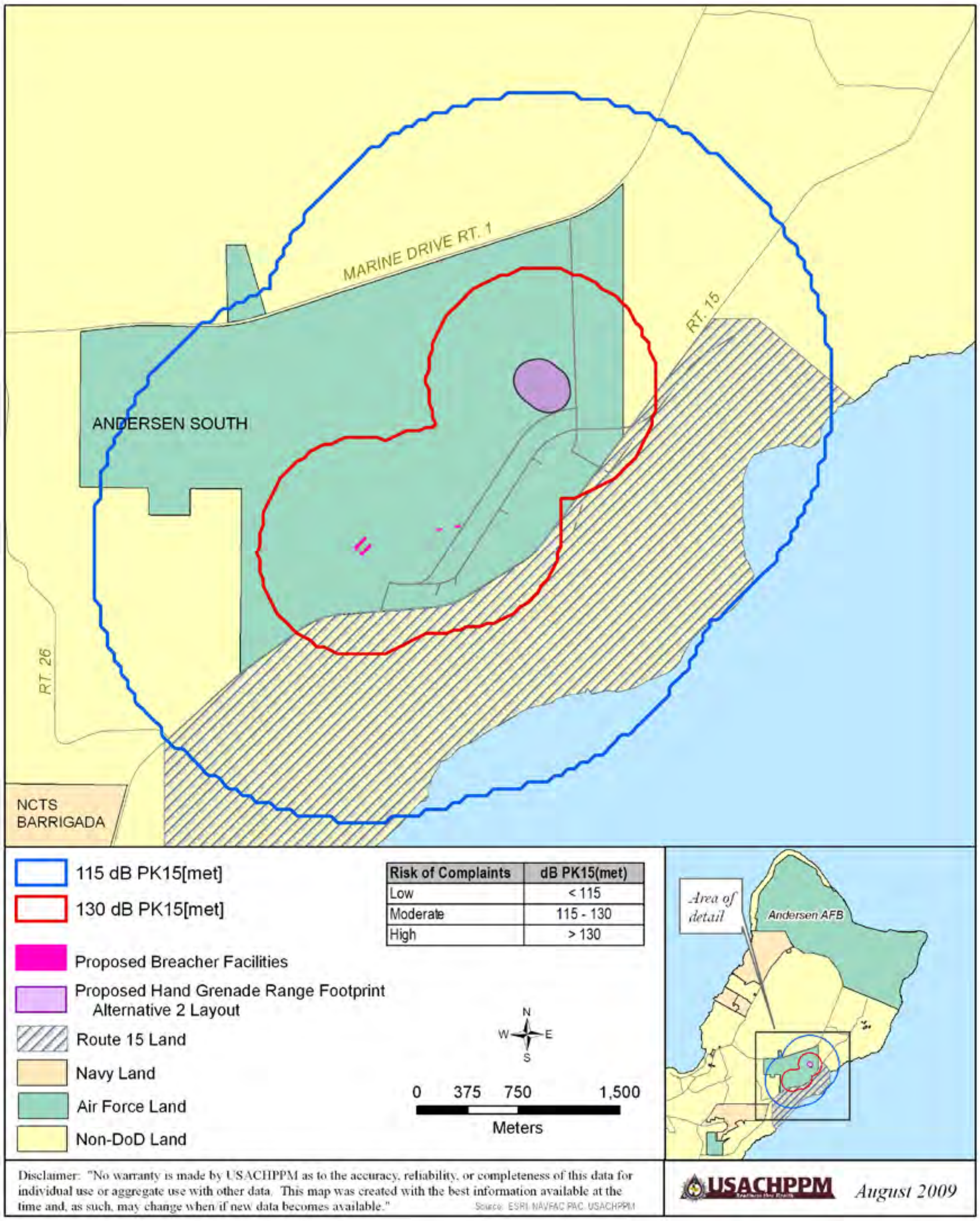

FIGURE 7. GUAM TRAINING RANGE - ANDERSEN SOUTH
BREACHER FACILITY AND HAND GRENADE RANGE ALTERNATIVE 2 LAYOUT
COMPLAINT RISK CONTOURS

b. Small Caliber Weapons Noise Contour Results.

(1) General. Table 4 lists the ranges and types of weapons utilized to create the projected small caliber weapons operational noise contours at the Andersen South training area.

TABLE 4. ANDERSEN SOUTH – PROJECTED SMALL CALIBER RANGE UTILIZATION.

	KD	MPMG	PISTOL	SQUARE BAY	UNKNOWN DISTANCE
PISTOL, 9mm			√	√	
PISTOL, .45 cal			√	√	
RIFLE, 5.56mm	√			√	√
MACHINE GUN, 7.62mm		√			
MACHINE GUN, .50 cal		√			

Note: cal = caliber, KD = Known Distance, mm = millimeter, MPMG = Multi-Purpose Machine Gun

(2) Route 15 Alternative A Layout. Figure 8 contains the small caliber weapons contours for the projected activity listed in Table 4 under the Route 15 Alternative A range layout. The Alternative A layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends up to 4,000 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends approximately 100 meters beyond the eastern boundary of Andersen South and the Route 15 Land.

(3) Route 15 Alternative B Layout. Figure 9 contains the small caliber weapons contours for the projected activity listed in Table 4 under the Route 15 Alternative B range layout. The Alternative B layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends 600 – 1,200 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone II [PK15(met) 87 dB] noise contour extends up to 1,400 meters beyond the western boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends less than 100 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends less than 70 meters beyond the western boundary of Andersen South and the Route 15 Land.

(4) Land Use Compatibility. Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial image shown in Appendix D, residential areas would fall within the Noise Zone II [PK15(met) 87 dB] contour. There may be scattered residences within the Noise Zone III [PK15(met) 104 dB] contour.

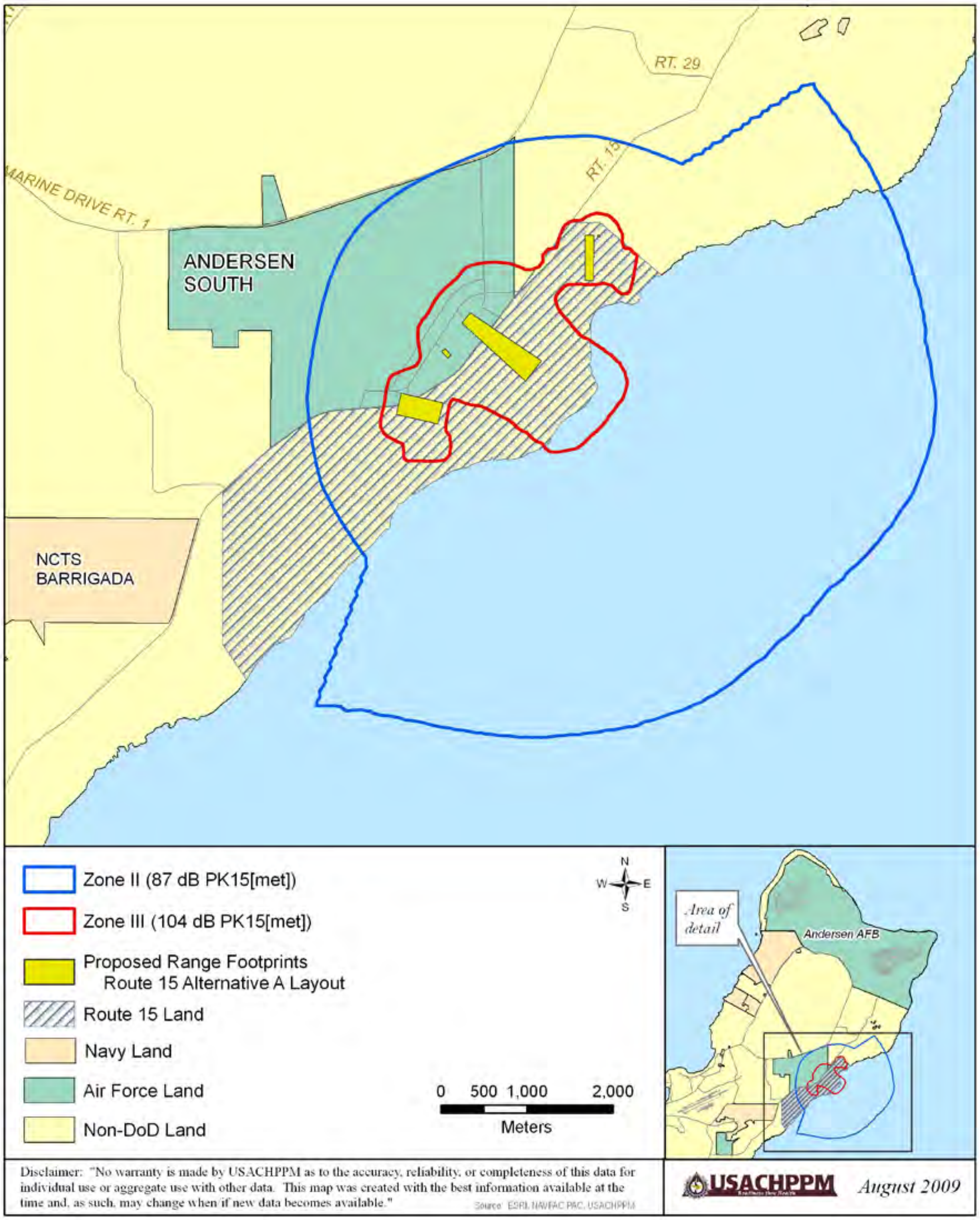

FIGURE 8. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE A PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

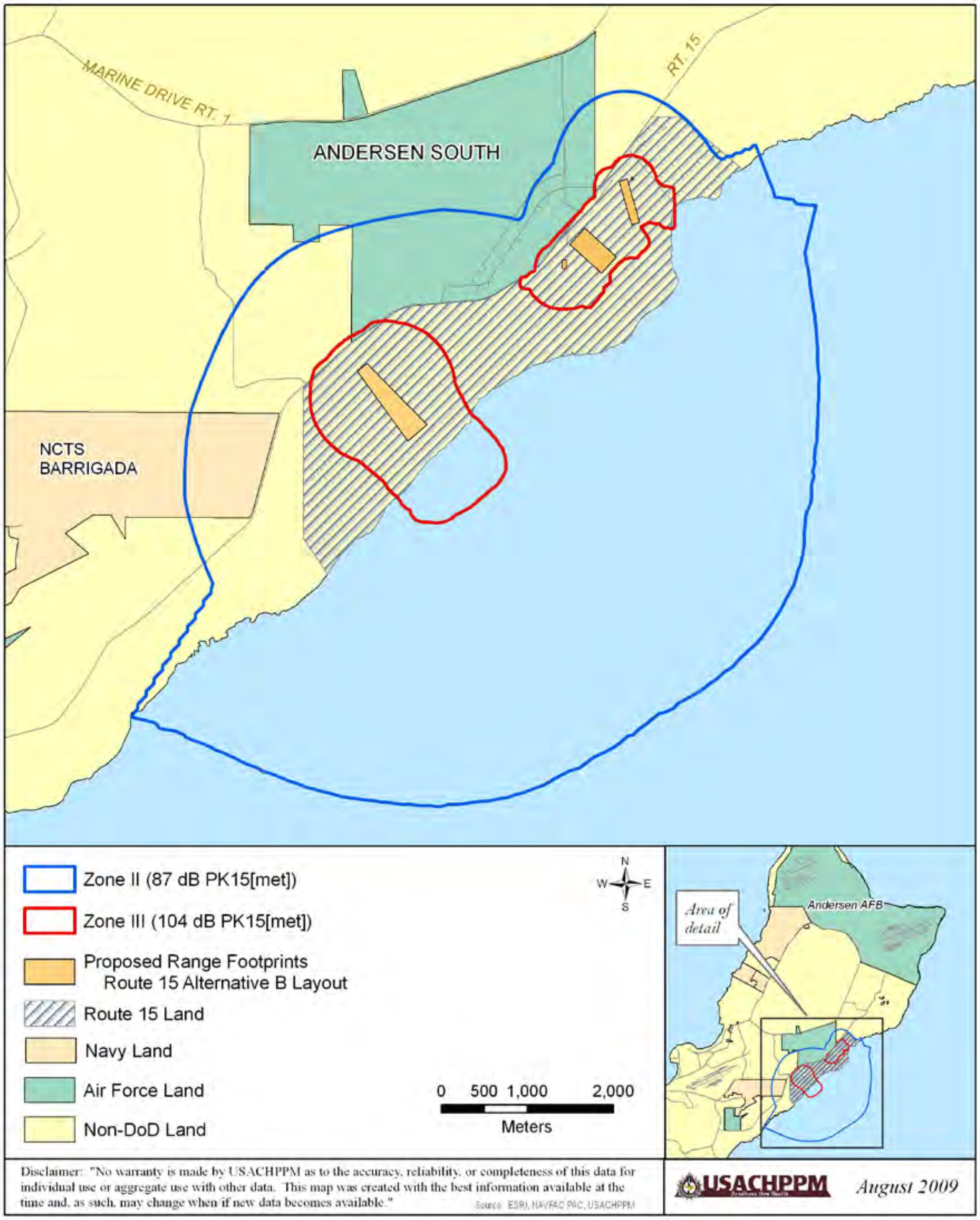

FIGURE 9. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE B PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

c. Shoot House Small Caliber Weapons Noise. The structures utilized in the Breacher Facility would also be utilized as Shoot Houses in the MOUT training environment. The proposed shoot houses are more than 850 meters from the boundary. The proposed weapon utilization would consist of the 12 gauge shot gun and 5.56mm rifle.

(1) To generate contours using SARNAM, specific firing point and target point locations must be entered into the computer. At a MOUT facility, there are no set firing point or target point locations; firing can occur at multiple locations and in multiple directions of fire. Therefore, noise contours for MOUT activity can not be modeled using SARNAM. However, by looking at the predicted peak levels for an 5.56mm blank round in Table 5, we can see that noise approaching Zone II levels [PK15(met) 87 dB] would extend out approximately 200 meters. Table 6 contains the predicted peak levels for a 12 gauge shotgun. We can see that noise approaching Zone II levels [PK15(met) 87 dB] would extend out approximately 800 meters.

TABLE 5. PREDICTED PEAK FOR 5.56mm BLANK ROUND.

	Predicted Level, dBP Azimuth		
Distance, meters	**0°**	**90°**	**180°**
100	87-97	86-96	87-97
200	80-90	79-89	80-90
400	69-79	68-78	69-79

Note: the 0° is directly in front of the weapon and the 180° azimuth is directly behind the weapon.

TABLE 6. PREDICTED PEAK FOR 12 GAUGE SHOTGUN.

	Predicted Level, dBP Azimuth		
Distance, meters	**0°**	**90°**	**180°**
100	117-127	105-115	106-116
200	110-120	98-108	100-110
400	99-109	88-98	90-100
800	90-100	79-89	82-92

Note: the 0° is directly in front of the weapon and the 180° azimuth is directly behind the weapon.

(2) Based upon the location of the Shoot Houses, the areas that could be exposed to Zone II levels from the small caliber operations do not extend beyond the Andersen South boundary.

7. MITIGATION TECHNIQUES TO REDUCE SMALL CALIBER WEAPONS NOISE LEVELS.

a. General. Small caliber PK15(met) contours are modeled to depict noise levels from individual weapons using weather conditions or wind direction that favors sound propagation. Gunshots are impulsive in nature and occur over a very short period in time, only a few thousandths of a second. The peak sound pressure level, PK, is defined as the level, expressed in decibels, of the highest instantaneous sound pressure that occurs during a given time period. Unlike topographic contours, noise contours are not intended to be precise representations of the noise zones. Meteorology and the receiver's perception of the source, etc. can influence the impact of noise. Noise contours do not clearly divide noise zones with one side of the line compatible and the other side incompatible.

b. Mitigation Potential- Operational.

(1) Small Arms Noise Zones are based on peak levels and computed using the loudest weapon fired at each location. Since the .50 caliber is significantly louder than the other rounds used for the assessment, though the contours would remain the same size, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities.

(2) Investigate the possibility of using the .50 caliber plastic bullet in place of the .50 caliber ball round. The acoustical energy “noise” from the .50 caliber plastic bullet is similar to the 7.62mm round. Although the Noise Zone II contour using the .50 caliber plastic bullet would still extend into the residential areas, the size of the Noise Zone II contour would be smaller.

c. Mitigation Potential- Physical Barrier.

(1) Barriers can be effective for small caliber weapons noise. The height of an effective noise reduction barrier must be considerably larger than the predominant wavelength, but the required height also depends on the barrier location relative to the source and the receiver, and on the amount of sound reduction that is needed to achieve the desired sound level. To be effective, barrier dimensions must be larger compared to the noise wavelength of the small caliber weapons utilized. The predominate frequency of the muzzle blast energy for the .50 caliber ball round is around 350 Hertz (Hz); wave length is about 1 meter (3 feet) high. The predominate frequency of muzzle blast energy for the 7.62mm and 5.56mm ball rounds is around 1000 Hz; wave length is about 1/3 meter (1 foot) high.

(2) The utility of constructing noise barriers in the vicinity of the MPMG, CPQC and KD ranges was investigated. The objective of this effort was to study the effectiveness of a barrier to reduce noise levels as well as to identify its dimensions. The SARNAM model (U.S. Army 2003b) was used to estimate the noise reduction that could be achieved with the placement of an earthen berm between the ranges and the residential areas. The SARNAM model is an analytical approximation of experimental data; the results provided by the formulation are consistent with the results of optical diffraction theory. Three sound diffraction paths are considered in the SARNAM: over the barrier, around the left side of the barrier, and around the right side of the barrier.

(3) As an indicator to the potential effectiveness of a barrier in noise reduction, one barrier design was analyzed for the CPQC and KD ranges and one barrier design for the MPMG ranges. Further modeling could be run to investigate if incorporating other barrier designs into the range would lessen the number of noise sensitive receptors within the Noise Zones.

(a) CPQC and KD Range Barrier Design. Based upon the location of the proposed ranges and the residential areas, a 3 meter high earthen berm would need to be constructed 3 meters behind the firing line; the berm would need to be the full width (uninterrupted) of the CPQC and KD range footprints, and extending 5 meters to either side of the range footprint (Figure 10). Although the layout for Alt A is shown in the figure, the barrier design would be the same for the CPQC and KD range locations in Alt B. Based upon the projected CPQC and KD range activity and location, a barrier of this design has the potential to provide up to 15 dB noise reduction.

(b) MPMG Range Barrier Design. Based upon the location of the proposed ranges and the residential areas, two earthen berms 3 meters high would need to be constructed for the MPMG range. One berm would be needed 3 meters behind the firing line and extending the full width (uninterrupted) of the MPMG range and extending 5 meters past the range footprint. A second berm would be needed along side of the range between the range footprint and the residential area. This side berm would need to join the berm behind the firing line and be 500 meters long (Figure 11). Although the layout for Alt B is shown in the figure, the barrier design would be the similar for the Alt A layout, with the side berm being constructed to the left side of the range (from the firing line point of view). Based upon the projected MPMG range activity and location, a barrier of this design has the potential to provide up to 10 dB noise reduction.

(c) Summary. The barrier designs presented have the potential to provide approximately a 10 -15 dB noise reduction dependant upon the weapon. However, construction barriers of this size may be cost prohibitive. Additionally, construction of a berm along side of the MPMG range may be limited in size or prohibited from a safety stand point.

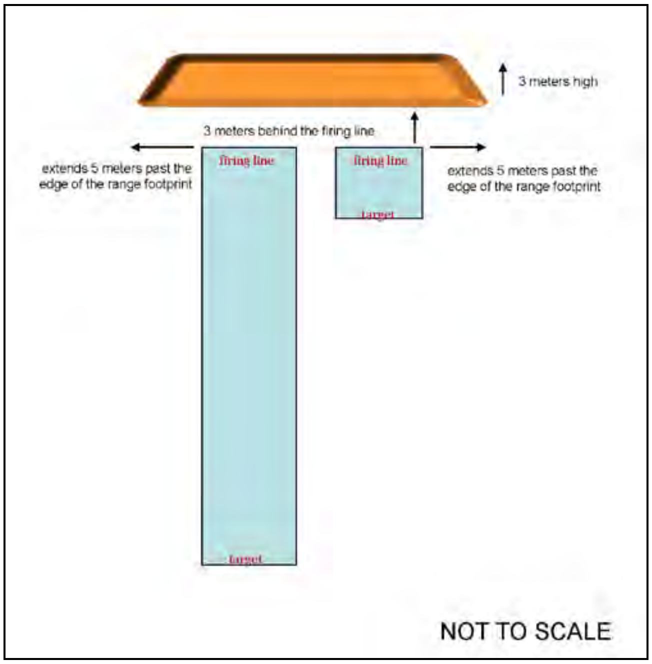

FIGURE 10. POTENTIAL BARRIER DESIGN FOR THE CPQC AND KD RANGES.

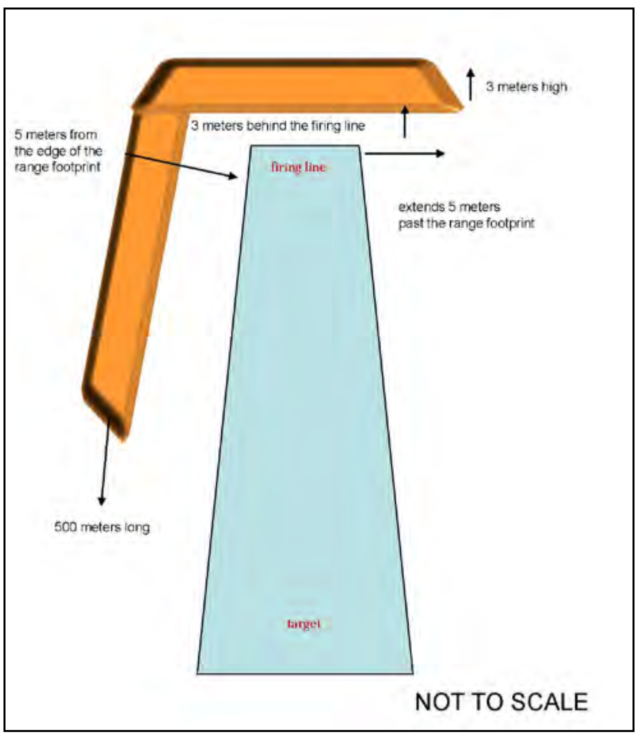

FIGURE 11. POTENTIAL BARRIER DESIGN FOR THE MPMG RANGES.

8. TINIAN TRAINING RANGES.

a. General. Appendix E shows the location of the proposed Tinian Training Ranges. The 90^{th} Street Option 1 is referred to as Alternative 1; the 90^{th} Street Option 2 is referred to as Alternative 2; and the West Field Option is referred to as Alternative 3. Table 7 lists the ranges and types of weapons utilized to create the projected activity operational noise contours at the Tinian Training Ranges.

TABLE 7. TINIAN – PROJECTED SMALL CALIBER RANGE UTILIZATION.

	CPQC	FIELD FIRE	KD	IPBC
PISTOLS, 9mm, .45 caliber	√			
RIFLE, 5.56mm		√	√	√

Note: CPQC = Combat Pistol Qualification Course, KD = Known Distance,
IPBC = Infantry Platoon Battle Course, mm = millimeter

b. Small Caliber Weapons Noise Contour Results.

(1) Alternative 1 Layout. Figure 12 contains the small caliber weapons contours for the projected activity under the Alternative 1 layout and the weapon utilization listed in Table 7. The Alternative 1 layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends approximately 200 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Tinian Training Range area.

(2) Alternative 2 Layout. Figure 13 contains the small caliber weapons contours for the projected activity under the Alternative 2 layout and the weapon utilization listed in Table 7. The Alternative 2 layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 150 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Tinian Training Range area.

(3) Alternative 3 Layout. Figure 14 contains the small caliber weapons contours for the projected activity under the Alternative 3 layout and the weapon utilization listed in Table 7. The Alternative 3 layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 950 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour extends approximately 200 meters into the San Jose Airport property.

c. Land Use Compatibility. Per AR 200-1, noise sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Under the Tinian alternatives, there are no noise sensitive land uses within the noise contours.

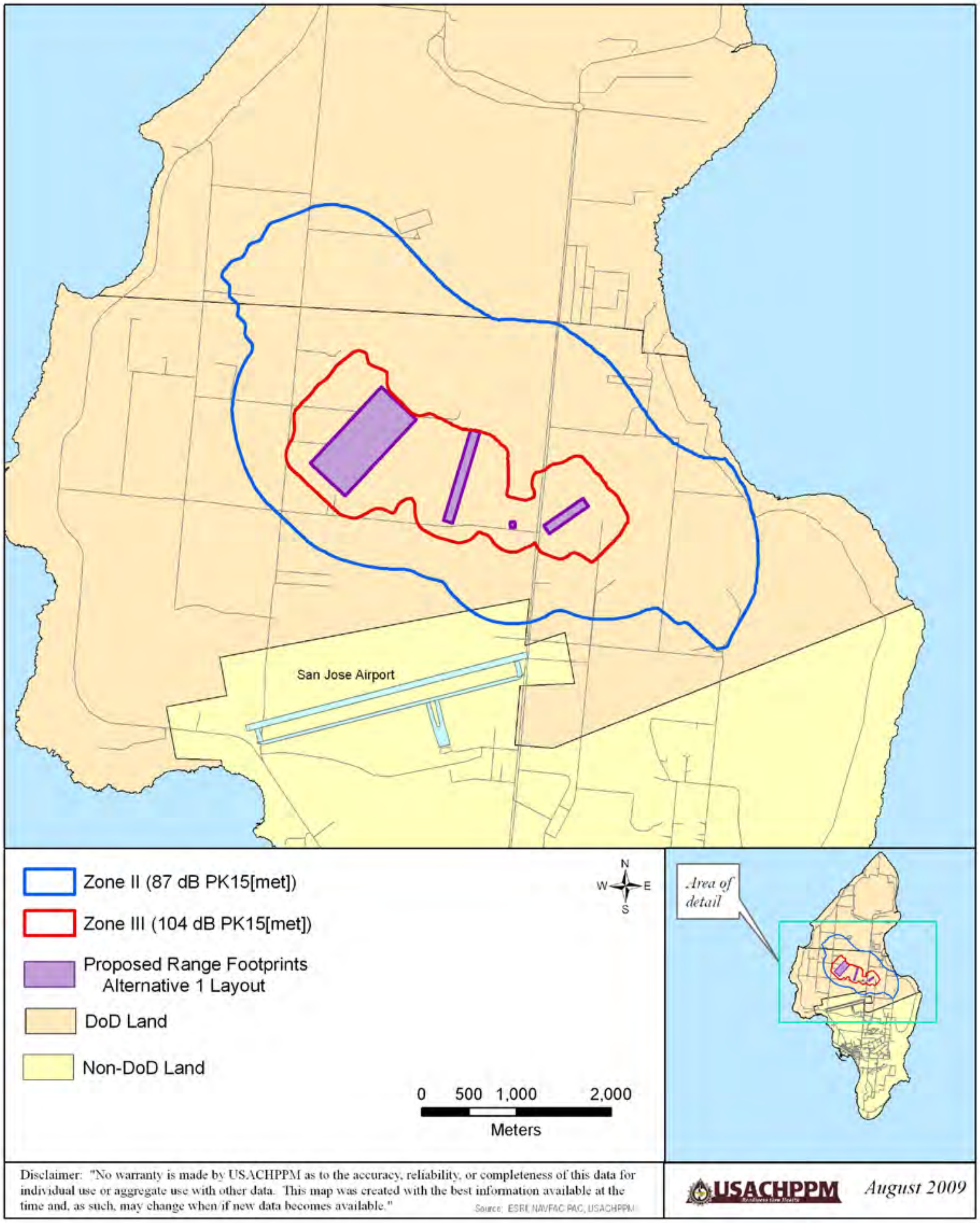

FIGURE 12. TINIAN TRAINING RANGE - ALTERNATIVE 1
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

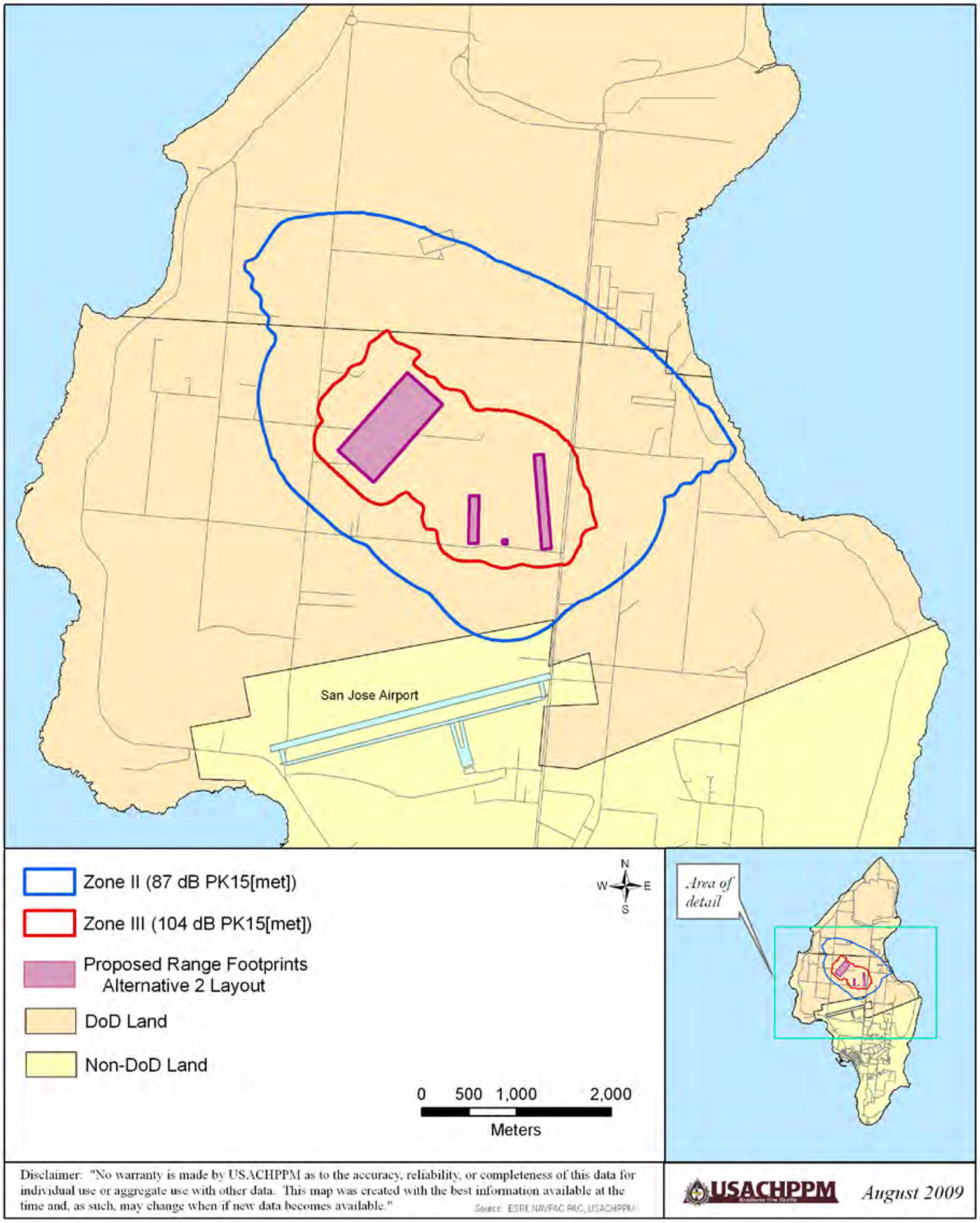

FIGURE 13. TINIAN TRAINING RANGE - ALTERNATIVE 2
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

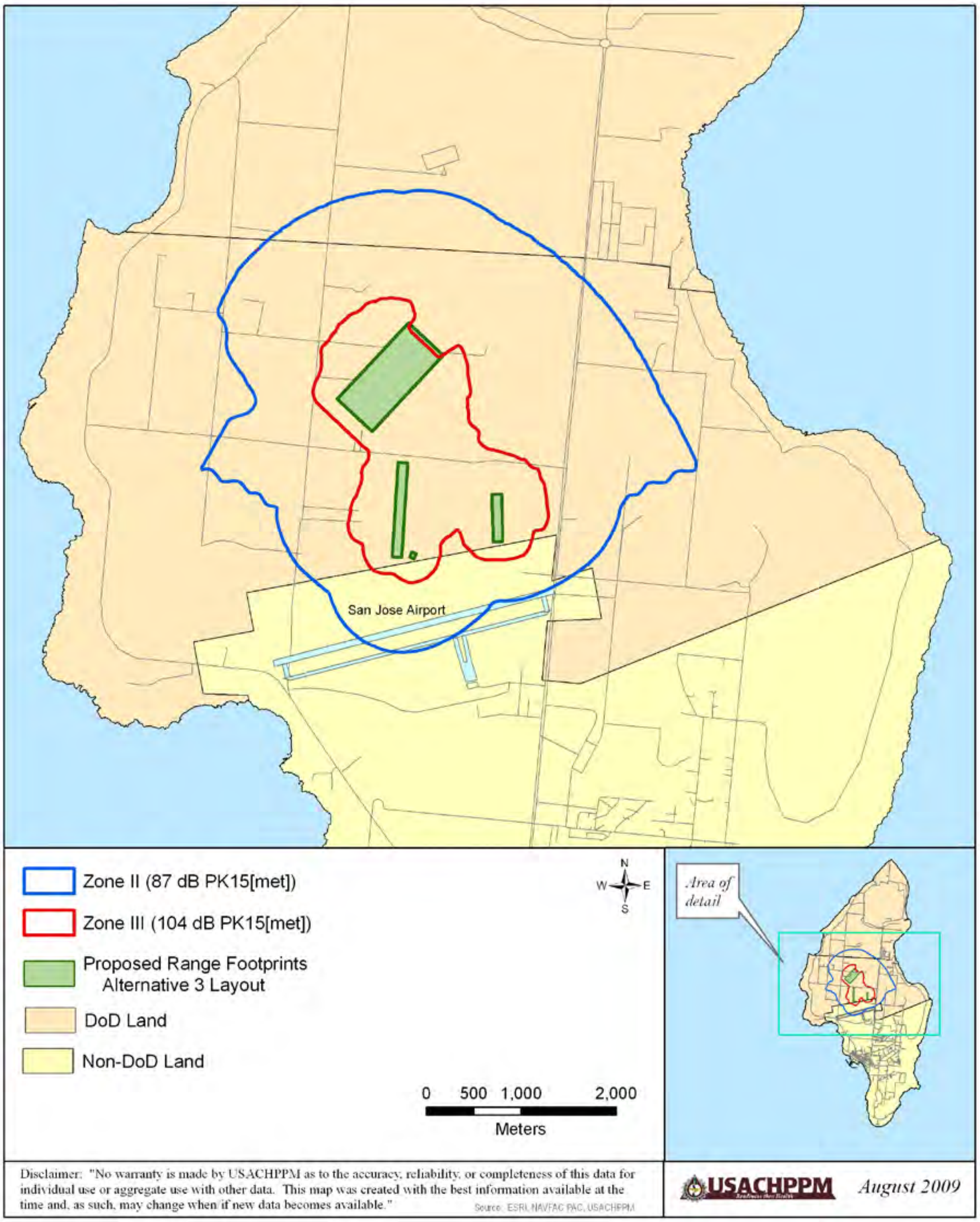

FIGURE 14. TINIAN TRAINING RANGE - ALTERNATIVE 3
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

9. GRENADE LAUNCHER.

a. Tables 8 and 9 contain the complaint risk criterion for the launch noise of the 40mm grenade launchers. The distances and levels listed represent a conservative approach and were calculated based upon hearing conservation criteria (U.S. Army 1999) and a known measurement (U.S. Army 1984). This data represents the best available scientific quantification for assessing the complaint risk for the launch noise of the 40mm grenade launcher until a detailed noise measurement study is completed.

TABLE 8. Complaint Risk to the Side of the 40mm Grenade Launcher, Inert* Round.

Risk of Complaints	Distance from Grenade Launcher	Noise Level PK15(met)
Low	> 300 meters^	< 115 dB
Moderate	65 - 300 meters^	115 dB
High	< 65 meters^	>130 dB
Risk of hearing damage for unprotected ears	< 19 meters+	>140 dB

* *-- Inert is defined as any round that does not make noise upon impact, such as smoke, illum, TP*
^ *– Calculated value*
+ *– Known value, hearing conservation criteria.*

TABLE 9. Complaint Risk to the Rear of the 40mm Grenade Launcher, Inert* Round.

Risk of Complaints	Distance from Grenade Launcher	Noise Level PK15(met)
Low	> 110 meters^	< 115 dB
Moderate	25 - 110 meters^	115 dB
High	< 25 meters^	>130 dB
Risk of hearing damage for unprotected ears	< 7 meters+	>140 dB

* *-- Inert is defined as any round that does not make noise upon impact, such as smoke, illum, TP*
^ *– Calculated value*
+ *– Known value, hearing conservation criteria.*

b. The proposed MPMG range activity may also include a 40mm grenade launcher. The proposed MPMG range locations at the Route 15 area are located such that the noise from the grenade launcher would be audible at the boundary. Both Route 15 alternative range locations are more than 300 meters from the rear of the grenade launcher to the boundary and 600 meters from the side of the grenade launcher to the boundary. The risk of complaints from the grenade launcher activity at the Route 15 Land area would be low.

10. CONCLUSIONS.

a. Guam Training Ranges.

(1) Northwest Field Weapons. The existing and projected "busy day" CDNL Noise Zone II (62 dB CDNL) and Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen AFB boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(2) Andersen South.

(a) Breacher Facility and Hand Grenade Range Alternative 1. Under the Breacher Facility and the Hand Grenade Alternative 1 location, the "busy day" CDNL Noise Zone II (62 dB CDNL) extends into a small portion of non-military land between Andersen South and the Route 15 Land. Based upon the available aerial image there appears to be no noise sensitive land uses in this area. The Noise Zone III (70 dB CDNL) contours do not extend beyond the Andersen South boundary. The contours remaining on base indicate that annual average noise levels from the demolition activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

(b) Breacher Facility and Hand Grenade Range Alternative 2. Under the Breacher Facility and the Hand Grenade Alternative 2 location, multiple residential areas exist within the "busy day" Noise Zone II (62 dB CDNL) contour. The Noise Zone III (70 dB CDNL) contour extends into the non-military land between Andersen South and the Route 15 Land. There may be a small number of residences within the Noise Zone III (70 dB CDNL) contour.

(c) Small Caliber Weapons Activity. The proposed Route 15 Alternatives would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the Andersen South boundary and the Route 15 Land. Under the Route 15 Alternatives, existing residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There may be scattered residences within the Noise Zone III (104 dB PK15[met]) contour.

(d) Grenade Launcher Activity. The proposed grenade launcher activity would be audible at the boundary but unlikely to generate complaints.

(e) Mitigation Potential. Small Arms Noise Zones are based on peak levels and computed using the loudest weapon fired at each location. Since the .50 caliber is significantly louder than the other rounds used for the assessment, though the contours would remain the same size, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities. Additionally, further modeling could be run to investigate if incorporating barriers into the range designs would lessen the number of noise sensitive receptors within the Noise Zones.

b. Tinian Training Ranges. The proposed small caliber weapon activity alternatives would generate a PK15(met) Noise Zone II (87 dB) and Noise Zone III (104 dB) contours that extend beyond the Tinian Training Range boundary. However, there are no noise sensitive land uses within the noise contours.

11. RECOMMENDATIONS.

a. Include the information from this consultation in the appropriate NEPA documentation.

b. Although no Federal Law prohibits the Department of Defense training and testing activities from making noise, the Services have always tried to be good neighbors. To reduce the risk of noise complaints from the proposed activity, the NAVFAC PAC should use the U.S. Army's Operational Noise Management Program guidance in conjunction with the Air Force's Air Installation Compatible Use Zone program to address the impulsive noise events. (Appendix F).

Kristy Broska

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APPROVED:

For: CATHERINE STEWART
Program Manager
Operational Noise

APPENDIX A

REFERENCES

1. U.S. Army, 2003a, U.S. Army Construction Engineering Research Laboratories, BNOISE2 Computer Model, Version 1.3.2003-07-03.

2. The U.S. Army, 2003b, U.S. Army Construction Engineering Research Laboratories, SARNAM Computer Model, Version 2.6.2003-06-06.

3. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise.

APPENDIX B

GLOSSARY OF TERMS, ACRONYMS & ABBREVIATIONS

B-1. GLOSSARY OF TERMS.

Average Sound Level - the mean-squared sound exposure level of all events occurring in a stated time interval, plus ten times the common logarithm of the quotient formed by the number of events in the time interval, divided by the duration of the time interval in seconds.

C-Weighted Sound Level - a quantity, in decibels, read from a standard sound level meter with C-weighting circuitry. The C-scale incorporates slight de-emphasis of the low and high portion of the audible frequency spectrum.

Day-Night Average Sound Level (DNL) - the 24-hour average frequency-weighted sound level, in decibels, from midnight to midnight, obtained after addition of 10 decibels to sound levels in the night from midnight up to 7 a.m. and from 10 p.m. to midnight (0000 up to 0700 and 2200 up to 2400 hours).

Decibels (dB) – a logarithmic sound pressure unit of measure.

Land Use Planning Zone (LUPZ) - DNL noise contours represent an annual average that separates the Noise Zone II from the Noise Zone I.

Noise – any sound without value.

PK15(met) - the maximum value of the instantaneous sound pressure for each unique sound source, and applying the 15 percentile rule accounting for meteorological variation.

B-2. GLOSSARY OF ACRONYMS AND ABBREVIATIONS.

AFB	Air Force Base
BNOISE2	Blast Noise Impact Assessment
cal	caliber
CPQC	Combat Pistol Qualification Course
dB	Decibels
CDNL	C-weight Day Night Level
IPBC	Infantry Platoon Battle Course
KD	Known Distance
mm	millimeter
MPMG	Multi-Purpose Machine Gun
NAVFAC PAC	Navy Facilities Engineering Command, Pacific
NCTS	Naval Computer and Telecommunications Station
NEPA	National Environmental Policy Act
NFW	Northwest Field Weapons
PK15(met)	Unweighted Peak, 15% Metric
SARNAM	Small Arms Range Noise Assessment Model
TNT	Trinitrotoluene

APPENDIX C

NOISE ZONE DESCRIPTIONS

C-1. REFERENCE. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise. The Air Force and the Navy uses the Army regulation in regards to noise from weapon activity.

C-2. For a detailed explanation of Noise Zone Descriptions and Land Use Guidelines see Army Regulation 200-1, Chapter 14 (U.S. Army 2007).

C-3. Day Night Level (DNL). The DNL is used to describe the cumulative or total noise exposure during a prescribed time period. The DNL is the energy average noise level calculated with a 10 decibel penalty for operations occurring between 2200 and 0700.

C-4. PK15(met) Noise Contour Description. The PK15(met) is the peak sound level, factoring in the statistical variations caused by weather, that is likely to be exceeded only 15 percent of the time (i.e., 85 percent certainty that sound will be within this range). This "85 percent solution" gives the installation and the community a means to consider the areas impacted by training noise without putting stipulations on land that would only receive high sound levels under infrequent weather conditions that greatly favor sound propagation. The PK15(met) does not take the duration or the number of events into consideration, so the size of the contours will remain the same regardless of the number of events.

C-5. Land Use Guidelines.

a. The Noise Zone III consists of the area around the noise source in which the level is greater than 70 decibels (dB) C-weighted day-night average sound level (CDNL) for large caliber weapons or greater than 104 dB PK15(met) for small caliber weapons. Noise-sensitive land uses (such as housing, schools, and medical facilities) are not recommended within Noise Zone III.

b. The Noise Zone II consists of an area where the DNL is between 62 and 70 dB CDNL for large caliber weapons or between 87 and 104 dB PK15(met) for small caliber weapons. Land within Noise Zone II should normally be limited to activities such as industrial, manufacturing, transportation, and resource production. However, if the community determines that land in Noise Zone II (attributable to small arms or aviation) areas must be used for residential purposes, then noise level reduction (NLR) features of 25 to 30 decibels should be incorporated into the design and construction of *new* buildings to mitigate noise levels. For large caliber weapons, NLR features can not adequately mitigate the low-frequency component of large caliber weapons noise.

c. The Noise Zone I includes all areas around a noise source in which the day-night sound level is less than 62 dB CDNL for large caliber weapons and less than 87 PK15(met) for small arms weapons. This area is usually acceptable for all types of land use activities.

d. The Land Use Planning Zone (LUPZ) DNL noise contours (57 dB CDNL) represent an annual average that separates the Noise Zone II from the Noise Zone I. Taking all operations that occur over the year and dividing by the number of training days generates the contours. But, the noise environment varies daily and seasonally because operations are not consistent through all 365 days of the year. In addition, the Federal Interagency Committee on Urban Noise document states “Localities, when evaluating the application of these guidelines to specific situations, may have different concerns or goals to consider.” For residential land uses, depending on attitudes and other factors, a 57 CDNL may be considered by the public as an impact on the community environment. In order to provide a planning tool that could be used to account for days of higher than average operations and possible annoyance, the LUPZ contour is being included on the noise contour maps.

e. See Table C-1 for land use guidelines.

Table C-1. LAND USE PLANNING GUIDELINES.

Noise Zones	**Large-Caliber Weapons dB CDNL**	**Small Arms dB PK15(met)**
LUPZ	57 – 62	n/a
I	< 62	<87
II	62 - 70	87-104
III	> 70	>104

C-6. Complaint Risk Guidelines for Demolition Activity and Large Caliber Weapons.

a. A peak contour is based upon the expected level that one could get on a sound level meter when a weapon was fired. Since weather conditions can cause noise levels to vary significantly from day to day (even from hour to hour) the programs calculate a range of peak levels. By plotting the PK15(met) contour, events would be expected to fall within the contours 85 percent of the time. This metric represents the best available scientific quantification for assessing the complaint risk of large caliber weapons ranges. The complaint risk areas for PK15(met) noise contours are defined as follows:

(1) The high risk of complaint consists of the area around the noise source in which PK15(met) is greater than 130 dB for large caliber weapons.

(2) The moderate risk of complaint area consists of where the PK15(met) noise contour is between 115 dB and 130 dB for large caliber weapons.

(3) The low risk of complaint area is where the PK15(met) noise level is less than 115 dB for large caliber weapons.

b. See Table C-2 for complaint risk guidelines.

Table C-2. COMPLAINT RISK GUIDELINES.

Risk of Complaints	Large Caliber Weapons PK15(met) dB Noise Contour
Low	< 115
Moderate	115 - 130
High	> 130

APPENDIX D

GUAM TRAINING RANGE AREA MAPS

FIGURE D-1. GUAM TRAINING RANGES VICINITY MAP

FIGURE D-2. ANDERSEN AIR FORCE BASE – NORTHWEST FIELD WEAPONS VICINITY MAP

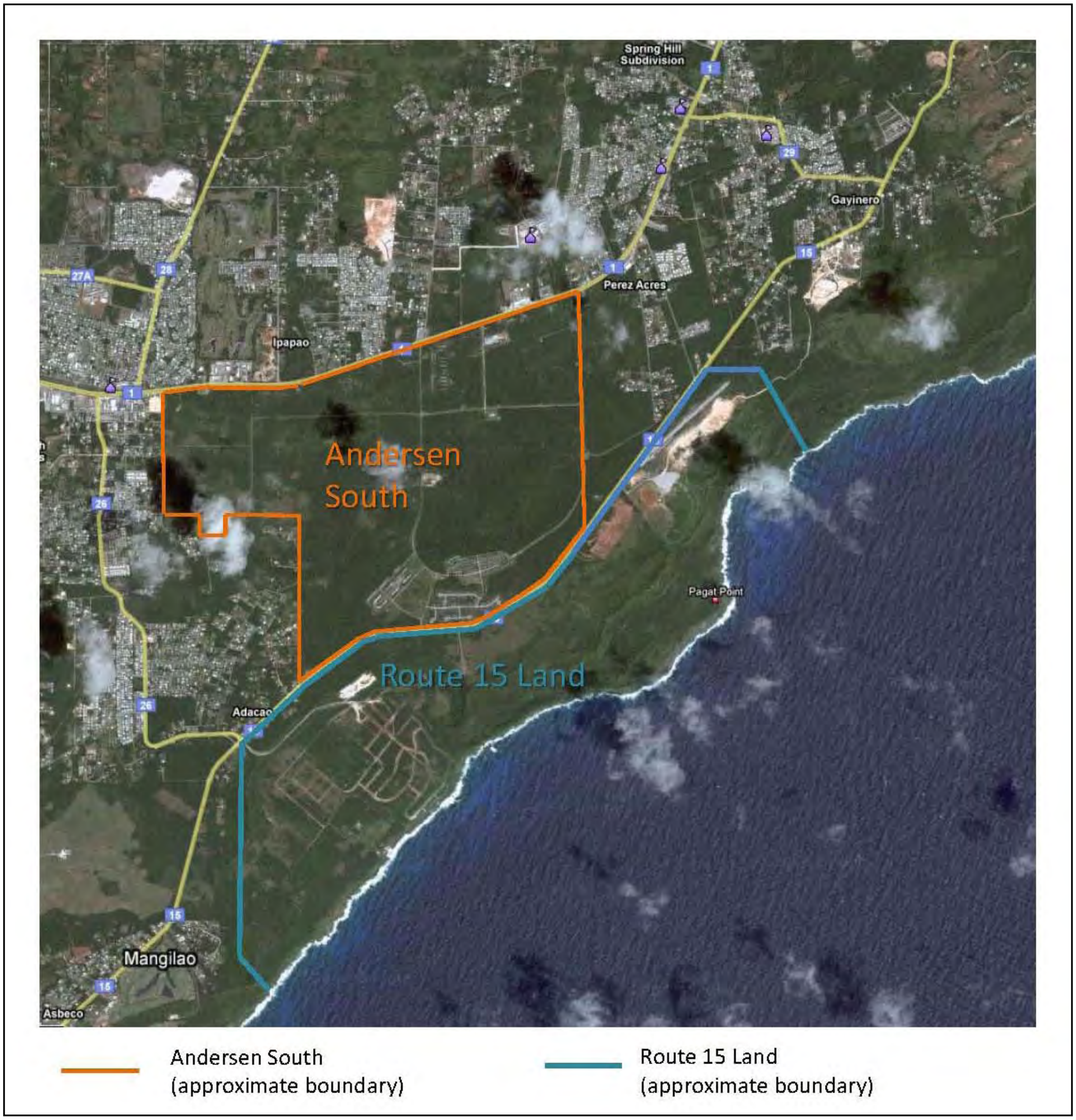


FIGURE D-3. ANDERSEN SOUTH AND ROUTE 15 LAND VICINITY MAP

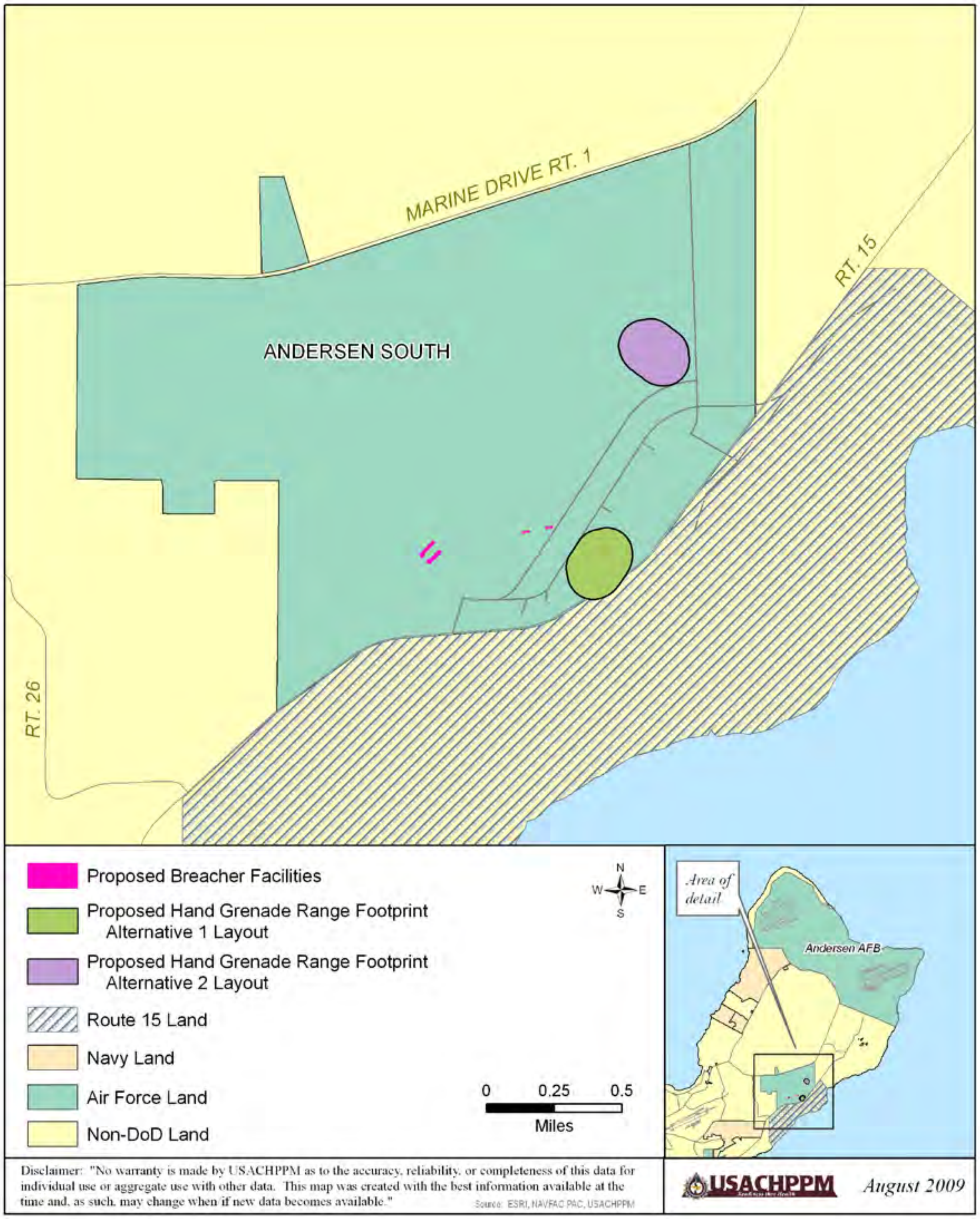


FIGURE D-4. GUAM TRAINING RANGES – ROUTE 15
PROPOSED BREACHER FACILITIES
PROPOSED HAND GRENADE RANGE ALTERNATIVES

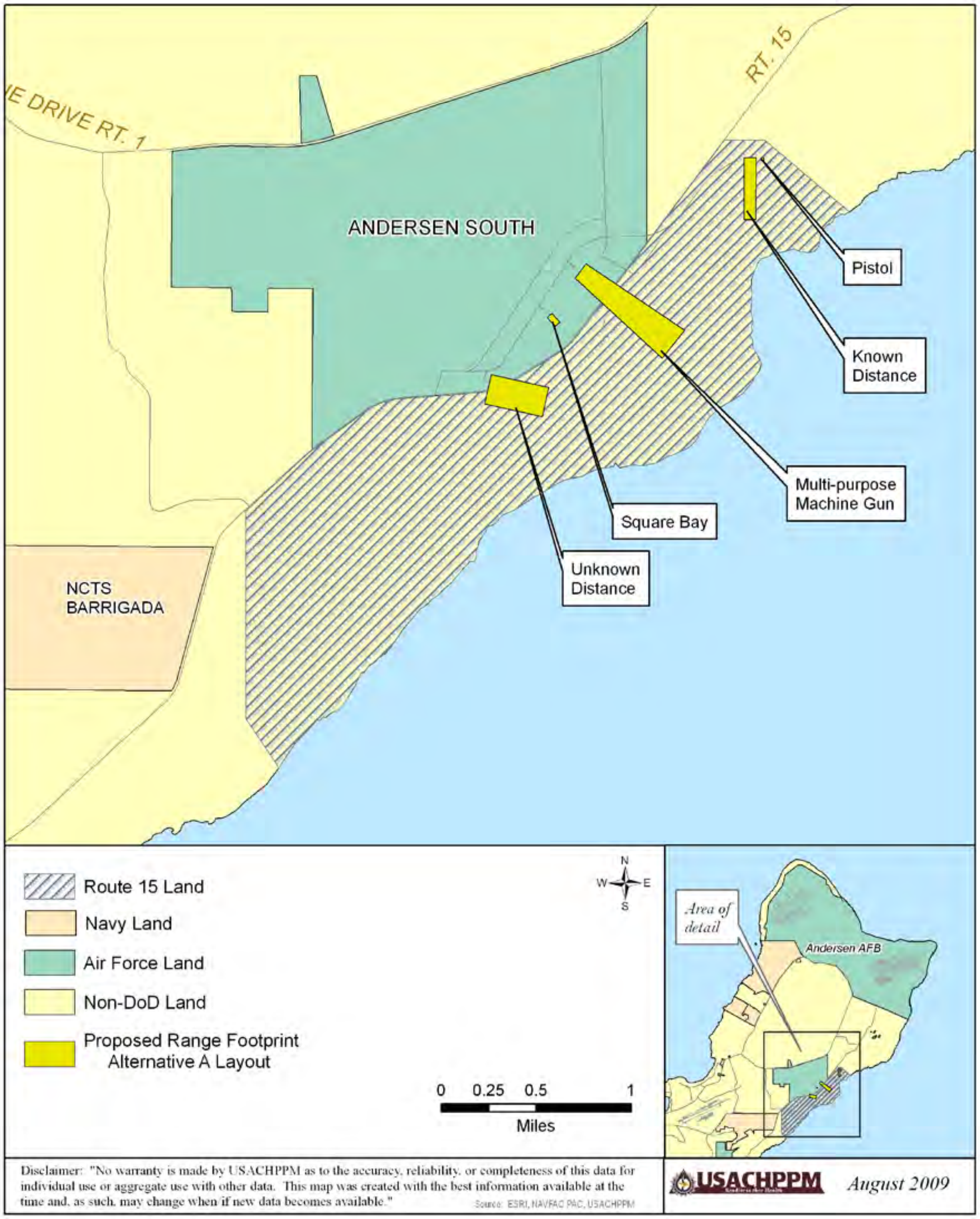


FIGURE D-5. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE A LAYOUT

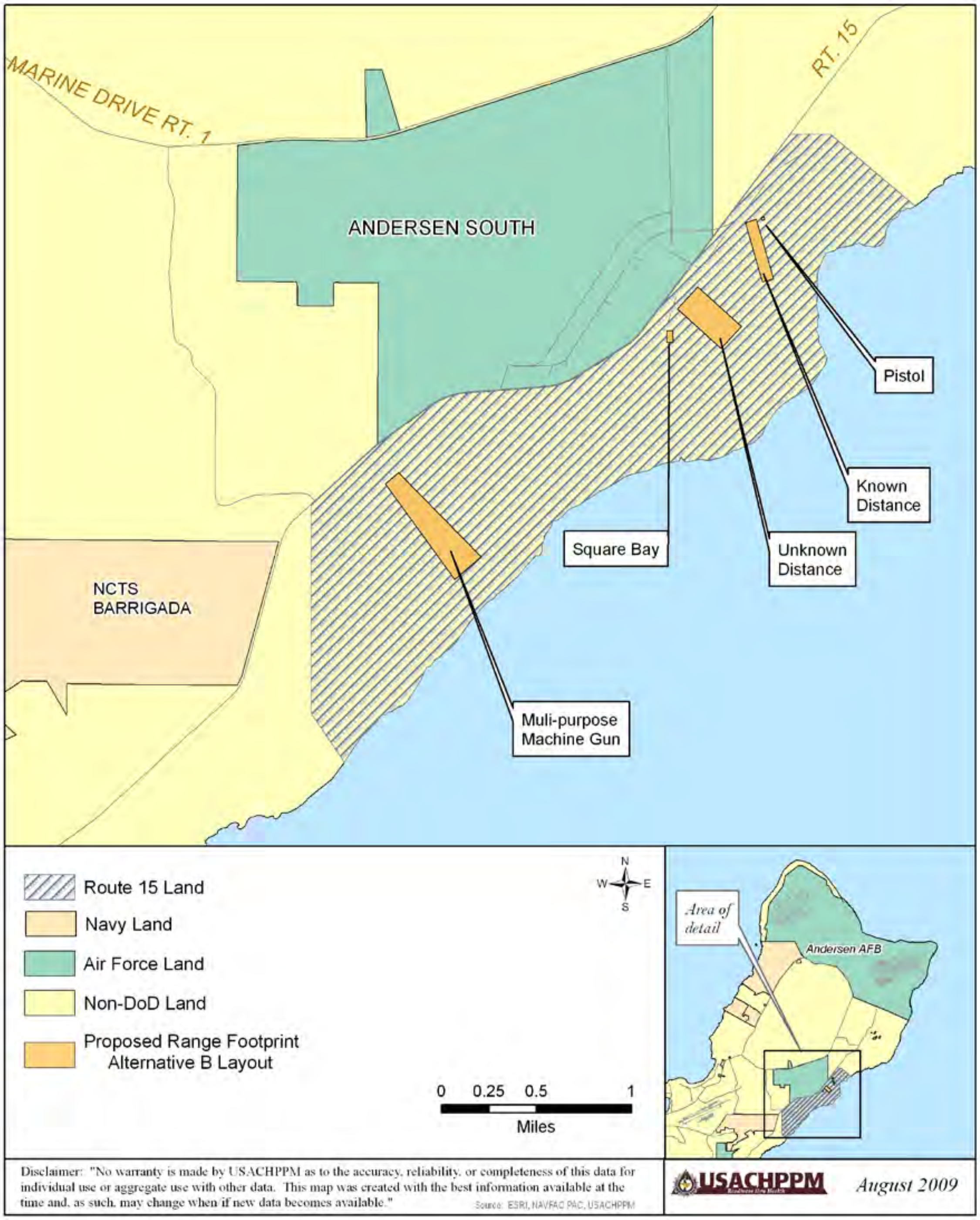


FIGURE D-6. GUAM TRAINING RANGES - ROUTE 15 ALTERNATIVE B LAYOUT

APPENDIX E

TINIAN TRAINING RANGES AREA MAPS

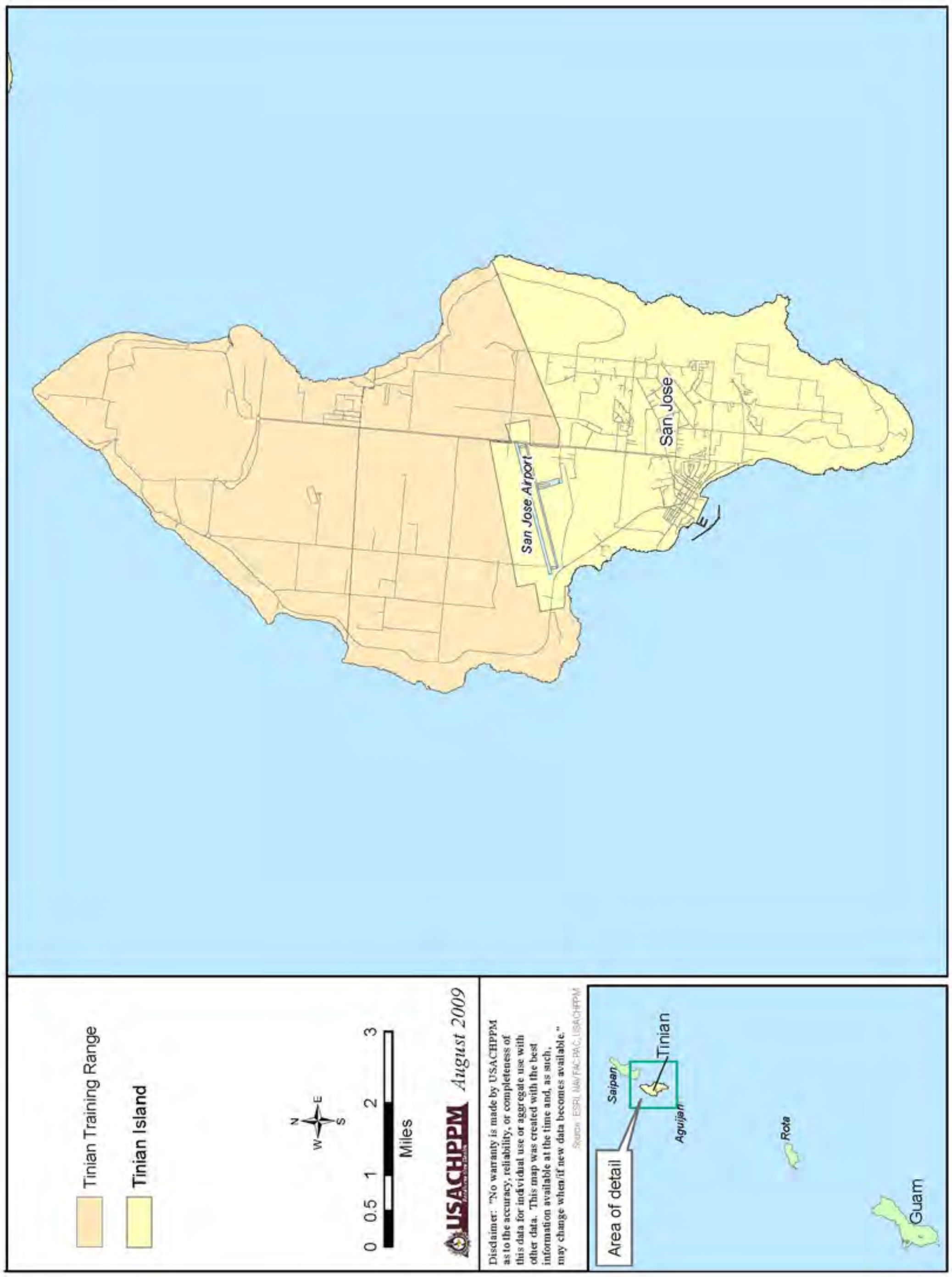


FIGURE E-1. TINIAN TRAINING RANGES VICINITY MAP

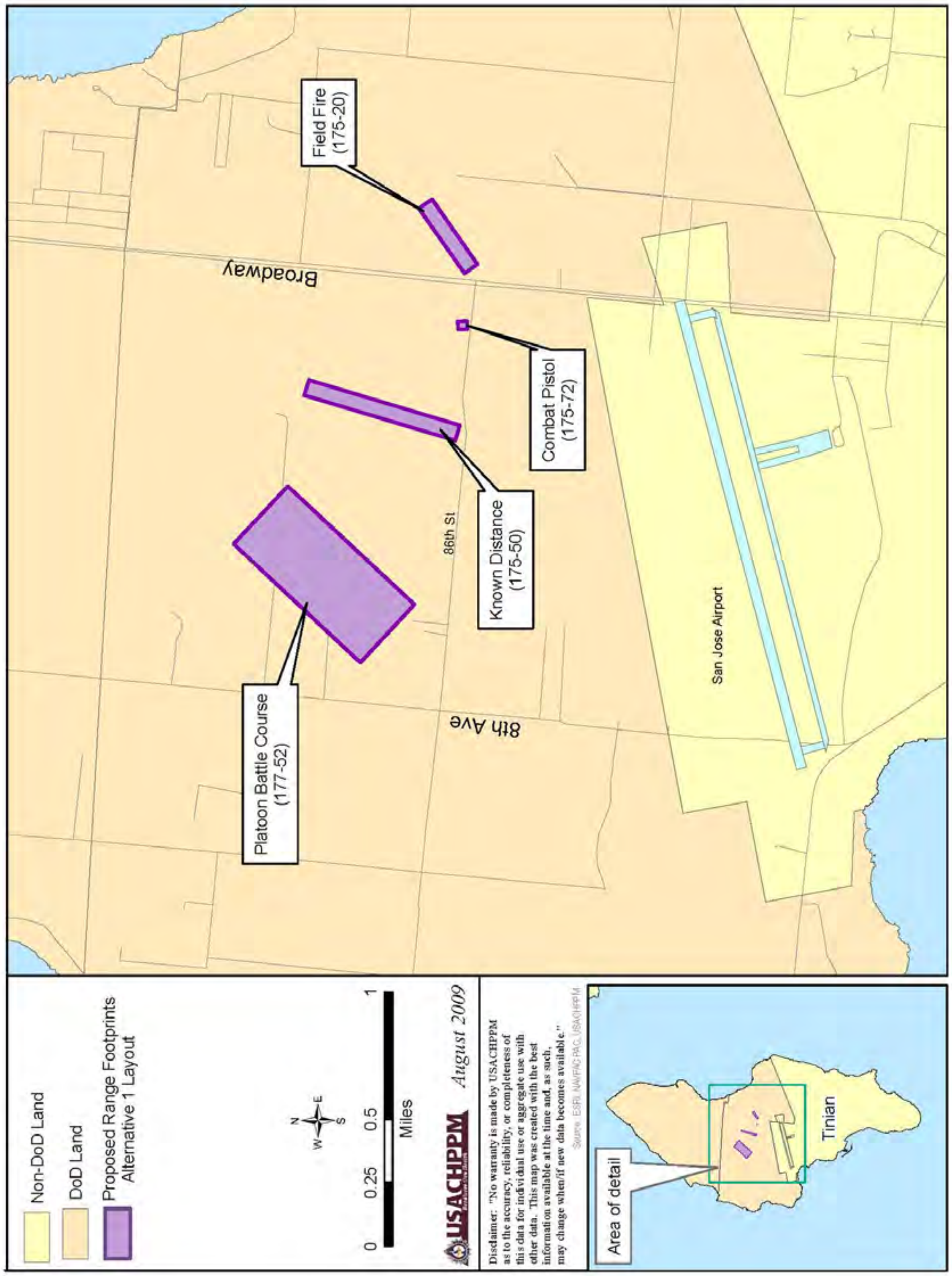


FIGURE E-2. TINIAN TRAINING RANGES ALTERNATIVE 1 LAYOUT

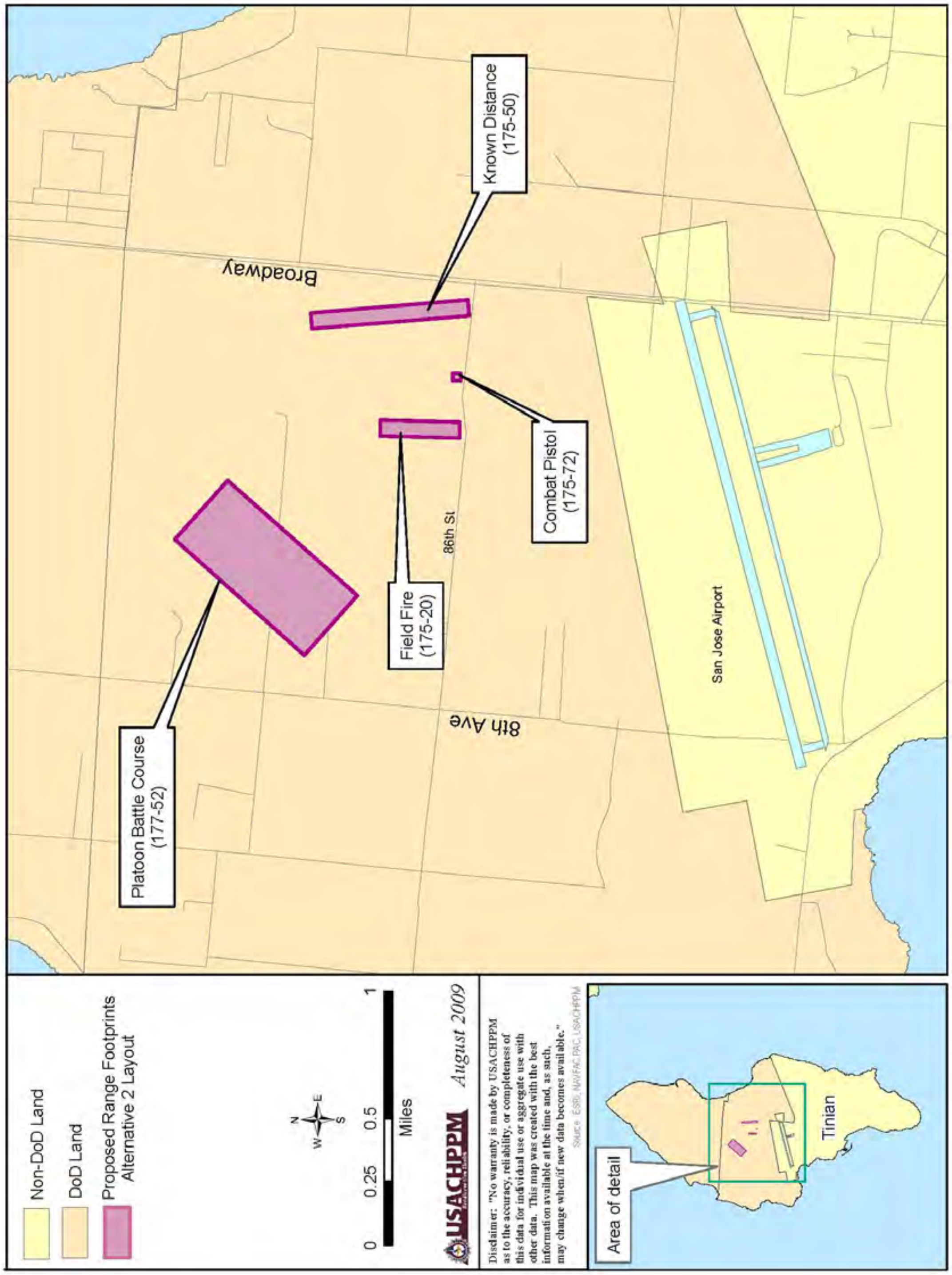


FIGURE E-3. TINIAN TRAINING RANGES ALTERNATIVE 2 LAYOUT

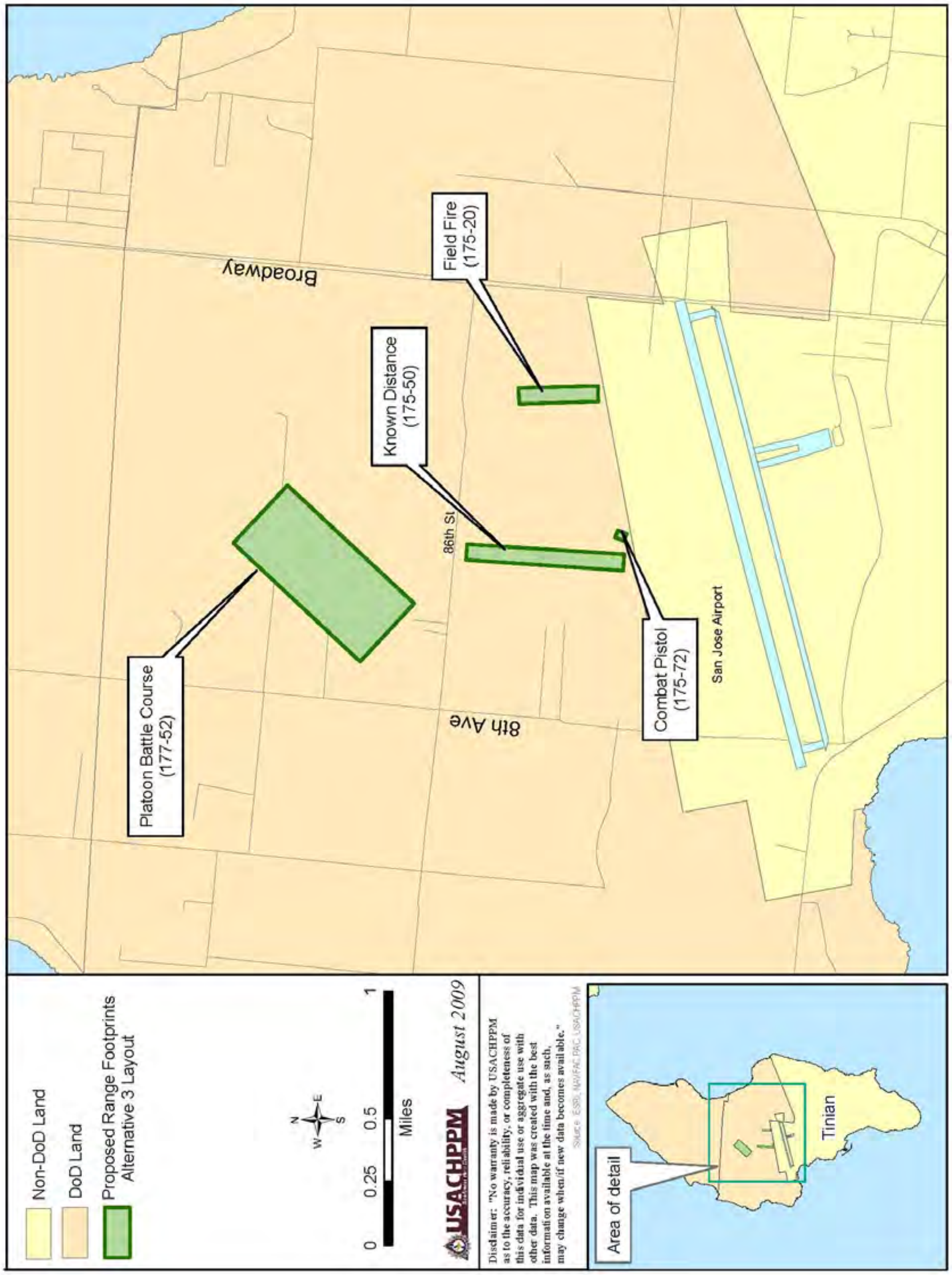


FIGURE E-4. TINIAN TRAINING RANGES ALTERNATIVE 3 LAYOUT

APPENDIX F

OPERATIONAL NOISE MANAGEMENT PROGRAM

F-1. REFERENCE. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise.

F-2. The Army developed the Operational Noise Management Program (ONMP) as method for the installation commanders to establish and maintain active programs to achieve the maximum feasible compatibility between the noise environment and noise-sensitive land uses, both on and off the installation. The program requires that all appropriate governmental bodies and citizens be fully informed whenever ONMP or other planning matters affecting the installation are under consideration. This includes a positive and continuous effort designed to:

a. Provide information, criteria, and guidelines to Federal, State, regional, and local planning bodies, civic associations, and similar groups.

b. Inform such groups of the requirements of the operational activity, noise exposure, aircraft accident potential, explosive testing, artillery firing, etc...

c. Describe the noise reduction measures, which are being or could be used.

d. Ensure that all reasonable, economical, and practical measures are taken to reduce or control the impact of noise-producing or hazardous activities so as to minimize the exposure of populated areas. This must be done without jeopardizing the safety or effectiveness of military operations.

e. Establishing a noise complaint management program.

F-3. Use the ONMP guidance in conjunction with the Air Installation Compatible Use Zone program to address the impulsive noise events at the proposed Guam and Tinian Training Ranges.

F-4. For further details regarding the ONMP contact the Operational Noise Program at the U.S. Army Center for Health Promotion and Preventive Medicine and Army Regulation 200-1, Chapter 14 (U.S. Army 2007).

wyle

September 25, 2009 J/N T56907

Mr. James Campe
TEC, Inc.
5361 Quail Hollow Ct
Pilot Hill, CA 95664

Subject: Noise Analysis for Guam Training EIS

References:

(1) Wyle Report WR 08-01, Aircraft Noise Study for Andersen Air Force Base, Guam, Wyle Laboratories, Inc., August 2008.
(2) West Coast Basing of the MV-22, Screencheck Final Environmental Impact Statement, Department of the Navy, August 2009.
(3) Andersen AFB Traffic Patterns (via email).
(4) HELSEACOMBATRON Two Five Instruction 3710.4, Course Rules, October 2006.
(5) Memorandum from Ashton B. Carter, Under Secretary of Defense, re: "Methodology for Assessing Hearing Loss Risk and Impacts in DoD Environmental Impact Analysis", June 16, 2009.

Dear Jim,

To support the Environmental Impact Statement/Offshore Overseas Environmental Impact Statement (EIS/OEIS) that TEC, Inc. (TEC) is preparing for Guam and the Commonwealth of Northern Mariana Islands Military Relocation, Wyle Laboratories, Inc. (Wyle) has completed analyses of aircraft noise exposure from proposed aircraft operations at the following locations on Guam: Andersen Air Force Base (AFB), Northwest Field (NWF), Andersen South, Naval Munitions Site (NMS) and Orote Field. Aircraft included in the proposed action are limited to CH-53E Super Stallion, MV-22B Osprey, AH-1W Super Cobra and UH-1 Huey.

Figure 1 shows the aforementioned locations. As described by TEC, proposed rotorcraft operations at Andersen AFB (AAFB) would consist of Field Carrier Landing Practice (FCLP) and Familiarization (FAM) sorties. FAM sorties would be comprised of interfacility flights to and from NWF. Proposed rotorcraft operations at Andersen South, NMS and Orote Field would consist of the following training sorties: Confined Area Landing (CAL), External Loads (EXT), Helicopter Insertion and Extraction (HIE) and Lifts associated with maneuver training (MAN-LFT). NWF would also support FCLP from the runways at NWF and CAL, EXT and HIE sorties with up to four (4) Landing Zones (LZs). The number of LZs would be two (2), five (5) and one (1) for Andersen South, NMS and Orote, respectively. LZs provided by TEC are shown in Figure 1. NMS would also support Terrain Following (TERF) sorties.

Noise modeling for AAFB was based on the "Proposed (CY2014) Scenario" from WR 08-01 (Reference 1). Table 1 shows the annual flight operations for AAFB. The additional flight operations associated with the EIS/OEIS provided by TEC are highlighted in green in Table 1. For the EIS/OEIS, AAFB includes approximately 7,000 additional flight operations relative to WR 08-01. Figure 2 shows the flight tracks modeled for the subject rotorcraft at AAFB and NWF. All FAM sorties were modeled on interfacility tracks to and from NWF and Andersen South. FCLP operations in Table 1 were modeled on existing track 6LT3 at AAFB. Interfacility tracks to and from NWF were modified relative to WR 08-01, and FCLP tracks at NWF were created for this project and based on modeling for the Helicopter Outlying Landing Field (HOLF) at Marine Corps Base Camp Pendleton in California (Reference 2). Interfacility tracks to/from Andersen South were modified relative to WR 08-01 to primarily overfly the ocean rather than overfly off-base land.

Runway utilization percentages, flight track utilization percentages, flight profiles (i.e., altitude, speed and aircraft attitude) and numbers of flying days for proposed rotorcraft were modeled identically to utilization percentages, profiles and flying days modeled for identical aircraft in WR 08-01. FCLP flight profiles were initially derived from modeling for the HOLF and adjusted for local course rules at AAFB and NWF. Representative FCLP and interfacility flight profiles for the subject aircraft types are presented in Appendix A. No additional maintenance run-ups were modeled for the EIS/OEIS relative to WR 08-01.

A total of 334 annual LZ sorties are proposed for NWF as shown in Table 2. The percentage of LZ sorties conducted between the hours of 2200-0700 (nighttime) would be five (5) percent. LZ sorties were modeled as distributed area sorties within an 800 ft square area generally centered on each LZ. In other words, it was assumed each LZ sortie would be flying uniformly throughout the modeled area. Table 3 lists the flight profiles for each type of LZ sortie in terms of average speed, sortie duration and altitude distribution. These profiles were primarily based on modeling for the HOLF (Reference 2). Busiest month sorties would be equal to the annual average monthly sorties and applicable aircraft would typically fly 30 days during the busiest month.

Consistent with WR 08-01, noise modeling for airfield-type flight operations was accomplished with NOISEMAP Version 7.2 for previously modeled fixed-wing aircraft and the Rotorcraft Noise Model (RNM) Version 7.1.1 for most rotary-wing aircraft. For the EIS/OEIS, RNM covered the CH-53E, MV-22B and AH-1W while NOISEMAP was used to model the UH-1. NOISEMAP and RNM compute Day-Night Average Sound Level (DNL) in A-weighted decibels (dBA). The Military Operations Area and Range Noise Model (MR_NMAP) Version 2.2 was used to model LZ and TERF activity. MR_NMAP computes Onset-rate Adjusted Monthly Day-Night Average Sound Level (L_{dnmr}) in dBA. L_{dnmr} is a derivative of DNL, customized for airspace operations. For NWF, Andersen South and Orote Field where airfield and LZ activity would be combined, DNL and L_{dnmr} exposure was combined. For brevity with regard to NWF, the combined noise exposure is labeled as DNL. For Andersen South and Orote Field, the combined noise exposure is labeled as "DNL/ L_{dnmr}". For NMS, the noise exposure is labeled as L_{dnmr}. Consistent with WR 08-01, 60 through 85 dB DNL is shown for AAFB/NWF. For all other locations, 65 through 85 dB DNL/L_{dnmr} is shown.

Figure 3 shows the 60 through 85 dB DNL contours, in 5 dB increments, for EIS/OEIS proposed (CY2014) average flying day operations at AAFB/NWF and average daily FCLP and LZ operations during the busiest month at NWF. Overall, the contours are very similar to Figure 6-1 from WR 08-01 except for the 65 and 70 dB DNL contours at NWF from the FCLP and LZ activity. Also noticeable are the contours due to LZ activity at Andersen South.

Figure 4 shows the 65 through 85 dB DNL/L_{dnmr} contours, in 5 dB increments, for EIS/OEIS proposed (CY2014) average flying day interfacility operations to/from AAFB and daily LZ sorties during the busiest month at Andersen South. The 65 dB DNL/L_{dnmr} contour would be approximately one mile in diameter and would contain some on-base housing. The 80 dB DNL/L_{dnmr} contour would be contained within the modeled flight area with no persons affected.

Figure 5 shows the 65 through 85 dB L_{dnmr} contours, in 5 dB increments, for EIS/OEIS proposed (CY2014) average daily LZ sorties during the busiest month at NMS. The 65 dB L_{dnmr} contours are mostly contained within the NMS boundary. Off-site 65 dB L_{dnmr} would not likely affect any housing. The 70 dB L_{dnmr} contours would be nearly completely contained within the modeled flight areas.

In addition to the LZ sorties, NMS would also experience approximately 100 annual TERF operations as listed in Table 2. Table 4 presents the modeled flight profiles. TERF activity would be between 50 and 200 ft AGL. The TERF route is geographically variable. With a maximum centerline L_{dnmr} of 53 dB, the route could be virtually anywhere within the boundary of the NMS while avoiding a noise impact (L_{dnmr} greater than or equal to 65 dB) outside of the NMS.

Figure 6 shows the 65 through 85 DNL/L_{dnmr} contours, in 5 dB increments, for EIS/OEIS proposed (CY2014) average flying day FCLP operations and daily LZ sorties during the busiest month at Orote Field. The 65 dB L_{dnmr} contours are contained wholly within the Orote boundary. No on- or off-base housing would be affected.

The noise analysis included the estimation of single-event sound levels for the subject aircraft. Table 5 lists the A-weighted Sound Exposure Level (SEL) and Maximum Sound Level (L_{max}) for cruise mode single events, while Table 6 lists the L_{max} for slow-speed single events. As footnoted in Table 5, RNM in its "single-track/research" mode was utilized to compute SEL and L_{max} values from 100 ft AGL to 1000 ft AGL for all listed aircraft except the UH-1. For the UH-1, MR_NMAP was used to compute the noise levels for altitudes of 100 ft AGL and greater. Noise levels for distances/altitudes less than 100 ft AGL were derived from fits of curves of noise vs. distance. Similarly, as footnoted in Table 6, RNM in its "single-track/research" mode was utilized to compute L_{max} values for 100 ft AGL and 150 ft AGL, while the values for 30 ft AGL and 60 ft AGL were derived from fits of curves of noise vs. distance. In general, noise levels for distances/altitudes less than 100 ft should be used with caution due to the lack of applicability of the reference acoustic data to these distances. Estimating noise levels for the hover (0 knots airspeed) condition was not possible due to the limitations of the reference acoustic data.

The noise analysis included estimation of Potential Hearing Loss (PHL) per policy set forth in Reference 5. This analysis focuses on residents. The only residents exposed to 80 dB DNL or greater would be on-base at AAFB, and only those associated with dormitory Buildings 25003 and 25017. Figure 7 shows the affected buildings and the 24-hour Equivalent Sound Level (Leq_{24}) contours for the No Action (CY2014) scenario and the Proposed Action (CY2014) scenario and the DNL contours for both scenarios. The methodology cited by Reference 5 employs the Leq_{24} metric. The No Action (CY2014) scenario is based on the same scenario from WR 08-01 but with the Andersen South interfacility tracks/profiles updated to fly primarily over the ocean. The estimated PHL for the No Action scenario would be approximately 3 dB. The estimated PHL for the Proposed Action would be identical to the No Action. Thus the Proposed Action would introduce no change to the No Action PHL.

Thank you for your business. This concludes our deliverables for the contract. If you have any additional needs, please contact me.

Sincerely,

Joseph J. Czech
Project Manager/Principal Engineer

JJC/vt

cc: L. Kosanke, Wyle Laboratories

Table 1. Proposed Action (CY2014) Annual Flight Operations for Andersen AFB

Mission Group	Assumed Type	Modeled Aircraft Type	Factor re No Action	Departure[14]			Interfacility to Departure to NWF			Nonbreak Arrival[14]			Interfacility from Northwest Field			Overhead Break Arrival			Touch and Go[1]			GCA Box[1]			FCLP [1][14]			Total		
				Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total	Day	Night	Total
Based Additions	VM Helo	**CH-53E[8]**	1	502	38	540	-	-	-	448	89	537	-	-	-	-	-	-	540	60	600	108	12	120	60	20	80	1,658	219	1,877
	VM Helo	**AH-1N[9]**	1	2,347	31	2,378	-	-	-	2,347	31	2,378	-	-	-	-	-	-	3,000	-	3,000	1,500	-	1,500	90	30	120	9,284	92	9,376
	VM Helo	**UH-1N[9]**	1	797	16	813	-	-	-	797	16	813	-	-	-	-	-	-	1,000	-	1,000	500	-	500	45	15	60	3,139	47	3,186
	VM Rotary	**MV-22B[9]**	1	1,244	797	2,041	-	-	-	185	135	320	-	-	-	1,119	662	1,781	566	-	566	707	-	707	180	60	240	4,001	1,654	5,655
	VM Jet	**F/A-18D**	1	1,170	25	1,195	-	-	-	168	8	176	-	-	-	985	10	995	1,752	73	1,825	374	24	398				4,426	138	4,564
	FAM[14]	**CH-53E**	1	5	1	6	5	1	6	5	1	6	5	1	6	-	-	-	-	-	-	-	-	-				20	2	22
		AH-1N	1	7	1	8	7	1	8	7	1	8	7	1	8	-	-	-	-	-	-	-	-	-				28	4	32
		UH-1N	1	2	1	2	2	1	2	2	1	2	2	1	2	-	-	-	-	-	-	-	-	-				6	2	8
		MV-22B	1	23	2	24	23	2	24	23	2	24	23	2	24	-	-	-	-	-	-	-	-	-				90	6	96
Based (HSC-25)	OM Helo	SH60B	1	2,966	91	3,057	2,966	91	3,057	2,598	459	3,057	2,598	459	3,057	-	-	-	11,738	489	12,227	585	25	610				17,887	1,064	18,951
Transient ISR Strike	Jet	**B-1**	1	188	28	216				188	28	216				-	-	-	376	56	432	376	56	432				1,128	168	1,296
	Jet	**B-2A**	1	42	6	48				42	6	48				-	-	-	84	12	96	84	12	96				252	36	288
	Jet	**B-52H**	1	188	28	216				188	28	216				-	-	-	376	56	432	376	56	432				1,128	168	1,296
	Jet	**F-15E**	1	341	5	346				102	2	104				239	4	242	1,736	27	1,763	307	5	311				2,724	41	2,765
	Jet	**F-22[7]**	1	1,362	21	1,383				408	6	414				953	15	968	6,945	106	7,050	1,226	19	1,244				10,892	166	11,058
	Jet	**KC-135R**	1	835	125	960				835	125	960				-	-	-	2,506	374	2,880	2,506	374	2,880				6,682	998	7,680
	Jet	**Global Hawk (modeled as T-45)**	1	187	33	220				187	33	220				-	-	-	187	33	220	-	-	-				561	99	660
Local & Transient	Jet	B-1	1	80	9	89				80	9	89				-	-	-	322	36	358	161	18	179				643	72	715
	Jet	B-2	1	49	6	55				49	6	55				-	-	-	198	22	220	99	11	110				395	45	440
	Jet	B-52H	1	95	10	105				95	10	105				-	-	-	322	36	358	161	18	179				673	74	747
	Jet	C-9A	1	14	3	17				14	3	17				-	-	-	-	-	-	-	-	-				28	6	34
	Jet	**KC-10A[2,7]**	1	201	235	436				324	112	436				-	-	-	372	42	414	186	21	207				1,083	410	1,493
	VM Rotary	**MV-22B[9][13]**	1	1,244	735	1,979				124	74	198				1,119	662	1,781	566	-	566	707	-	707				3,760	1,471	5,231
	Jet	C-21A[4]	1	24	6	30				24	6	30				-	-	-	-	-	-	-	-	-				48	12	60
	Prop	C-130H&N&P[3,5]	1	43	-	43				22	-	22				22	-	22	172	-	172	86	-	86				345	-	345
	Jet	KC-135R	1	1,164	123	1,287				1,164	123	1,287				-	-	-	3,720	414	4,134	1,860	207	2,067				7,908	867	8,775
	Jet	**F-15A**	1	2,392	-	2,392				44	-	44				2,352	-	2,352	3,856	-	3,856	-	-	-				8,644	-	8,644
	Jet	**F-16C**	1	36	-	36				-	-	-				36	-	36	-	-	-	-	-	-				72	-	72
Transient	VM Helo	CH-46E[6]	1	19	-	19				19	-	19				-	-	-	-	-	-	-	-	-				38	-	38
	VM Helo	CH-53E	1	6	16	22				6	16	22				-	-	-	-	-	-	-	-	-				12	32	44
	Jet	C-5A	1	46	186	232				209	23	232				-	-	-	-	-	-	-	-	-				255	209	464
	Jet	**C-17[7]**	1	112	238	350				274	77	351				-	-	-	-	-	-	-	-	-				386	315	701
	Jet	C-20	1	2	-	2				2	-	2				-	-	-	-	-	-	-	-	-				4	-	4
	Prop	C-12[6]	1	19	-	19				19	-	19				-	-	-	-	-	-	-	-	-				38	-	38
Transient CVN Wing[10]	VM Jet	**EA-18G (as F/A-18E/F)**	3	68	-	68				4	-	4				64	-	64	-	-	-	-	-	-				136	-	136
	VM Jet	**F-18A/C**	3	484	-	484				48	-	48				440	-	440	-	-	-	-	-	-				972	-	972
	VM Jet	**F-18E/F**	3	584	-	584				56	-	56				524	-	524	-	-	-	-	-	-				1,164	-	1,164
	VM Jet	C-21A[4]	1	17	-	17				17	-	17				-	-	-	-	-	-	-	-	-				34	-	34
	VM Prop	**E-2C[5]**	3	104	-	104				12	-	12				92	-	92	-	-	-	-	-	-				208	-	208
	VM Helo	**SK70 (UH-60A) BLACKH[6]**	3	148	8	156				148	8	156				-	-	-	-	-	-	-	-	-				296	16	312
Transient MMA	VM Jet	**P-8A (modeled as B-737-700)**	1	78	11	89				78	11	89				-	-	-	-	-	-	-	-	-				156	22	178
Civilian (Transient)	Civilian	B-747-SP (N)	1	104	166	270				104	166	270				-	-	-	-	-	-	-	-	-				208	332	540
	Civilian	B-757-200-RR	1	33	8	41				33	8	41				-	-	-	-	-	-	-	-	-				66	16	82
Based Total				9,062	1,002	10,064				6,579	742	7,321				2,104	672	2,776	18,596	622	19,218	3,774	61	3,835	375	125	500	40,539	3,228	43,767
Military Transient Total				10,171	1,832	12,003				4,782	706	5,487				5,841	680	6,521	21,738	1,213	22,951	8,134	796	8,930	-	-	-	50,665	5,227	55,891
Civilian (Transient) Total				137	174	311				137	174	311				-	-	-	-	-	-	-	-	-	-	-	-	274	348	622
Grand Total				19,370	3,008	22,378				11,498	1,621	13,119				7,945	1,352	9,297	40,334	1,835	42,169	11,908	857	12,765	375	125	500	91,478	8,803	100,280

Day = 0700-2159 local; Night = 2200-0659 Local

Notes:
(1) Each Closed Pattern event (Touch and Go, GCA Box, and FCLP) is counted here as 2 operations (1 landing + 1 departure)
(2) KC-10A Closed Pattern operations (Touch and Go, GCA Box) modeled as KC-135R
(3) C-130H&N&P Closed Pattern operations (Touch and Go, GCA Box) not modeled
(4) C-21A Local & Transient operations modeled as C-21A Transient CVN Wing
(5) Overhead Break Arrivals modeled as Nonbreak Arrivals
(6) Ops from AFCEE's modeling of Baseline for 1993
(7) Include add'l transient ops per AMC & Base Ops
(8) Excludes LHA T&G and CLA T&G from FRF Camp Schwab
(9) Excludes LHA T&G from FRF Camp Schwab
(10) Obtained for CVW-5 data from NAVAIR
(11) **BOLD = changes from Baseline**
(12) FCLP and FAM are split 50% day (0700-1859), 25% evening (1900-2159, included in day ops) and 25% night (2200-0659)
(13) Transient MV-22B squadrons would be on Guam one at a time nearly all the time, transient ops modeled identical to based MV-22 ops
(14) One Nonbreak arrival and one departure has been added for every 4 FCLP operations and for every 2 FAM operations for interfacility operations.

Source: Wyle, 2008; Table 6-1; USMC, 2009 (scope tables)

wyle

Table 2. Flight Activity for Training Sites (non-FCLP and non-FAM) for Airspace Noise Modeling

(a) Annual Sorties for LZ Training Sites (non-FCLP and non-FAM)

			CH-53			MV-22			AH-1			UH-1			TOTAL		
Location	**Mission**	**%Dark**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**
NWF (4 sites)	CAL	10%	19	1	20	57	3	60	28	2	30	14	1	15	118	7	125
	EXT	10%	19	1	20	57	3	60	-	-	-	14	1	15	90	5	95
	HIE	10%	23	1	24	68	4	72	-	-	-	17	1	18	108	6	114
Andy South (2 sites)	CAL	10%	19	1	20	57	3	60	28	2	30	14	1	15	118	7	125
	EXT	10%	12	1	13	38	2	40	-	-	-	9	1	10	59	4	63
	HIE	10%	23	1	24	68	4	72	-	-	-	17	1	18	108	6	114
	MAN-LFT	10%	684	36	720	-	-	-	-	-	-	-	-	-	684	36	720
Orote Field (1 site)	EXT	10%	19	1	20	57	3	60	-	-	-	14	1	15	90	5	95
NMS (5 sites)	CAL	10%	19	1	20	57	3	60	28	2	30	14	1	15	118	7	125
	EXT	10%	12	1	13	38	2	40	-	-	-	9	1	10	59	4	63
	MAN-LFT	10%	182	10	192	-	-	-	-	-	-	-	-	-	182	10	192
NMS	TERF	10%	15	1	16	46	2	48	23	1	24	11	1	12	95	5	100
Subtotals																	
NWF			61	3	64	182	10	192	28	2	30	45	3	48	316	18	334
Andy South			738	39	777	163	9	172	28	2	30	40	3	43	969	53	1,022
Orote Field			19	1	20	57	3	60	-	-	-	14	1	15	90	5	95
NMS			228	13	241	141	7	148	51	3	54	34	3	37	454	26	480
Total			**1,046**	**56**	**1,102**	**543**	**29**	**572**	**107**	**7**	**114**	**133**	**10**	**143**	**1,829**	**102**	**1,931**

Day = 0700-2200; Night = 2200-0700
Night is 50% of %Dark sorties
Source: DOPAA, 2009; USMC, 2009

(b) Modeled Interfacility Flights to/from AAFB and Anderson South

	CH-53			MV-22			AH-1			UH-1			TOTAL		
Mission	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**	**Day**	**Night**	**Total**
Departure to Andy South	22	1	23	6	4	10	113	-	113	38	-	38	179	5	184
Arrival from Andy South	19	4	23	6	4	10	113	-	113	38	-	38	176	8	184
Total	41	5	46	12	8	20	226	-	226	76	-	76	355	13	368

Table 3. Day (0700-2200) and Night (2200-0700) Profiles for Area-type Sorties for Any of the 12 LZs on Guam

Notes	MISSION	AIRCRAFT ID	Average SPEED (KIAS)	Average TIME PER SORTIE (MINUTES)	Altitude Distribution (% @ ft AGL)			
					0-500	500- 1k	1k - 2k	TOTAL
2(1)	CAL	CH-53E	120	20	65	15	20	100
2(1)		MV-22	110	20	100			100
2(1)		AH-1G	100	20	65	15	20	100
2(1)		UH-1N(1), (2), (4)	80	20	65	15	20	100
3(1)	EXT	CH-53E	120	20	65	15	20	100
3(1)		MV-22	110	60	100			100
3(1)		AH-1G	100	20	65	15	20	100
3(1)		UH-1N(1), (2), (4)	80	20	65	15	20	100
3(1)	HIE	CH-53E	120	20	65	15	20	100
3(1)		MV-22	110	60	100			100
3(1)		AH-1G	100	20	65	15	20	100
3(1)		UH-1N(1), (2), (4)	80	20	65	15	20	100
3(1)	MAN-LFT	CH-53E	120	20	65	15	20	100
3(1)		MV-22	110	60	100			100
3(1)		AH-1G	100	20	65	15	20	100
3(1)		UH-1N(1), (2), (4)	80	20	65	15	20	100

(1) Same profile is assumed to apply to each site at all locations
(2) Profile based on MV22 West Coast Homebasing EIS, MCB Camp Pendleton CAL modeling
(3) Profile based on MV22 West Coast Homebasing EIS, MCB Camp Pendleton LZ modeling; EXT includes hover @ 30 ft for 1.5 minutes times 5 per sortie; HIE includes hover @ 30 ft for 1 minute times 3 per sortie
(4) Modeled power settings of "FLT AT 80KTS", 100% RPM
Daytime = 0700-2200; Nighttime = 2200-0700

Table 4. Day (0700-2200) and Night (2200-0700) Profiles for Route-type Sorties for Naval Munitions Site

AIRSPACE ID	Notes	MISSION	AIRCRAFT ID	Average SPEED (KIAS)	Average TIME PER SORTIE (MINUTES)	Altitude Distribution (% @ ft AGL)			
						50-200	500- 1k	1k - 2k	TOTAL
TERF Routes	1	TERF	CH-53E	120	n/a	100			100
	1	LAT	MV-22	110	n/a	100			100
	1	TERF	AH-1G	100	n/a	100			100
	1	TERF	UH-1N(1), (2)	80	n/a	100			100

(1) Profile based on MV22 West Coast Homebasing EIS, MCB Camp Pendleton TERF modeling;
Altitude band per DOPAA (April 2009)
(2) Modeled power settings of FLT AT 80KTS, 100% RPM
Daytime = 0700-2200; Nighttime = 2200-0700

Table 5. Single Event Noise Levels for Cruising Speeds

Altitude (ft AGL) [6]	MV-22B[1] 220 kts		CH-53E[1] 120 kts		AH-1W[1] 100 kts		UH-1N[2] 80 kts		CH-46E[1] 120 kts		C-130[2], [5] 160 kts	
	SEL	L_{max}	SEL	L_{max}	SEL	L_{max}	SEL	L_{max}	SEL	L_{max}	SEL	L_{max}
30	107	116	113	118	105	109	114	108	111	117	111	117
60	103	110	109	111	101	102	109	102	108	111	105	110
100	108	104	106	106	98	97	106	97	105	106	101	104
200	97	98	102	100	95	91	102	91	102	100	97	98
250	96	96	101	98	94	89	100	89	101	98	95	95
500	92	89	98	91	91	83	96	83	98	92	90	88
1000	88	82	94	85	87	76	91	76	94	86	84	81

Notes:

(1) Computed with RNM in Single-Track Mode
Receiver directely below flyover and at 5 feet AGL
Timespacing equal to 0.1 seconds

(2) Computed with MRNMAP single track flyover using Lmax or SEL metric mode

(3) Temperature = 80 deg F, Relative Humidity = 80%

(4) All levels in A-weighted decibels

(5) Modeled as C-130H&N&P

(6) SEL and Lmax levels for 30 and 60 feet were extrapolated from a curve fit of values from 100 ft AGL to 2000 ft AGL

Table 6. Single Event Maximum Noise Levels (Lmax, dBA) for Low-speed Flights

Altitude (ft AGL)	MV-22B(1) 64 kts	CH-53E(1) 65 kts	AH-1W (1) 65 kts	UH-1N(2) 65 kts
30	117	112	110	110
60	110	106	103	103
100	106	101	99	97
150	102	97	95	94

Notes:

(1) Computed with RNM in Single-Track Mode
Receiver directely below flyover and at 5 feet AGL
Timespacing equal to 0.1 seconds
Modeled utilizing the appropriate slowest speed sound sphere available for each aircraft;

(2) Computed with MRNMAP single track flyover using Lmax metric mode

(3) Temperature = 80 deg F, Relative Humidity = 80%

(4) All levels in A-weighted decibels

(5) Lmax levels for 30 and 60 feet were extrapolated from a curve fit of values from 100 ft AGL to 2000 ft AGL

Figure 1.
Regional Map of Guam

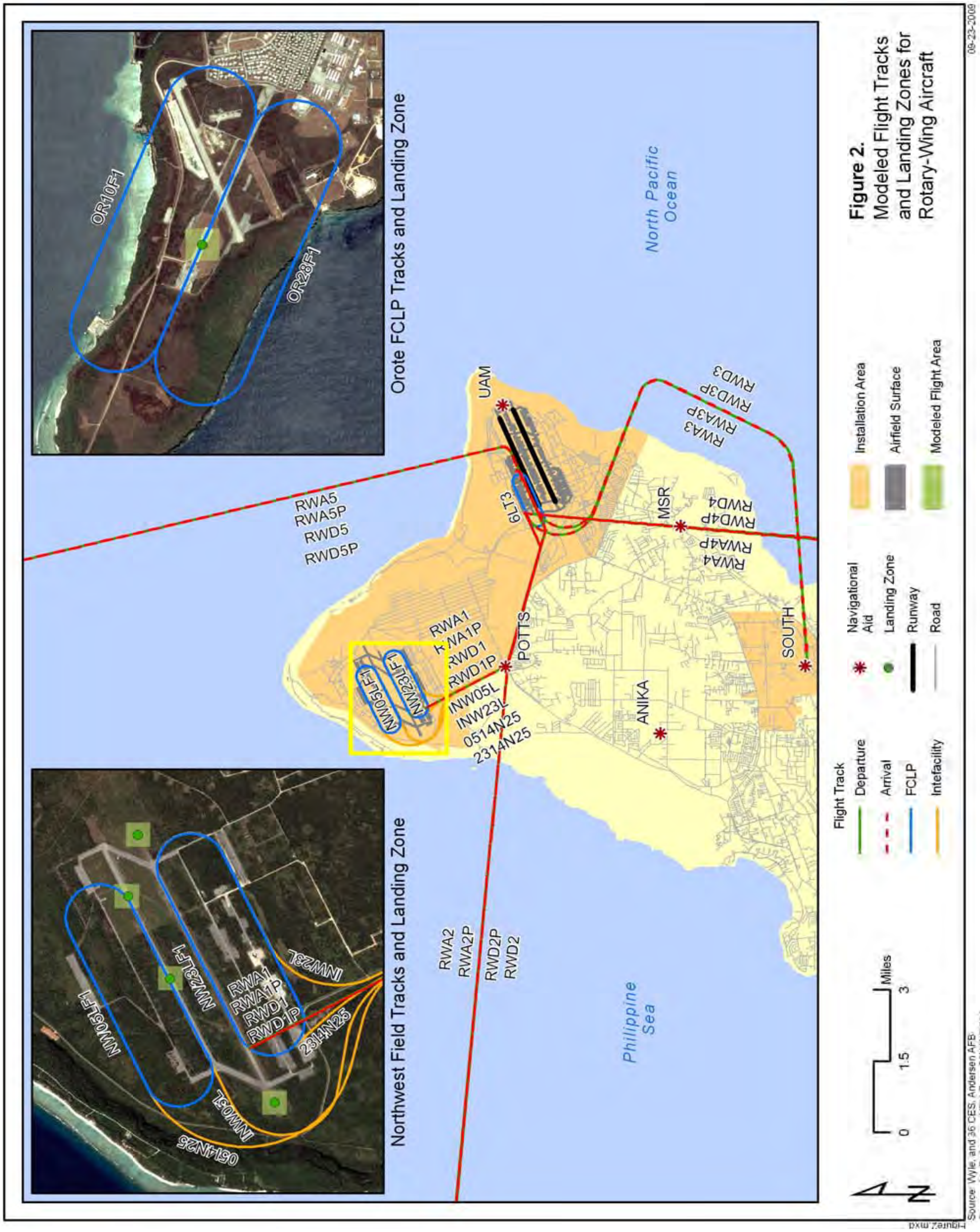


Figure 2. Modeled Flight Tracks and Landing Zones for Rotary-Wing Aircraft

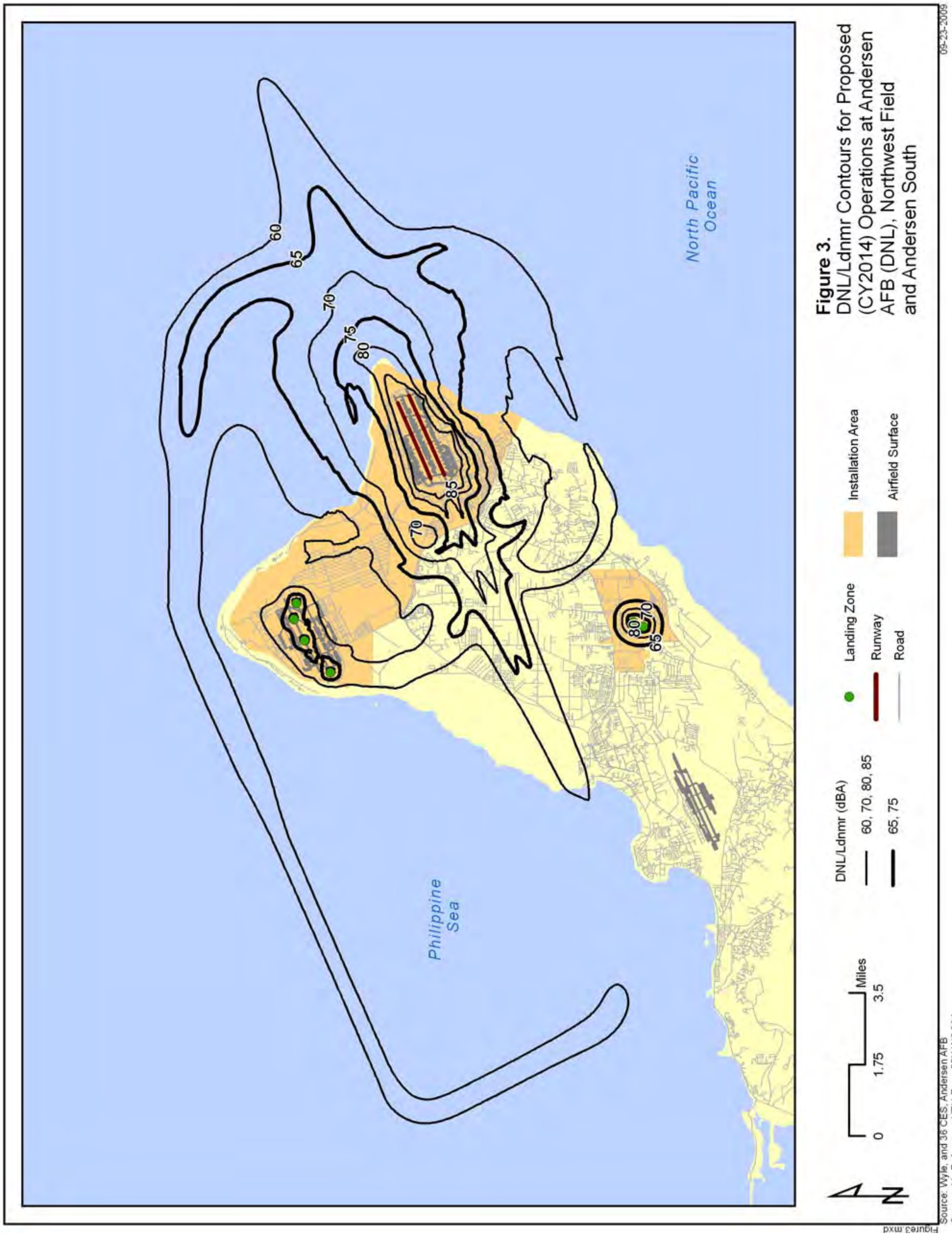


Figure 3.
DNL/Ldnmr Contours for Proposed (CY2014) Operations at Andersen AFB (DNL), Northwest Field and Andersen South

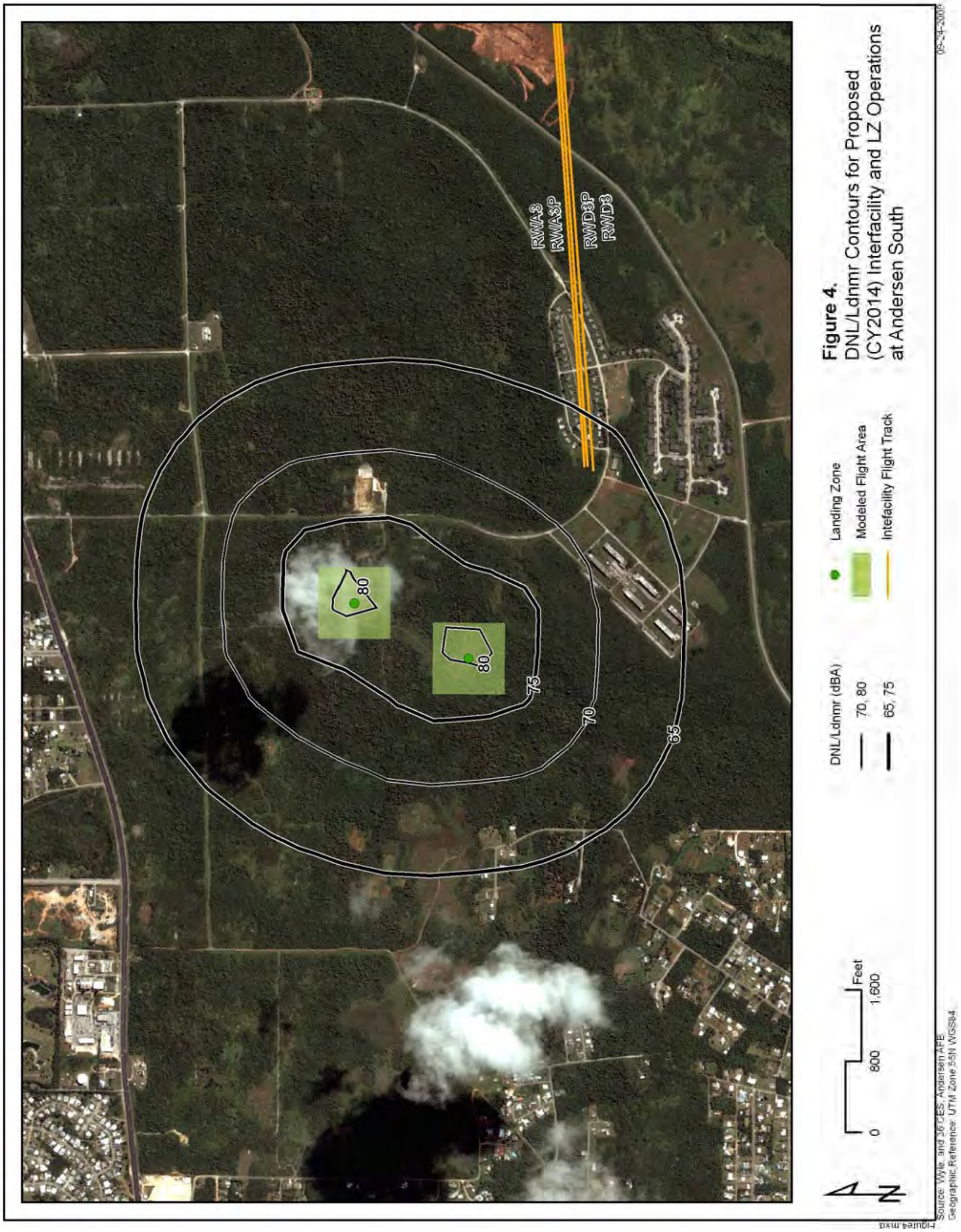


Figure 4.
DNL/Ldnmr Contours for Proposed (CY2014) Interfacility and LZ Operations at Andersen South

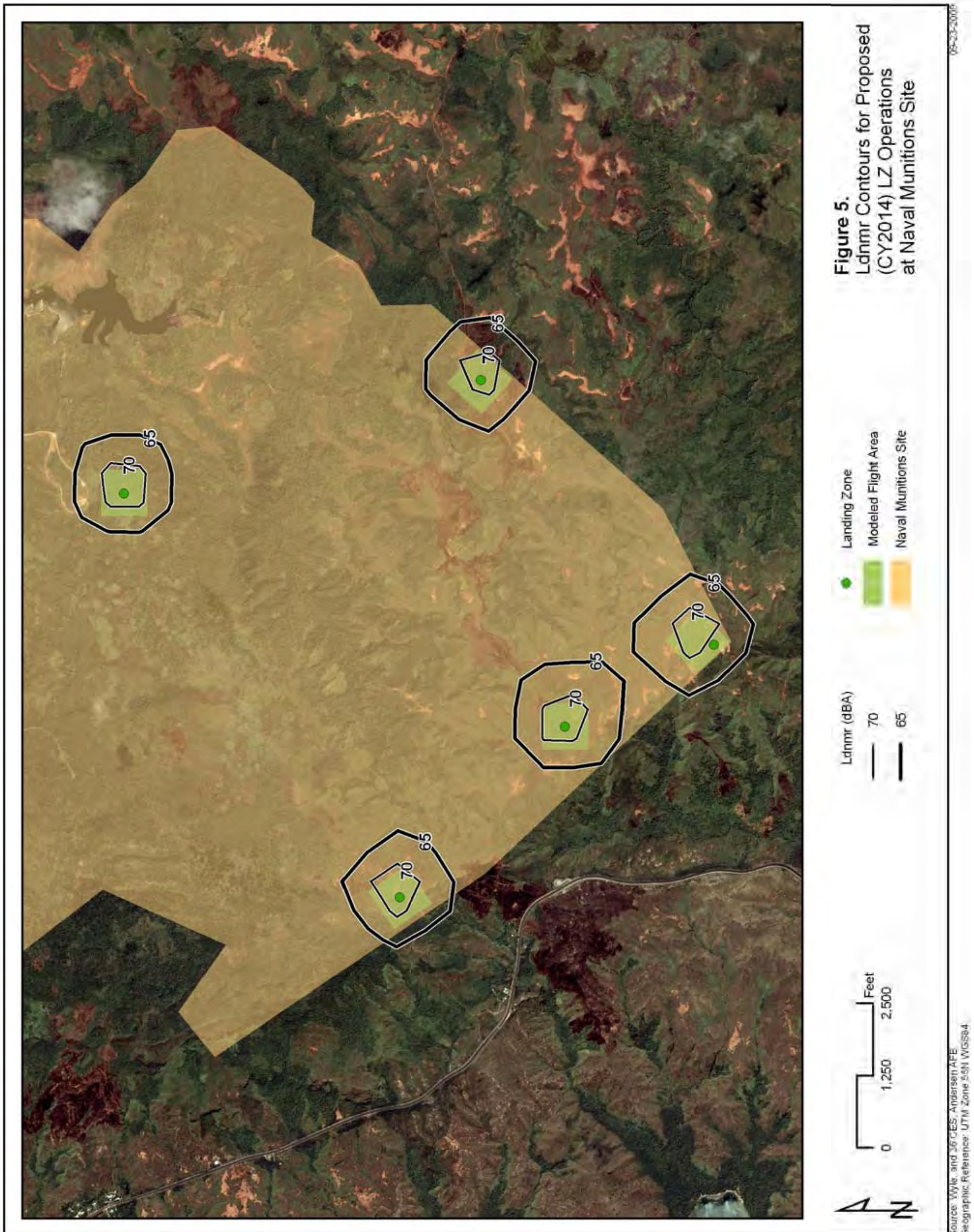


Figure 5.
Ldnmr Contours for Proposed (CY2014) LZ Operations at Naval Munitions Site

Figure 6.
DNL/Ldnmr Contours for Proposed (CY2014) FCLP and LZ Operations at Orote Field

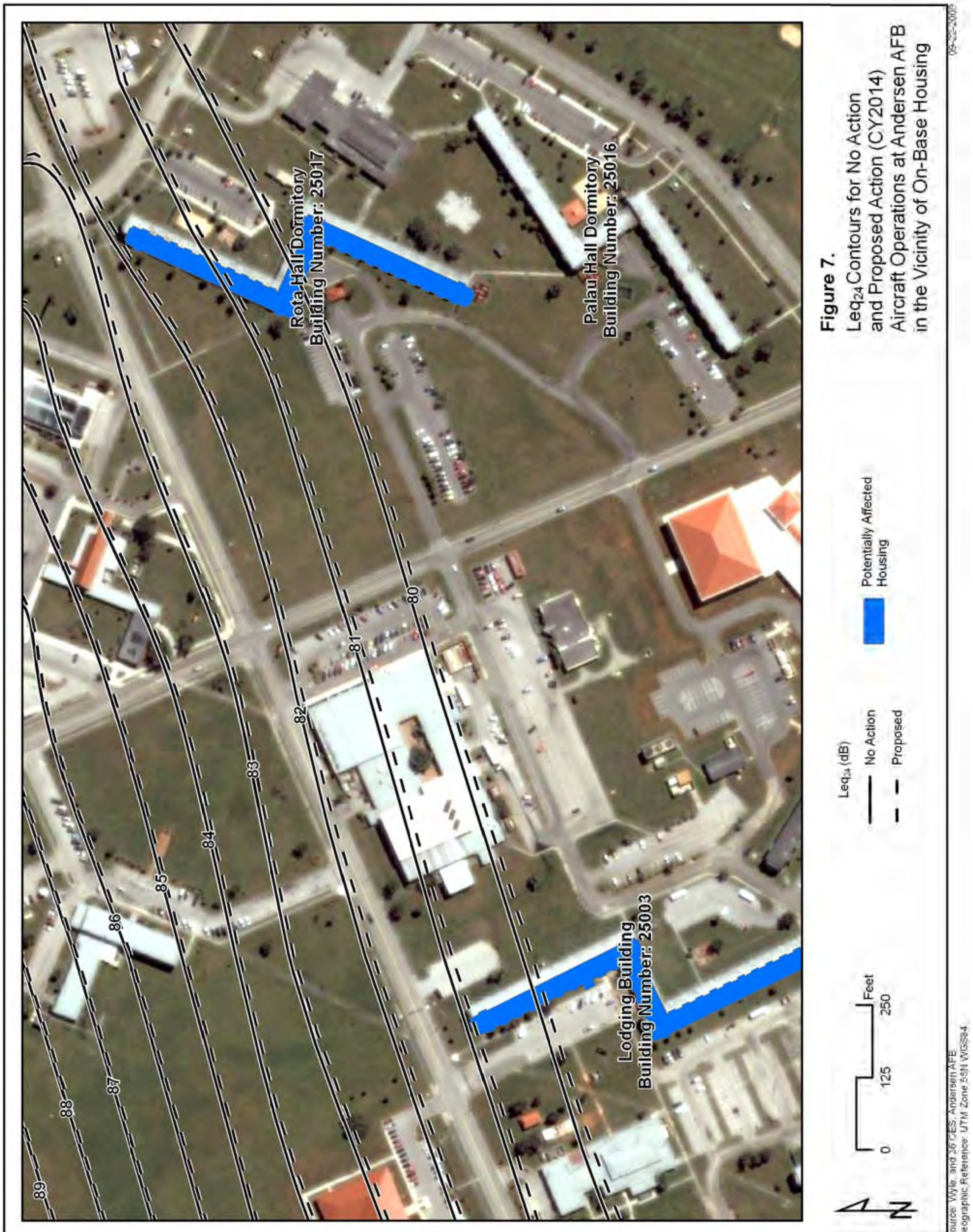


Figure 7.
Leq_{24} Contours for No Action and Proposed Action (CY2014) Aircraft Operations at Andersen AFB in the Vicinity of On-Base Housing

APPENDIX A

Representative Flight Profiles of Proposed Aircraft

This 32-page appendix provides scaled plots of representative flight profiles for each modeled aircraft type. The following navigational aid is depicted on the maps:

- UAM Tactical Air Navigation (TACAN) antenna.

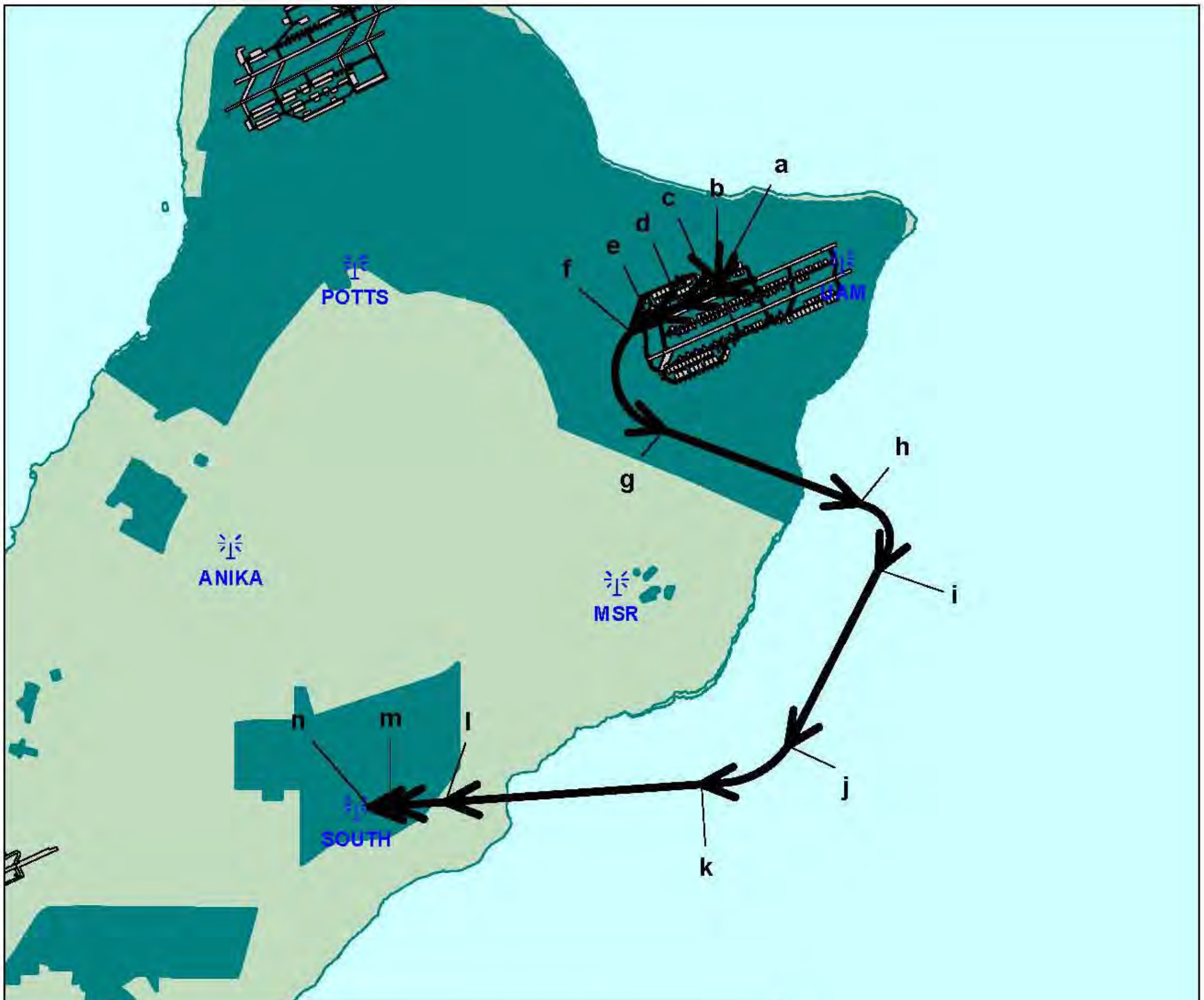
The flight profiles are shown in the following order:

Profile Pages	Aircraft
A-3 – A-9	AH-1W
A-10 – A-16	CH53E (CH-53E)
A-17 – A-23	MV22B (MV-22B)
A-24 – A-30	UH-1N

Each figure includes a table describing the profile parameters of the associated flight track. The columns of the profile data tables are described below:

Column Heading	Description
Point	Sequence letter along flight track denoting change in flight parameters
Distance (feet)	Distance along flight track from runway threshold in feet
Height (feet)	Altitude of aircraft in feet Above Ground Level (AGL) or relative to Mean Sea Level (MSL)
Power (Appropriate Unit)*	Engine power setting and Drag Configuration/Interpolation Code (defines sets of interpolation code in NOISEMAP (F for FIXED, P for PARALLEL, V for VARIABLE))
Speed (kts)	Indicated airspeed of aircraft in knots
Yaw Angle (degrees)**	Angle of the aircraft relative to its vertical axis in degrees; positive nose left
Angle of Attack (degrees)**	Angle of the aircraft, not of the wing; angle between the climb angle and the pitch angle, in degrees, positive nose up. The climb angle is the angle between the horizontal and the velocity vector (same convention). The pitch angle is the angle between the horizontal and the thrust vector (same convention)
Roll Angle (degrees)**	Angle of the aircraft relative to its longitudinal axis in degrees; positive left side down.
Nacelle Angle (degrees)***	Angle of engine nacelle pylon relative to the horizontal (airplane) mode; positive up; maximum of 90

Notes: * not applicable to CH-53E and MV-22B
** for CH-53E and MV-22B only
*** for tiltrotor aircraft (e.g., MV-22B) only; fixed to 90 degrees for RNM helicopters

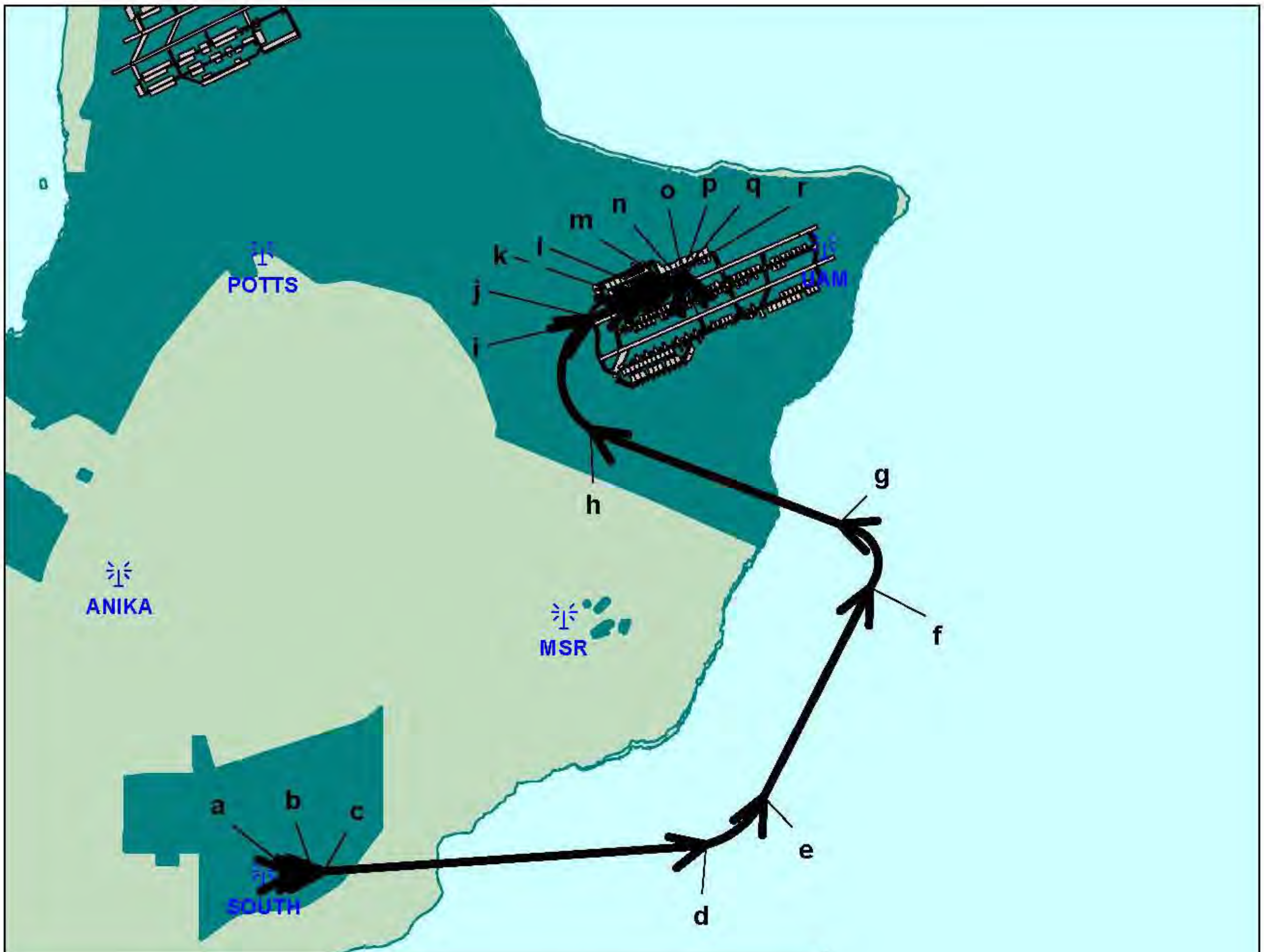


Flight Profile AH1D08 on DepartureTrack RWD3P

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle
a	0	0 AGL	0	0	0	0	90
b	500	25 AGL	50	0	-5	0	90
c	1,000	60 AGL	70	0	-5	0	90
d	3,000	475 AGL	80	0	-5	0	90
e	4,982	490 AGL	103	0	0	0	90
f	6,319	500 AGL	120	0	0	25	90
g	13,815	500 AGL	120	0	0	0	90
h	26,206	500 AGL	120	0	0	-25	90
i	31,158	500 AGL	120	0	0	0	90
j	42,914	500 AGL	120	0	0	-25	90
k	48,791	500 AGL	120	0	0	0	90
l	64,042	250 AGL	90	0	0	0	90
m	67,323	50 AGL	40	0	0	0	90
n	68,538	25 AGL	40	0	0	0	90

Flight Profile AH1D08 - Proposed AH-1Z Dep to Andy South
Based AH-1W
on Runway 6N25, Flight Track RWD3P - HSC-25 Dep MSR to Andy South

Scale in Feet 1:131,000 (1 inch = 10,900 feet)



Flight Profile AH1A08 on Nonbreak ArrivalTrack RWA3P

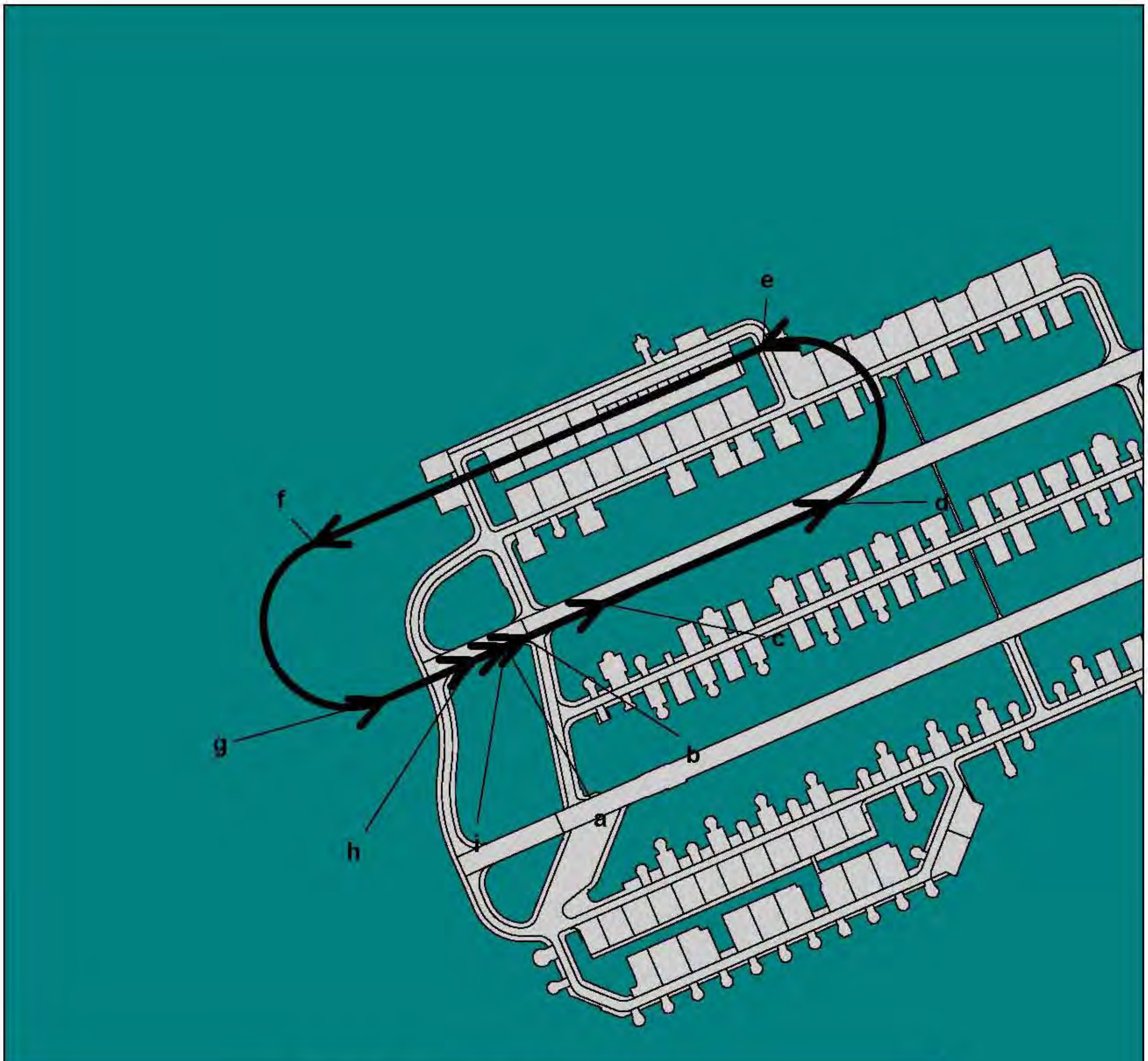
Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle
a	67,786	0 AGL	0	0	0	0	90
b	66,796	25 AGL	50	0	0	0	90
c	66,240	60 AGL	70	0	0	0	90
d	46,495	500 AGL	100	0	-2	30	90
e	42,522	500 AGL	100	0	-2	0	90
f	30,405	500 AGL	100	0	-2	30	90
g	25,946	500 AGL	100	0	-2	0	90
h	12,229	500 AGL	100	0	-2	-30	90
i	5,712	500 AGL	100	0	-2	-20	90
j	5,347	500 AGL	100	0	-2	0	90
k	3,000	500 AGL	90	0	-1	0	90
l	2,000	500 AGL	80	0	-1	0	90
m	1,000	300 AGL	70	0	0	0	90
n	500	200 AGL	60	0	0	0	90
o	300	100 AGL	40	0	0	0	90
p	150	50 AGL	20	0	2	0	90
q	75	25 AGL	10	0	0	0	90
r	0	10 AGL	0	0	0	0	90

Flight Profile AH1A08 - Proposed AH-1Z Arr from Andy South
Based AH-1W
on Runway 4N25, Flight Track RWA3P - Proposed RW arr from Andy South via MSR

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000 36,000 40,000

Scale in Feet 1:119,000 (1 inch = 9,950 feet)

N

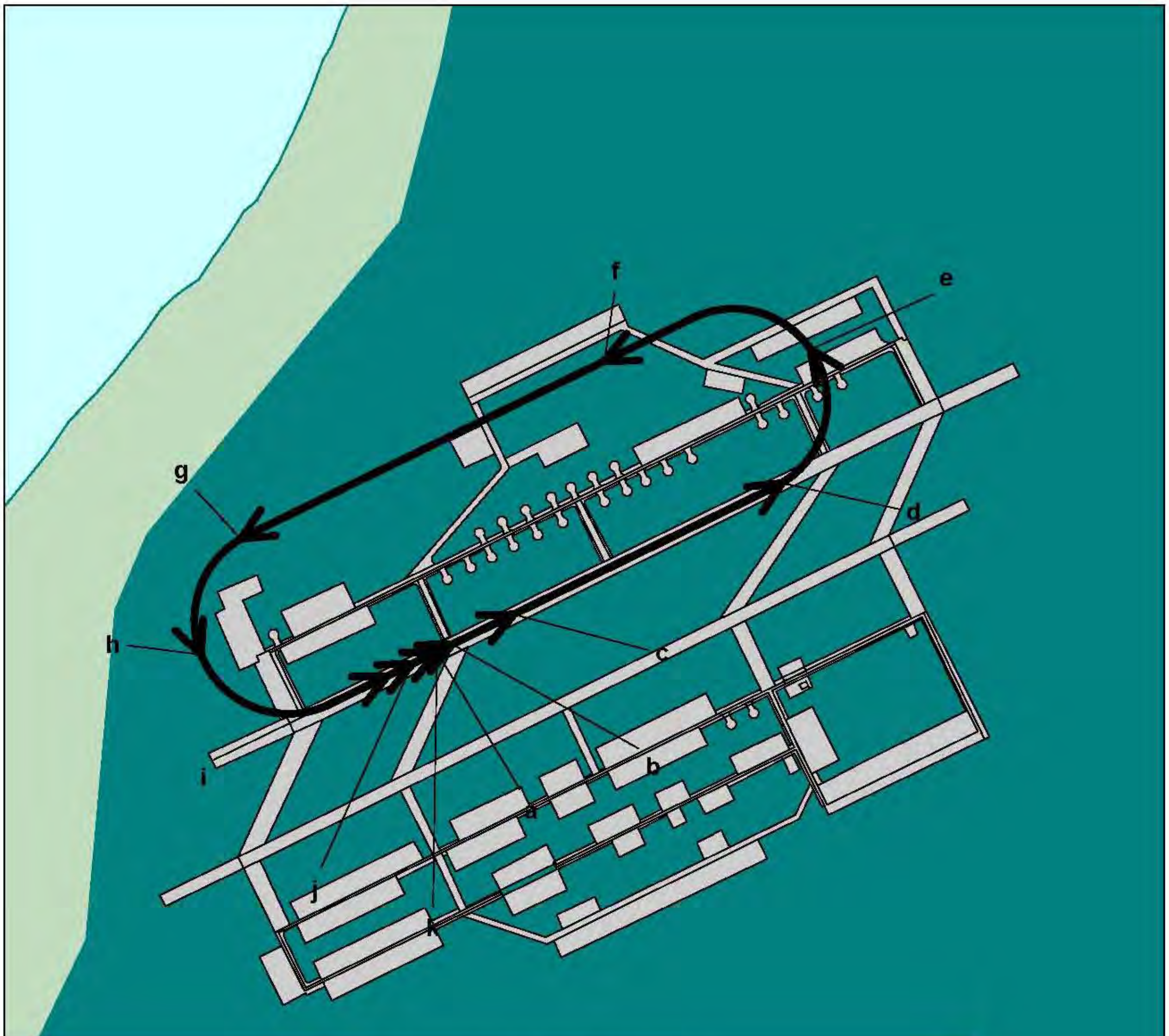


Flight Profile AH1F01 on FCLPTrack 6LT3

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	25 AGL	50	0	-5	0	90	
b	200	50 AGL	70	0	-5	0	90	
c	1,000	200 AGL	80	0	-5	0	90	
d	3,330	300 AGL	80	0	-5	-25	90	shifted pt; begin turn
e	5,843	300 AGL	80	0	-2	0	90	begin downwind
f	10,423	300 AGL	76	0	1	-25	90	end downwind
g	12,937	125 AGL	70	0	1	0	90	
h	13,862	50 AGL	60	0	1	0	90	
i	14,187	25 AGL	50	0	1	0	90	

Flight Profile AH1F01 - Normal Pattern
Based AH-1W
on Runway 06L, Flight Track 6LT3 - HELICOPTER VFR

Scale in Feet 1:19,700 (1 inch = 1,640 feet)

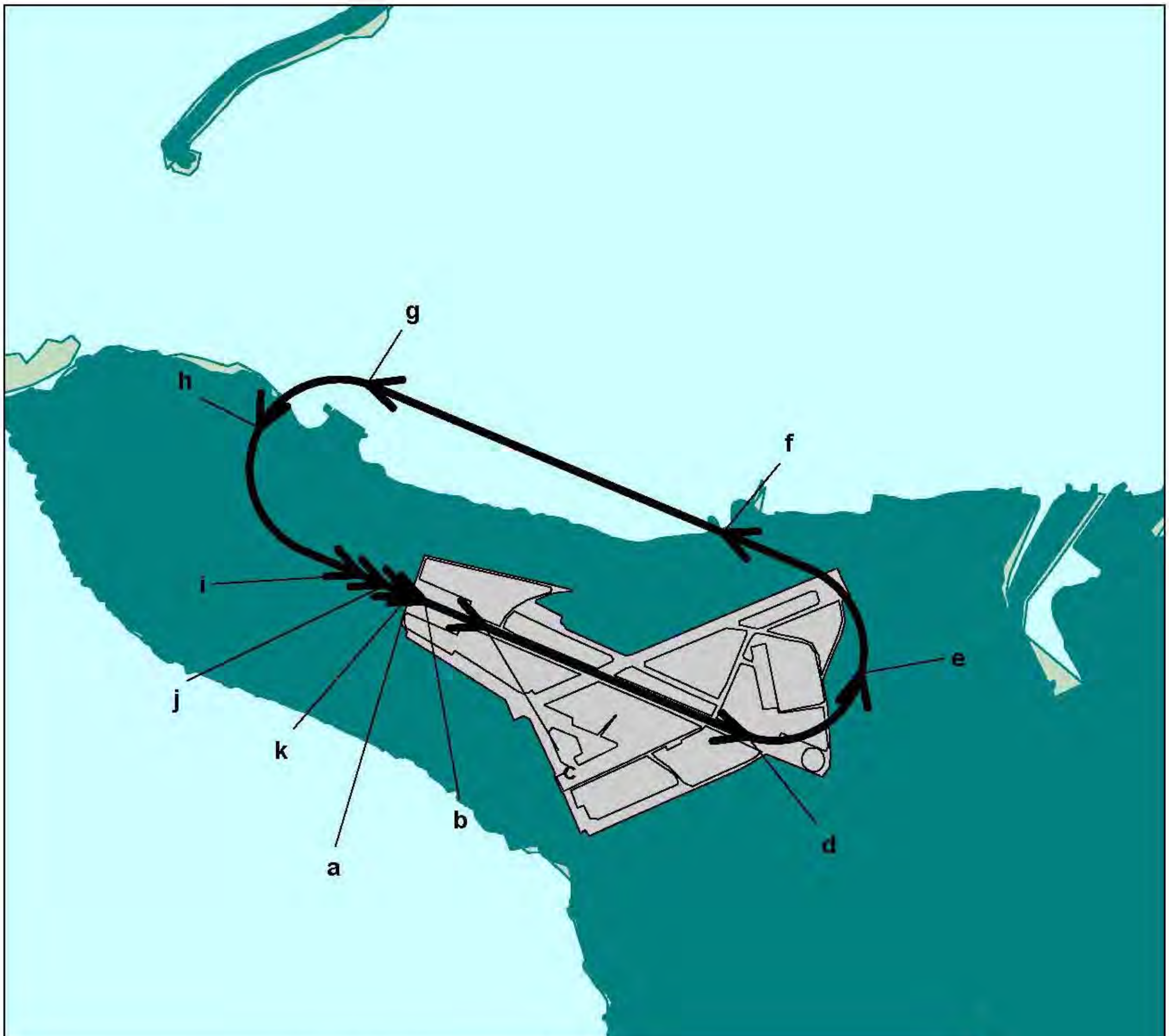


Flight Profile AH1F03 on FCLP Track NW05LF1

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	555 MSL	50	0	-5	0	90	
b	200	580 MSL	70	0	-5	0	90	
c	1,000	730 MSL	80	0	-5	0	90	
d	4,500	830 MSL	80	0	-5	-25	90	interpolated; begin turn
e	6,292	830 MSL	80	0	-2	-25	90	interpolated; crosswing
f	9,000	830 MSL	80	0	-2	0	90	
g	13,740	830 MSL	80	0	1	-25	90	end downwind
h	15,301	830 MSL	76	0	1	-25	90	interpolated crosswing
i	17,864	655 MSL	70	0	1	0	90	
j	18,187	580 MSL	60	0	1	0	90	
k	18,512	555 MSL	50	0	1	0	90	

Flight Profile AH1F03 - Normal Pattern
Based AH-1W
on Runway NW05L, Flight Track NW05LF1 - Helo FCLP

Scale in Feet 1:25,100 (1 inch = 2,090 feet)



Flight Profile AH1F05 on FCLPTrack OR10F1

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	115 MSL	50	0	-5	0	90	
b	200	140 MSL	70	0	-5	0	90	
c	1,000	290 MSL	80	0	-5	0	90	
d	4,500	390 MSL	80	0	-5	-25	90	interpolated; begin turn
e	6,292	390 MSL	80	0	-2	-25	90	interpolated; crosswing
f	9,000	390 MSL	80	0	-2	0	90	
g	13,740	390 MSL	80	0	1	-25	90	end downwind
h	15,301	390 MSL	76	0	1	-25	90	interpolated crosswing
i	17,864	215 MSL	70	0	1	0	90	
j	18,187	140 MSL	60	0	1	0	90	
k	18,512	115 MSL	50	0	1	0	90	

Flight Profile AH1F05 - Normal Pattern

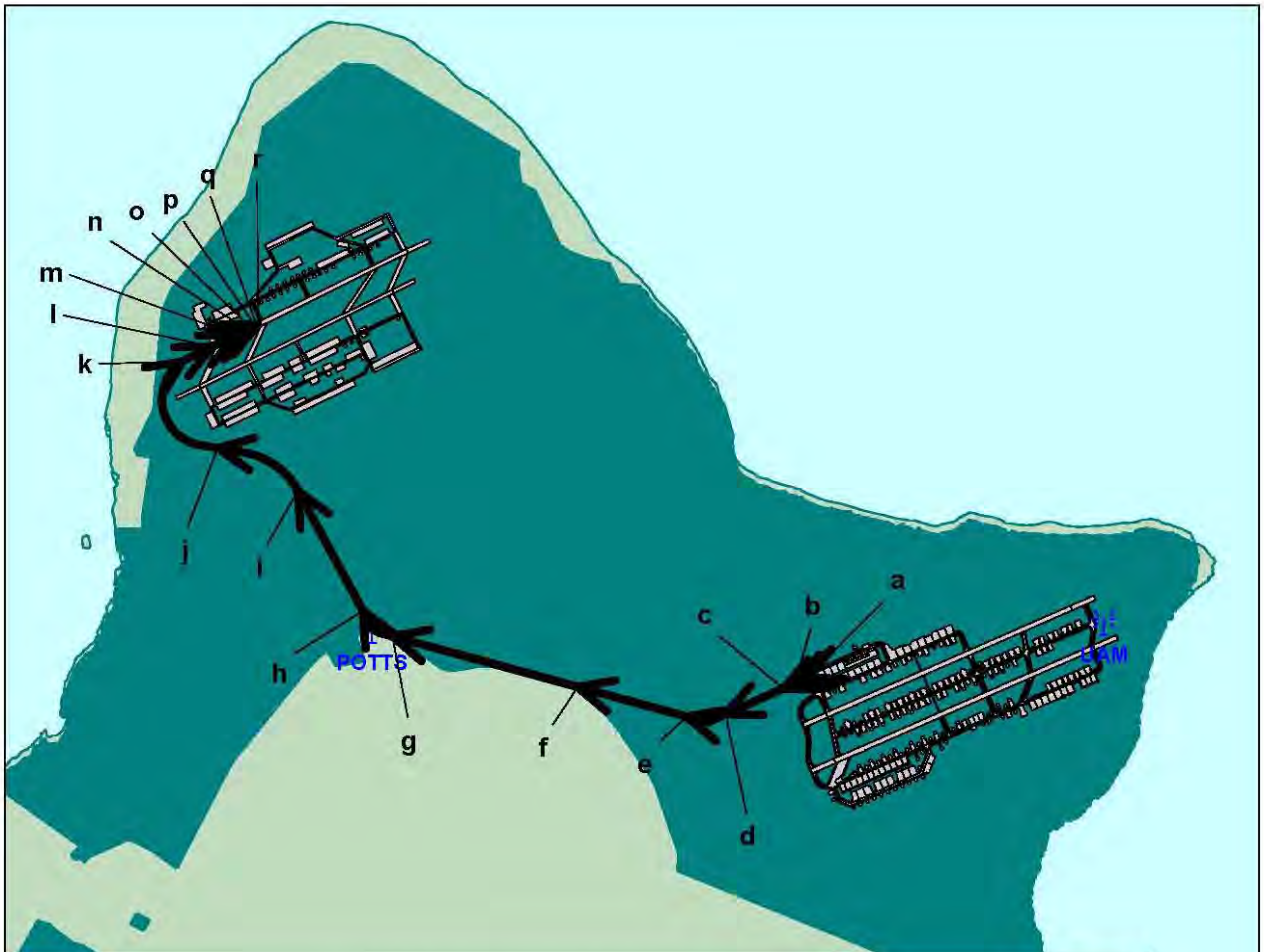
Based AH-1W

on Runway OROTE10, Flight Track OR10F1 - Helo FCLP

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000

Scale in Feet 1:26,300 (1 inch = 2,200 feet)

N



Flight Profile AH1I01 on InterfacilityTrack INW05L

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	0 AGL	0	0	0	0	90	
b	500	25 AGL	50	0	-5	0	90	
c	1,000	60 AGL	70	0	-5	0	90	
d	3,500	500 AGL	80	0	-5	-25	90	Shifted forward 500'; begin turn
e	5,133	500 AGL	90	0	-5	0	90	Interpolated pt; end turn
f	9,600	500 AGL	120	0	0	0	90	
g	17,198	500 AGL	120	0	0	-25	90	added pt; begin turn
h	18,837	500 AGL	120	0	0	0	90	added pt; end turn
i	24,231	500 AGL	120	0	0	25	90	added pt; begin turn
j	28,000	500 AGL	120	0	-2	-25	90	end left turn; begin right turn
k	33,028	1,030 MSL	90	0	-1	0	90	End turn
l	34,351	1,030 MSL	80	0	-1	0	90	
m	35,384	830 MSL	70	0	0	0	90	
n	35,870	730 MSL	60	0	0	0	90	
o	36,053	630 MSL	40	0	0	0	90	
p	36,234	580 MSL	20	0	2	0	90	
q	36,296	555 MSL	10	0	0	0	90	
r	36,356	530 MSL	0	0	0	0	90	

Flight Profile AH1I01 - Interfacility to NW Field

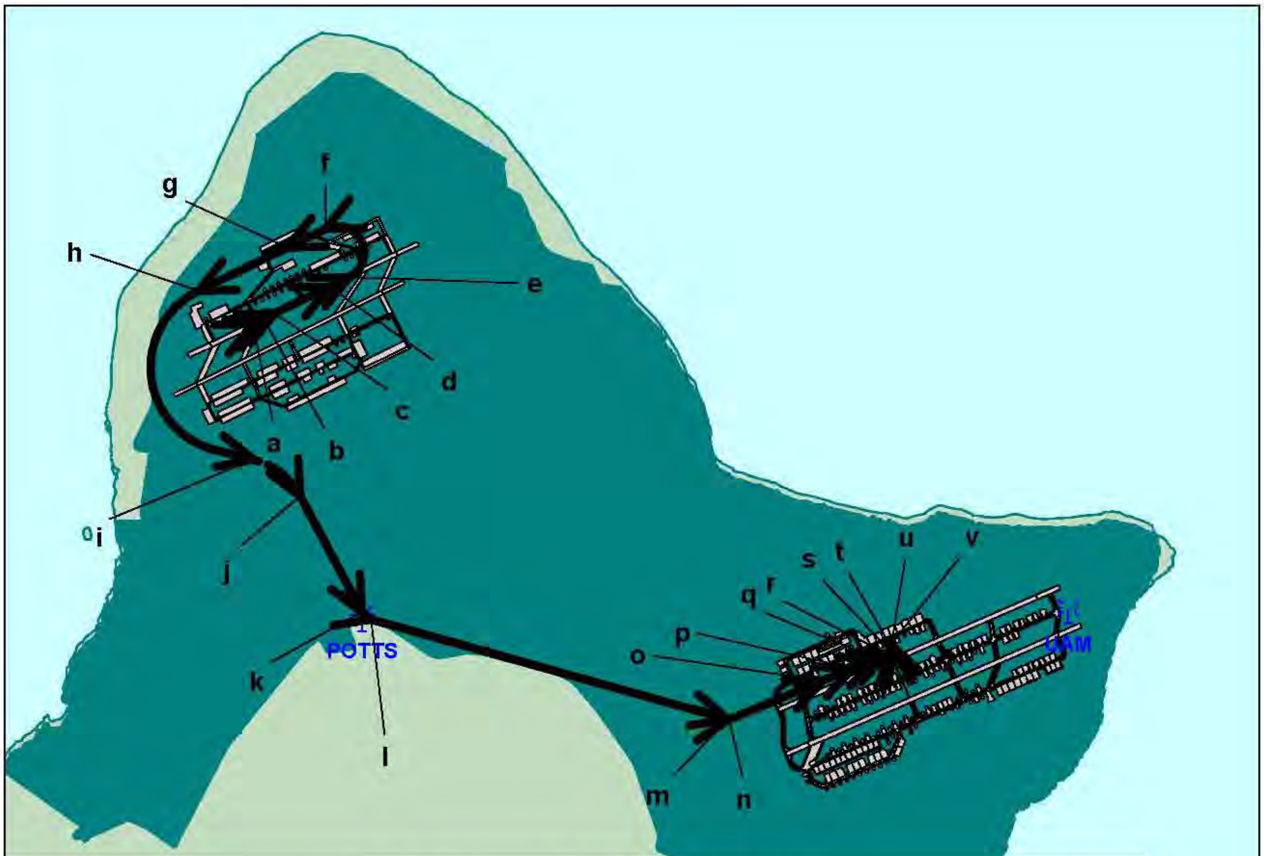
Based AH-1W

on Runway 4N1, Flight Track INW05L - Andersen AFB to NW Field via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000

Scale in Feet 1:91,600 (1 inch = 7,630 feet)

N



Flight Profile AH1I03 on InterfacilityTrack 05I4N25

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	530 MSL	0	0	0	0	90	
b	500	555 MSL	50	0	-5	0	90	
c	1,000	590 MSL	70	0	-5	0	90	
d	3,500	1,030 MSL	80	0	-5	0	90	Shifted forward 500'; begin turn
e	4,400	1,030 MSL	90	0	-5	25	90	Interpolated pt; end turn
f	7,856	1,030 MSL	120	0	0	0	90	added pt; end turn
g	9,600	1,030 MSL	120	0	0	0	90	
h	13,656	1,030 MSL	120	0	0	25	90	added pt; begin turn
i	23,808	1,030 MSL	120	0	0	-25	90	End left turn; begin right turn
j	26,321	1,030 MSL	120	0	0	0	90	End right turn
k	31,721	1,030 MSL	120	0	0	25	90	begin left turn
l	32,212	1,030 MSL	120	0	0	0	90	end turn
m	47,402	500 AGL	120	0	-2	25	90	begin left turn
n	47,467	500 AGL	120	0	-2	0	90	end turn
o	51,627	500 AGL	90	0	-1	0	90	End turn
p	52,950	500 AGL	80	0	-1	0	90	
q	53,983	300 AGL	70	0	0	0	90	
r	54,482	200 AGL	60	0	0	25	90	
s	54,652	100 AGL	40	0	0	25	90	
t	54,833	50 AGL	20	0	2	20	90	
u	54,895	25 AGL	10	0	0	10	90	
v	54,955	0 AGL	0	0	0	0	90	

Flight Profile AH1I03 - Interfacility from NW Field

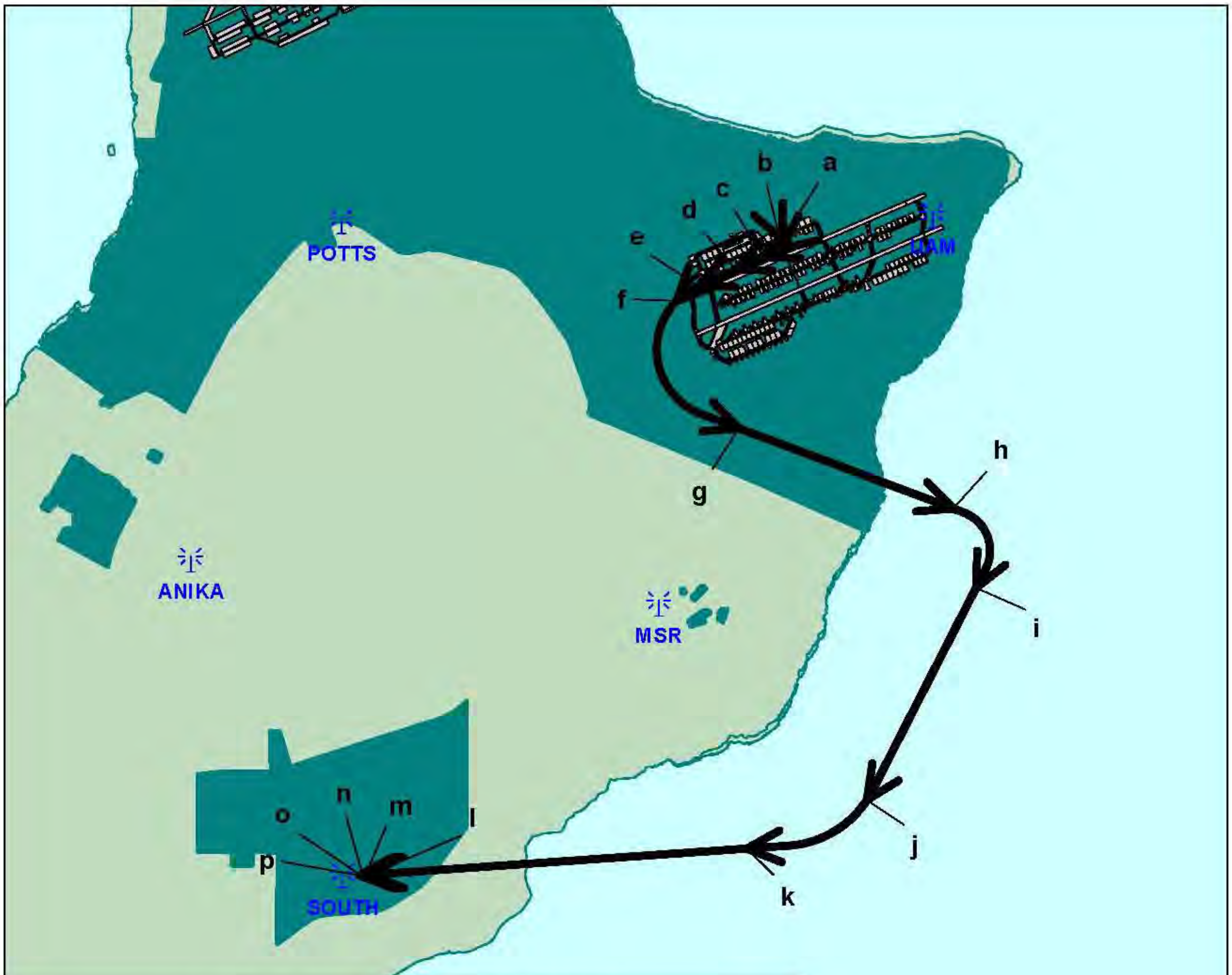
Based AH-1W

on Runway NW05L, Flight Track 05I4N25 - NW Field to Andersen AFB via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000

Scale in Feet 1:95,000 (1 inch = 7,920 feet)

N



Flight Profile H53D08 on DepartureTrack RWD3P

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle
a	0	0 AGL	0	0	0	0	90
b	500	50 AGL	10	0	5	0	90
c	1,500	200 AGL	60	0	-5	0	90
d	3,000	500 AGL	90	0	0	0	90
e	5,000	500 AGL	100	0	5	20	90
f	6,291	500 AGL	100	0	5	20	90
g	15,000	500 AGL	100	0	3	0	90
h	26,208	500 AGL	100	0	3	-20	90
i	31,149	500 AGL	100	0	3	0	90
j	42,854	500 AGL	100	0	3	-25	90
k	49,508	500 AGL	100	0	3	0	90
l	68,038	200 AGL	60	0	3	0	90
m	68,238	100 AGL	40	0	3	0	90
n	68,388	50 AGL	20	0	3	0	90
o	68,463	25 AGL	10	0	3	0	90
p	68,538	10 AGL	0	0	3	0	90

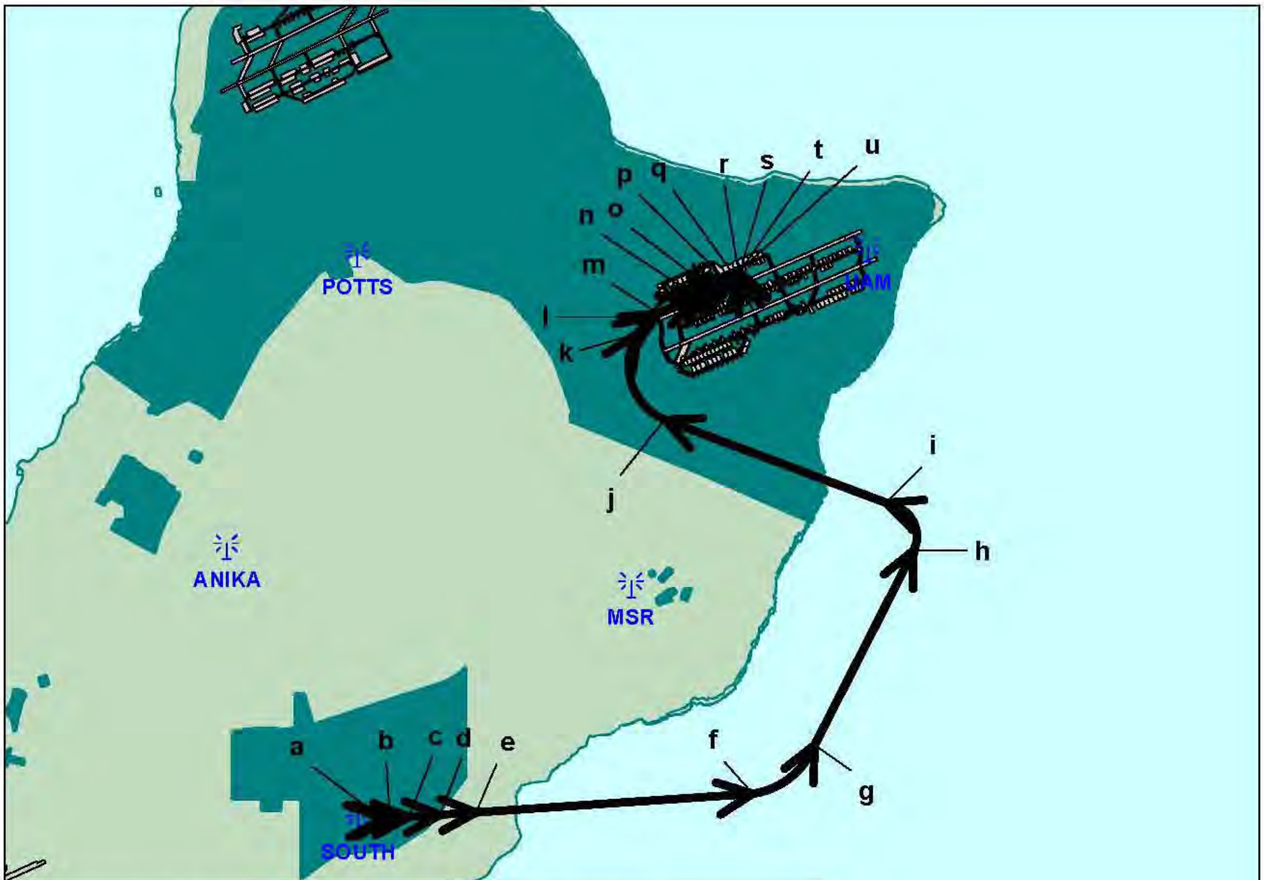
Flight Profile H53D08 - Proposed CH-53E Dep to Shore via Potts Jxn
Based CH53E
on Runway 6N25, Flight Track RWD3P - HSC-25 Dep MSR to Andy South

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000 36,000

Scale in Feet 1:111,000 (1 inch = 9,220 feet)

N

wyle



Flight Profile H53A08 on Nonbreak ArrivalTrack RWA3P

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle
a	67,979	10 AGL	0	0	5	0	90
b	67,549	50 AGL	10	0	3	0	90
c	66,484	200 AGL	60	0	5	0	90
d	64,704	500 AGL	90	0	5	0	90
e	62,668	500 AGL	90	0	3	0	90
f	46,948	500 AGL	100	0	5	30	90
g	42,267	500 AGL	100	0	5	0	90
h	29,872	500 AGL	100	0	5	30	90
i	26,243	500 AGL	100	0	5	0	90
j	12,823	500 AGL	100	0	5	-30	90
k	7,000	500 AGL	100	0	7	-30	90
l	5,712	500 AGL	97	0	3	-20	90
m	5,347	500 AGL	96	0	3	0	90
n	3,000	500 AGL	90	0	8	0	90
o	2,000	500 AGL	80	0	9	0	90
p	1,000	300 AGL	70	0	9	0	90
q	500	200 AGL	60	0	9	0	90
r	300	100 AGL	40	0	9	0	90
s	150	50 AGL	20	0	9	0	90
t	75	25 AGL	10	0	5	0	90
u	0	0 AGL	0	0	0	0	90

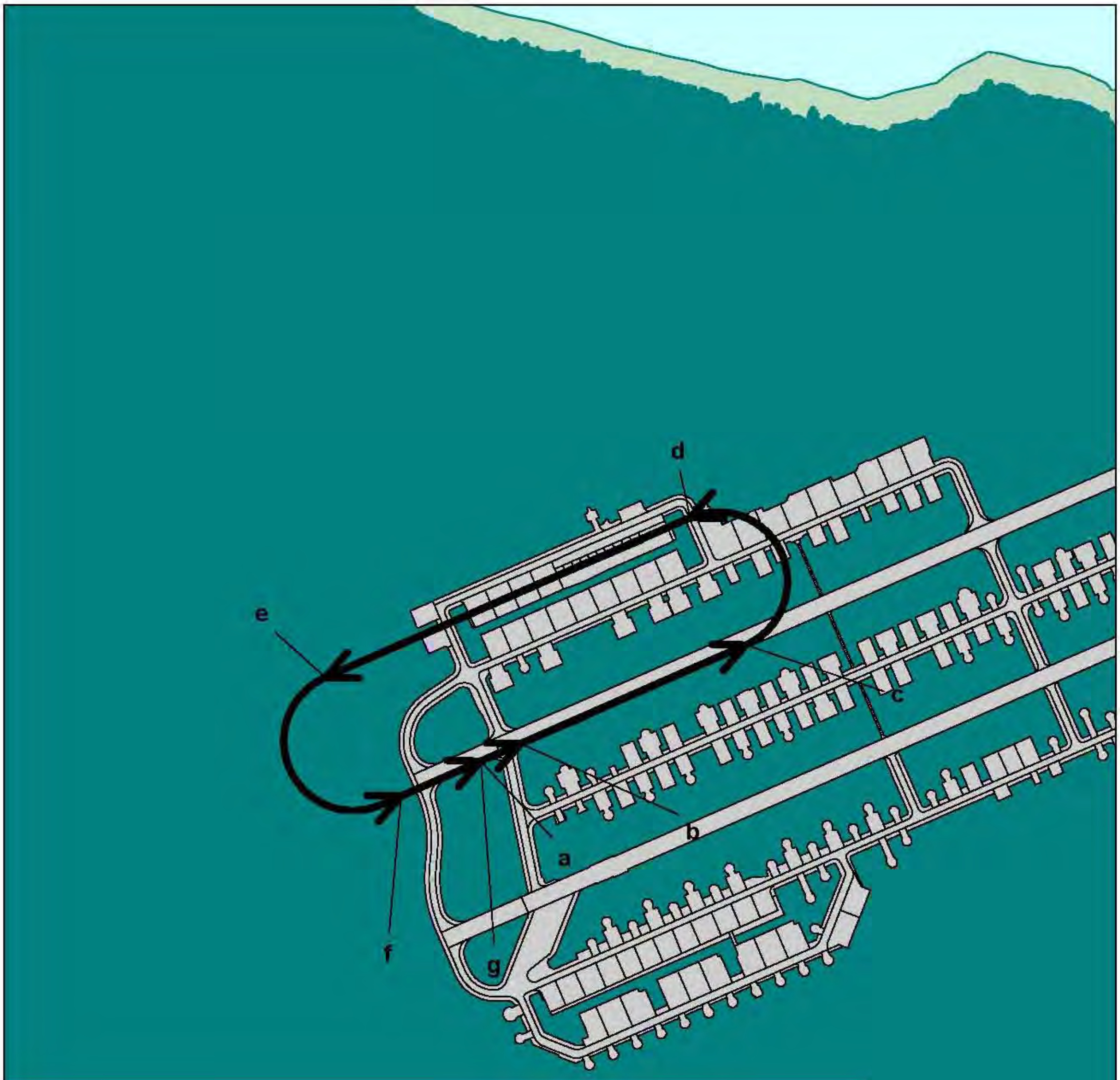
Flight Profile H53A08 - Proposed CH-53E Arr from Andy South
Based CH53E
on Runway 4N25, Flight Track RWA3P - Proposed RW arr from Andy South via MSR

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000 36,000 40,000 44,000

Scale in Feet 1:131,000 (1 inch = 10,900 feet)

N

wyle

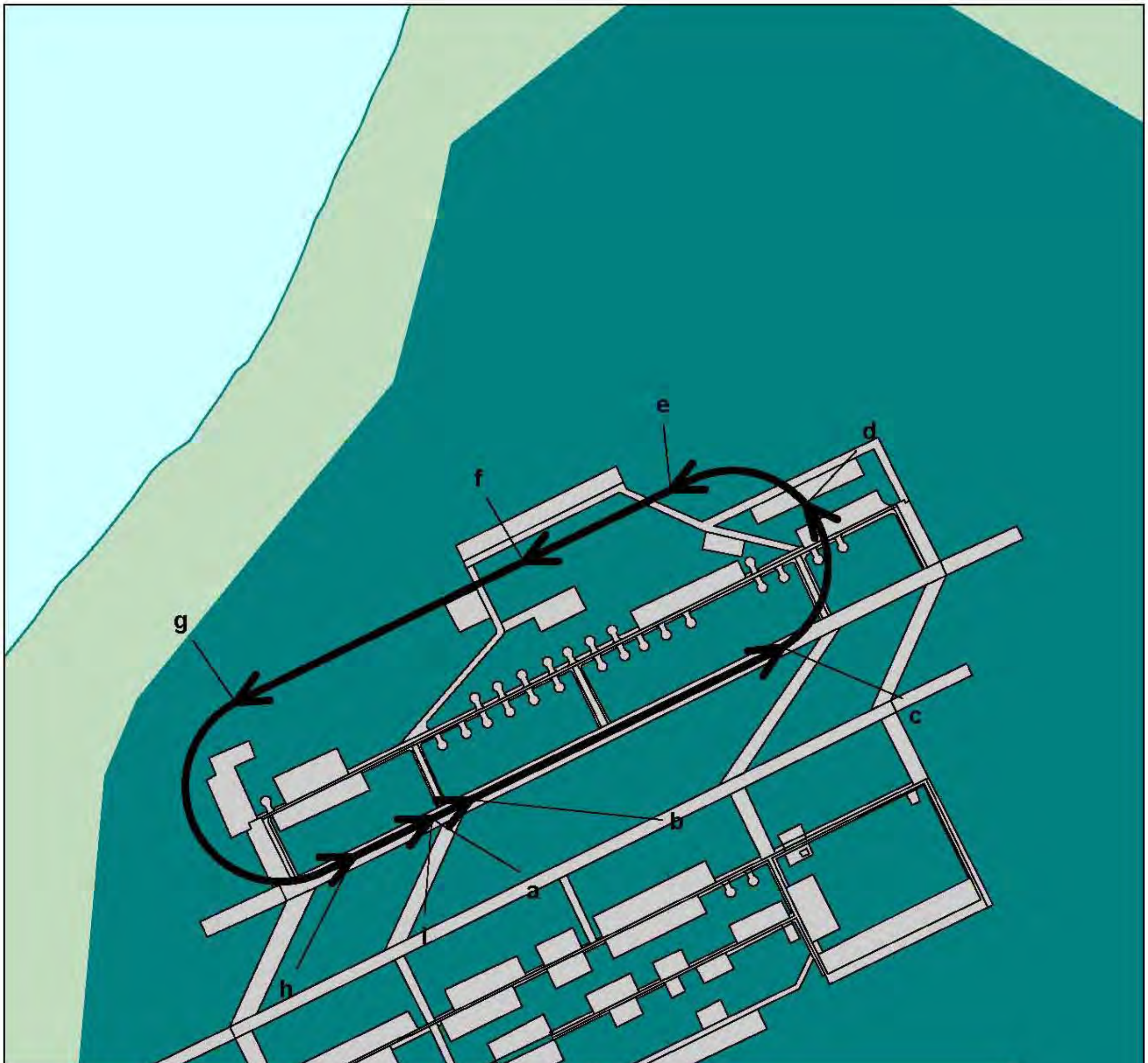


Flight Profile H53F01 on FCLPTrack 6LT3

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	50 AGL	5	0	0	0	90	
b	500	200 AGL	60	0	-5	0	90	
c	3,330	200 AGL	103	0	0	25	90	Begin turn
d	5,843	200 AGL	120	0	0	0	90	start downwin
e	10,423	300 AGL	120	0	0	25	90	
f	13,186	200 AGL	60	0	5	0	90	end turn
g	14,187	50 AGL	5	0	0	0	90	

Flight Profile H53F01 - 04L-Normal Pattern
Based CH53E
on Runway 06L, Flight Track 6LT3 - HELICOPTER VFR

Scale in Feet 1:23,600 (1 inch = 1,970 feet)



Flight Profile H53F03 on FCLPTrack NW05LF1

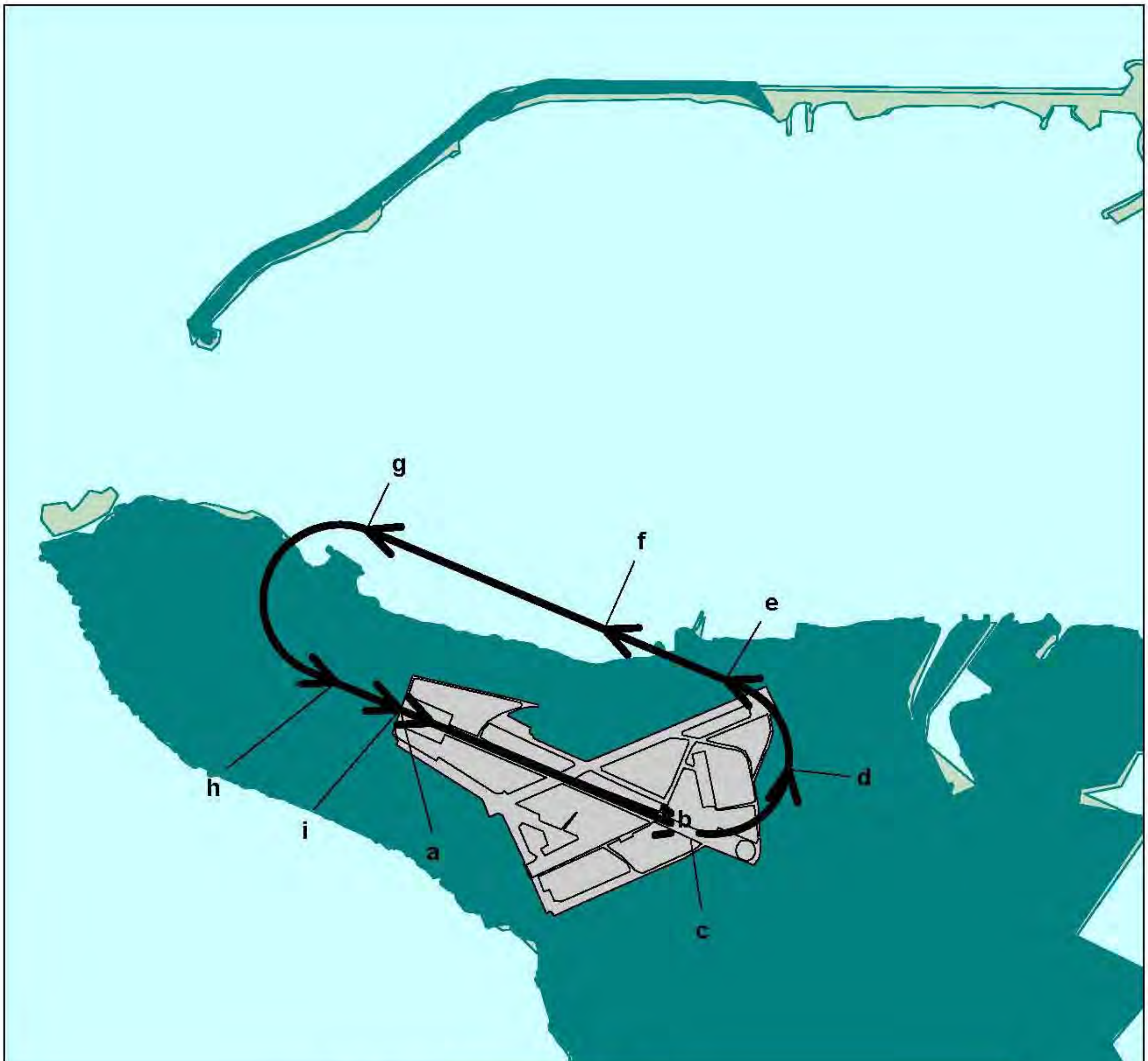
Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	580 MSL	5	0	0	0	90	
b	500	730 MSL	60	0	-5	0	90	
c	4,500	730 MSL	103	0	0	25	90	interpolated pt; begin turn
d	6,394	730 MSL	120	0	0	25	90	
e	8,114	830 MSL	120	0	0	0	90	Shifted back 400 ft; end turn
f	10,000	830 MSL	120	0	0	0	90	
g	13,700	830 MSL	120	0	0	25	90	shifted back 200 ftt; begin turn
h	17,511	730 MSL	60	0	5	0	90	end turn
i	18,511	580 MSL	5	0	0	0	90	

Flight Profile H53F03 - 04L-Normal Pattern

Based CH53E

on Runway NW05L, Flight Track NW05LF1 - Helo FCLP

Scale in Feet 1:24,300 (1 inch = 2,020 feet)



Flight Profile H53F05 on FCLPTrack OR10F1

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	140 MSL	5	0	0	0	90	
b	500	290 MSL	60	0	-5	0	90	
c	4,500	290 MSL	103	0	0	25	90	interpolated pt; begin turn
d	6,394	290 MSL	120	0	0	25	90	
e	8,114	390 MSL	120	0	0	0	90	Shifted back 400 ft; end turn
f	10,000	390 MSL	120	0	0	0	90	
g	13,700	390 MSL	120	0	0	25	90	shifted back 200 ftt; begin turn
h	17,511	290 MSL	60	0	5	0	90	end turn
i	18,511	140 MSL	5	0	0	0	90	

Flight Profile H53F05 - 04L-Normal Pattern
Based CH53E
on Runway OROTE10, Flight Track OR10F1 - Helo FCLP

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000 10,000

Scale in Feet 1:30,200 (1 inch = 2,520 feet)

N

wyle

Flight Profile H53I01 on InterfacilityTrack INW05L

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	0 AGL	0	0	0	0	90	
b	200	20 AGL	20	0	-5	0	90	
c	2,000	500 AGL	105	0	-5	0	90	
d	3,500	500 AGL	107	0	-5	-25	90	Shifted forward 500'; begin turn
e	6,000	500 AGL	110	0	-5	0	90	Interpolated pt; end turn
f	9,000	500 AGL	120	0	0	0	90	
g	17,198	500 AGL	120	0	0	-25	90	added pt; begin turn
h	18,837	500 AGL	120	0	0	0	90	added pt; end turn
i	24,230	1,030 MSL	120	0	0	25	90	added pt; begin turn
j	28,000	1,030 MSL	120	0	5	-25	90	end left turn; begin right turn
k	33,028	980 MSL	80	0	5	0	90	Shiftef forward 600'; End turn
l	35,356	630 MSL	60	0	5	0	90	
m	36,356	580 MSL	0	0	0	0	90	

Flight Profile H53I01 - Interfacitlity to NW Field

Based CH53E

on Runway 4N1, Flight Track INW05L - Andersen AFB to NW Field via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000

Scale in Feet 1:72,900 (1 inch = 6,070 feet)

N

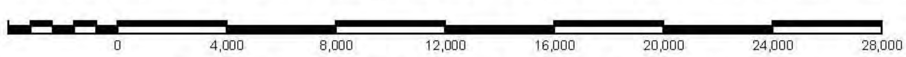
Flight Profile H53I03 on InterfacilityTrack 05I4N25

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	530 MSL	0	0	0	0	90	
b	200	550 MSL	20	0	-5	0	90	
c	2,000	1,030 MSL	105	0	-5	0	90	
d	3,000	1,030 MSL	107	0	-5	0	90	
e	4,400	1,030 MSL	108	0	-5	25	90	Interpolated pt; begin turn
f	7,856	1,030 MSL	118	0	-5	0	90	Interpolated pt; end turn
g	9,000	1,030 MSL	120	0	0	0	90	
h	13,656	1,030 MSL	120	0	0	25	90	added pt; begin turn
i	23,808	1,030 MSL	120	0	0	-25	90	added pt; end left turn, begin right turn
j	26,321	1,030 MSL	120	0	0	0	90	added pt; end turn
k	31,721	1,030 MSL	120	0	0	25	90	added pt; begin turn
l	32,212	1,030 MSL	120	0	0	0	90	added pt; end turn
m	47,402	500 AGL	120	0	5	25	90	begin turn
n	47,467	500 AGL	120	0	0	0	90	added pt; end turn
o	51,027	450 AGL	80	0	5	0	90	
p	53,955	100 AGL	60	0	5	0	90	
q	54,955	50 AGL	10	0	0	0	90	

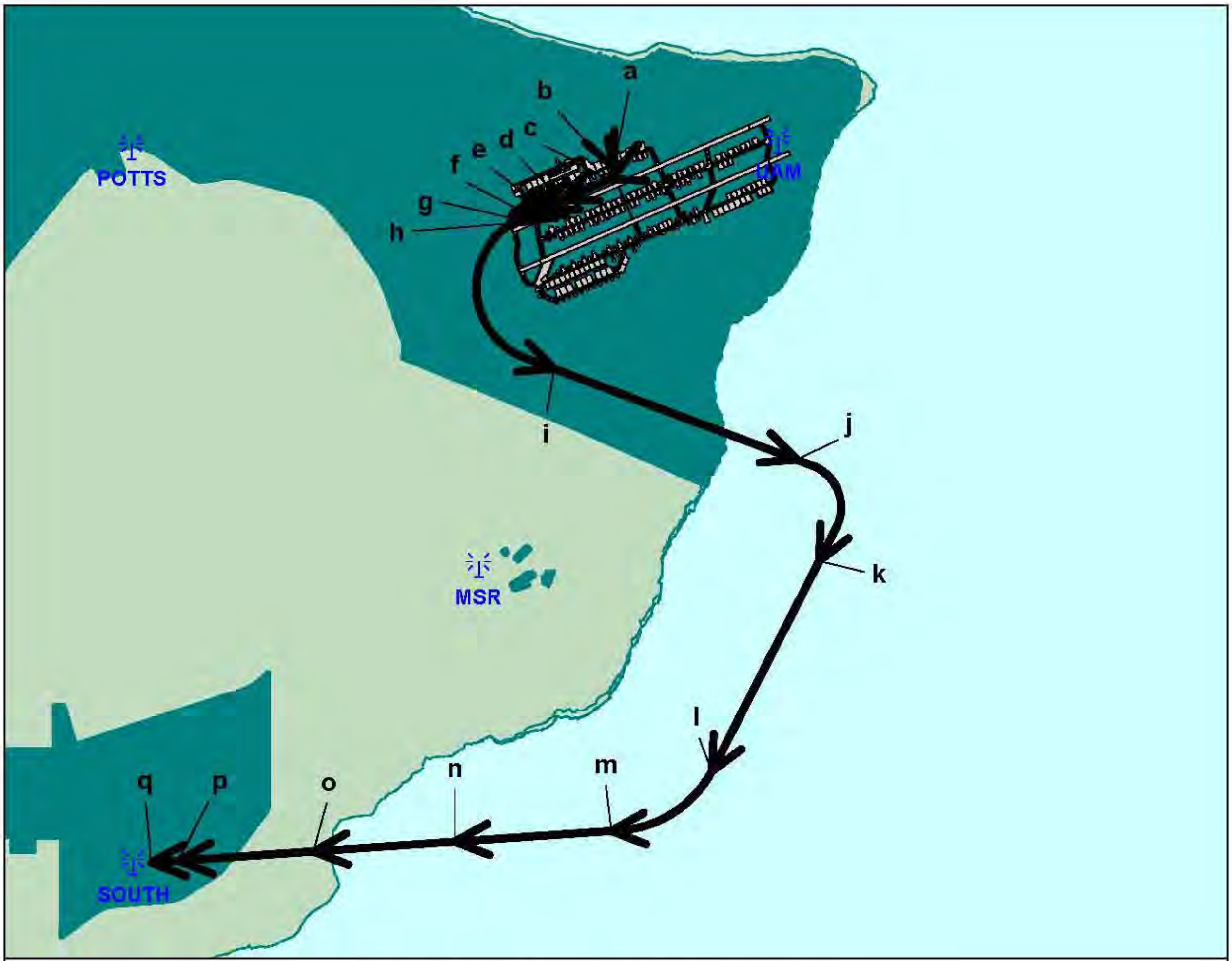
Flight Profile H53I03 - Interfacitlity from NW Field

Based CH53E

on Runway NW05L, Flight Track 05I4N25 - NW Field to Andersen AFB via Potts Jxn



Scale in Feet 1:84,900 (1 inch = 7,080 feet)

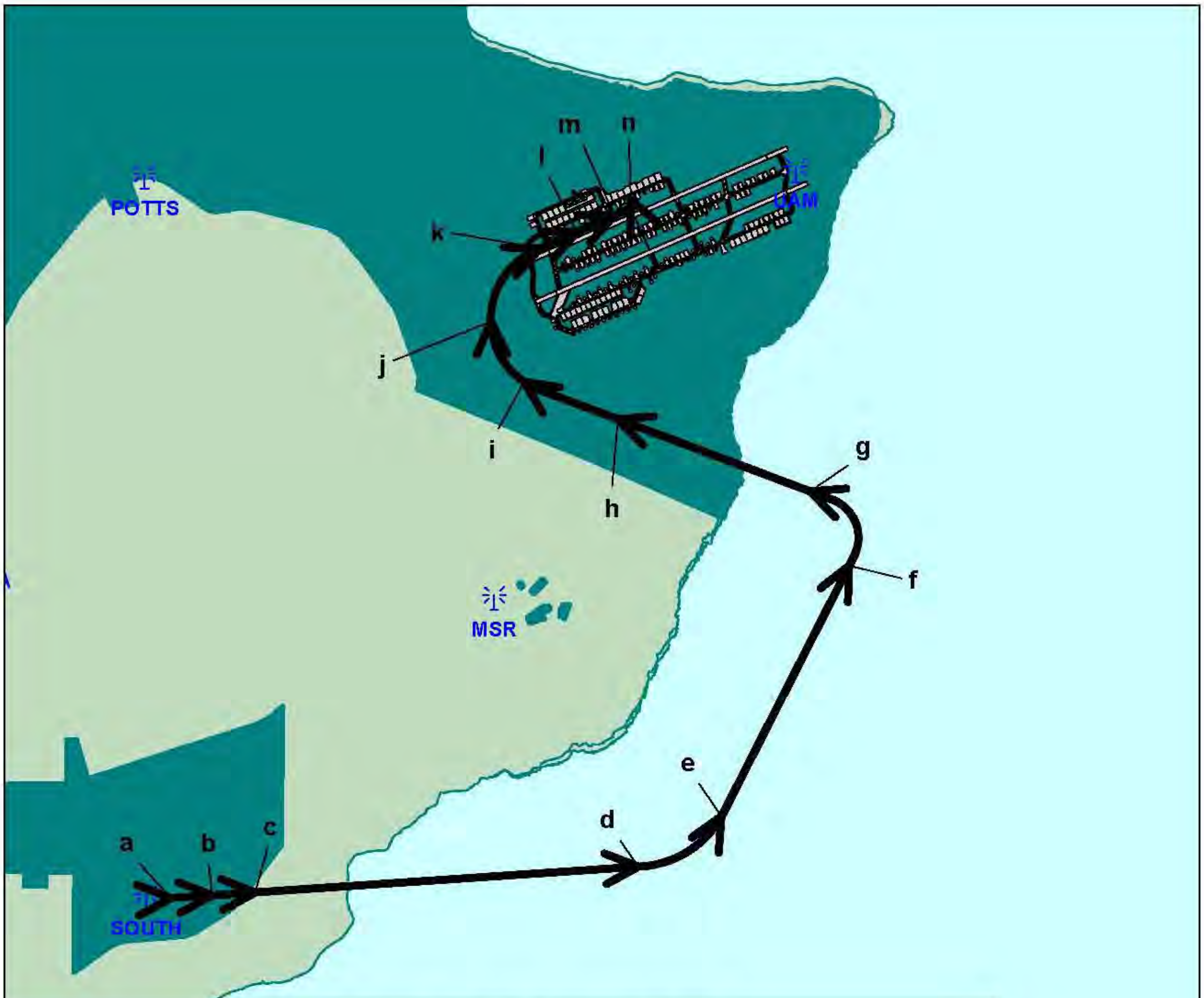


Flight Profile V22D08 on DepartureTrack RWD3P

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	15 AGL	5	0	0	0	60	Normal 60 STO transition to APLN to 1500 ft
b	334	50 AGL	50	0	-4	0	60	
c	730	167 AGL	66	0	-2	0	60	
d	3,000	650 AGL	125	0	5	0	9	
e	4,000	823 AGL	135	0	10	0	0	
f	4,655	925 AGL	145	0	7	0	0	
g	5,175	1,000 AGL	155	0	6	0	0	
h	5,500	1,000 AGL	170	0	7	25	0	
i	14,402	1,000 AGL	170	0	7	0	0	
j	26,006	1,000 AGL	170	0	7	-25	0	
k	31,806	1,000 AGL	170	0	7	0	0	
l	42,391	1,000 AGL	170	0	7	-25	0	
m	47,881	1,000 AGL	170	0	7	0	0	
n	54,902	1,000 AGL	170	0	7	0	0	
o	61,247	500 AGL	80	0	7	0	60	
p	67,323	200 AGL	60	0	7	0	80	
q	68,538	20 AGL	5	0	0	0	90	

Flight Profile V22D08
Based MV22B
on Runway 6N25, Flight Track RWD3P - HSC-25 Dep MSR to Andy South

Scale in Feet 1:101,000 (1 inch = 8,430 feet)



Flight Profile V22A08 on Nonbreak ArrivalTrack RWA3P

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	68,255	20 AGL	5	0	0	0	60	
b	66,419	167 AGL	66	0	-2	0	60	
c	64,505	500 AGL	135	0	10	0	0	
d	47,418	500 AGL	170	0	5	30	0	
e	42,900	500 AGL	170	0	5	0	0	
f	30,381	500 AGL	170	0	5	30	0	
g	25,804	500 AGL	170	0	5	0	0	begin 1800 fpm desc;
h	16,667	500 AGL	150	0	-1	0	10	700 fpm desc
i	12,172	500 AGL	150	0	-1	-30	20	1800 fpm desc
j	9,000	500 AGL	80	0	0	-30	79	400 fpm desc; 3deg gs
k	4,800	300 AGL	80	0	0	0	80	400 fpm desc; 3deg gs
l	3,000	200 AGL	60	0	-1	0	87	200 fpm desc; 2deg gs
m	1,200	150 AGL	50	0	5	0	90	300 fpm desc; 6deg gs
n	0	20 AGL	5	0	0	0	90	5 knot stop

Flight Profile V22A08

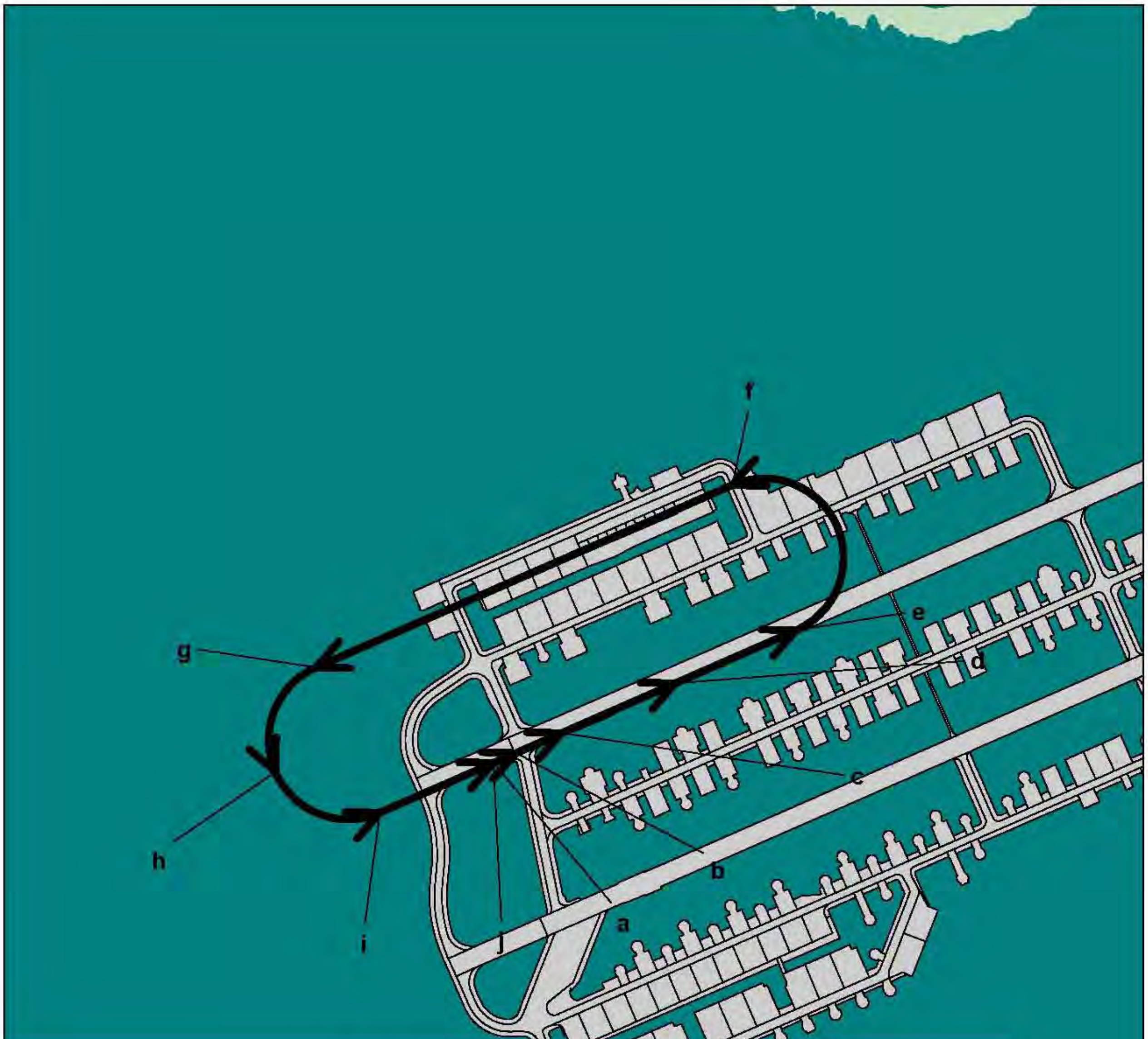
Based MV22B

on Runway 4N25, Flight Track RWA3P - Proposed RW arr from Andy South via MSR

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000

Scale in Feet 1:98,200 (1 inch = 8,180 feet)

N



Flight Profile V22F01 on FCLPTrack 6LT3

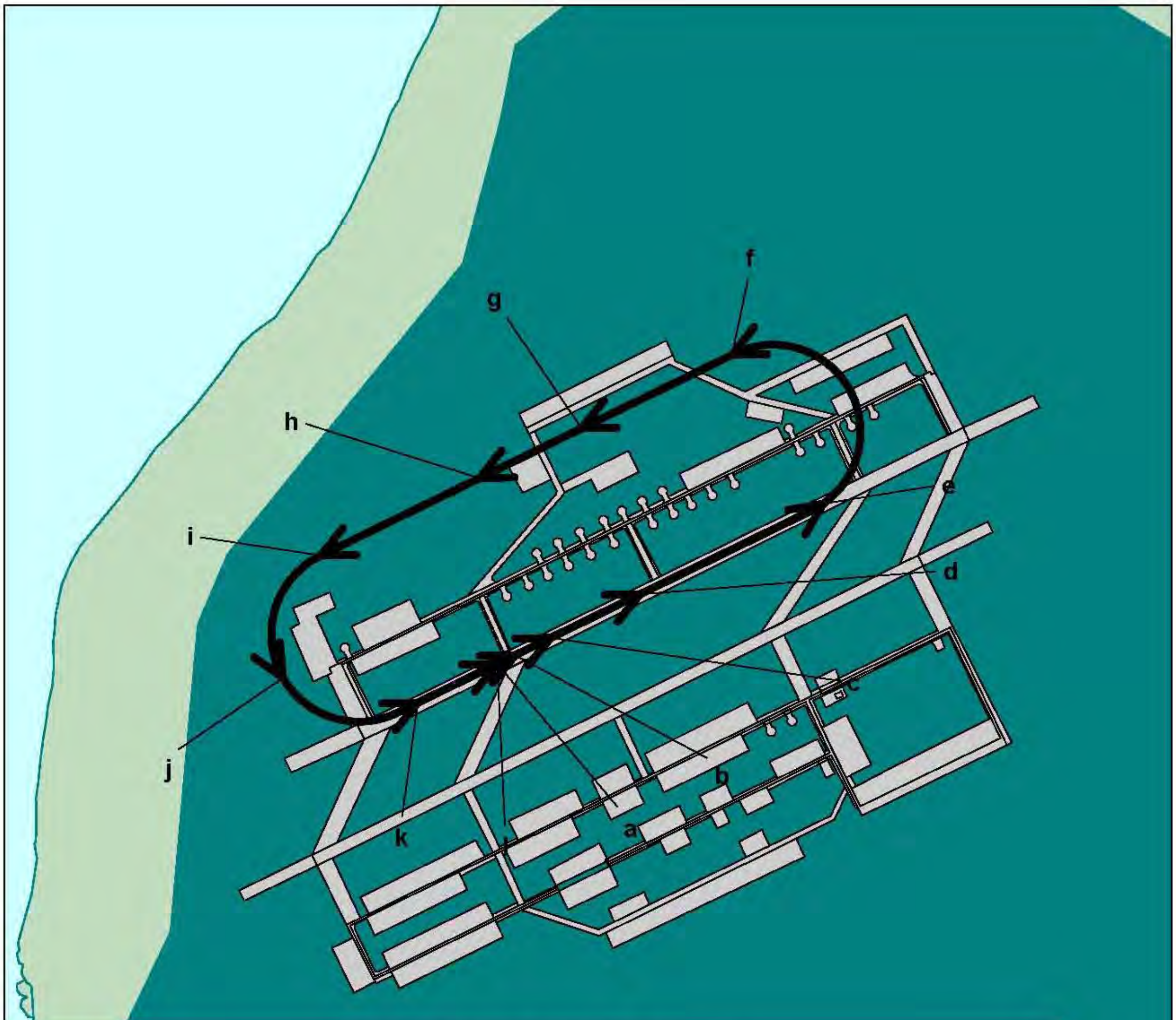
Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	20 AGL	5	0	0	0	60	5 kt start
b	250	30 AGL	45	0	-6	0	60	
c	750	150 AGL	65	0	0	0	60	
d	2,000	300 AGL	110	0	3	0	30	
e	3,330	300 AGL	110	0	10	25	0	begin turn
f	5,843	300 AGL	150	0	7	0	0	begin downwind
g	10,423	300 AGL	150	0	0	25	60	shifted back 200 ft; begin turn
h	11,680	200 AGL	60	0	0	25	87	
i	12,937	95 AGL	32	0	0	0	89	Interpolated; end turn
j	14,187	20 AGL	5	0	0	0	90	

Flight Profile V22F01 - 04L-Normal Pattern
Based MV22B
on Runway 06L, Flight Track 6LT3 - HELICOPTER VFR

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000

Scale in Feet 1:21,200 (1 inch = 1,770 feet)

N



Flight Profile V22F03 on FCLPTrack NW05LF1

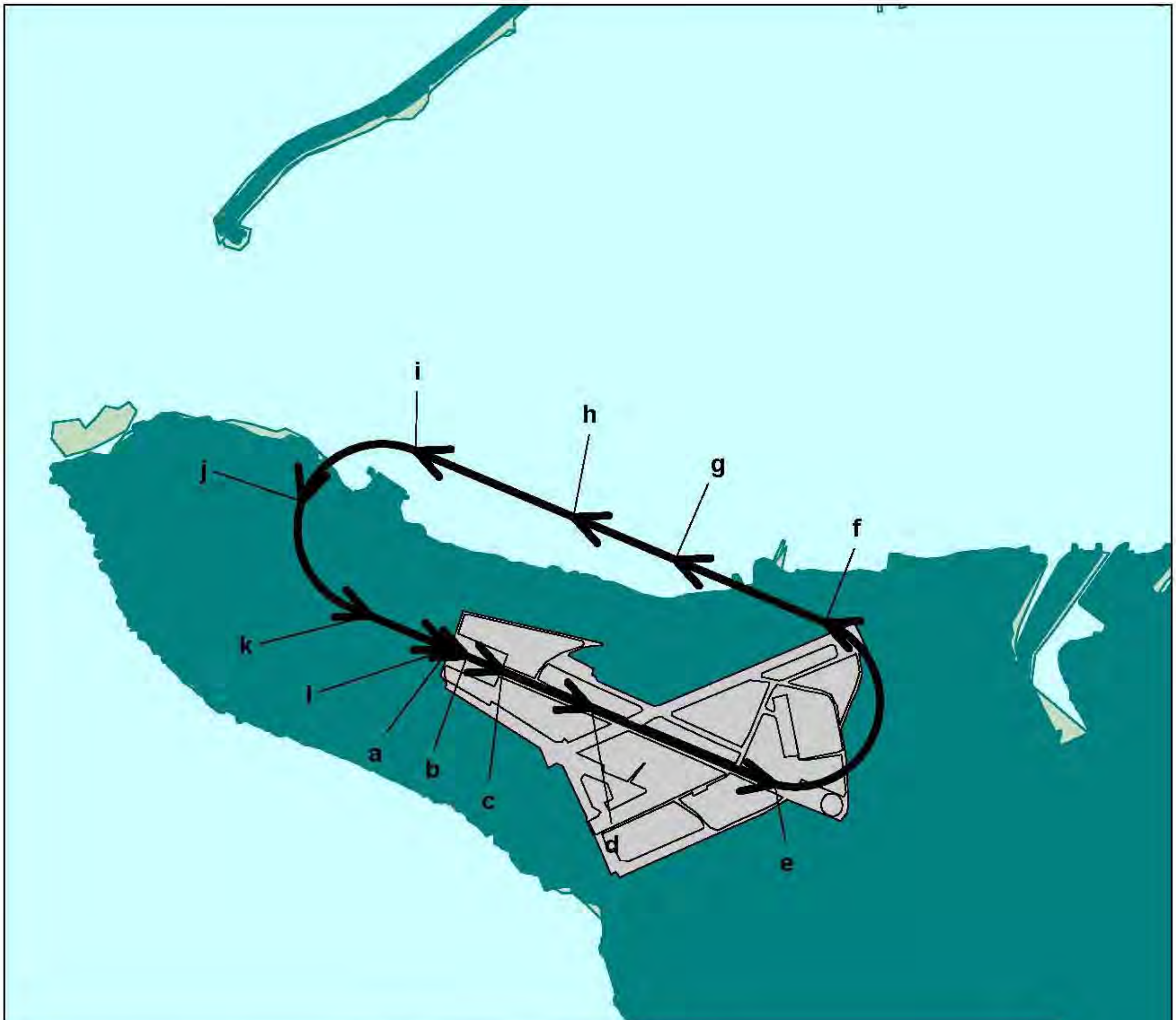
Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	550 MSL	5	0	0	0	60	5 kt start
b	250	560 MSL	45	0	-6	0	60	
c	750	680 MSL	65	0	0	0	60	
d	2,000	830 MSL	110	0	3	0	30	
e	4,570	830 MSL	155	0	10	25	0	shifted forward 500 ft; begin turn
f	7,895	830 MSL	170	0	7	0	0	shifted back 600 ft; end turn
g	10,000	830 MSL	170	0	3	0	0	
h	11,431	830 MSL	140	0	3	0	0	
i	13,650	830 MSL	110	0	0	25	60	shifted back 200 ft; begin turn
j	15,458	730 MSL	60	0	0	25	87	
k	17,400	625 MSL	32	0	0	0	89	Interpolated; end turn
l	18,512	550 MSL	5	0	0	0	90	

Flight Profile V22F03 - 04L-Normal Pattern
Based MV22B
on Runway NW05L, Flight Track NW05LF1 - Helo FCLP

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000

Scale in Feet 1:27,100 (1 inch = 2,260 feet)

N

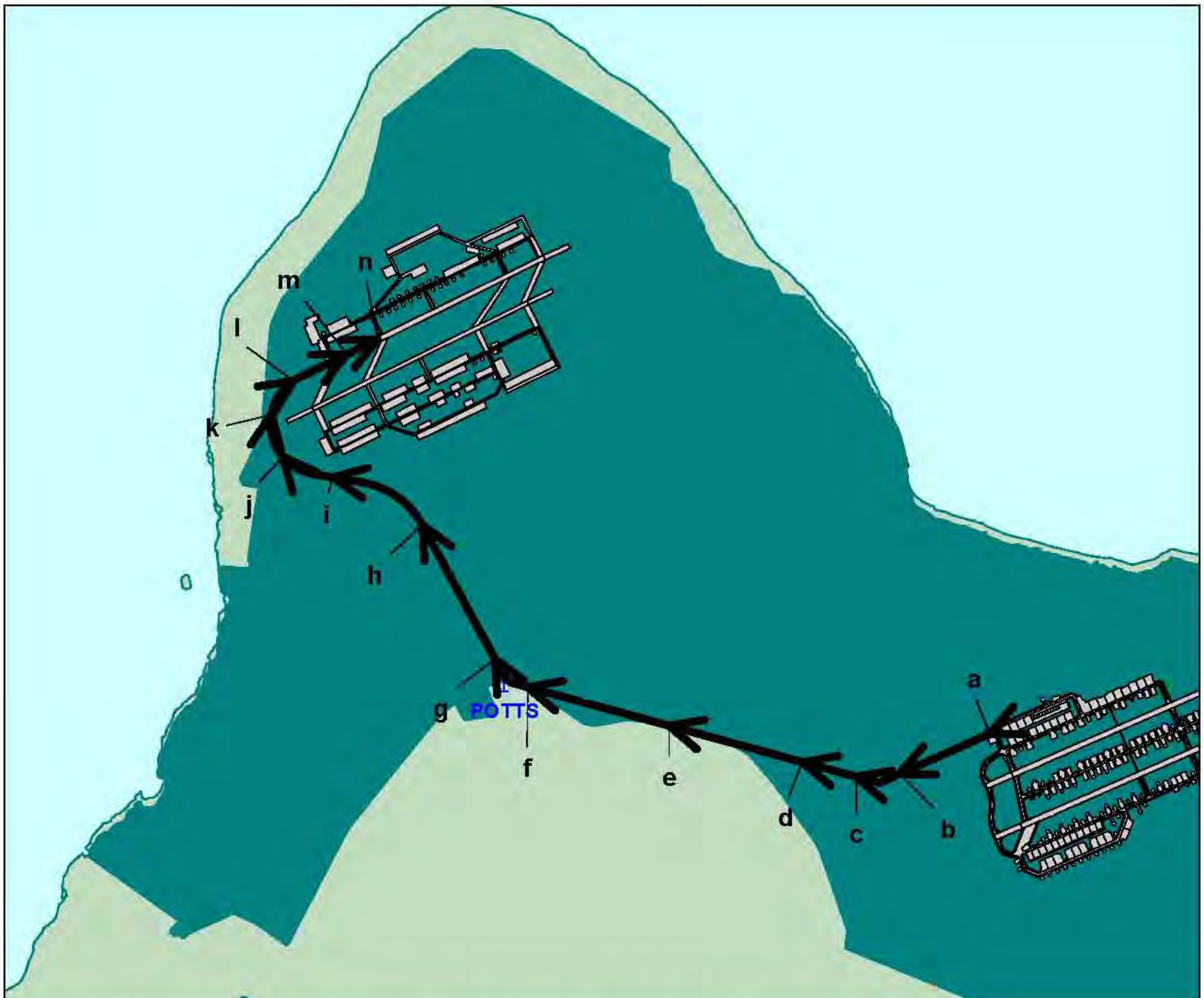


Flight Profile V22F05 on FCLPTrack OR10F1

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	110 MSL	5	0	0	0	60	5 kt start
b	250	120 MSL	45	0	-6	0	60	
c	750	240 MSL	65	0	0	0	60	
d	2,000	390 MSL	110	0	3	0	30	
e	4,570	390 MSL	155	0	10	25	0	shifted forward 500 ft; begin turn
f	7,895	390 MSL	170	0	7	0	0	shifted back 600 ft; end turn
g	10,000	390 MSL	170	0	3	0	0	
h	11,431	390 MSL	140	0	3	0	0	
i	13,650	390 MSL	110	0	0	25	60	shifted back 200 ft; begin turn
j	15,458	290 MSL	60	0	0	25	87	
k	17,400	185 MSL	32	0	0	0	89	Interpolated; end turn
l	18,512	110 MSL	5	0	0	0	90	

Flight Profile V22F05 - 04L-Normal Pattern
Based MV22B
on Runway OROTE10, Flight Track OR10F1 - Helo FCLP

Scale in Feet 1:27,900 (1 inch = 2,330 feet)



Flight Profile V22I01 on InterfacilityTrack INW05L

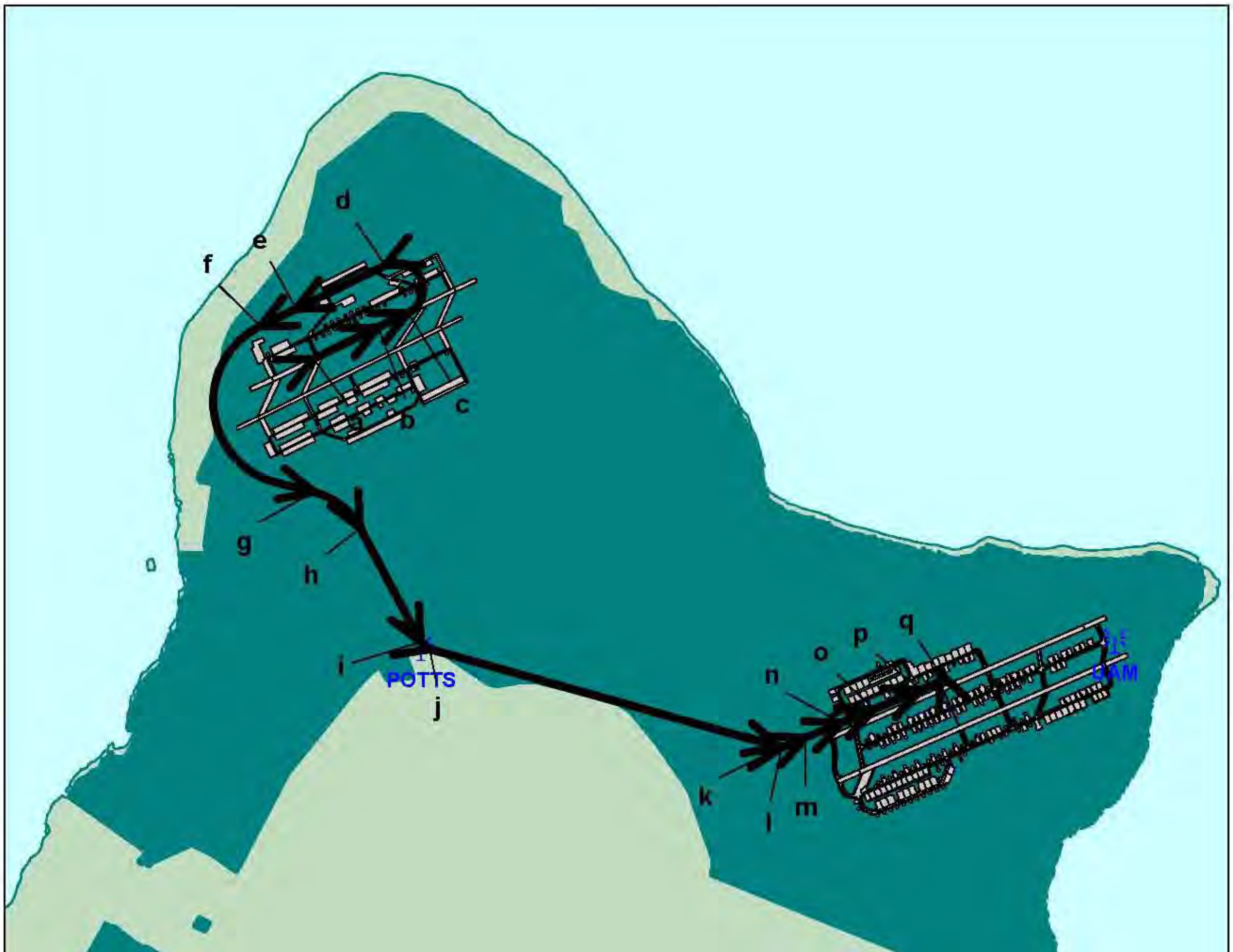
Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	20 AGL	5	0	0	0	87	
b	3,500	188 AGL	71	0	0	-25	77	Shifted pt forward 500'; begin turn
c	5,133	300 AGL	115	0	0	0	70	Shifted pt forward 100'; end turn
d	7,100	500 AGL	136	0	0	0	27	
e	12,000	500 AGL	170	0	0	0	16	
f	17,198	1,030 MSL	170	0	-1	-25	0	begin turn
g	18,837	1,030 MSL	170	0	-1	0	0	end turn
h	24,231	1,030 MSL	170	0	-1	25	0	begin turn
i	28,000	1,030 MSL	150	0	0	-25	20	Shifted forward 600'; end turn, begin turn right
j	29,956	944 MSL	80	0	0	-25	79	
k	31,556	830 MSL	60	0	0	-25	80	
l	33,028	730 MSL	60	0	-1	0	87	Shifted back 300'; end turn
m	35,156	680 MSL	50	0	5	0	90	
n	36,356	550 MSL	5	0	0	0	90	

Flight Profile V22I01 - Interfaciltiy to NW Field
Based MV22B
on Runway 4N1, Flight Track INW05L - Andersen AFB to NW Field via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000 24,000

Scale in Feet 1:78,200 (1 inch = 6,520 feet)

N



Flight Profile V22I03 on InterfacilityTrack 05I4N25

Point	Distance ft	Height ft	Speed kts	Yaw Angle	Angle of Attack	Roll Angle	Nacelle Angle	Notes
a	0	550 MSL	5	0	0	0	87	
b	3,000	718 MSL	71	0	0	0	77	
c	4,400	830 MSL	115	0	0	25	70	Shifted pt back 600'; begin turn
d	7,856	1,030 MSL	136	0	0	0	27	Shifted pt forward 600'; end turn
e	12,000	1,030 MSL	170	0	0	0	16	
f	13,656	1,030 MSL	170	0	-1	25	0	begin turn
g	23,808	1,030 MSL	170	0	-1	-25	0	end turn
h	26,321	1,030 MSL	170	0	-1	0	0	end turn
i	31,721	1,030 MSL	170	0	-1	25	0	end turn
j	32,212	500 AGL	170	0	-1	0	0	end turn
k	47,402	500 AGL	150	0	-1	25	18	end turn
l	47,467	500 AGL	150	0	0	0	20	Shifted forward 600'; end turn
m	48,555	414 AGL	80	0	0	0	79	
n	50,155	300 AGL	60	0	0	0	80	
o	51,627	200 AGL	60	0	-1	0	87	Shifted back 300'; end turn
p	53,755	150 AGL	50	0	5	0	90	
q	54,955	20 AGL	5	0	0	0	90	

Flight Profile V22I03 - Interfaciltiy from NW Field

Based MV22B

on Runway NW05L, Flight Track 05I4N25 - NW Field to Andersen AFB via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000

Scale in Feet 1:94,400 (1 inch = 7,860 feet)

Flight Profile UH1D08 on DepartureTrack RWD3P

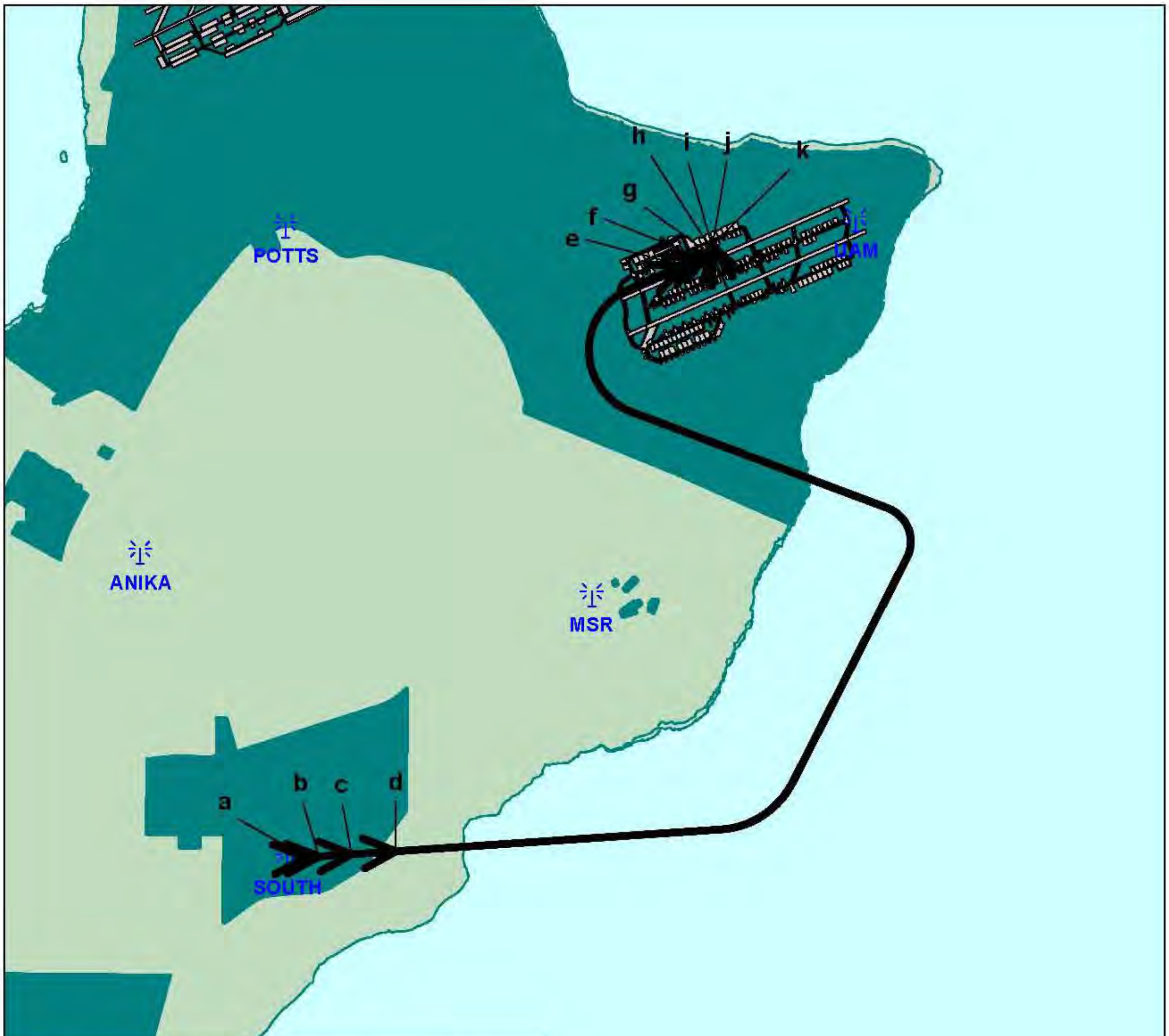
Point	Distance ft	Height ft	Power % RPM
a	0	0 AGL	Flt at 80 kts
b	500	25 AGL	Flt at 80 kts
c	1,000	50 AGL	Flt at 80 kts
d	3,000	500 AGL	Flt at 80 kts
e	64,100	500 AGL	Flt at 80 kts
f	67,538	150 AGL	Flt at 80 kts
g	68,038	50 AGL	Flt at 80 kts
h	68,238	75 AGL	Flt at 80 kts
i	68,388	25 AGL	Flt at 80 kts
j	68,463	15 AGL	Flt at 80 kts
k	68,538	10 AGL	Flt at 80 kts

Flight Profile UH1D08 - Proposed UH-1N Dep to Shore via Potts Jxn
Based UH-1N
on Runway 6N25, Flight Track RWD3P - HSC-25 Dep MSR to Andy South

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000 36,000

Scale in Feet 1:109,000 (1 inch = 9,050 feet)

N



Flight Profile UH1A08 on Nonbreak ArrivalTrack RWA3P

Point	Distance ft	Height ft	Power % RPM
a	68,406	0 AGL	Flt at 80 kts
b	67,738	25 AGL	Flt at 80 kts
c	66,072	50 AGL	Flt at 80 kts
d	63,828	500 AGL	Flt at 80 kts
e	2,000	500 AGL	Flt at 80 kts
f	1,000	150 AGL	Flt at 80 kts
g	500	75 AGL	Flt at 80 kts
h	300	50 AGL	Flt at 80 kts
i	150	25 AGL	Flt at 80 kts
j	75	15 AGL	Flt at 80 kts
k	0	10 AGL	Flt at 80 kts

Flight Profile UH1A08 - Proposed UH-1N Arr from Andy South

Based UH-1N

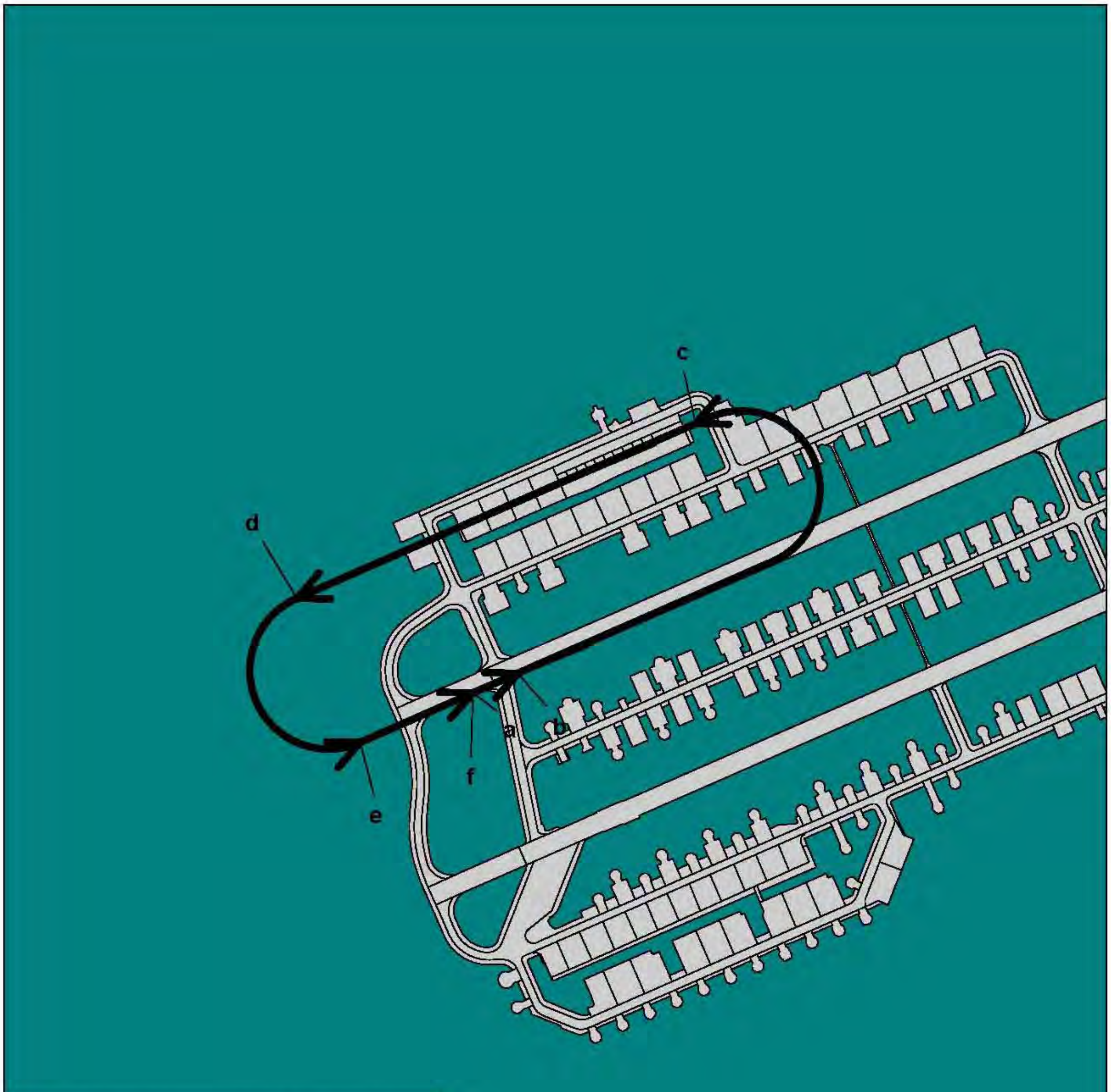
on Runway 4N25, Flight Track RWA3P - Proposed RW arr from Andy South via MSR

0 4,000 8,000 12,000 16,000 20,000 24,000 28,000 32,000 36,000

Scale in Feet 1:109,000 (1 inch = 9,070 feet)

N

wyle



Flight Profile UH1F01 on FCLPTrack 6LT3

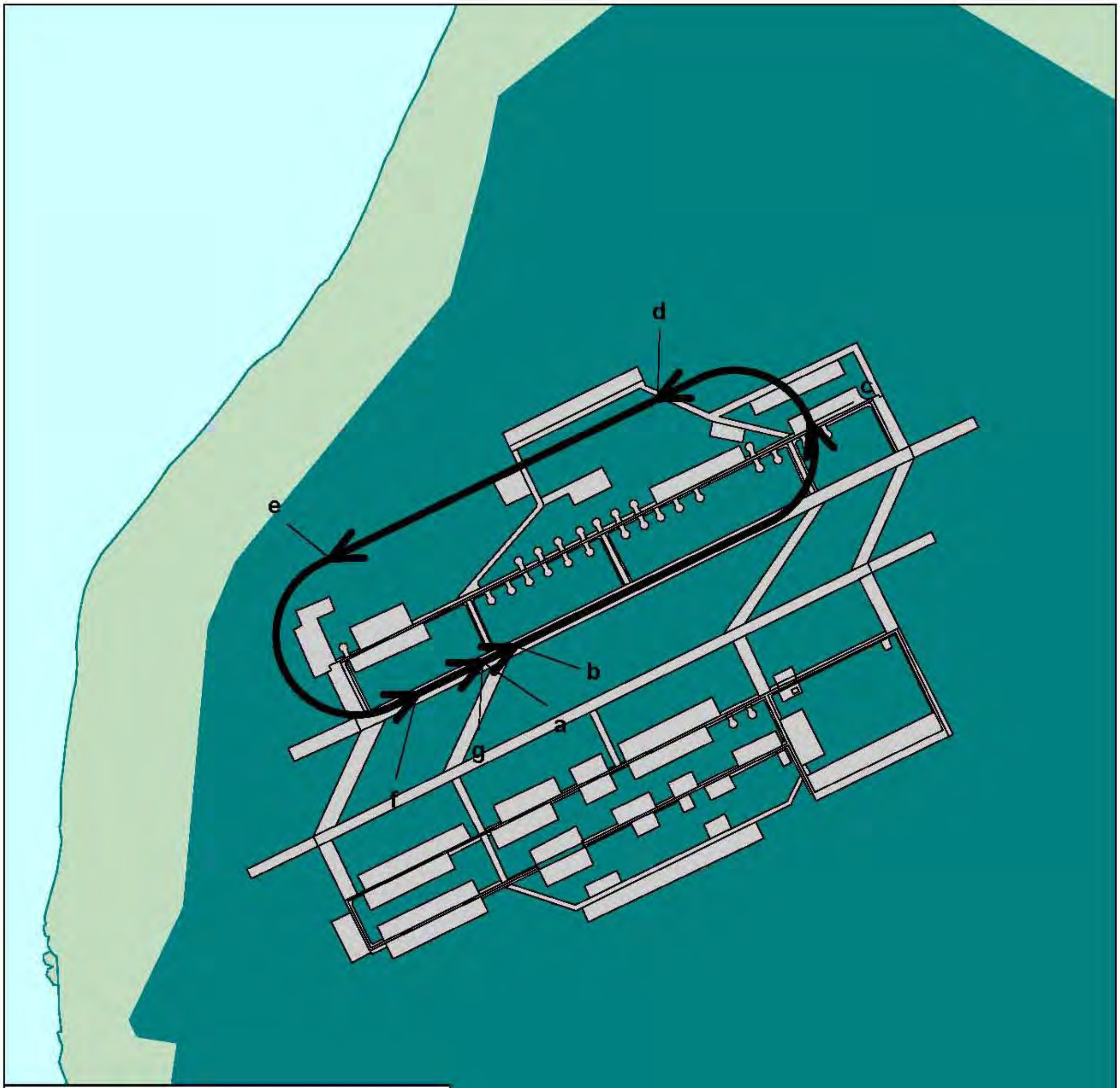
Point	Distance ft	Height ft	Power % RPM
a	0	50 AGL	Flt at 80 kts
b	500	200 AGL	Flt at 80 kts
c	6,000	300 AGL	Flt at 80 kts
d	10,423	300 AGL	Flt at 80 kts
e	12,937	200 AGL	Flt at 80 kts
f	14,187	50 AGL	Flt at 80 kts

Flight Profile UH1F01 - 04R-Normal Pattern
Based UH-1N
on Runway 06L, Flight Track 6LT3 - HELICOPTER VFR

0 1,000 2,000 3,000 4,000 5,000 6,000

Scale in Feet 1:20,700 (1 inch = 1,720 feet)

N

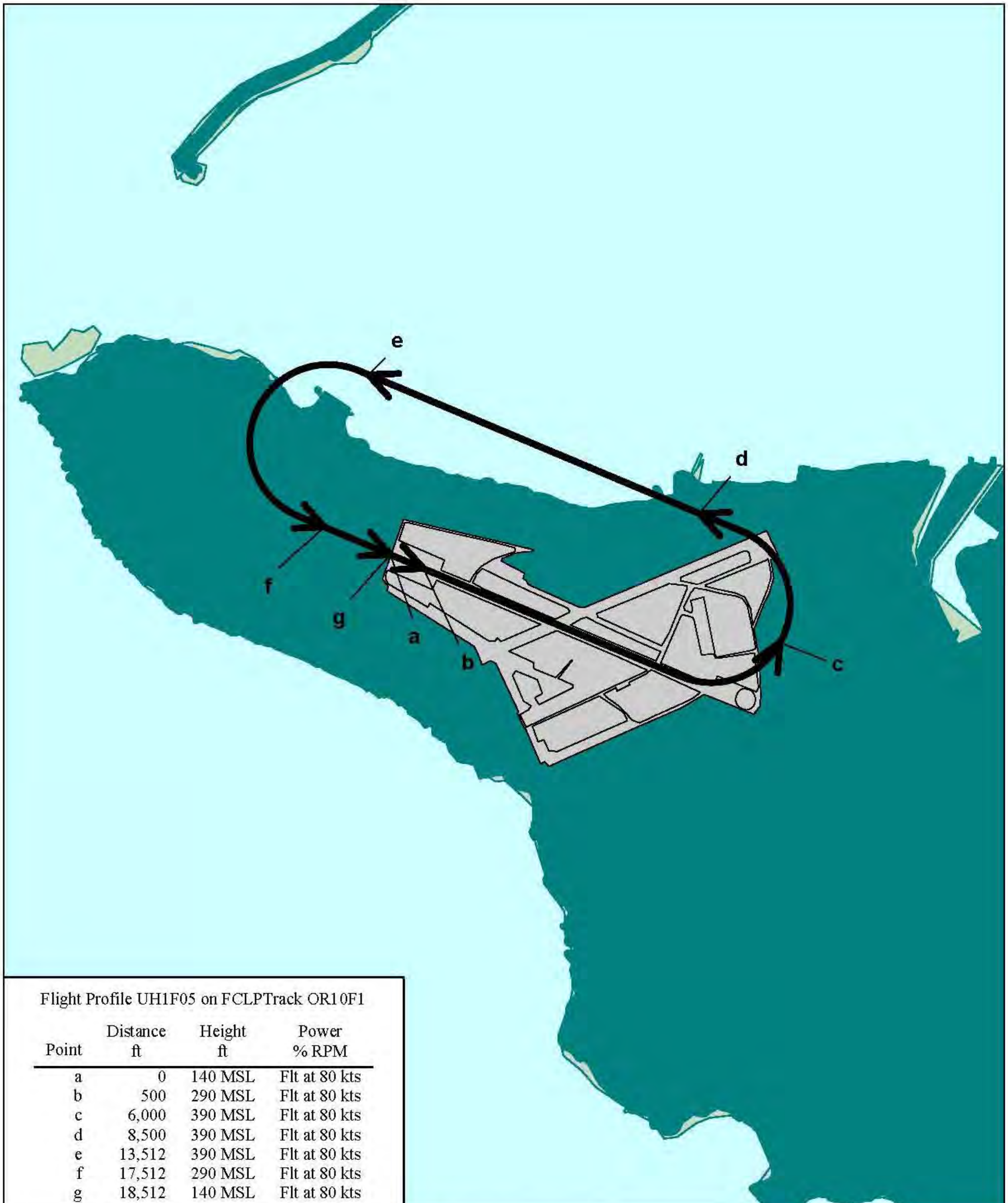


Flight Profile UH1F03 on FCLPTrack NW05LF1

Point	Distance ft	Height ft	Power % RPM
a	0	580 MSL	Flt at 80 kts
b	500	730 MSL	Flt at 80 kts
c	6,000	830 MSL	Flt at 80 kts
d	8,500	830 MSL	Flt at 80 kts
e	13,512	830 MSL	Flt at 80 kts
f	17,512	730 MSL	Flt at 80 kts
g	18,512	580 MSL	Flt at 80 kts

Flight Profile UH1F03 - 04R-Normal Pattern
Based UH-1N
on Runway NW05L, Flight Track NW05LF1 - Helo FCLP

Scale in Feet 1:28,200 (1 inch = 2,350 feet)

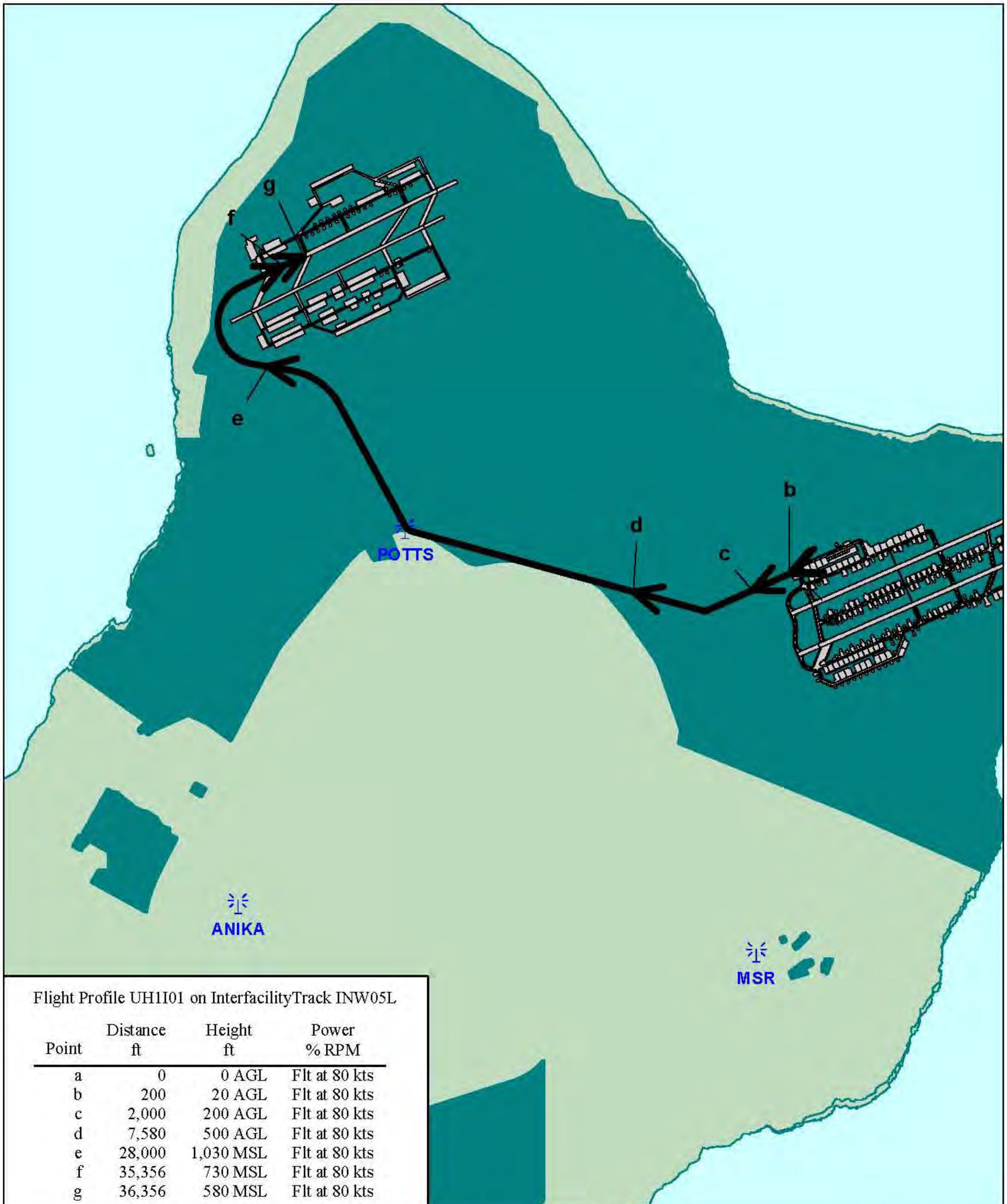


Flight Profile UH1F05 on FCLPTrack OR10F1

Point	Distance ft	Height ft	Power % RPM
a	0	140 MSL	Flt at 80 kts
b	500	290 MSL	Flt at 80 kts
c	6,000	390 MSL	Flt at 80 kts
d	8,500	390 MSL	Flt at 80 kts
e	13,512	390 MSL	Flt at 80 kts
f	17,512	290 MSL	Flt at 80 kts
g	18,512	140 MSL	Flt at 80 kts

Flight Profile UH1F05 - 04R-Normal Pattern
Based UH-1N
on Runway OROTE10, Flight Track OR10F1 - Helo FCLP

Scale in Feet 1:25,800 (1 inch = 2,150 feet)



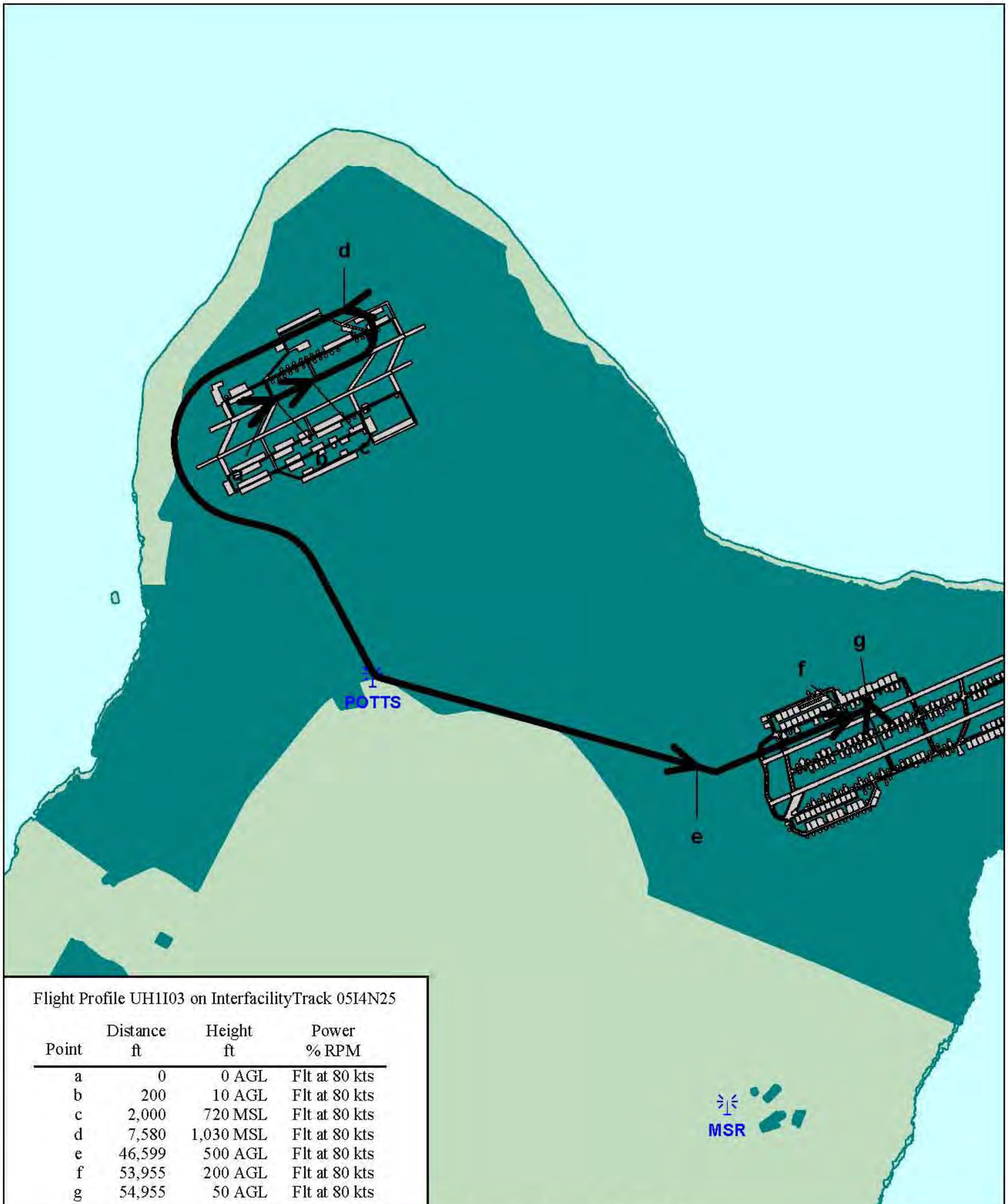
Flight Profile UH1I01 on InterfacilityTrack INW05L

Point	Distance ft	Height ft	Power % RPM
a	0	0 AGL	Flt at 80 kts
b	200	20 AGL	Flt at 80 kts
c	2,000	200 AGL	Flt at 80 kts
d	7,580	500 AGL	Flt at 80 kts
e	28,000	1,030 MSL	Flt at 80 kts
f	35,356	730 MSL	Flt at 80 kts
g	36,356	580 MSL	Flt at 80 kts

Flight Profile UH1I01 - Interfacility to NW Field
Based UH-1N
on Runway 4N1, Flight Track INW05L - Andersen AFB to NW Field via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000 24,000

Scale in Feet 1:81,700 (1 inch = 6,810 feet)



Flight Profile UH1I03 on InterfacilityTrack 05I4N25

Point	Distance ft	Height ft	Power % RPM
a	0	0 AGL	Flt at 80 kts
b	200	10 AGL	Flt at 80 kts
c	2,000	720 MSL	Flt at 80 kts
d	7,580	1,030 MSL	Flt at 80 kts
e	46,599	500 AGL	Flt at 80 kts
f	53,955	200 AGL	Flt at 80 kts
g	54,955	50 AGL	Flt at 80 kts

Flight Profile UH1I03 - Interfacility from NW Field
Based UH-1N
on Runway NW05L, Flight Track 05I4N25 - NW Field to Andersen AFB via Potts Jxn

0 4,000 8,000 12,000 16,000 20,000 24,000

Scale in Feet 1:81,000 (1 inch = 6,750 feet)

DEPARTMENT OF THE ARMY
US ARMY PUBLIC HEALTH COMMAND (PROVISIONAL)
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MD 21010-5403

MCHB-TS-EON 23 APR 2010

MEMORANDUM FOR Navy Facilities Engineering Command, Pacific (Mid-Pacific Planning Division/Mr. Wes Ishizu), 258 Makalapa Drive, Suite 100, Pearl Harbor, HI 96860

SUBJECT: Addendum to Operational Noise Consultation, 52-EN-0BVU-09, Operational Noise Contours for Proposed Range Development at Guam and Tinian, 5 April 2010

1. We are enclosing 2 copies of the consultation.

2. Please contact us if this consultation or any of our services did not meet your needs or expectations.

3. The point of contact is Ms. Kristy Broska, Environmental Protection Specialist or Ms. Catherine Stewart, Program Manager, Operational Noise, US Army Public Health Command (Provisional) [formerly US Army Center for Health Promotion and Preventive Medicine], at DSN 584-3829, Commercial (410) 436-3829, or email: kristy.broska@us.army.mil or catherine.stewart@us.army.mil.

FOR THE COMMANDER:

William J. Bettin

Encl

WILLIAM J. BETTIN
LTC, MS
Director, Environmental Health Engineering

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U.S. Army Public Health Command
(Provisional)

USAPHC

ADDENDUM TO OPERATIONAL
NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
5 APRIL 2010

Preventive Medicine Survey: 40-5f1

DEPARTMENT OF THE ARMY
US ARMY PUBLIC HEALTH COMMAND (PROVISIONAL)
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MD 21010-5403

MCHB-TS-EON

EXECUTIVE SUMMARY
ADDENDUM TO OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
5 APRIL 2010

1. PURPOSE.

a. To provide the Navy Facilities Engineering Command, Pacific (NAVFAC PAC) updated noise contours for the appropriate National Environmental Policy Act (NEPA) documentation for the proposed actions at Guam and Tinian.

b. The updated contours are based on the August 2009 footprints and address:

- Construction of barriers on the Alternative A ranges.
- Dense vegetation in the Alternative A and B range areas.

2. CONCLUSIONS.

a. GUAM TRAINING RANGES.

(1) The Alternative A range layout without the foliage attenuation would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the boundary. Residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There are no residential properties within the Noise Zone III (104 dB PK15[met]) contour.

(2) The Alternative B range layout without the foliage attenuation would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the boundary. Residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There are scattered residential properties within the Noise Zone III (104 dB PK15[met]) contour.

(3) Accounting for the foliage attenuation greatly reduces the overall footprint of the Noise Zone II (87 dB) peak contours. With the foliage attenuation, the Noise Zone III (104 dB) peak contour does not extend beyond the boundary.

(4) The proposed barrier designs in Alternative A will slightly change the small caliber peak noise contours that extend beyond the boundary. The proposed barriers were designed primarily for safety rather than noise mitigation.

(5) The Alternative A range layout would generate a Noise Zone 1 (55-64 ADNL) and a Noise Zone 2 (65-74 ADNL) that extend beyond the eastern boundary of Andersen South and the Route 15 Land. The Alternative A range layout would generate a Noise Zone 3 (75-79 ADNL) that extends slightly beyond the Route 15 Land boundary. Per the Marine Corps Order 3550.11, noise-sensitive land uses are generally compatible in the Noise Zone 1. Noise-sensitive land uses in Noise Zone 2 are generally not compatible. Within Noise Zone 2, residential use is discouraged between 65 and 69 ADNL and *strongly* discouraged between 70 and 74 ADNL. Noise-sensitive land uses in Noise Zone 3 are not compatible. Residential areas would fall within the Noise Zone 1 and Noise Zone 2 contours. There are no residential properties within the Noise Zone 3 contours.

(6) The Alternative B range layout would generate a Noise Zone 1 (55-64 ADNL); that extends beyond the boundaries of Andersen South and the Route 15 Land. The Alternative B range layout would generate a Noise Zone 2 (65-74) that covers the area non-military land between Andersen South and the Route 15 Land. The Alternative B range layout would generate a Noise Zone 3 (75-79) that extends slightly into the non-military land between Andersen South and the Route 15 Land. Residential areas would fall within the Noise Zone 1 and Noise Zone 2 contours. There are no residential properties within the Noise Zone 3 contours.

b. TINIAN TRAINING RANGES.

(1) The proposed small caliber range alternatives would generate PK15(met) Noise Zone II (87 dB) and Noise Zone III (104 dB) contours that extend beyond the Tinian Training Range boundary. There are no noise-sensitive land uses within the noise contours.

(2) The Tinian Alternative 1 range layout would generate a Noise Zone 1 (55-64 ADNL) that extends slightly beyond the southern boundary. The Noise Zone 2 (65-74 ADNL) and Noise Zone 3 (>75 ADNL) do not extend beyond the boundary.

(3) The ADNL noise contours generated by the Alternative 2 range layout do not extend beyond the boundary.

(4) The Tinian Alternative 3 range layout would generate a Noise Zone 1 (55-64 ADNL); a Noise Zone 2 (65-74 ADNL); and a Noise Zone 3 (>75 ADNL) that extend beyond the southern boundary into the San Jose Airport property.

3. RECOMMENDATIONS.

a. Include the information from this consultation in the appropriate NEPA documentation.

b. As suggested in the original consultation, to reduce the risk of noise complaints from the proposed activity, the NAVFAC PAC should use the U.S. Army's Operational Noise Management Program guidance in conjunction with the Air Force's Air Installation Compatible Use Zone program to address the impulsive noise events.

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ADDENDUM TO OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0BVU-09
OPERATIONAL NOISE CONTOURS
PROPOSED RANGE DEVELOPMENT
GUAM AND TINIAN
05 APRIL 2010

1. REFERENCES. A list of the references used in this consultation is in Appendix A. A glossary of terms and abbreviations used are in Appendix B. Appendices C and D contain the Noise Zone Descriptions and Land Use Guidelines used in this consultation.

2. AUTHORITY. The Navy Facilities Engineering Command, Pacific (NAVFAC PAC) funded this consultation.

3. PURPOSE. To provide the NAVFAC PAC updated noise contours for the proposed range development for use in the appropriate National Environmental Policy Act (NEPA) documentation.

4. GENERAL.

a. In August 2009, an Operational Noise Consultation was developed to address proposed range development at Guam and Tinian (U.S. Army 2009).

b. In March 2010, the NAVFAC PAC provided updated site plans for the proposed ranges at Guam. The updated contours are based on the August 2009 footprints and address:

- Construction of barriers on the Alternative A ranges.
- Dense vegetation in the Alternative A and B range areas.

5. MITIGATION TECHNIQUES TO REDUCE SMALL CALIBER WEAPONS NOISE LEVELS.

a. One mitigation technique to reduce small caliber weapons noise is a physical barrier between the source and the receiver. Details regarding the proposed Alternative A barrier designs utilized in the noise contour development are shown in Appendix E.

b. The extremely dense and tall vegetation in the Guam range area is another form of a physical barrier.

(1) Typically trees and bushes are very poor noise barriers; they provide very little attenuation as a result of shielding. However, if the foliage is dense enough to completely obstruct the view, and if it also intercepts the path of acoustic propagation, there is some additional attenuation due to propagation through the foliage. The attenuation for propagation through each meter of dense foliage is given in Table 1 for each octave band of frequency. The attenuation rates are only valid for up to 200 meters of path length through the foliage. After 200 meters, the dominate factor in propagation are the atmospheric effects. (Harris 1998)

TABLE 1. ATTENUATION DUE TO PROPAGATION THROUGH FOLIAGE. (Harris 1998)

		Octave-band Center Frequency, Hz							
		31.5	63	125	500	1000	2000	400	8000
$A_{foliage}$	dB/m	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.12

Note: A = attenuation; dB = decibel; Hz = Hertz; m = meter

(2) The predominate frequency of the muzzle blast energy for the .50 caliber ball round is around 350 Hertz (Hz); wave length is about 1 meter (3 feet) high. The predominate frequency of muzzle blast energy for the 7.62mm and 5.56mm ball rounds is around 1000 Hz; wave length is about 1/3 meter (1 foot) high.

(3) Based on Table 1 and the weapons utilized, the existing vegetation has the potential to provide a 6 decibel (dB) noise reduction. During range construction, for maximum noise reduction, a minimum of 200 meters of the dense vegetation should be left between the range and the boundary/receiver.

c. When both a barrier and vegetation are present, only the larger values of attenuation calculated for these two effects should be used. The sum of both effects should not be added. (UFC 2003b)

6. SMALL CALIBER NOISE CONTOURING PROCEDURES.

a. Gunshots are impulsive in nature and occur over a very short period in time, only a few thousandths of a second. Unlike topographic contours, noise contours are not intended to be precise representations of the noise zones. Meteorology and the receiver's perception of the source, etc. can influence the level or impact of noise. Noise contours do not clearly divide noise zones with one side of the line compatible and the other side incompatible.

b. The noise simulation program used to assess small caliber weapons (.50 caliber and below) noise is the Small Arms Range Noise Assessment Model (SARNAM) (U.S. Army 2003a). The SARNAM program requires operational data concerning types of weapons and range layout. The SARNAM calculation algorithms assume weather conditions or wind direction that favor sound propagation are present.

7. GUAM TRAINING RANGES. SMALL CALIBER NOISE CONTOURING RESULTS – PEAK.

a. General. The noise contours in this section were created using PK15(met) as prescribed in Army Regulation (AR) 200-1 (U.S. Army 2007). The contours show the predicted peak levels for individual rounds (metric term is PK15(met)). Since the contours are based on peak levels rather than a cumulative or average level, the size of the contours will not change if the number of rounds fired increases or decreases.

b. Operational Input. The inputs utilized to generate the small caliber noise contours are shown in Table 2. The August 2009 range footprint was utilized.

TABLE 2. GUAM TRAINING RANGES. PROJECTED SMALL CALIBER RANGE UTILIZATION.

	KD	MPMG	PISTOL	SQUARE BAY (Non-Standard)	UNKNOWN DISTANCE
PISTOL, 9mm			√	√	
PISTOL, .45 cal			√	√	
RIFLE, 5.56mm	√			√	√
MACHINE GUN, 7.62mm		√			
MACHINE GUN, .50 cal		√			

Note: cal = caliber, KD = Known Distance, mm = millimeter, MPMG = Multi-Purpose Machine Gun

c. Route 15 Alternative A Layout. Figure 1 contains the small caliber weapons contours for the projected activity under the Route 15 Alternative A range layout. These contours were previously presented in the August 2009 consultation. The Alternative A layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends up to 4,000 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends approximately 100 meters beyond the eastern boundary of Andersen South and the Route 15 Land.

d. Route 15 Alternative A Layout with Foliage Attenuation. The SARNAM noise model cannot directly account for the attenuation of the dense foliage and ground cover. The model output was modified to depict the peak noise levels reflecting 6 dB of attenuation. Figure 2 compares the small caliber weapons contours with and without attenuation from the dense foliage. With the 6 dB foliage attenuation factor, the Alternative A layout generates a Zone II [PK15(met) 87 dB] noise contour that extends up to 2,000 meters beyond the eastern boundary of Andersen South and the Route 15 Land. With the 6 dB foliage attenuation factor, the Zone III [PK15(met) 104 dB] noise contour extends approximately less than 50 meters beyond the eastern boundary of Andersen South and the Route 15 Land.

e. Route 15 Alternative A Layout with Barriers. Details regarding the proposed barrier designs utilized in the noise contour development are shown in Appendix E. The proposed barriers were designed primarily for safety rather than noise mitigation. Figure 3 contains the small caliber weapons contours for the projected activity with barriers constructed on the ranges. The addition of barriers to the Alternative A layout does not significantly change the noise contours.

f. Foliage Attenuation and Barriers. As stated previously, in theoretical calculations, when both a barrier and dense vegetation occurs simultaneously, the sum of both effects should not be added to the calculations.

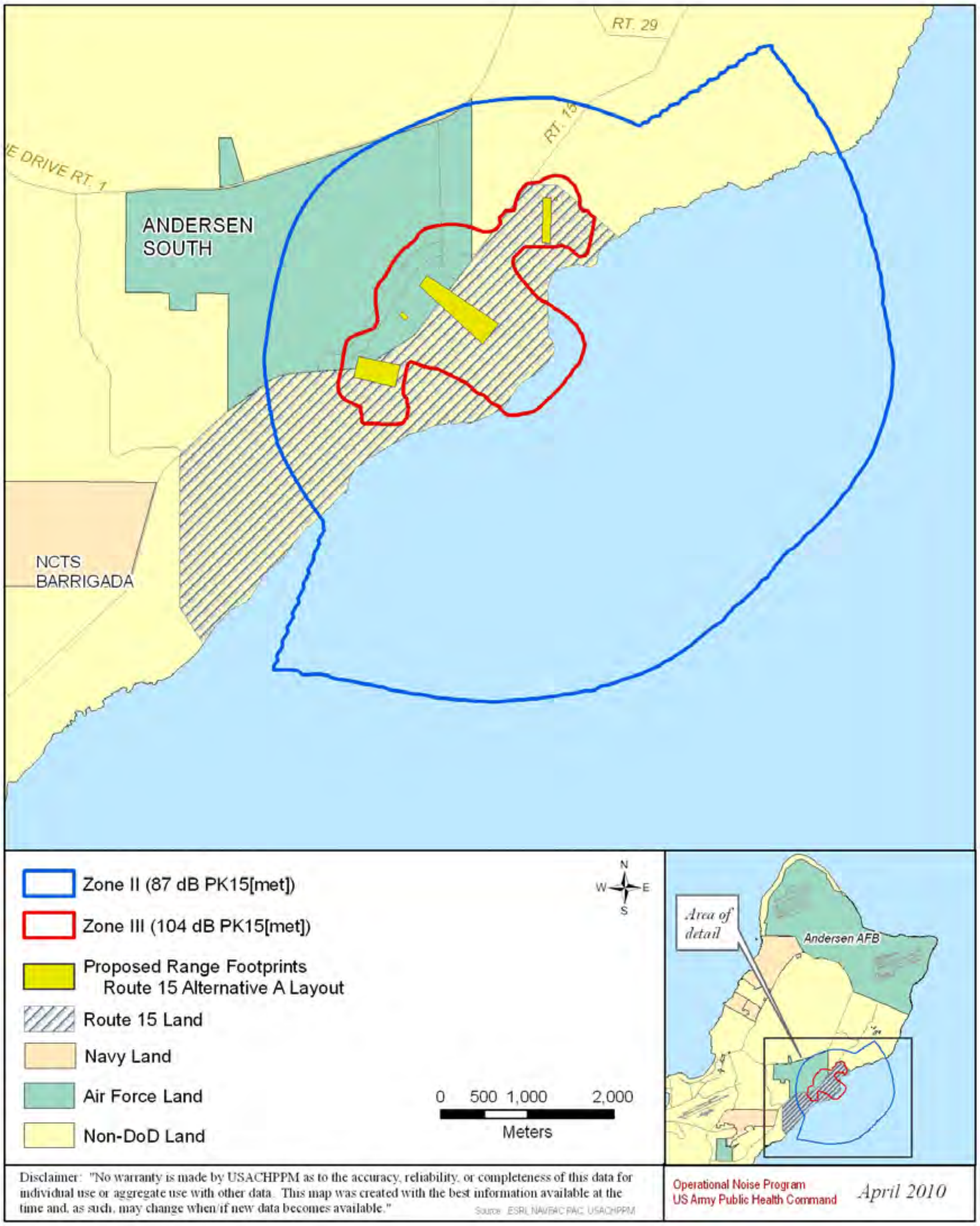

FIGURE 1. ROUTE 15 ALTERNATIVE A
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

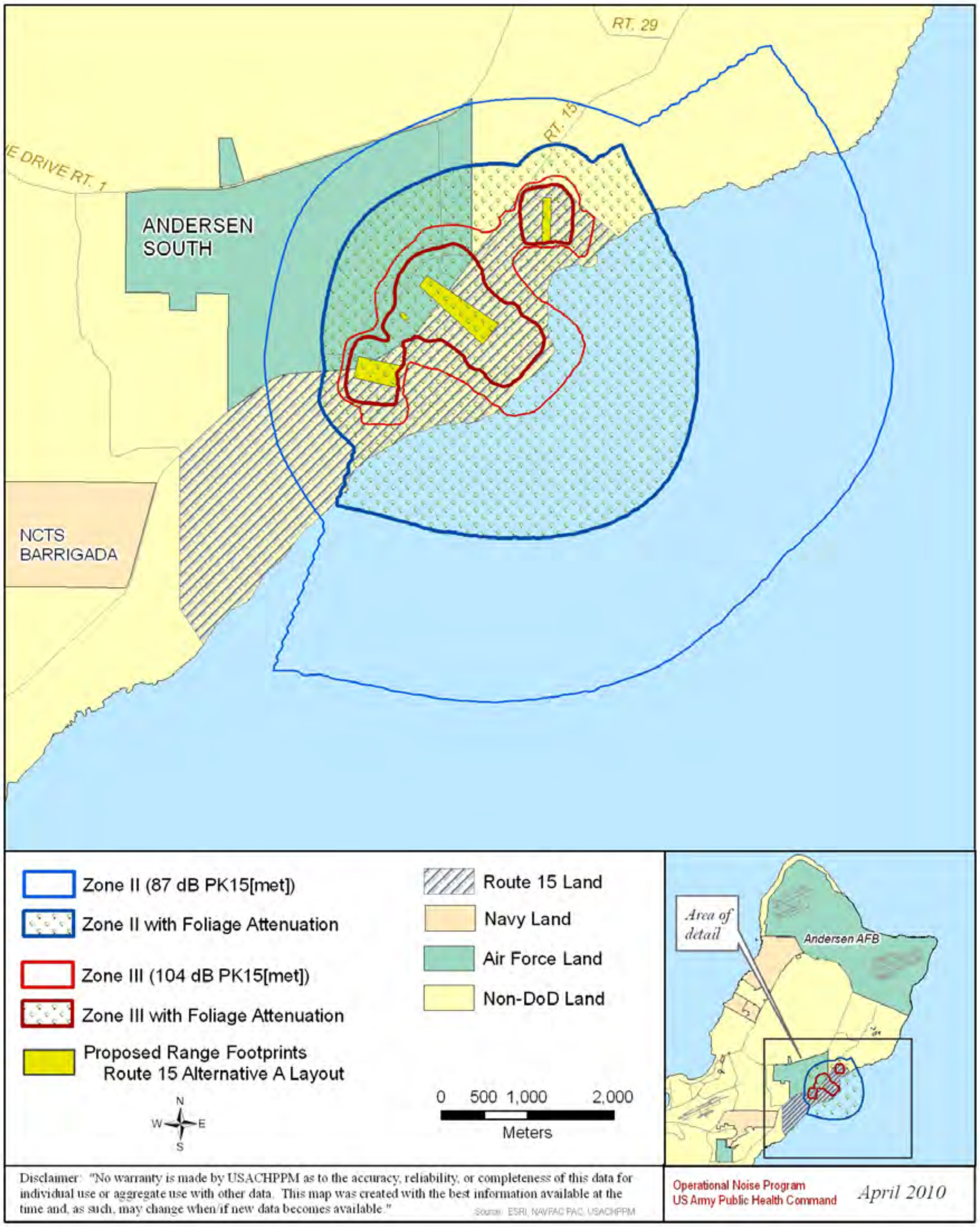

FIGURE 2. ROUTE 15 ALTERNATIVE A
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS
WITH FOLIAGE ATTENUATION

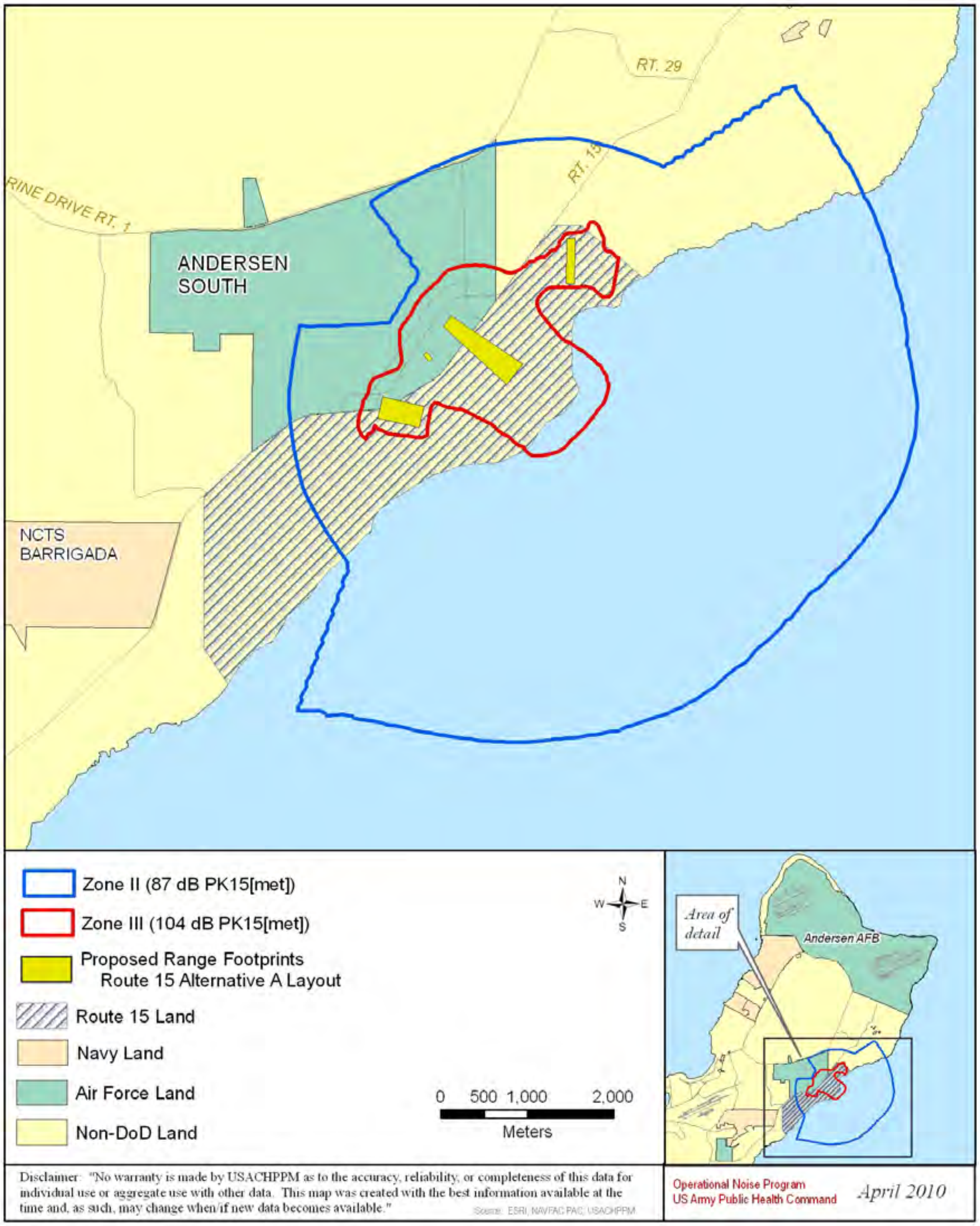

FIGURE 3. ROUTE 15 ALTERNATIVE A
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS
WITH BARRIER ATTENUATION

g. Route 15 Alternative B Layout. Figure 4 contains the small caliber weapons contours for the projected activity under the Route 15 Alternative B range layout. These contours were previously presented in the August 2009 consultation. The Alternative B layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends 600 – 1,200 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Alternative B layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends up to 1,400 meters beyond the western boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends approximately 100 meters beyond the eastern boundary of Andersen South and the Route 15 Land. The Zone III [PK15(met) 104 dB] noise contour extends less than 70 meters beyond the western boundary of Andersen South and the Route 15 Land.

h. Route 15 Alternative B Layout with Foliage Attenuation. The SARNAM noise model cannot directly account for the attenuation of the dense foliage and ground cover. The model output was modified to depict the peak noise levels reflecting 6 dB of attenuation. Figure 5 compares the small caliber weapons contours with and without attenuation from the dense foliage. With the 6 dB foliage attenuation factor, the Alternative B layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 300 meters beyond the eastern boundary of Andersen South and the Route 15 Land. With the 6 dB foliage attenuation factor, the Alternative B layout generates a Zone II [PK15(met) 87 dB] noise contour that extends up to 600 meters beyond the eastern boundary of Andersen South and the Route 15 Land. With the 6 dB foliage attenuation factor the Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Route 15 Land.

i. Land Use Compatibility. The Air Force and the Navy typically follow Army policy regarding noise from weapon activity. Per Army Regulation (AR) 200-1, noise-sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). Based upon the available aerial image shown in Appendix E, residential areas would fall within the Noise Zone II [PK15(met) 87 dB] contour. There are scattered residences properties within the Noise Zone III [PK15(met) 104 dB contour]. Appendix F contains the Guam noise contours overlaid on aerial imagery.

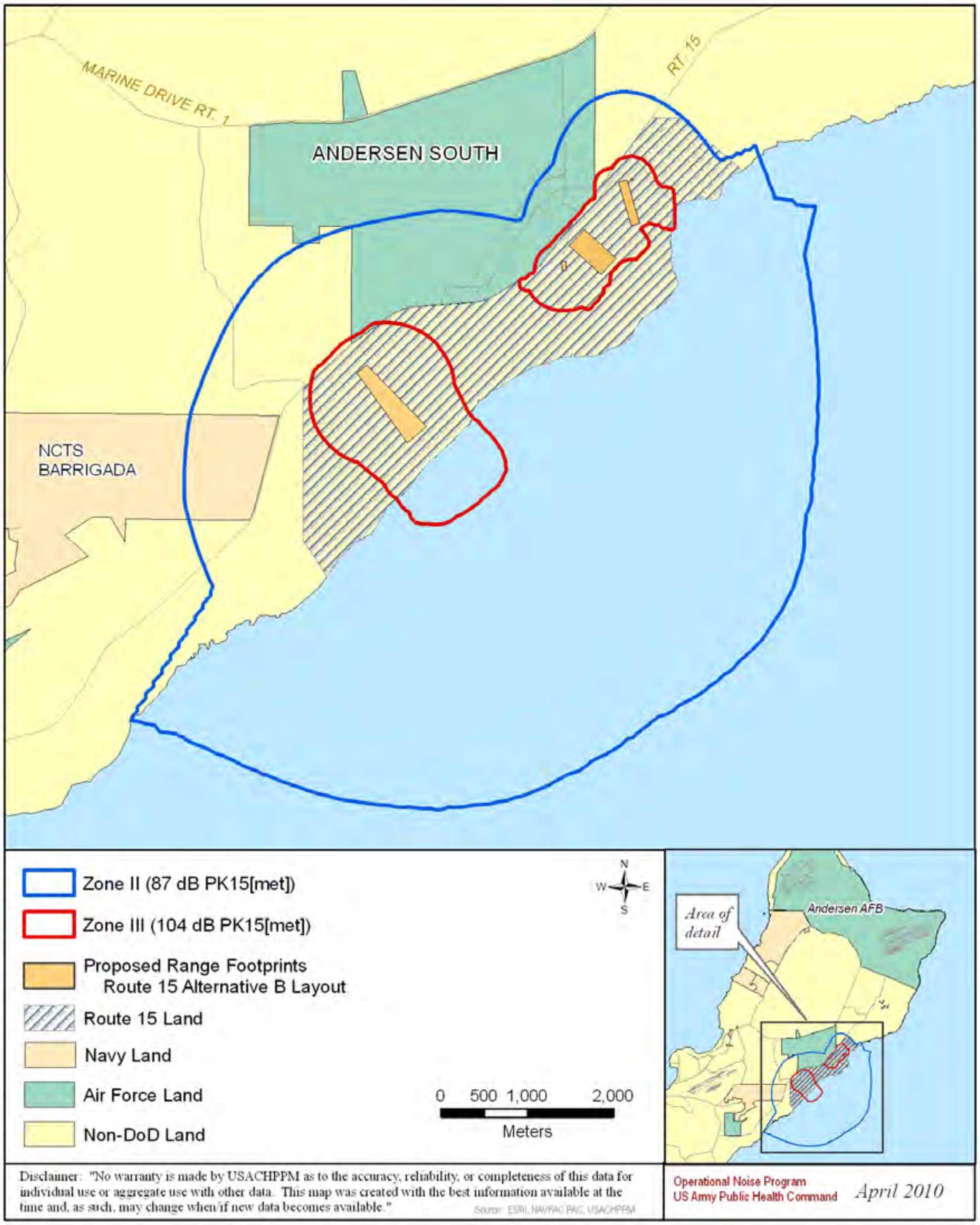

FIGURE 4. ROUTE 15 ALTERNATIVE B
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

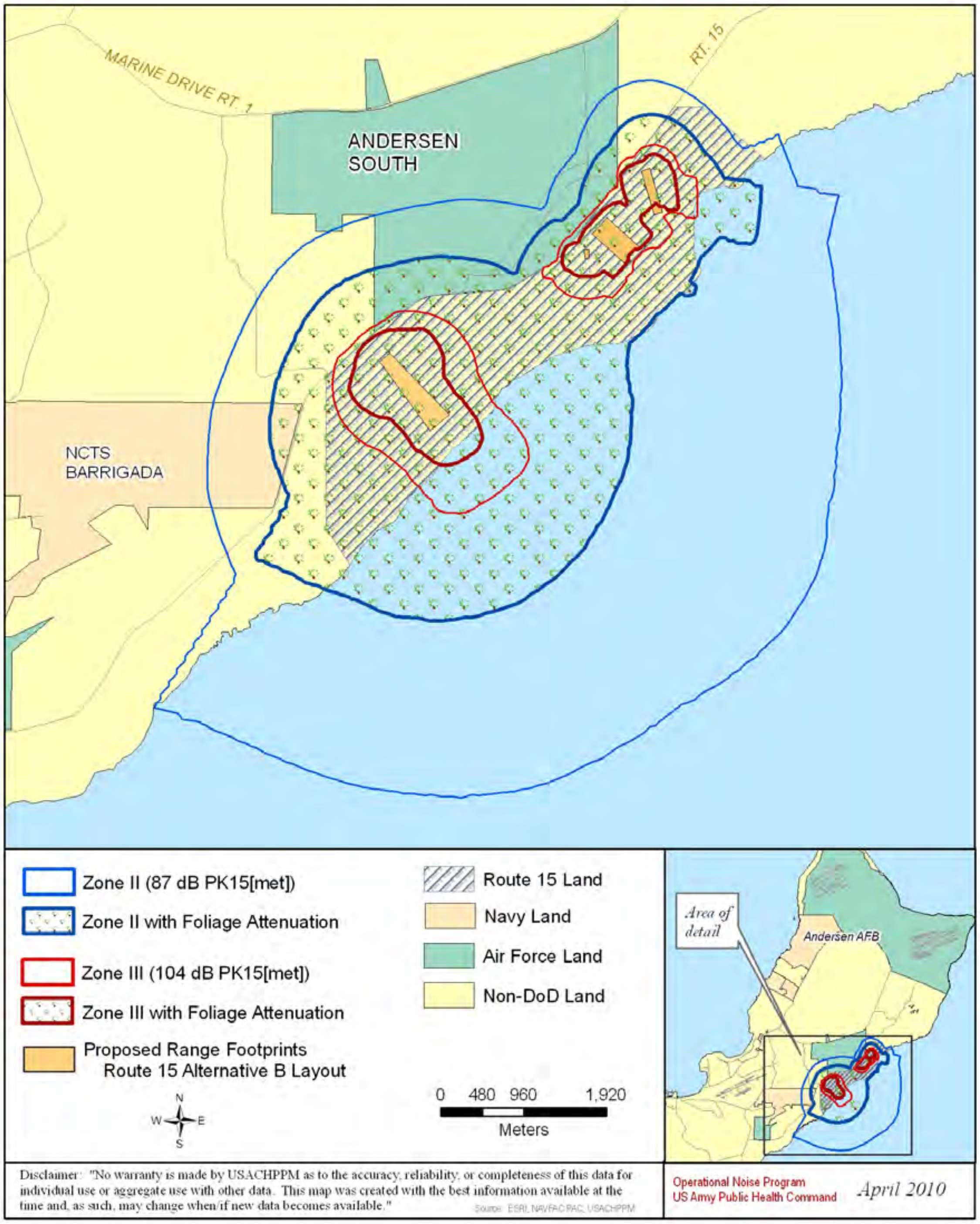

FIGURE 5. ROUTE 15 ALTERNATIVE B
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS
WITH FOLIAGE ATTENUATION

8. GUAM TRAINING RANGES. EFFECTS OF THE HEAVY MACHINE GUN .50 CALIBER ROUND.

a. Since the .50 caliber is significantly louder than the other rounds used for the assessment, limiting the hours or number of days the .50 caliber is fired would lessen the noise impact on surrounding communities.

b. Figure 6 reflects peak noise contours for the Alternative A layout with the foliage attenuation on days when the heavy machine gun with a .50 caliber round <u>is not</u> in use. This information is supplemental and provided for informational purposes only.

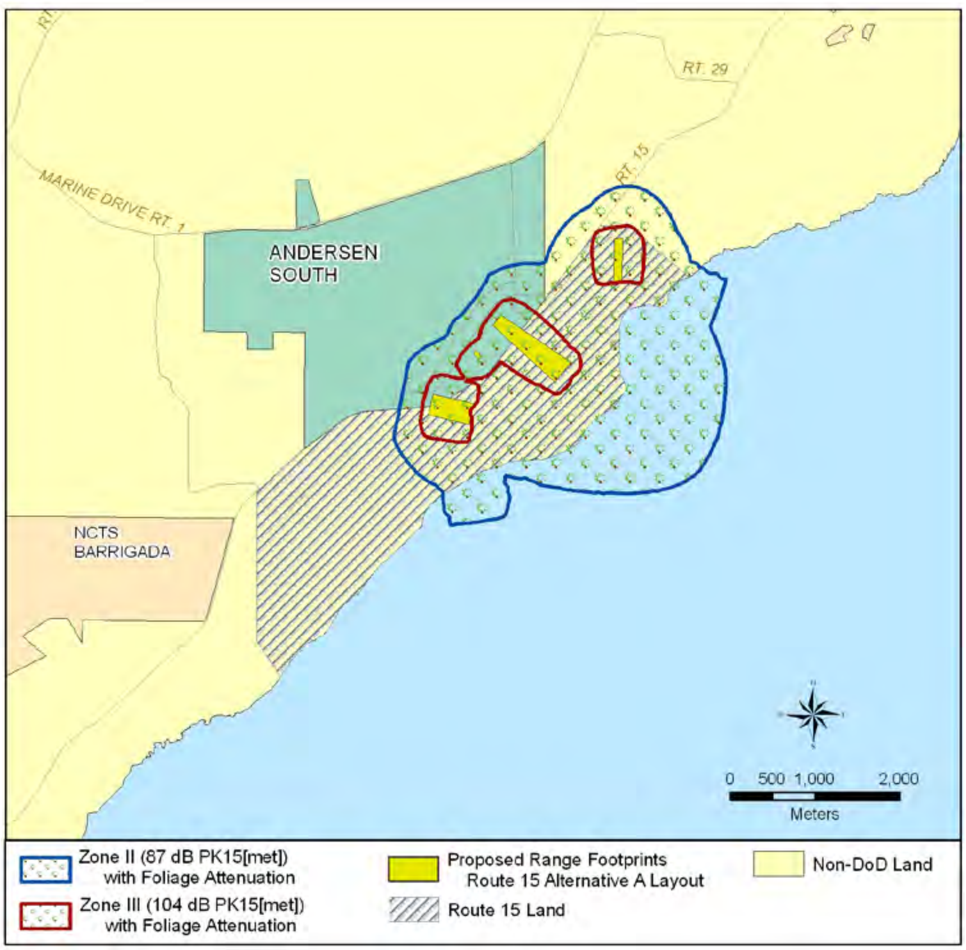

FIGURE 6. ROUTE 15 ALTERNATIVE A, PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS WITH FOLIAGE ATTENUATION WITHOUT .50 CALIBER HEAVY MACHINE GUN

9. GUAM TRAINING RANGES. SMALL CALIBER NOISE CONTOURING RESULTS – ADNL.

a. The NAVFAC PAC requested development of ADNL noise contours for the small caliber weapon activity.

b. Appendix D contains key pages from the Operational Naval Instruction 3550.1A/Marine Corps Order 3550.11 [Range Air Installations Compatible Use Zones Program (RAICUZ)]. The Marine Corps Order states that Day Night Levels (DNL) should be used to generate ordnance noise contours. However, the order does not specifically address or exclude small arms activity. In instances where DNL is used to assess small arms, A-weighting is applied to account for the higher frequencies of the small caliber weapons.

c. Typically, the Air Force and the Navy follow the Army policy in regards to noise from weapon activity. The Army addresses small caliber weapons noise using peak noise levels. One of the reasons the Army does not use DNL to address small caliber noise is due to the number of rounds required to generate a noise contour which is useful for land use planning. To generate a DNL contour that extends beyond the range footprint, the ammunition expenditure is in the order of hundreds of thousands of rounds per range per year. The DNL contours often indicate that land use is compatible everywhere except within the range footprint itself. This small size can be misleading and one could mistakenly make the assumption that the small caliber weapon firing would not be heard beyond the range.

d. The ADNL contours in this consultation are provided as supplemental information. As prescribed in Order 3550.11, the DNL levels to be identified are:

- Noise Zone 1 – < 55 DNL; 55-64 DNL
- Noise Zone 2 – 65-69 DNL; 70-74 DNL
- Noise Zone 3 – 75-79 DNL; 80-84 DNL; > 85 DNL

e. The projected activity at the Guam Ranges generates ADNL noise contours (Table 3).

TABLE 3. GUAM TRAINING RANGES. PROJECTED SMALL CALIBER AMMUNITION EXPENDITURE.

		Days per Year Range Utilized	Ammunition Expenditure Estimate		
			Average Day		
Range	Weapon Ammunition		Day (0700-2200)	Night (2200-0700)	Annual
Known Distance	Rifle, 5.56mm	200	12,250	0	2,450,000
MPMG	MG, 7.62mm	225	4,089	0	920,000
	MG, .50 cal	225	1,511	0	340,000
Pistol	Pistol, 9mm	225	10,000	0	2,250,000
Square Bay (Non-standard	Rifle, 5.56mm	225	6,750	0	1,518,750
	Pistol, 9mm	225	5,250	0	1,181,250
Unknown Distance	Rifle, 5.56mm	225	6,190	0	1,392,750

Note: cal = caliber, mm = millimeter, MG = Machine Gun; MPMG = Multi-Purpose Machine Gun

f. <u>Route 15 Alternative A Layout.</u> Figure 7 contains the ADNL contours for the projected activity under the Route 15 Alternative A range layout. The Alternative A layout would generate a Noise Zone 1 (55-64 ADNL); a Noise Zone 2 (65-74 ADNL); and a Noise Zone 3 (75-79 ADNL) that extend beyond the eastern boundary of Andersen South and the Route 15 Land.

g. <u>Route 15 Alternative A Layout with Barriers.</u> Details regarding the proposed barrier designs utilized in the noise contour development are shown in Appendix E. The proposed barriers were primarily designed for safety considerations. Figure 8 contains the ADNL contours for the projected activity under the Route 15 Alternative A range layout with barriers. The addition of barriers to the Alternative A layout does reduce the extent in which the noise zones extend beyond the boundary. The Alternative A layout with barriers would generate a Noise Zone 1 (55-64 ADNL) and a Noise Zone 2 (65-74 ADNL) that extend beyond the eastern boundary of Andersen South and the Route 15 Land.

h. Route 15 Alternative B Layout. Figure 9 contains the ADNL contours for the projected activity under the Route 15 Alternative B range layout. The Alternative B range layout would generate a Noise Zone 1 (55-64 ADNL); that extends beyond the boundaries of Andersen South and the Route 15 Land. The Alternative B range layout would generate a Noise Zone 2 (65-74) that covers the area non-military land between Andersen South and the Route 15 Land. The Alternative B range layout would generate a Noise Zone 3 (75-79) that extends slightly into the non-military land between Andersen South and the Route 15 Land.

i. Route 15 Alternative B Layout with Barriers. Barriers were not developed for the Alternative B layout.

j. Land Use Compatibility. Per the Marine Corps Order 3550.11, noise-sensitive land uses, such as housing, schools, and medical facilities are generally compatible in the Noise Zone 1. Noise-sensitive land uses in Noise Zone 2 are generally not compatible. Within Noise Zone 2, residential use is discouraged within 65-69 ADNL and residential use is *strongly* discouraged within 70-74 ADNL. Noise-sensitive land uses in Noise Zone 3 are not compatible. Based upon the available aerial image shown in Appendix F, residential areas would fall within the Noise Zone 1 and Noise Zone 2 contours. Appendix F contains the Guam noise contours overlaid on aerial imagery.

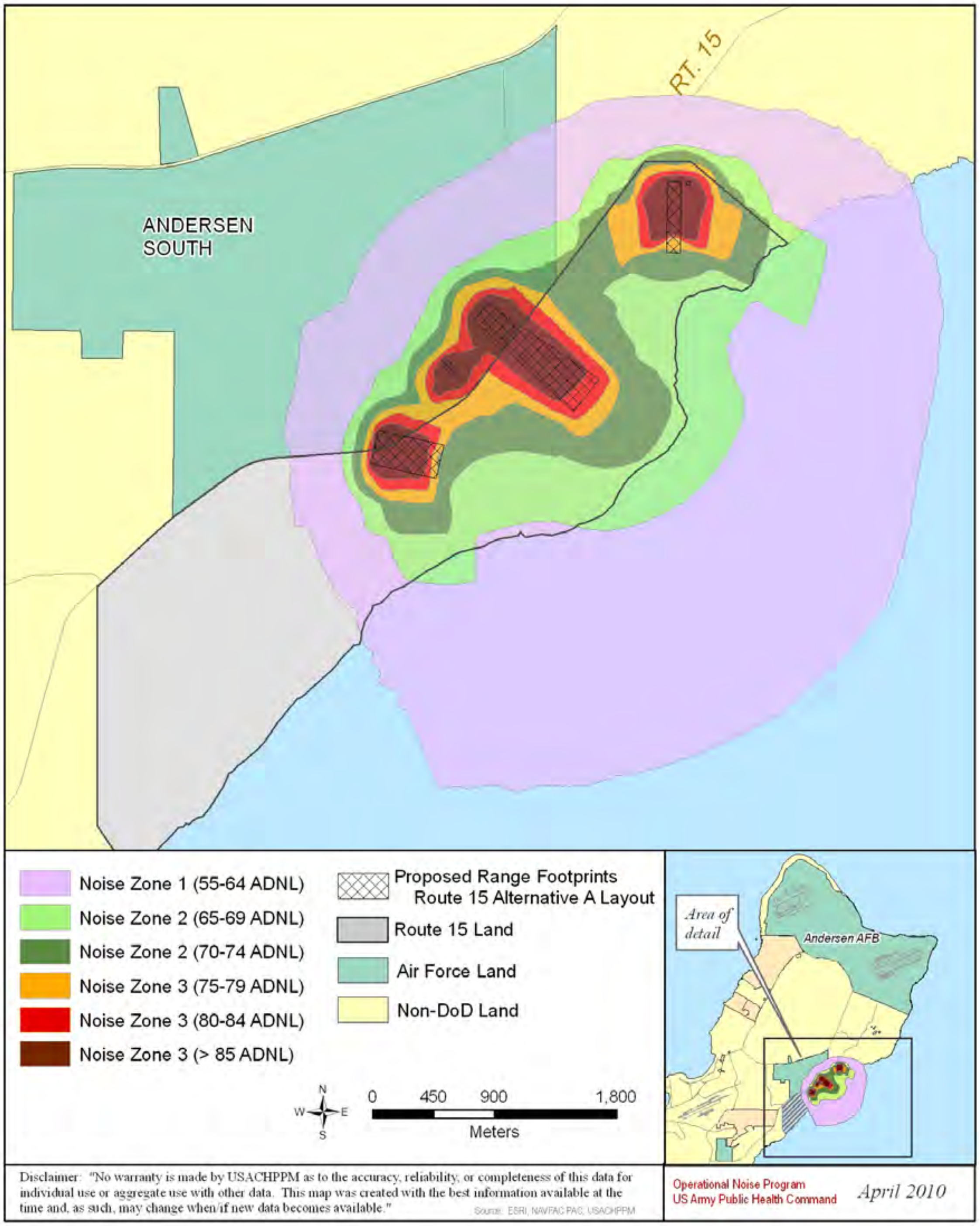

FIGURE 7. ROUTE 15 ALTERNATIVE A
PROJECTED SMALL CALIBER OPERATIONAL ADNL NOISE CONTOURS

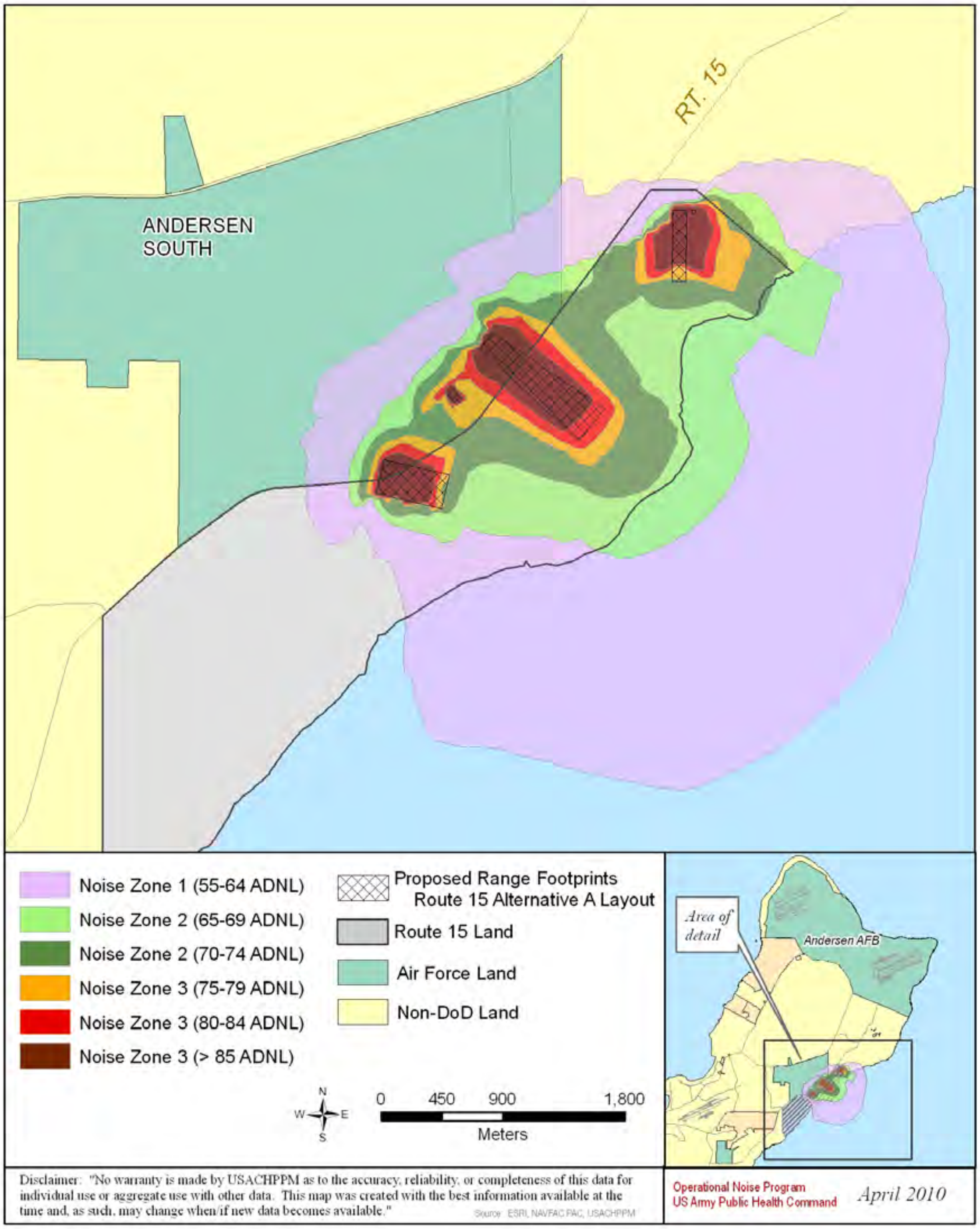

FIGURE 8. ROUTE 15 ALTERNATIVE A
PROJECTED SMALL CALIBER OPERATIONAL ADNL NOISE CONTOURS
WITH BARRIER ATTENUATION

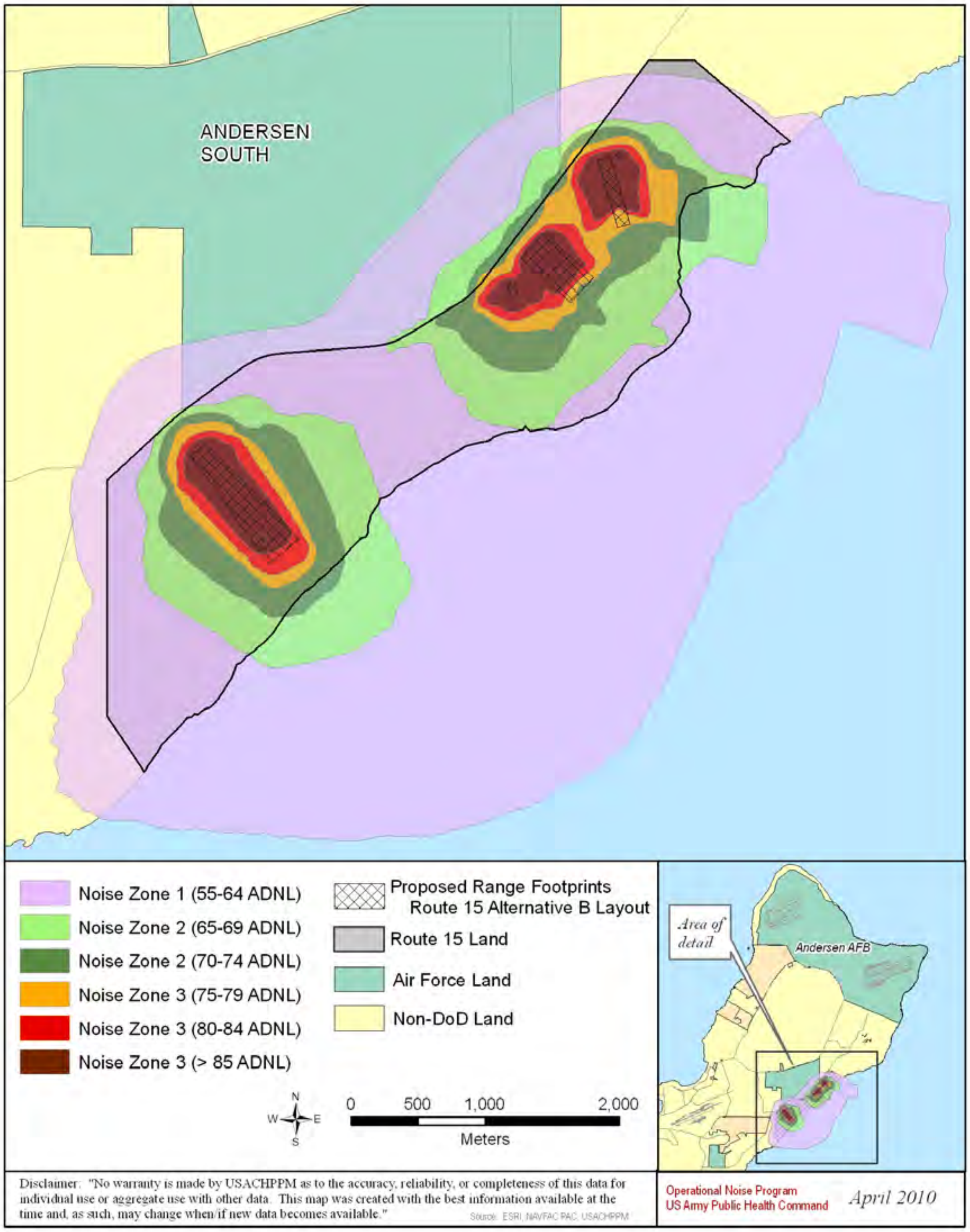

FIGURE 9. ROUTE 15 ALTERNATIVE B
PROJECTED SMALL CALIBER OPERATIONAL ADNL NOISE CONTOURS

10. GUAM HAND GRENADE RANGE. The proposed barrier deigns also included surrounding the hand grenade range. The 16 foot high barriers on the hand grenade range would be ineffective at reducing the noise levels due to the low-frequencies generated by hand grenades.

11. TINIAN TRAINING RANGES. SMALL CALIBER NOISE CONTOURING RESULTS – PEAK.

a. General. The noise contours in this section were created using PK15(met) as prescribed in Army Regulation (AR) 200-1 (U.S. Army 2007). The contours show the predicted peak levels for individual rounds (metric term is PK15(met)). Since the contours are based on peak levels rather than a cumulative or average level, the size of the contours will not change if the number of rounds fired increases or decreases.

b. Operational Input. The inputs utilized to generate the small caliber noise contours are shown in Table 4. The August 2009 range footprint was utilized.

TABLE 4. TINIAN TRAINING RANGES. PROJECTED SMALL CALIBER RANGE UTILIZATION.

	CPQC	FIELD FIRE	KD	IPBC
PISTOLS, 9mm, .45 caliber	√			
RIFLE, 5.56mm		√	√	√

Note: CPQC = Combat Pistol Qualification Course, KD = Known Distance, IPBC = Infantry Platoon Battle Course, mm = millimeter

(1) Alternative 1 Layout. Figure 10 contains the small caliber weapons contours for the projected activity under the Alternative 1 layout and the weapon utilization listed in Table 4. The Alternative 1 layout would generate a Zone II [PK15(met) 87 dB] noise contour that extends approximately 200 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Tinian Training Range area.

(2) Alternative 2 Layout. Figure 11 contains the small caliber weapons contours for the projected activity under the Alternative 2 layout and the weapon utilization listed in Table 4. The Alternative 2 layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 150 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour does not extend beyond the Tinian Training Range area.

(3) Alternative 3 Layout. Figure 12 contains the small caliber weapons contours for the projected activity under the Alternative 3 layout and the weapon utilization listed in Table 4. The Alternative 3 layout generates a Zone II [PK15(met) 87 dB] noise contour that extends approximately 950 meters into the San Jose Airport property. The Zone III [PK15(met) 104 dB] noise contour extends approximately 200 meters into the San Jose Airport property.

c. Land Use Compatibility. Per AR 200-1, noise-sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Noise Zone I, normally not recommended in Noise Zone II, and not recommended in Noise Zone III (U.S. Army 2007). There are no noise-sensitive land uses within the noise contours.

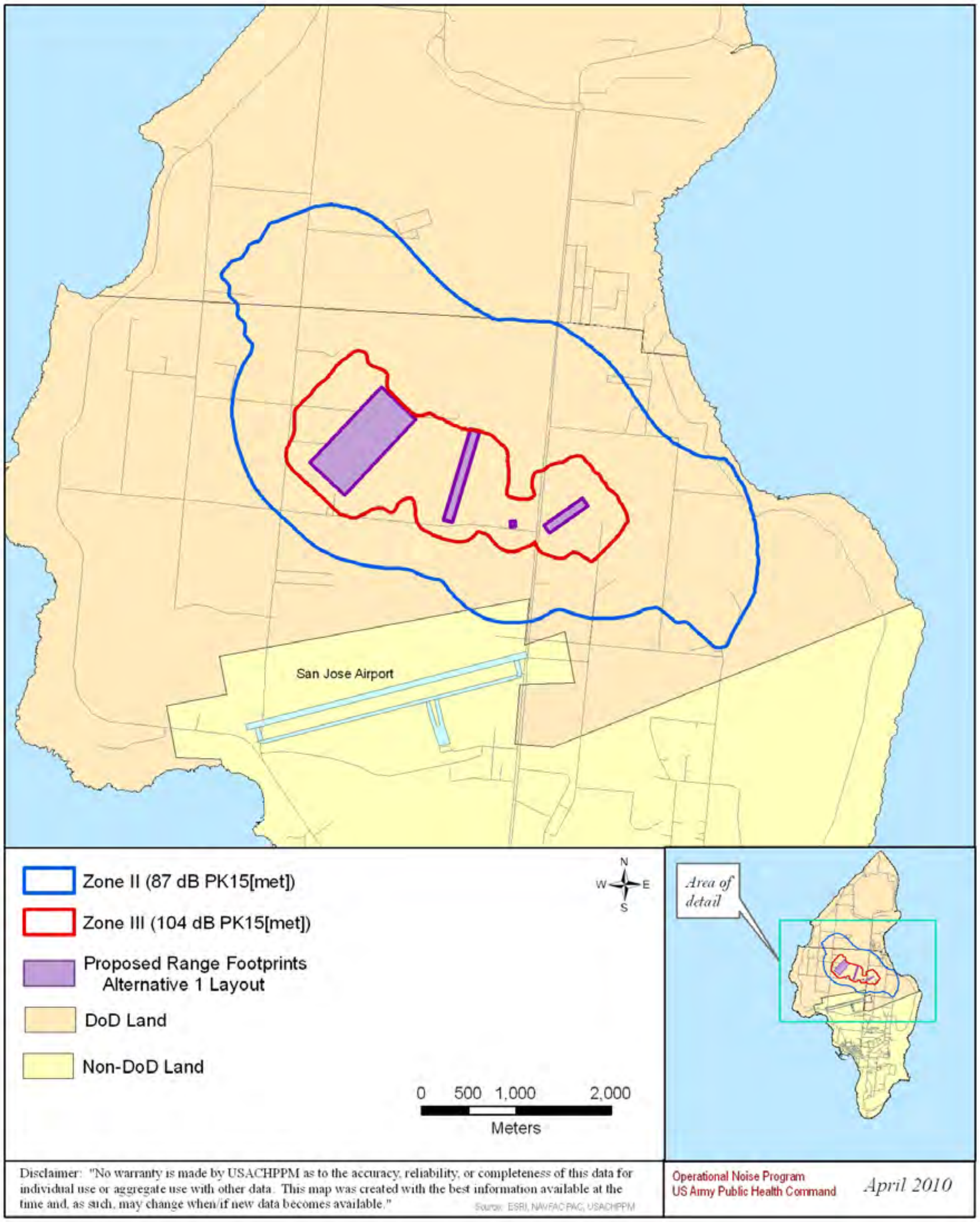

FIGURE 10. TINIAN TRAINING RANGE - ALTERNATIVE 1
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

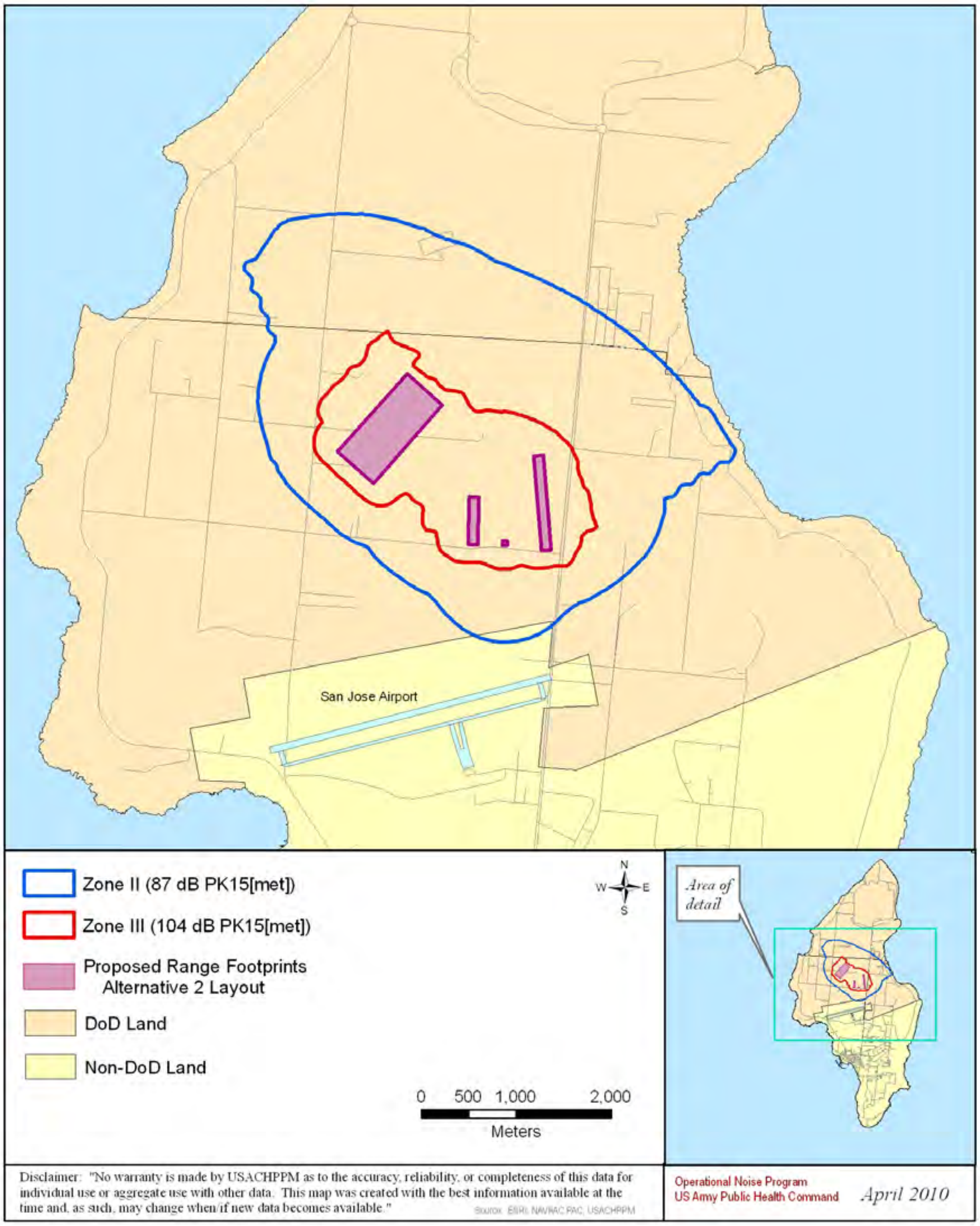

FIGURE 11. TINIAN TRAINING RANGE - ALTERNATIVE 2
PROJECTED SMALL CALIBER OPERATIONAL NOISE CONTOURS

12. TINIAN TRAINING RANGES SMALL CALIBER NOISE CONTOURING RESULTS – ADNL.

a. The NAVFAC PAC requested development of ADNL noise contours for the small caliber weapon activity.

b. The ADNL contours in this consultation are provided as supplemental information. As prescribed in Order 3550.11 the DNL levels to be identified are:

- Noise Zone 1 – < 55 DNL; 55-64 DNL
- Noise Zone 2 – 65-69 DNL; 70-74 DNL
- Noise Zone 3 – 75-79 DNL; 80-84 DNL; > 85 DNL

c The projected activity at the Tinian Ranges generates ADNL noise contours (Table 5).

TABLE 5. TINIAN TRAINING RANGES. PROJECTED SMALL CALIBER AMMUNITION EXPENDITURE.

		Days per Year Range Utilized	Ammunition Expenditure Estimate		
			Average Day		
Range	Weapon Ammunition		Day (0700-2200)	Night (2200-0700)	Annual
Combat Pistol Qualification	Pistol, 9mm	60	5,000	0	300,000
	Pistol, .45 cal	20	5,000	0	100,000
Field Fire	Rifle, 5.56mm	80	11,000	1,000	960,000
Infantry Platoon Battle Course	Rifle, 5.56mm	80	6,750	2,250	720,000
	SAW, 5.56mm	80	2,250	750	240,000
Known Distance	Rifle, 5.56mm	80	12,000	0	960,000

Note: cal = caliber, mm = millimeter

d. <u>Tinian Alternative 1 Layout.</u> Figure 13 contains the ADNL contours for the projected activity under the Alternative 1 range layout. The Alternative 1 layout would generate a Noise Zone 1 (55-64 ADNL) that extends slightly beyond the southern boundary. The Noise Zone 2 (65-74 ADNL) and Noise Zone 3 (>75 ADNL) do not extend beyond the boundary.

e. Tinian Alternative 2 Layout. Figure 14 contains the ADNL contours for the projected activity under the Alternative 2 range layout. The ADNL noise contours generated by the Alternative 2 layout do not extend beyond the boundary.

f. Tinian Alternative 3 Layout. Figure 15 contains the ADNL contours for the projected activity under the Alternative 3 range layout. The Alternative 3 layout would generate a Noise Zone 1 (55-64 ADNL); a Noise Zone 2 (65-74 ADNL); and a Noise Zone 3 (>75 ADNL) that extend beyond the southern boundary into the San Jose Airport property.

g. Land Use Compatibility. Per the Marine Corps Order 3550.11, noise-sensitive land uses, such as housing, schools, and medical facilities are generally compatible in the Noise Zone 1. Noise-sensitive land uses in Noise Zone 2 is generally not compatible. Within Noise Zone 2, residential use is discouraged within 65-69 ADNL and is *strongly* discouraged within 70-74 ADNL. Noise-sensitive land uses in Noise Zone 3 are not compatible. There are no noise-sensitive land uses within the noise contours.

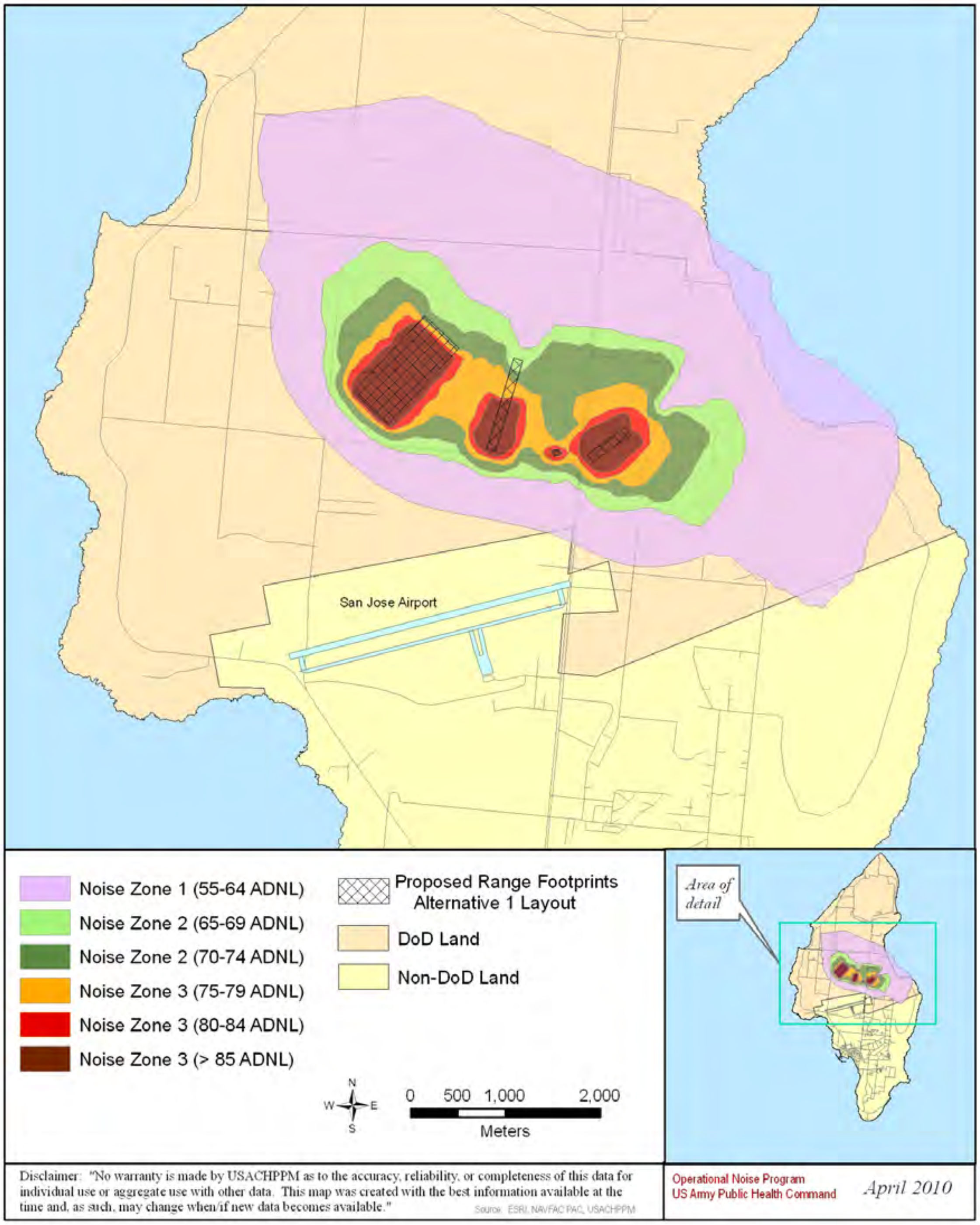

FIGURE 13. TINIAN TRAINING RANGE ALTERNATIVE 1
PROJECTED SMALL CALIBER OPERATIONAL ADNL NOISE CONTOURS

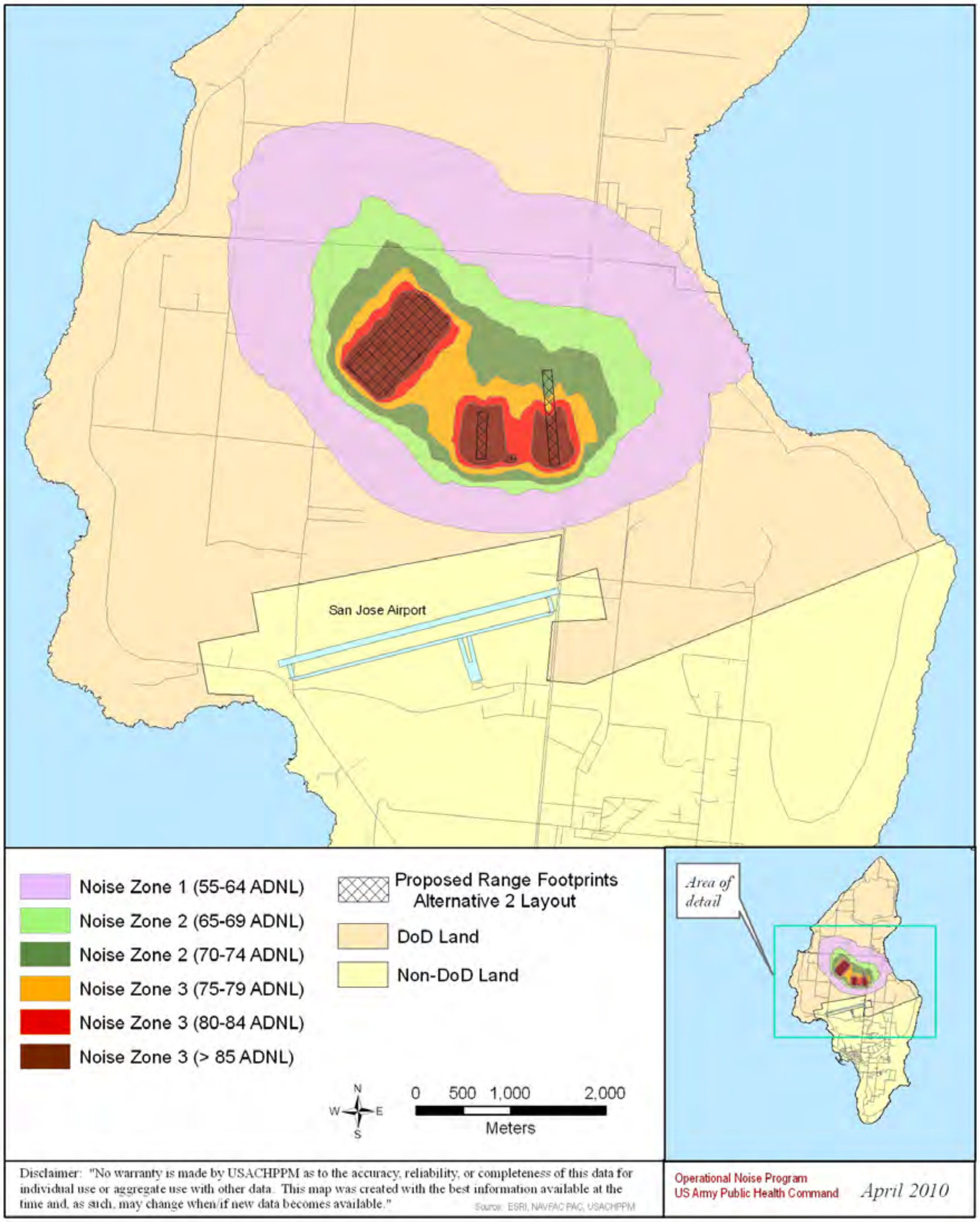

FIGURE 14. TINIAN TRAINING RANGE ALTERNATIVE 2
PROJECTED SMALL CALIBER OPERATIONAL ADNL NOISE CONTOURS

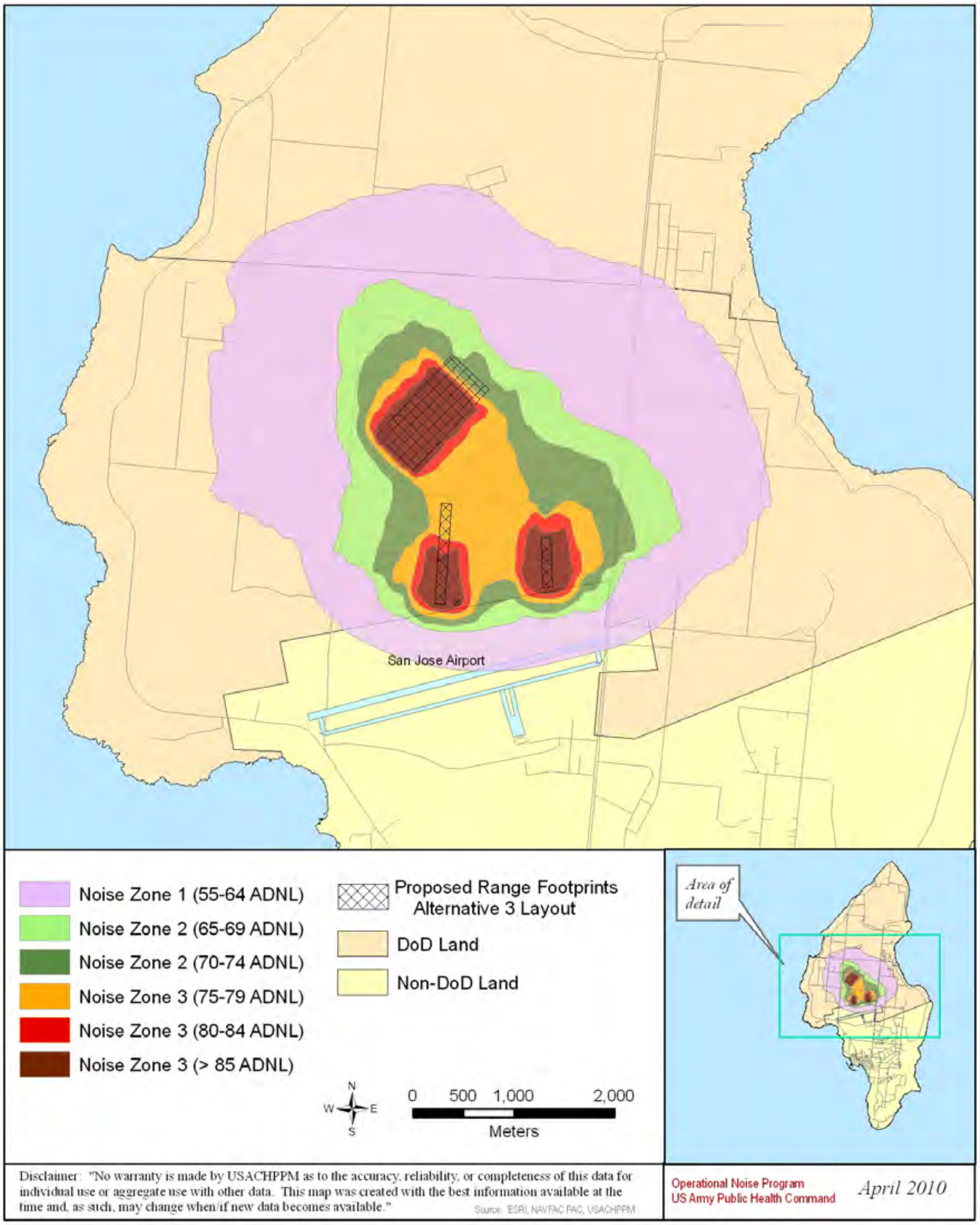

FIGURE 15. TINIAN TRAINING RANGE ALTERNATIVE 3
PROJECTED SMALL CALIBER OPERATIONAL ADNL NOISE CONTOURS

13. CONCLUSIONS.

a. GUAM TRAINING RANGES.

(1) The Alternative A range layout without the foliage attenuation would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the boundary. Residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There are no residential properties within the Noise Zone III (104 dB PK15[met]) contour.

(2) The Alternative B range layout without the foliage attenuation would generate PK15(met) Noise Zone II (87 dB) and Zone III (104 dB) contours that extend beyond the boundary. Residential areas would fall within the Noise Zone II (87 dB PK15[met]) contour. There are scattered residential properties within the Noise Zone III (104 dB PK15[met]) contour.

(3) Accounting for the foliage attenuation greatly reduces the overall footprint of the Noise Zone II (87 dB) peak contours. With the foliage attenuation, the Noise Zone III (104 dB) peak contour does not extend beyond the boundary.

(4) The proposed barrier designs in Alternative A will slightly change the small caliber peak noise contours that extend beyond the boundary. The proposed barriers were designed based primarily for safety rather than noise mitigation.

(5) The Alternative A range layout would generate a Noise Zone 1 (55-64 ADNL); a Noise Zone 2 (65-74 ADNL); and a Noise Zone 3 (75-79 ADNL) that extend beyond the eastern boundaries of Andersen South and the Route 15 Land. Per the Marine Corps Order 3550.11, noise-sensitive land uses are generally compatible in the Noise Zone 1. Noise-sensitive land uses in Noise Zone 2 are generally not compatible. Within Noise Zone 2, residential use is discouraged within 65-69 ADNL and is *strongly* discouraged within 70-74 ADNL. Noise-sensitive land uses in Noise Zone 3 are not compatible. Residential areas would fall within the Noise Zone 1 and Noise Zone 2 contours. There are no residential properties within the Noise Zone 3 contours.

(6) The Alternative B range layout would generate a Noise Zone 1 (55-64 ADNL) that extends beyond the boundaries of Andersen South and the Route 15 Land. The Alternative B range layout would generate a Noise Zone 2 (65-74) that covers the area of non-military land between Andersen South and the Route 15 Land. The Alternative B range layout would generate a Noise Zone 3 (75-79) that extends slightly into the non-military land between Andersen South and the Route 15 Land. Residential areas would fall within the Noise Zone 1 and Noise Zone 2 contours. There are no residential properties within the Noise Zone 3 contours.

b. TINIAN TRAINING RANGES.

(1) The proposed small caliber range alternatives would generate PK15(met) Noise Zone II (87 dB) and Noise Zone III (104 dB) contours that extend beyond the Tinian Training Range boundary. There are no noise-sensitive land uses within the noise contours.

(2) The Alternative 1 range layout would generate a Noise Zone 1 (55-64 ADNL) that extends slightly beyond the southern boundary. The Noise Zone 2 (65-74 ADNL) and Noise Zone 3 (>75 ADNL) do not extend beyond the boundary.

(3) The ADNL noise contours generated by the Alternative 2 range layout do not extend beyond the boundary.

(4) The Alternative 3 range layout would generate a Noise Zone 1 (55-64 ADNL); a Noise Zone 2 (65-74 ADNL); and a Noise Zone 3 (>75 ADNL) that extend beyond the southern boundary into the San Jose Airport property.

14. RECOMMENDATIONS.

a. Include the information from this consultation in the appropriate NEPA documentation.

b. As suggested in the original consultation, to reduce the risk of noise complaints from the proposed activity, the NAVFAC PAC should use the U.S. Army's Operational Noise Management Program guidance in conjunction with the Air Force's Air Installation Compatible Use Zone program to address impulsive noise events.

Kristy Broska

KRISTY BROSKA
Environmental Protection Specialist
Operational Noise

APPROVED:

Catherine Stewart

CATHERINE STEWART
Program Manager
Operational Noise

APPENDIX A

REFERENCES

1. The U.S. Marine Corps, 2008, MC Order 3550.11, Range Air Installations Compatible Use Zones, 28 January 2008.

2. The U.S. Army, 2003a, U.S. Army Construction Engineering Research Laboratories, SARNAM Computer Model, Version 2.6.2003-06-06.

3. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise.

4. United Facilities Criteria, 2003b, UFC 3-450-01, Noise and Vibration Control, 15 May 2003.

5. The U.S. Army, 2009, Center for Health Promotion and Preventive Medicine, Operational Noise Consultation 52-EN-0BVU-09, Operational Noise Contours for Proposed Range Development at Guam and Tinian, August 2009.

APPENDIX B

GLOSSARY OF TERMS, ACRONYMS & ABBREVIATIONS

B-1. GLOSSARY OF TERMS.

A-weighted Sound Level - the ear does not respond equally to sounds of all frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound pressure level of a noise containing a wide range of frequencies in a manner approximating the response of the ear, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. Thus, the low and high frequencies are de-emphasized with the A-weighting. The A-scale sound level is a quantity, in decibels, read from a standard sound-level meter with A-weighting circuitry. The A-scale weighting discriminates against the lower frequencies according to a relationship approximating the auditory sensitivity of the human ear. The A-scale sound level measures approximately the relative "noisiness" or "annoyance" of many common sounds.

Average Sound Level - the mean-squared sound exposure level of all events occurring in a stated time interval, plus ten times the common logarithm of the quotient formed by the number of events in the time interval, divided by the duration of the time interval in seconds.

Day-Night Average Sound Level (DNL) - the 24-hour average frequency-weighted sound level, in decibels, from midnight to midnight, obtained after addition of 10 decibels to sound levels in the night from midnight up to 7 a.m. and from 10 p.m. to midnight (0000 up to 0700 and 2200 up to 2400 hours).

Decibels (dB) – a logarithmic sound pressure unit of measure.

Noise – any sound without value.

PK15(met) - the maximum value of the instantaneous sound pressure for each unique sound source, and applying the 15 percentile rule accounting for meteorological variation.

B-2. GLOSSARY OF ACRONYMS AND ABBREVIATIONS.

ADNL	A-weighted Day Night average Level
dB	Decibels
DNL	Day Night average Level
NEPA	National Environmental Policy Act
PK15(met)	Unweighted Peak, 15% Metric
mm	millimeter
MPMG	Multi-Purpose Machine Gun
NAVFAC PAC	Navy Facilities Engineering Command, Pacific
NEPA	National Environmental Policy Act
SARNAM	Small Arms Range Noise Assessment Model

APPENDIX C

NOISE ZONE DESCRIPTIONS

C-1. REFERENCE. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise. The Air Force and the Navy follow the Army policy in regards to noise from weapon activity.

C-2. For a detailed explanation of Noise Zone Descriptions and Land Use Guidelines see Army Regulation 200-1, Chapter 14 (U.S. Army 2007).

C-3. The PK15(met) Noise Contour Description. The PK15(met) is the peak sound level, factoring in the statistical variations caused by weather, that is likely to be exceeded only 15 percent of the time (i.e., 85 percent certainty that sound will be within this range). This “85 percent solution” gives the installation and the community a means to consider the areas impacted by training noise without putting stipulations on land that would only receive high sound levels under infrequent weather conditions that greatly favor sound propagation. The PK15(met) does not take the duration or the number of events into consideration, so the size of the contours will remain the same regardless of the number of events.

C-4. Land Use Guidelines.

a. The Noise Zone III consists of the area around the noise source in which the level greater than 104 dB PK15(met) for small caliber weapons. Noise-sensitive land uses (such as housing, schools, and medical facilities) are not recommended within Noise Zone III.

b. The Noise Zone II consists of an area where the level is between 87 and 104 dB PK15(met) for small caliber weapons. Land within Noise Zone II should normally be limited to activities such as industrial, manufacturing, transportation, and resource production. However, if the community determines that land in Noise Zone II (attributable to small arms or aviation) areas must be used for residential purposes, then noise level reduction (NLR) features of 25 to 30 decibels should be incorporated into the design and construction of *new* buildings to mitigate noise levels. For large caliber weapons, NLR features cannot adequately mitigate the low-frequency component of large caliber weapons noise.

c. The Noise Zone I includes all areas around a noise source in which the levels is less than 87 PK15(met) for small arms weapons. This area is usually acceptable for all types of land use activities.

d. See Table C for land use guidelines.

Table C. LAND USE PLANNING GUIDELINES.

Noise Zones	**Small Arms dB PK15(met)**
LUPZ	n/a
I	<87
II	87-104
III	>104

APPENDIX D

UNITED STATES MARINE CORPS ORDER 3550.11

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
2000 NAVY PENTAGON
WASHINGTON, DC 20350-2000
AND
HEADQUARTERS UNITED STATES MARINE CORPS
3000 MARINE CORPS PENTAGON
WASHINGTON, DC 20350-3000

OPNAVINST 3550.1A
MCO 3550.11
N4/CMC (I&L)
28 Jan 08

OPNAV INSTRUCTION 3550.1A
MARINE CORPS ORDER 3550.11

From: Chief of Naval Operations
Commandant of the Marine Corps

Subj: RANGE AIR INSTALLATIONS COMPATIBLE USE ZONES (RAICUZ) PROGRAM

Ref: (a) OPNAVINST 11010.36B
(b) OPNAVINST 5090.1B
(c) MCO P5090.2 (NOTAL)
(d) MCO 3550.10
(e) MCO 3570.1B
(f) OPNAVNOTE 11010 (NOTAL)
(g) DOD Directive 3200.15 of 10 Jan 03
(h) OPNAVINST 5100.27A/MCO 5104.1B
(i) OPNAVINST 3770.2

Encl: (1) RAICUZ Program Procedures and Guidelines for Air-to-Ground Range Installations

1. Purpose. To revise Department of the Navy policy, procedures, and guidelines for implementation of the RAICUZ Program. This instruction provides guidance from the Chief of Naval Operations and Commandant of the Marine Corps.

2. Cancellation. OPNAVINST 3550.1.

3. Background. The Department of the Navy's RAICUZ program is designed to protect public health, safety, and welfare, and to prevent encroachment from degrading the operational capabilities of air-to-ground ranges. This program is similar to the Air Installations Compatible Use Zones (AICUZ) Program issued by reference (a). The RAICUZ program includes range safety and noise analyses, and provides land use recommendations which will be compatible with Range Compatibility Zones (RCZs) and noise

levels associated with the military range operations. Program implementation procedures for the Navy and Marine Corps are contained in enclosure (1).

4. Discussion. The RAICUZ Program depends upon the installation commander's efforts to work with the nearby communities and other federal, state, local agencies and federally recognized Native American tribes to prevent incompatible development of land adjacent to military training ranges. The RAICUZ process involves four steps:

a. Develop, and periodically update, a RAICUZ Study for each air-to-ground range installation to quantify range compatibility zones and aircraft noise zones; consult with stakeholders to develop strategies for lands affected by potential weapons or noise impacts, both on and off the range; prepare a compatible land use plan for the range and surrounding areas; and develop a strategy to promote compatible development on land within these areas.

b. Develop a near-term RAICUZ analysis to illustrate impact of known future missions on RAICUZ implementation.

c. Implement the RAICUZ Study for the installation including coordination with federal, state, and local officials to maintain public awareness of RAICUZ.

d. Identify and program land acquisition in critical areas where actions to achieve compatibility within the RAICUZ through local land controls appears unlikely.

5. Responsibilities. The Deputy Chief of Naval Operations, CNO for Fleet Readiness and Logistics (N4), provides relevant policy, resources, structures, and mechanisms to meet leadership

defined readiness requirements of Navy operating forces and their associated shore installations.

a. CNO (N46) (Director, Ashore Readiness) plans and programs resources for the RAICUZ program.

b. CNO (N43) (Director, Fleet Readiness) as director of the Navy Range Office, ensures Navy Policy and decision making support the Fleet's tactical warfighter requirements.

c. Commander Fleet Forces Command (CFFC), is responsible for approving all operational requirements on Navy training ranges, programming resources for new Weapon Danger Zones (WDZs) tool and approving waivers to standard modeling protocols for training ranges and the WDZ (SAFE-RANGE) computer software tool.

d. Commander, Naval Strike and Air Warfare Center (NSAWC), is responsible for developing all Navy tactics, techniques and procedures (TTP) that are employed on Navy ranges. Marine Corps aviation TTP tactics are standardized and taught by Marine Air Ground Task Force Training Command and Marine Aviation Weapons and Tactics Squadron One.

e. Commander Navy Installations Command (CNI)(N5), as the RAICUZ program executive agent, provides technical expertise, policy oversight and program management for the Navy.

f. The Deputy Commandant for Installations & Logistics (DC I&L) acts on behalf of the Commandant in designated matters of installations and logistics policy and management. DC I&L shall exercise approval authority and responsibility for the RAICUZ program within the Marine Corps.

g. The Commanding General, Marine Corps Combat Development Command (CG MCCDC) (C465) is the executive agent and resources sponsor for aviation and ground range and training area (RTA) management programs, and the proponent for all range safety matters.

6. Applicability. This instruction applies to all Navy and Marine Corps air-to-ground range installations within the confines of the United States, its territories, trusts, and possessions. RAICUZ studies, or portions thereof, may be developed for U.S. activities in foreign countries if such action supports host nation policy for protecting the operational capabilities of those activities, or for on base U.S. facility planning goals.

7. Action. Addressees shall comply with the procedures outlined herein.

E. G. USHER III
Deputy Commandant for
Installations and Logistics

M. L. LOOSE
Vice Admiral, CEC, U.S. Navy
Deputy Chief of Naval Operations
(Fleet Readiness and Logistics)

OPNAVINST 3550.1A
MCO 3550.11
28 Jan 08

DEPARTMENT OF THE NAVY

RANGE AIR INSTALLATIONS COMPATIBLE USE ZONES

RAICUZ

PROGRAM PROCEDURES

TABLE OF CONTENTS

SECTION IV

4. NOISE EXPOSURE

4.1. GENERAL

In addition to Range Compatibility Zones, the RAICUZ study should consider potential noise impacts in the vicinity of the range. For air-to-ground ranges where adjacent or nearby noise-sensitive land uses exist or the potential for development is present, a detailed noise impact analysis is warranted. Such noise analysis should address aircraft noise, ordnance (blast noise), and supersonic operations, if applicable.

4.2. DEVELOPMENT OF NOISE EXPOSURE CONTOURS

Part of the RAICUZ study includes preparation of a noise plan to develop noise exposure contours and compare them to prior noise contours published in the last approved RAICUZ document. The noise contours are developed by a computerized simulation of aircraft activity at the range and reflect site-specific conditions (e.g., terrain) and operational data (e.g., flight tracks, type and mix of aircraft, aircraft profiles (airspeed, altitude, power settings)), and number/types of weapons employed as well as the frequency and times of operations. RAICUZ program experience indicates that future year planning is necessary to consider the effects of expected changes in mission, aircraft, and range operational levels, etc. Therefore, in addition to the current year analysis of operations, RAICUZ updates will include an analysis of projected operations. The resultant noise contours will be referred to as the "prospective" noise contours. Projections of aircraft and range operations will be based upon currently available unclassified estimates of future mission requirements. Where such estimates are not available, or where little or no change is expected in the next 5 to 10 years, the current year noise contours may also be used as the prospective noise contours. Noise impacts from aircraft and ordnance operations will be graphically portrayed, and operational alternatives that could reduce noise impact on the installation and on the nearby community should be evaluated when practicable from the perspectives of aircraft safety and ability to maintain operational and training requirements. The activity shall recommend the most appropriate noise footprints for approval by CNO/CMC.

4.2.1. General

Since land use compatibility guidelines are based on yearly average noise levels, noise contours should be developed based on Average Annual Day (AAD) operations. However, where the documented nature of AAD air operations at a specific range does not adequately represent the noise impacts at that range, the Average Busy Day (ABD) can be used with supporting rationale (i.e., there are times when a detachment uses the range creating several days of higher noise impact). Range Managers are encouraged to contact CNI (N531)/ CMC (LF) for further guidance.

The operations level on an AAD is calculated by dividing the total annual range operations by 365 days. An ABD occurs when the range operations levels on a given day are at least 50 percent of the Average Annual Day operations level. The ABD is calculated by determining the number of operations on busy days and dividing the total number of operations on those busy days by the number of busy days.

4.2.2. Noise Zones and Noise Models

4.2.2.1 Day-Night Average Sound Level (DNL) shall be used in all RAICUZ Studies except at California ranges, which will use Community Noise Equivalent Level (CNEL). Where applicable, noise contours 60, 65, 70, 75, and 80 shall be plotted on maps for Navy and Marine Corps ranges as part of RAICUZ studies. Contours below 60 DNL/CNEL are not required but may be provided if local conditions warrant discussion of lower noise levels or where significant noise complaints have been received in areas outside DNL/CNEL 60.

4.2.2.2. The NOISEMAP program or MR_NMAP may be used for developing noise contours for fixed-wing aircraft and the Rotorcraft-Noise Model (RNM) program will be used for developing noise contours for rotary-wing and tilt-rotor aircraft operations.

4.2.2.3 For ranges with a fixed run-in heading, NOISEMAP will be utilized.

4.2.2.4 For ranges with variable run-in headings, the MOA and Range Noise Map program (MR_NMAP) will be utilized.

4.2.2.5. For low-level military training routes (MTR) to and from the range, MR_NMAP will be utilized.

4.2.2.6. Noise from ordnance delivery (blast noise) is impulsive in nature and of short duration. Blast noise is often a source of discomfort for persons, and vibrations of buildings and structures included by blast noise may result in increased annoyance. Where noise sensitive uses are located in the vicinity of a range, blast noise contours will be developed using the latest version of the Department of Defense BNOISE program.

4.2.2.7. The use of the C-weighted average sound level (CDNL) is an appropriate noise metric to represent the effects of blast noise from both air-to-ground ranges using live ordnance and Marine Corps ground training ranges. Initial BNOISE analysis input data should be coordinated with the Noise Staff of the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM). Blast noise C-weighted contours of 57, 62, 70, 75 and 80 CDNL should be included.

4.2.2.8. Supplemental metrics can also help explain special situations (e.g., noise at a school during school hours; noise at certain peak periods of the year when a major exercise is conducted, etc.). Single event noise data (e.g., SELs at various distances during a single aircraft over flight; peak PK15 (events), etc.) may be employed where appropriate to provide additional information on the effects of noise in certain situations.

4.2.3. Selection of Final Noise Contours to be used in the RAICUZ Plan

The selection criteria and rationale for the noise contours (e.g., current year or prospective used to reflect aircraft noise and blast noise must be documented in the request for approval of the RAICUZ plan) shall be made by the installation, concurred with by the chain of command, and approved by CNO (N5) or CMC (LF).

4.3. COMPATIBLE LAND USE GUIDELINES FOR NOISE ZONES

For land use planning purposes, the noise exposure from aircraft is divided into three noise zones: Noise Zone 1 (DNL/CNEL less than 65) is an area of lesser impact where sound attenuation is not normally recommended; Noise Zone 2 (DNL/CNEL 65-74) is an area of moderate impact where some land use controls for noise-sensitive uses are desired; and Noise Zone 3 (DNL/CNEL 75 and above) is the area of highest potential noise impact and requires the greatest degree of compatible land use control. In addition to the noise zones, areas of concern may be defined where noise levels are not considered to be objectionable (less than 65 DNL/CNEL,), but some degree of land use controls are recommended (e.g., areas under ingress and egress routes to and from training ranges). Appendix B provides compatibility guidelines for noise zones.

Where specific local land uses are not adequately described in the standard guidance documents, refinement and interpretation of the basic data is encouraged, within the constraints of accepted land use planning practice and with prior coordination with CNO(N53)or CMC(LF).

APPENDIX B

SUGGESTED LAND USE COMPATIBILITY IN NOISE ZONES

LAND USE	Noise Zone 1		Noise Zone 2		Noise Zone 3		
	< 55	55-64	65-69	70-74	75-79	80-84	85+
RESIDENTIAL - SINGLE FAMILY, DUPLEX, MOBILE HOMES	Y	Y^1	N^1	N^1	N	N	N
RESIDENTIAL - MULTIPLE FAMILY HOMES	Y	Y^1	N^1	N^1	N	N	N
TRANSIENT LODGING	Y	Y^1	N^1	N^1	N	N	N
SCHOOL CLASSROOMS, LIBRARIES, CHURCHES	Y	Y^1	25	30	N	N	N
HOSPITALS	Y	Y^1	25	30	N	N	N
NURSING HOMES	Y	Y	N^1	N^1	N	N	N
AUDITORIUMS, CONCERT HALLS	Y	Y^1	25	30	N	N	N
OFFICE BUILDINGS - PERSONAL, BUSINESS, PROFESSIONAL	Y	Y	Y	Y^2	Y^3	Y^4	N
COMMERCIAL, RETAIL	Y	Y^1	Y	25	30	N	N
MANUFACTURING	Y	Y	Y	Y^2	Y^3	Y^4	N
UTILITIES	Y	Y	Y	Y^2	Y^3	Y^4	N
PLAYGROUNDS, NEIGHBORHOOD PARKS	Y	Y^1	Y^1	Y^1	N	N	N
GOLFCOURSES, RIDING STABLES, WATER RECREATION, CEMETARIES	Y	Y^1	Y^1	25	30	N	N
OUTDOOR SPECTATOR SPORTS	Y	Y^1	Y^5	Y^5	N	N	N
INDUSTRIAL, WAREHOUSE, SUPPLIES	Y	Y	Y	Y^2	Y^3	Y^4	N
LIVESTOCK, FARMING, ANIMAL BREEDING	Y	Y	Y^6	Y^7	N	N	N
AGRICULTURAL (EXCEPT LIVESTOCK), MINING, FISHING	Y	Y	Y	Y	Y	Y	Y
RECREATIONAL, WILDERNESS AREAS	Y	Y^1	Y^1	Y^1	N	N	N

NOTES:

Y (Yes) — Land Use and related structure compatible withot restrictions.
N (NO) — Land Use and related structures are not compatible and should be prohibited.

Y^X (Yes with Restrictions) — The land use and related structures are generaly compatible. However, see note(s) indicated by the superscript.

NOTES FOR APPENDIX B - SUGGESTED LAND USE COMPATIBILITY IN NOISE ZONES

1.
a) Although local conditions regarding the need for housing may require residential use in these Zones, residential use is discouraged in DNL 65-69 and strongly discouraged in DNL 70-74. The absence of viable alternative development options should be determined and an evaluation should be conducted locally prior to local approvals indicating that a demonstrated community need for the residential use would not be met if development were prohibited in these Zones.

b) Where the community determines that these uses must be allowed, measures to achieve and outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB in DNL 65-69 and NLR of 30 dB in DNL 70-74 should be incorporated into building codes and be in individual approvals; for transient housing a NLR of at least 35 dB should be incorporated in DNL 75-79.

c) Normal permanent construction can be expected to provide a NLR of 20 dB, thus the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation, upgraded Sound Transmission Class (STC) ratings in windows and doors and closed windows year round. Additional OPNAVINST 11010.36B 19 Dec 2002 consideration should be given to modifying NLR levels based on peak noise levels or vibrations.

d) NLR criteria will not eliminate outdoor noise problems. However, building location and site planning, design and use of berms and barriers can help mitigate outdoor noise exposure NLR particularly from ground level sources. Measures that reduce noise at a site should be used wherever practical in preference to measures that only protect interior spaces.

2. Measures to achieve NLR of 25 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

3. Measures to achieve NLR of 30 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

4. Measures to achieve NLR of 35 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

APPENDIX E

GUAM TRAINING RANGE AREA MAPS

FIGURE E-1. GUAM TRAINING RANGES VICINITY MAP

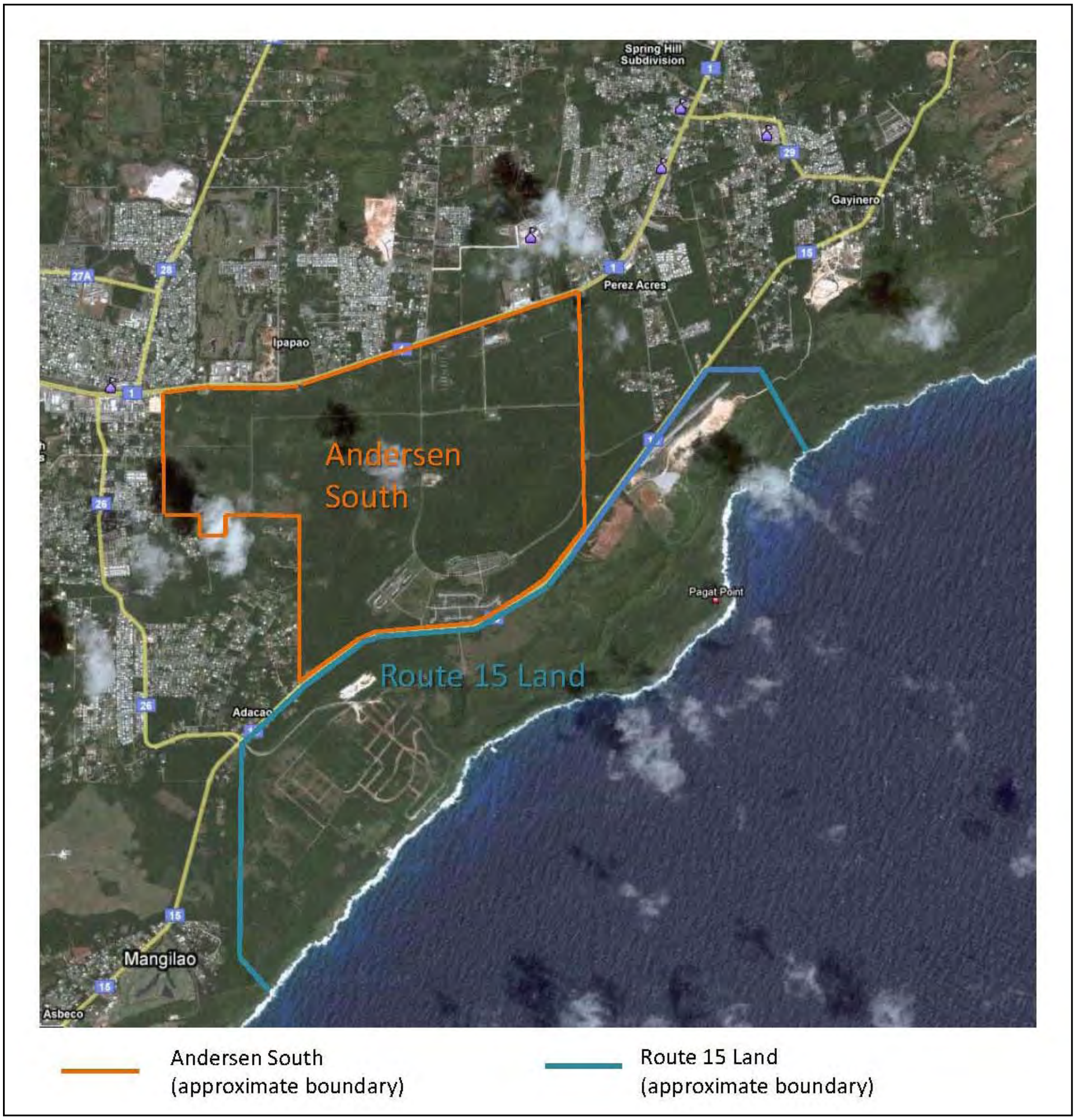

FIGURE E-2. ANDERSEN SOUTH AND ROUTE 15 LAND VICINITY MAP

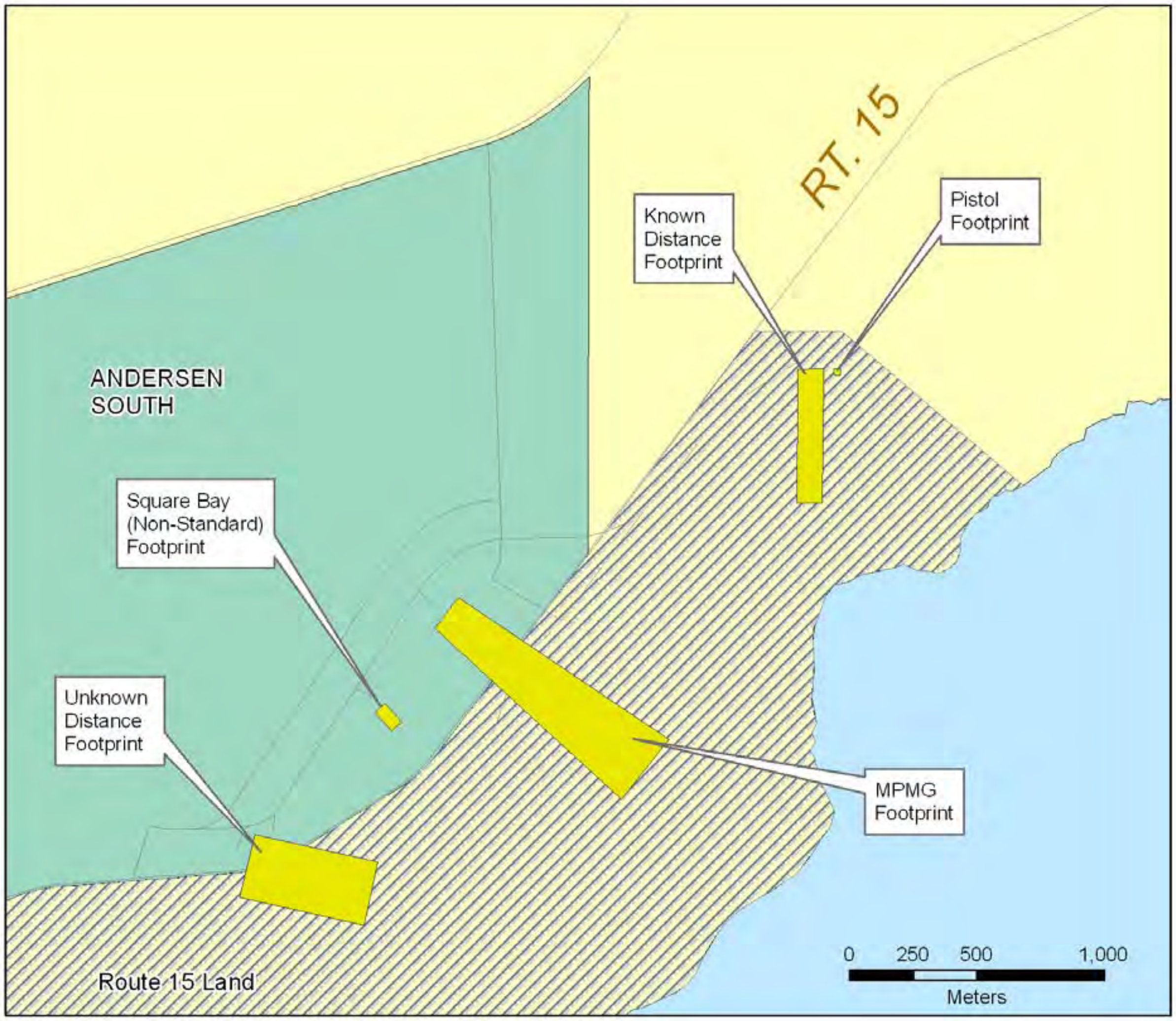

FIGURE E-3. ROUTE 15 ALTERNATIVE A, AUGUST 2009 FOOTPRINT LAYOUT

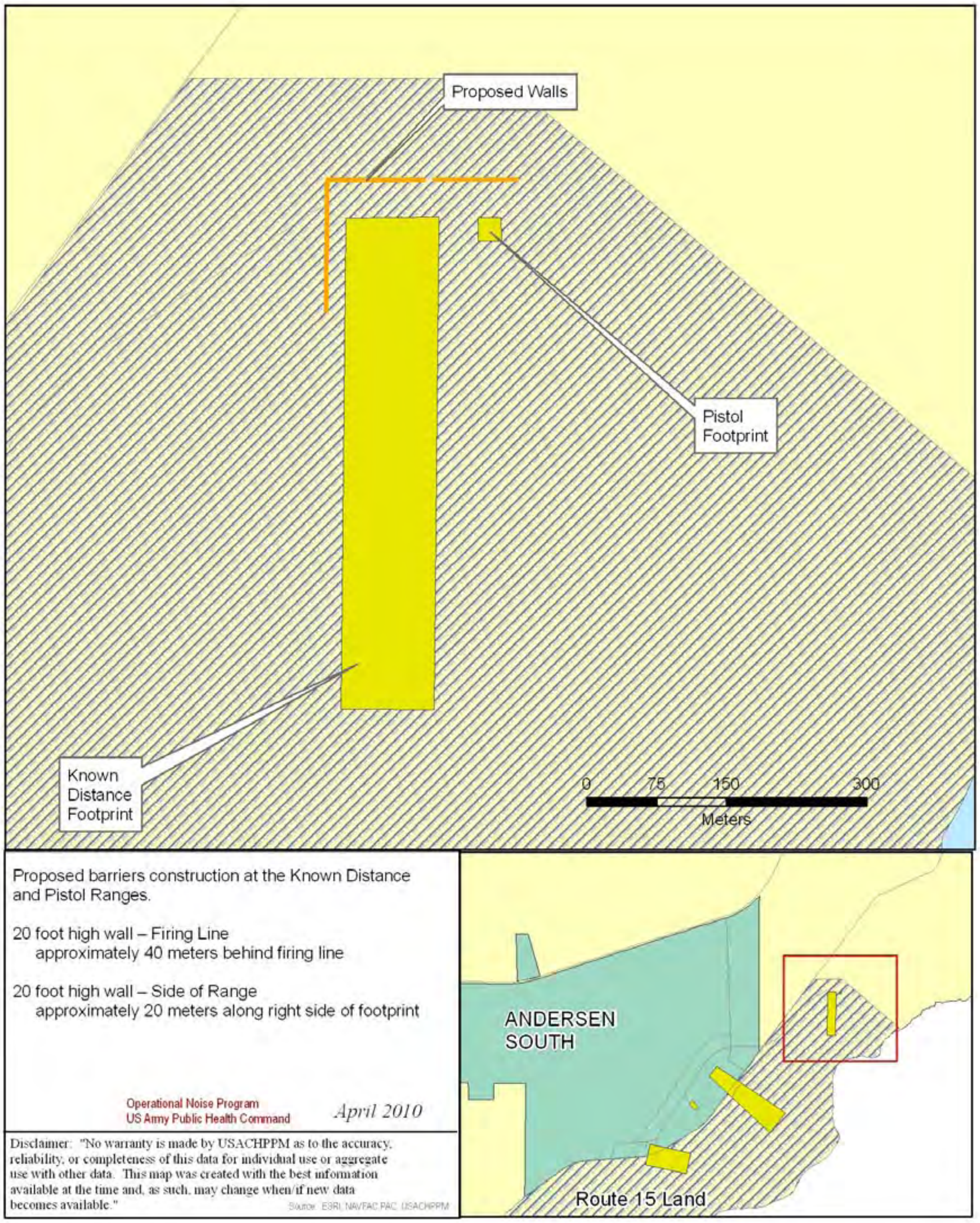

FIGURE E-4. ROUTE 15 ALTERNATIVE A LAYOUT
BARRIER DESIGN PISTOL AND KD RANGES

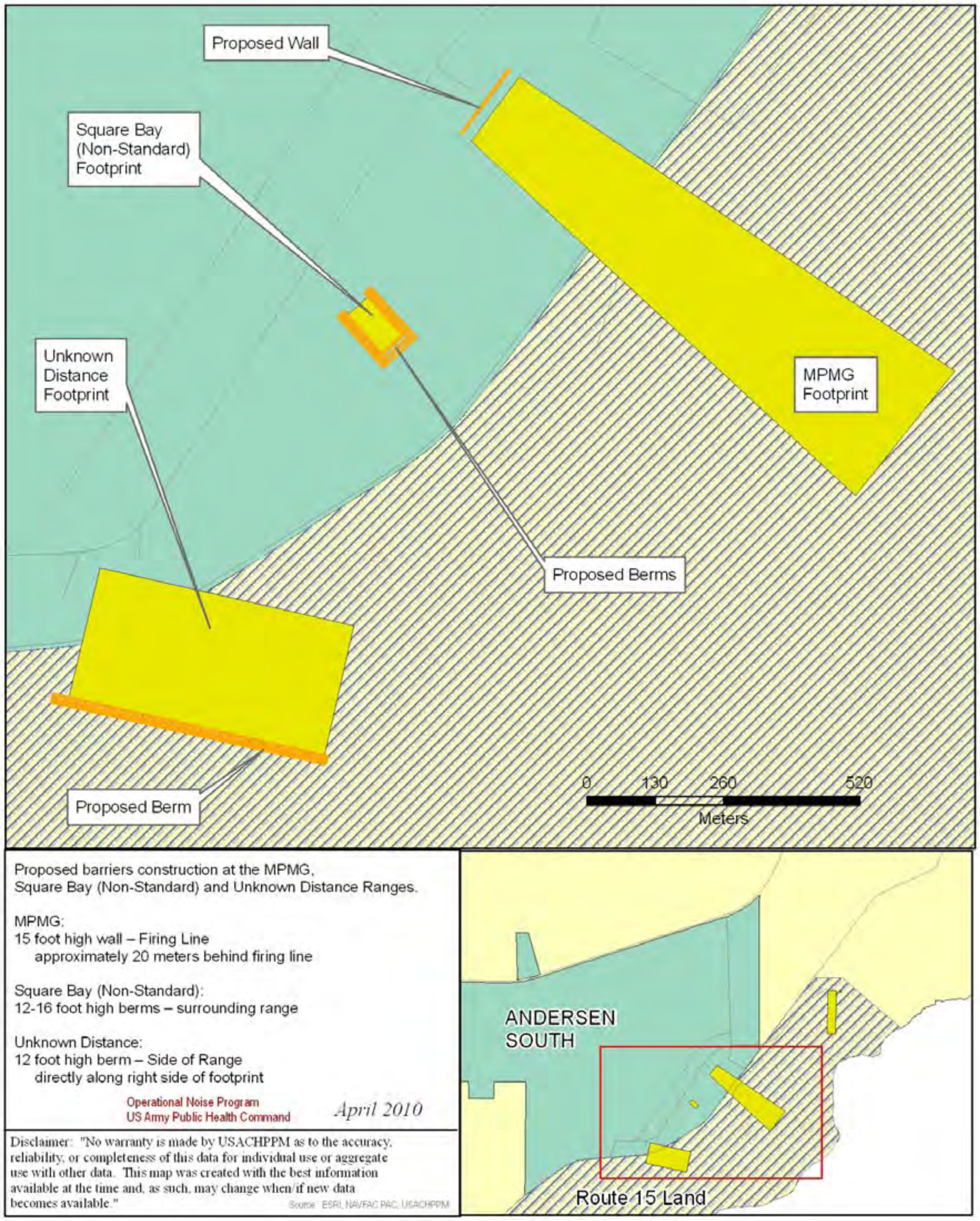

FIGURE E-5. ROUTE 15 ALTERNATIVE A LAYOUT
BARRIER DESIGN MPMG, SQUARE BAY, AND UNKNOWN DISTANCE RANGES

APPENDIX F

GUAM NOISE CONTOURS OVERLAID ON AERIAL IMAGERY

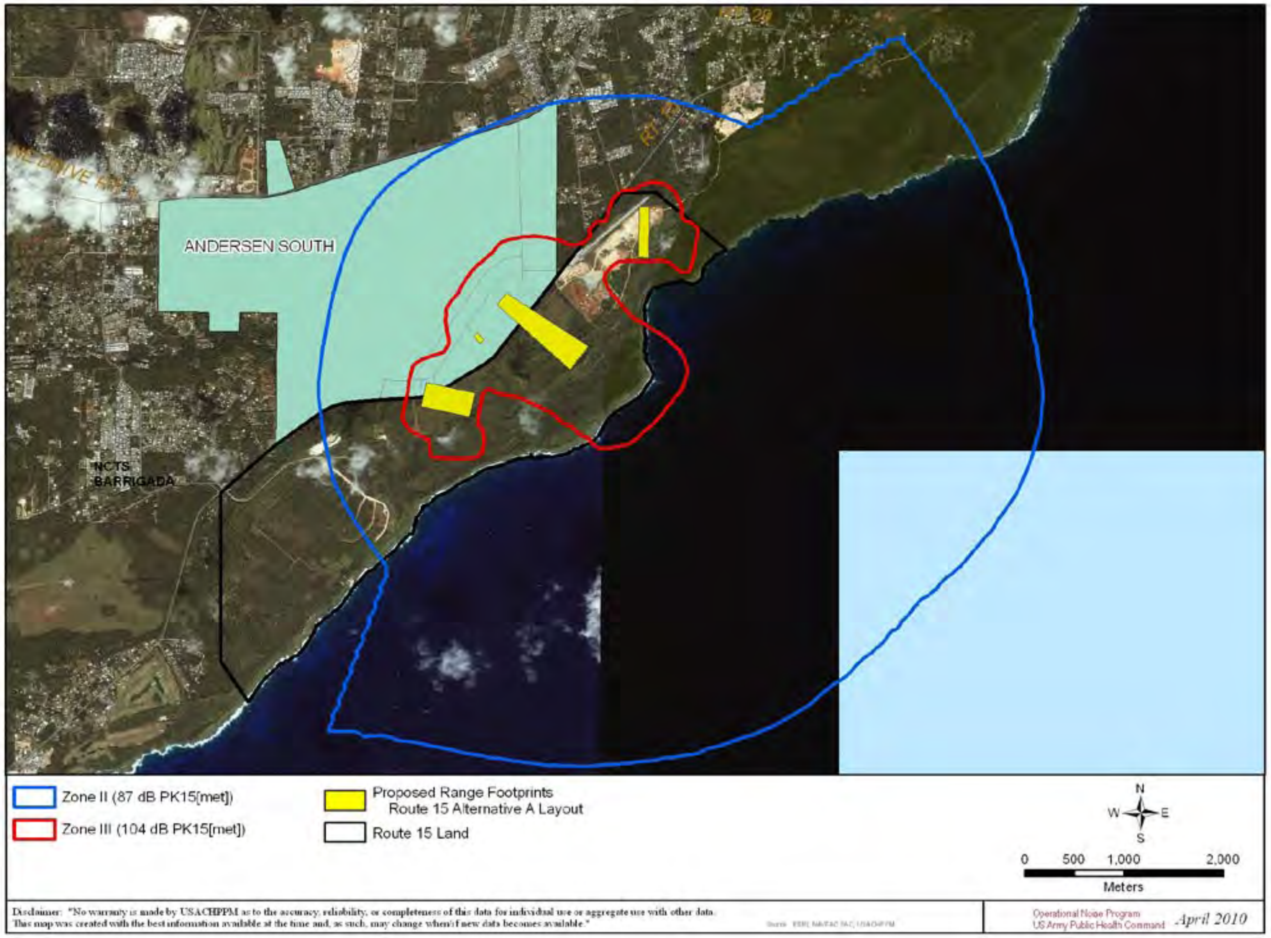

Figure F-1. Route 15 Alternative A, Projected Small Caliber Operational Noise Contours

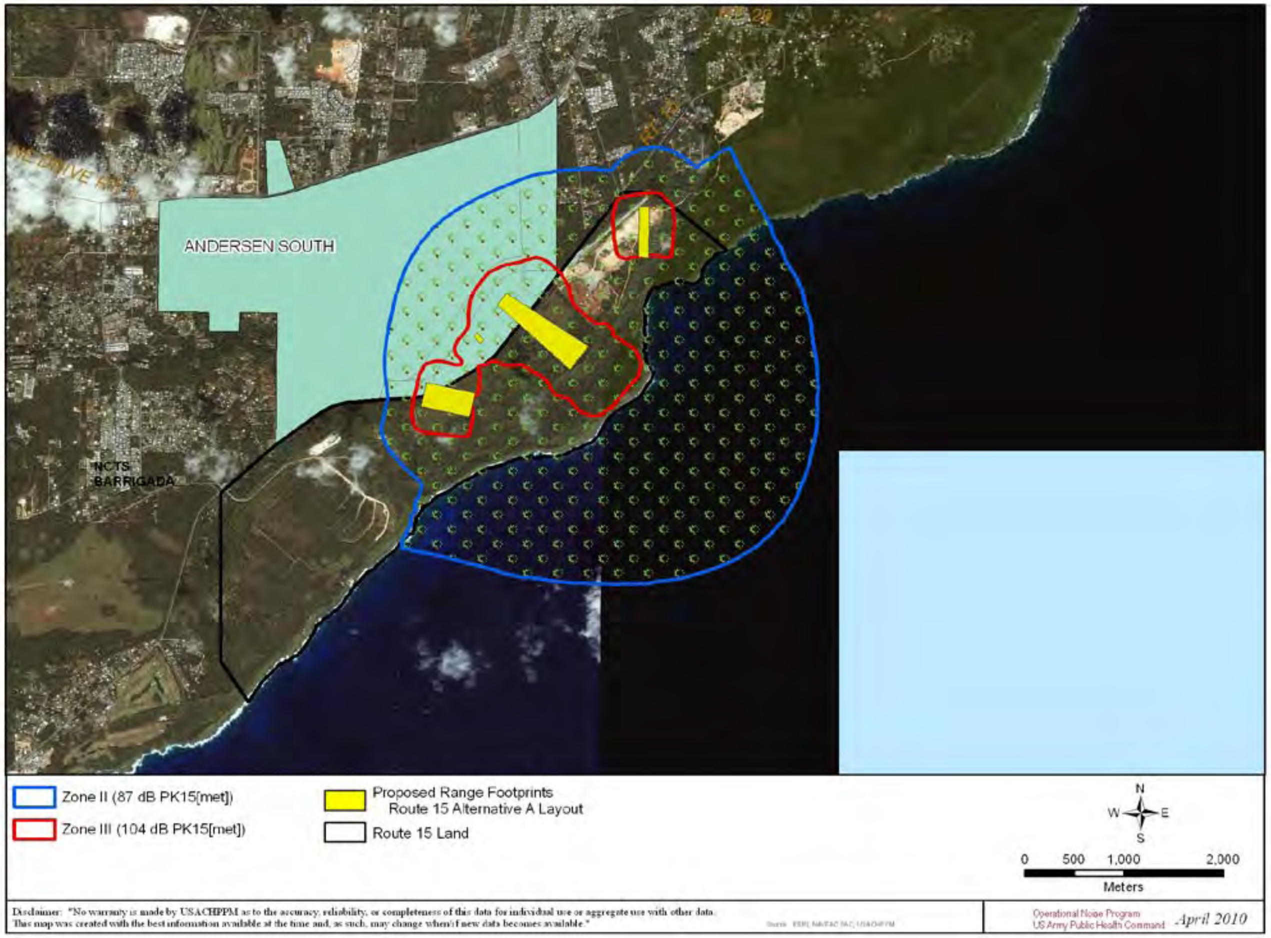

Figure F-2 . Route 15 Alternative A, Projected Small Caliber Operational Noise Contours with Foliage Attenuation

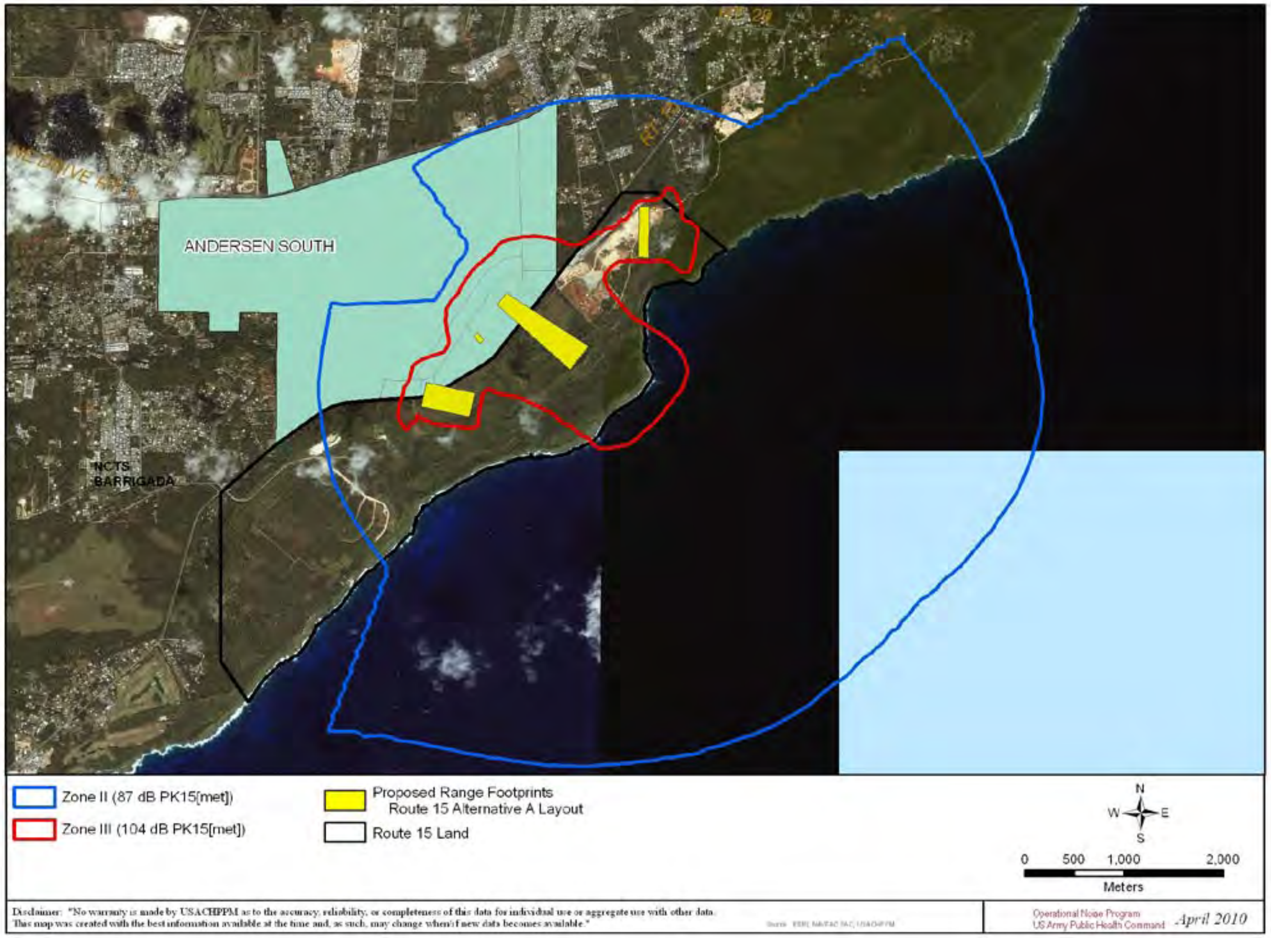

Figure F-3. Route 15 Alternative A, Projected Small Caliber Operational Noise Contours with Barrier Attenuation

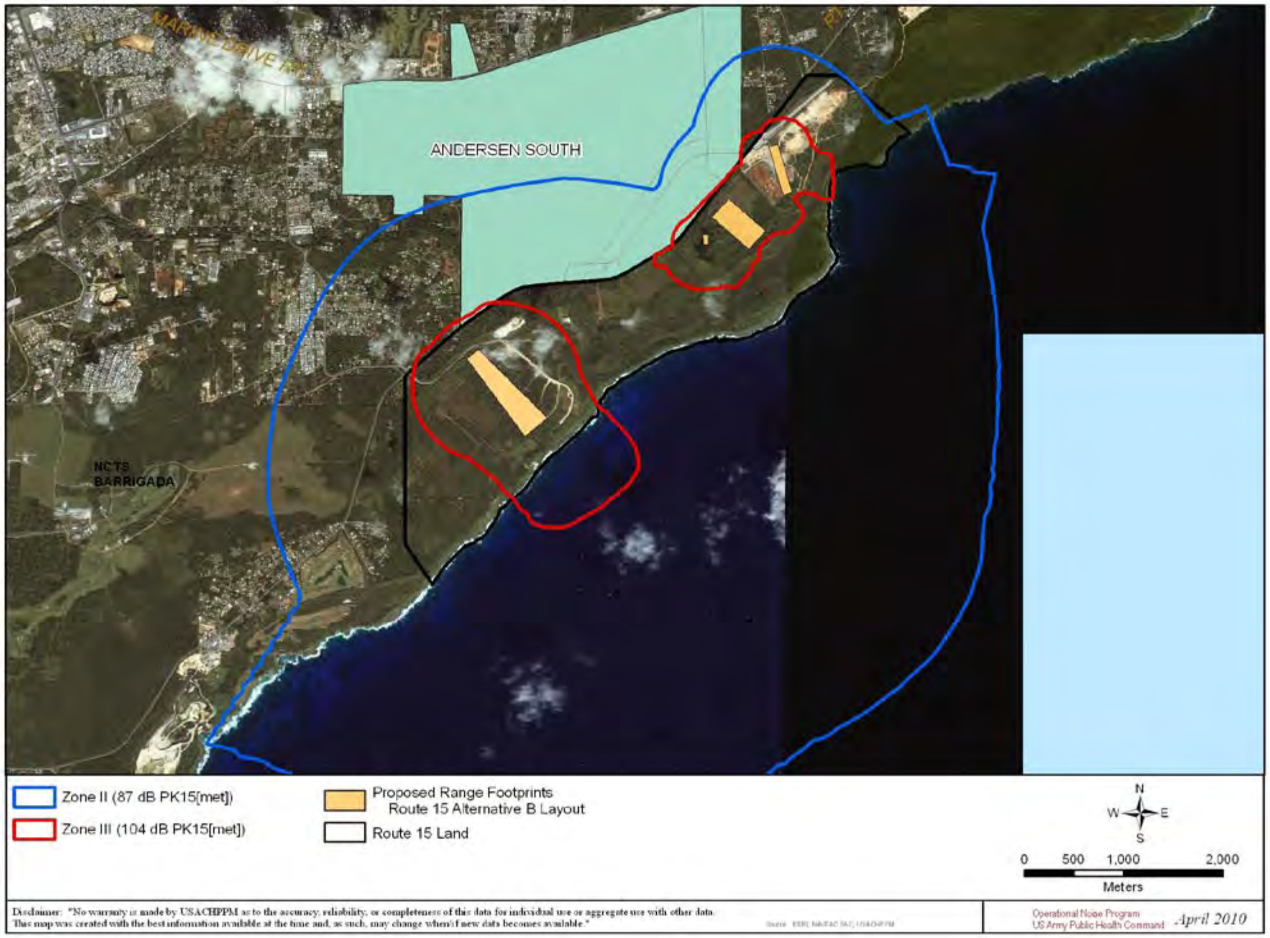

Figure F-4. Route 15 Alternative B, Projected Small Caliber Operational Noise Contours

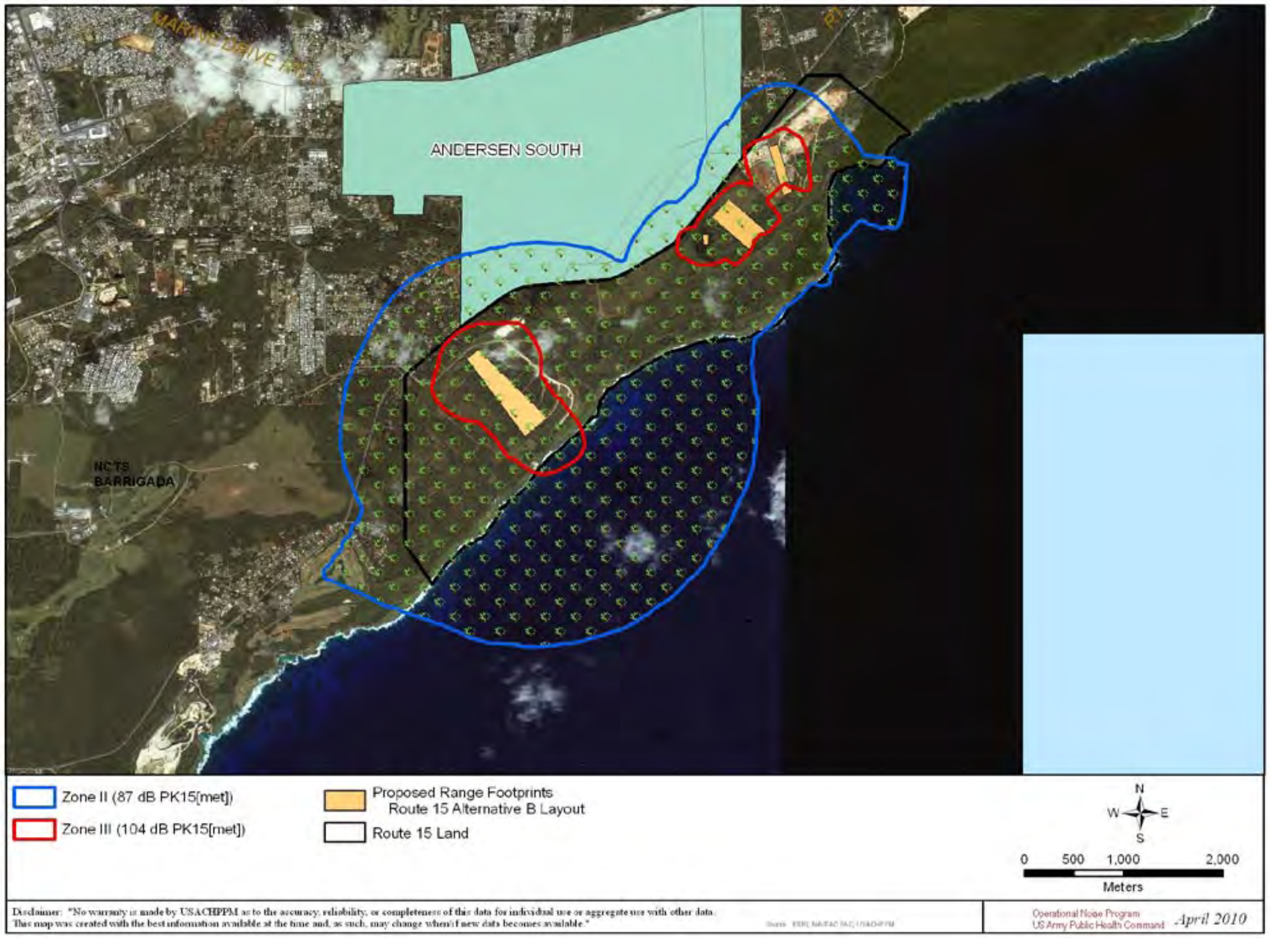

Figure F-5. Route 15 Alternative B, Projected Small Caliber Operational Noise Contours with Foliage Attenuation

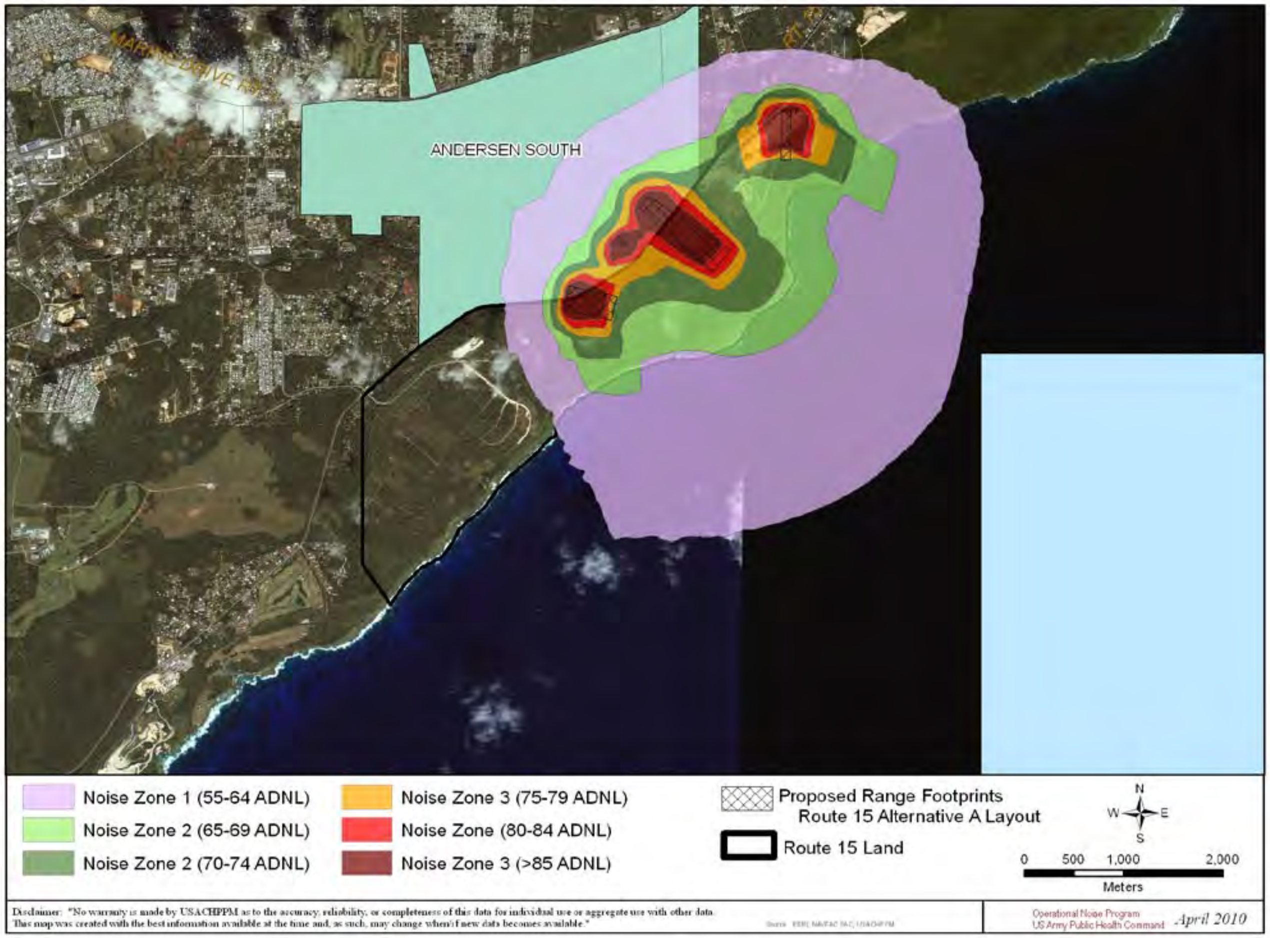

Figure F-6. Route 15 Alternative A, Projected Small Caliber Operational ADNL Noise Contours

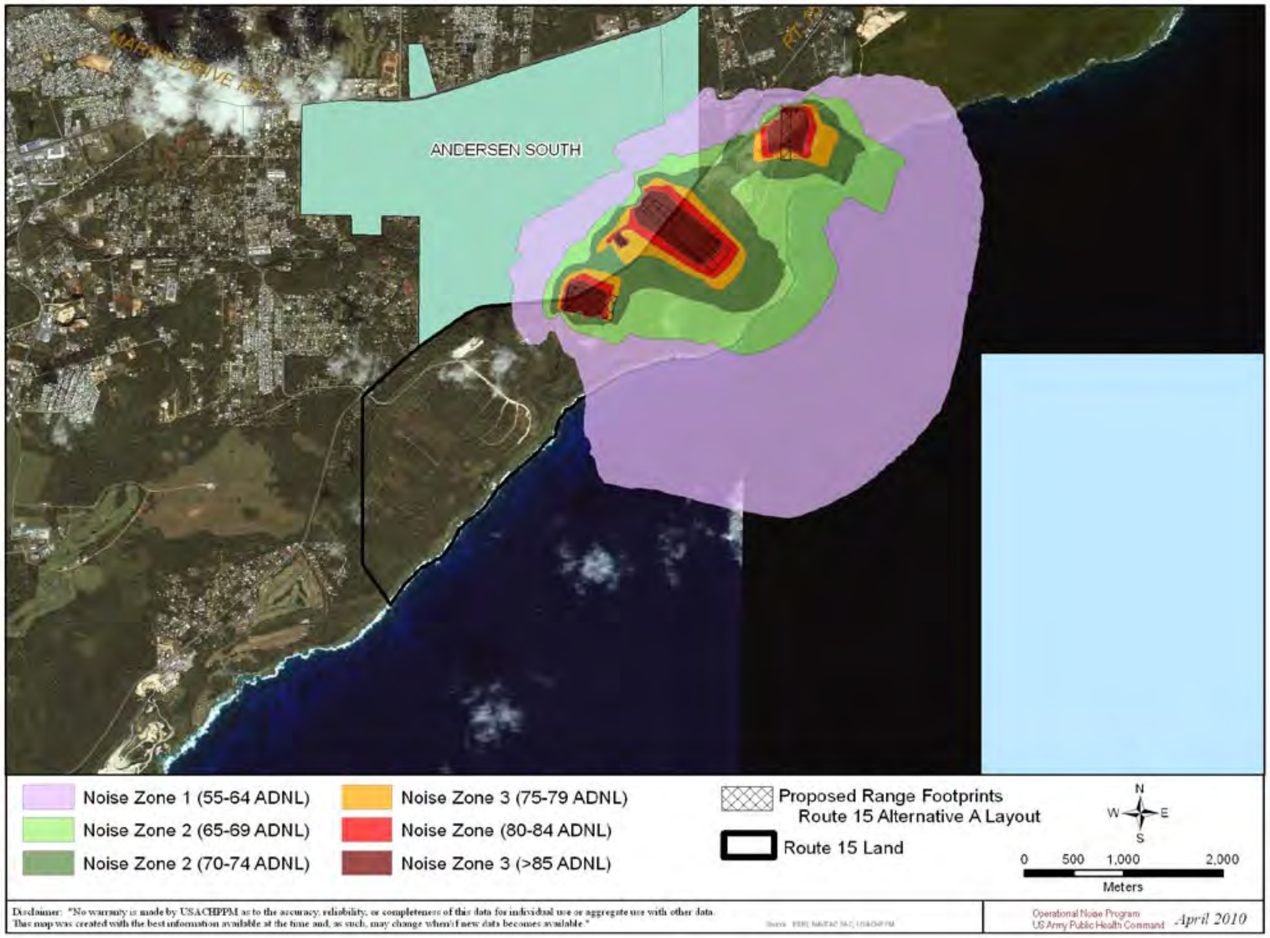

Figure F-7. Route 15 Alternative A, Projected Small Caliber Operational ADNL Noise Contours with Barrier Attenuation

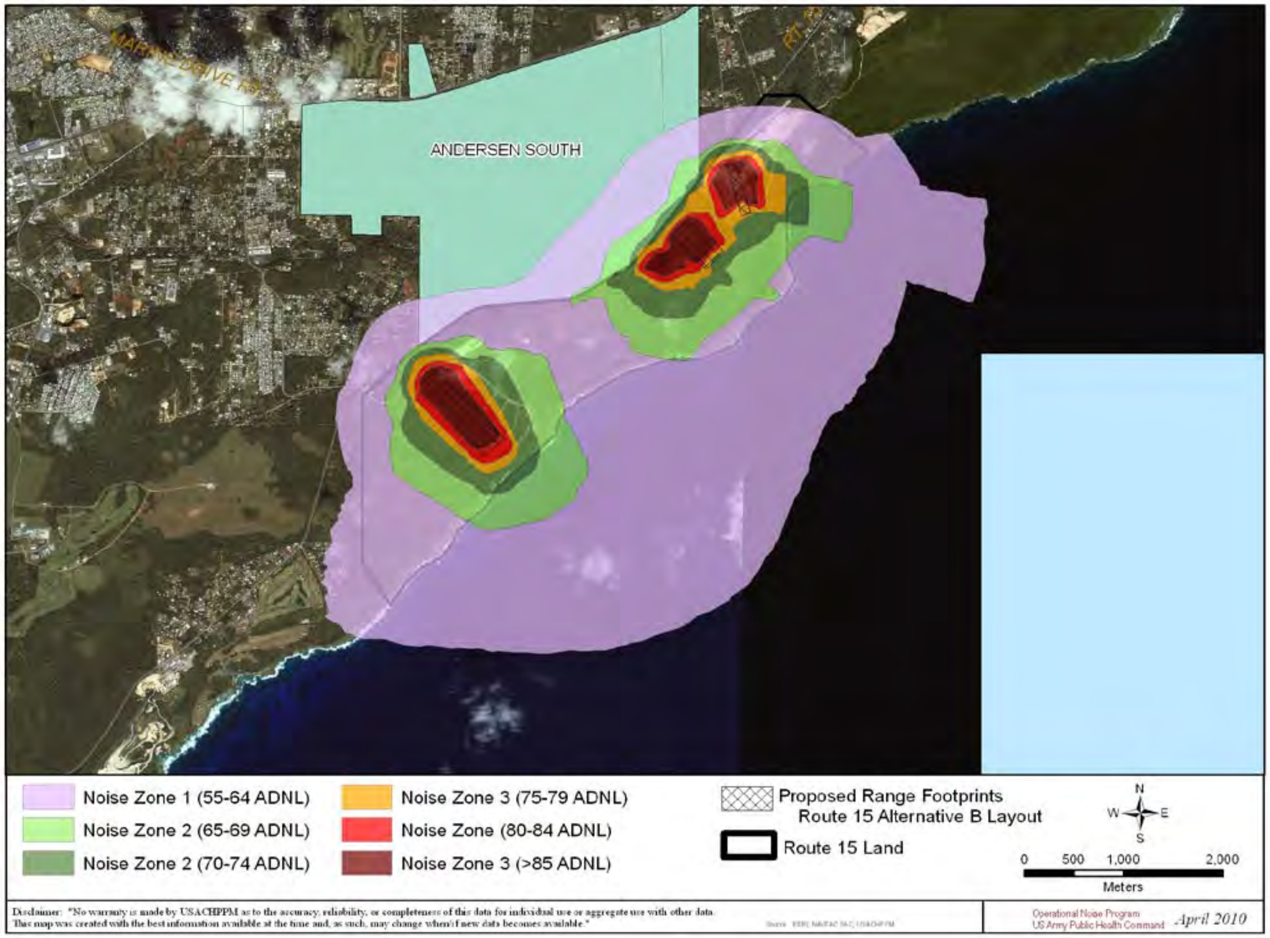

Figure F-8. Route 15 Alternative B, Projected Small Caliber Operational ADNL Noise Contours