CHAPTER 3. GEOLOGICAL AND SOIL RESOURCES

3.1 AFFECTED ENVIRONMENT

3.1.1 Definition of Resource

This chapter discusses existing conditions and assesses how the proposed Guam Relocation action alternatives would potentially affect geological and soil resources within the region of influence (ROI). Geology describes the surface and subsurface materials of which a land area is composed, including soils and rocks. The characteristics of soils and underlying rocks include stability, slope, compatibility, shear strength, and productivity. Discussions of this resource area typically identify existing geological conditions and determine how action alternatives would likely affect geological and soil resources. Because geology and soils relate to the physical foundation of Guam, the proposed land uses associated with the action alternatives would affect characteristics of erosion and surface changes (such as land clearing, slope cuts) but not the overall geological and soil conditions. Instead, geology and soils considerations are more pertinent with respect to the placement or location of a particular land use; for example, a sinkhole could provide an obstacle to establishing a housing land use. Consequently, the geological and soil characteristics of an area would have impact on the proposed action as well as the proposed action impacting the geology.

This chapter is organized to first discuss existing conditions, followed by an analysis and identification of impacts for each alternative and area component (North, Central, Apra Harbor, and South Guam). The chapter concludes with a comparison of impacts among all alternatives and the identification and discussion of any potential mitigation measures if significant impacts have been identified.

3.1.1.1 Geologic Overview

Guam is located on the Mariana Ridge, a volcanic arc approximately 100 miles (mi) (160 kilometers [km]) west of the Mariana Trench. This ridge was formed as a result of subduction of the Pacific Plate, the oceanic plate of the earth's crust, under the Philippine Plate (COMNAV Marianas 2001). See Section 3.1.7 for more details on plate tectonics in this region.

The geology of individual islands in the Marianas is largely dependent on the degree of recent volcanism. The older southern islands, including Guam, generally consist of a volcanic core covered by coralline limestone in layers up to several hundred meters thick. As the original volcanoes subsided beneath the ocean surface, coral formations grew, ultimately forming the limestone caps on these southern islands. The limestone plateaus were formed by alternating sea level heights and wave action. Uplifting of the Philippine Plate resulted in the limestone caps being pushed several hundred meters above sea level. The volcanic core is exposed in some areas through either recent volcanic activities or erosion.

The foundation of the island of Guam is volcanic rock that is covered in limestone over approximately 60% of its surface. The volcanic rock has low permeability due to its texture and poor sorting, while the limestone tends to be highly permeable due to its high porosity (Gingerich 2003).

Guam can be divided into four distinct geophysical regions: (1) the volcanic remnants of south Guam; (2) the deformed beds of the Alutom Formation of central Guam (the Alutom Formation underlies all exposed rocks); (3) the limestone formations of the northern plateau; and (4) the coastal lowlands. A geologic map of Guam is provided in Figure 3.1-1.

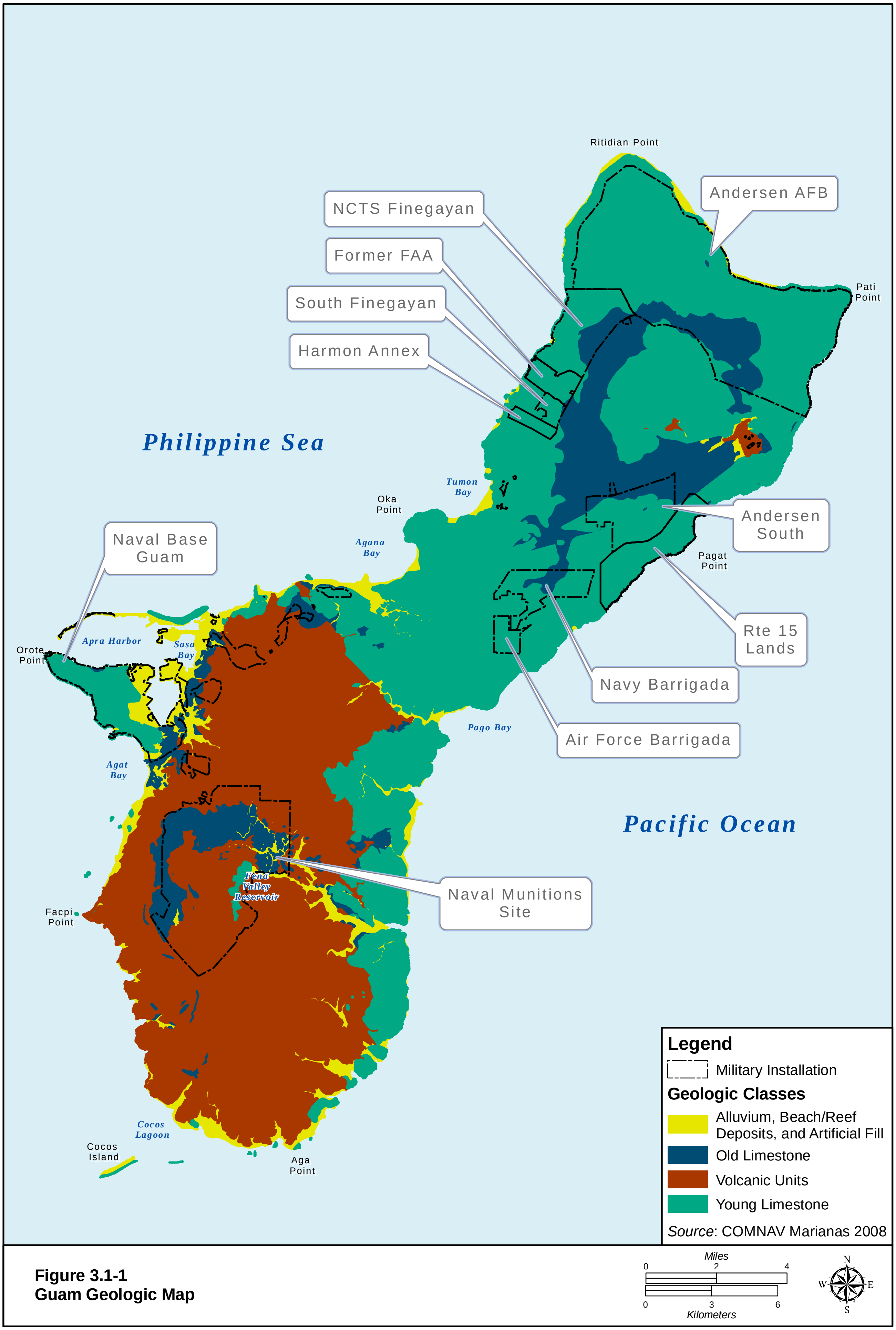

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Figure 3.1-1
Guam Geologic Map

3.1.1.2 Topography

Topography comprises the natural and man-made features of a place or region that shows relative positions and elevations. Topography generally dictates the suitability of land for building purposes, and can be a major factor in defining an appropriate use of an area.

Northern Guam is a flat limestone plateau ranging in elevation from 98 feet (ft) (30 meters [m]) to 482 ft (147 m). There are no permanent streams for surface drainage from this portion of the island because all water percolates through the highly permeable limestone. Seasonal streams exist in times of heavy rainfall. Central Guam is composed of rolling limestone hills and plateaus, while southern Guam is mountainous with numerous rivers running through. Figure 3.1-2 shows Guam's topography, and the differences between the north, central, and southern parts of the island.

3.1.1.3 Geologic Units

A geologic unit is a volume of rock or ice of identifiable origin and age range that is defined by the distinctive, dominant, easily-mapped and recognizable physical characteristics and features that characterize it. Guam comprises seven major geologic units (Gingerich 2003) as summarized below.

All rock units on the island are underlain by the Facpi and Alutom Formations that are volcanic in origin. These formations are exposed over approximately 20% of the island's surface and are found at the highest elevations of northern Guam and on the highlands of central and southern Guam. Contained within these formations are pillow basalts and pyroclastic rocks from tuffaceous shale, conglomerates of coarse boulders, and breccia. Due to their variable composition, the permeability of these formations is low.

The Umatac Formation is exposed over approximately 15% of the island, mainly in the southern and central highlands and plateaus. This formation is underlain by the Alutom Formation. The Umatac Formation increases in thickness moving south to 1,050 ft (320 m) along its southwestern edge. It is composed of reef limestone, tuff breccias, volcanic conglomerate, and basalt flows. The permeability of this unit is low due to its composition.

Overlying the Alutom and Umatac Formations are three limestone units: Bonya and Alifan Limestones, and the Janum Formation. These units cover approximately 5% of the island's surface and range in thickness from 70 ft (21 m) to 200 ft (61 m). The Bonya Limestone and Janum Formation are considered to be permeable but contain only small amounts of water due to their small size. The Alifan Limestone is highly permeable and acts as a feed for perennial springs on the southern part of Guam.

The Barrigada Limestone covers approximately 9% of Guam's surface and contains much of the groundwater in the northern part of the island. The material is highly permeable, formed of fine-grained foraminifera detrial limestone greater than 540 ft (165 m) thick.

The Mariana Limestone covers much of the northern half and parts of the southeastern area of Guam, approximately 45% of the surface area. The material is composed of fore-reef faces and lagoonal limestone that is rich in clay near the uplands. The areas without clay are considered highly permeable due to the abundance of fissures and channels, while permeability in the clay-rich areas is moderate to high. The unit is thickest near the coast and thins to near zero thickness inland.

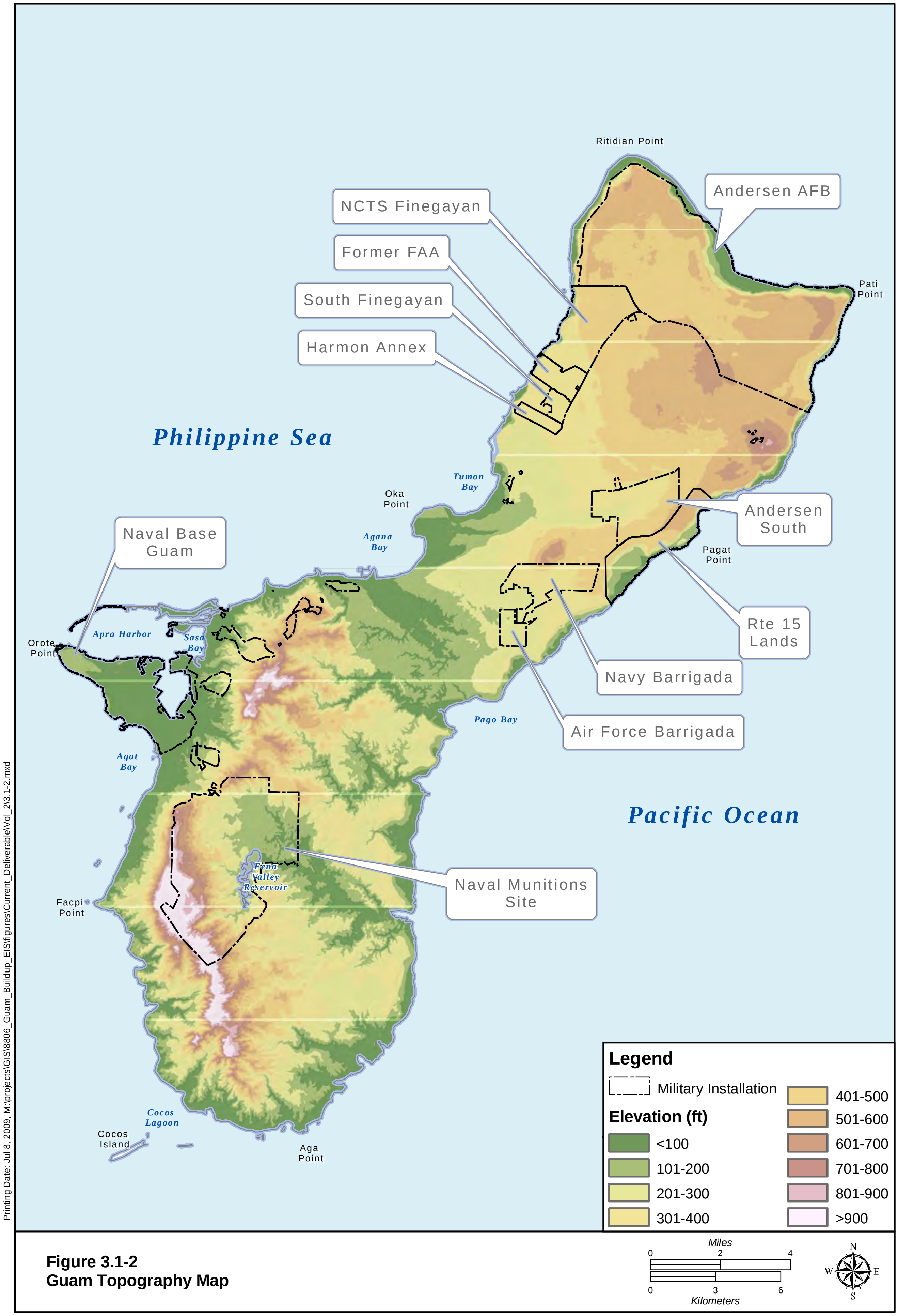

Figure 3.1-2
Guam Topography Map

Approximately 7% of the island surface is covered by reef beach deposits. These deposits are composed of poorly consolidated sediments, the origin of which is calcareous sand and gravel and volcanic sand. Such deposits reach thicknesses up to 200 ft (61 m) near river mouths. Merizo Limestone is composed of reef deposits and may be 12 ft (4 m) in thickness, while stream valleys and coastal lowlands are covered with alluvial clay deposits.

Karst Geology

Karst is a distinctive topography formed by dissolution of underlying soluble rocks by surface water or groundwater. Karst geology occurs when rainwater dissolves carbonate rocks, such as limestone, causing voids including epikarst, sinkholes, and caves in the surface and subsurface. Limestone is a soluble rock, primarily composed of calcium carbonate. Mylroie et al. (1999) discuss karst geology in Guam, including epikarst, sinkholes, and caves.

Epikarst is defined as the upper layer of eroded rock, characterized by rough surfaces, little soil, and small cavities. Epikarst acts as a medium for flow of surface water to the aquifer below either by diffusion or through pits connected directly to the groundwater. Unsaturated epikarst may provide a large amount of water storage in voids. The fast flow of water through the joints and planes of the epikarst does not allow for adsorption, uptake, or microbial processes to remove pollution from groundwater (Islam 2005).

Sinkholes are a result of karst collapse that occurs when material overlying the karst geologic formations subsides down along the karst cavity. Sinkholes are concave areas in the ground surface that act as catchments for surface water. The collected surface water then infiltrates to the aquifer below. Northern Guam has 1,252 identified sinkholes that range in depth to over 98 ft (30 m) and attain lengths of hundreds of feet (Taborosi 2004). Fewer sinkholes are located in southern Guam, with only 197 identified. The largest concentration is found northeast of Fena Reservoir (Taborosi 2004).

Although sinkholes can be hazardous and cause many environmental problems, they also provide an outlet for movement of stormwater. During times of heavy rain, sinkholes support natural ponding; however, severe flooding can occur if a sinkhole is blocked by debris or inundated by excess runoff. Filling sinkholes or using them as receptacles for solid waste increases flooding risk. Additionally, sinkholes may collapse, thereby destroying any structures built above. Subsurface voids must be identified and examined before construction occurs in areas of karst geology (Taborosi 2004). Construction activities are major sources of karst collapse and can occur as a result of excavation, change of drainage patterns, and lowering of groundwater (Islam 2005). Soil disturbance from construction causes deposits to form in openings near the bedrock surface that get heavier when saturated, causing the underlying structure to collapse. Sinkholes are not only relevant to geological processes, they can potentially contain archaeological resources and be culturally significant.

Caves are the third type of karst feature. Three main types of caves are found on Guam: stream caves, pit caves, and flank margin caves. Stream caves are formed through the contact of streams with soluble limestone surfaces and tend to form large springs. They may be found near the Naval Magazine and Mount Alamagosa in the south, or the flanks of Mount Santa Rosa in the north. Pit caves are conglomerations of voids that transport water from the epikarst to groundwater. These caves, although not usually large in size, increase the rate of water transport to the subsurface. Flank margin caves are low, wide chambers that form where the freshwater lens contacts the underlying salt water. Due to their shape and orientation, these caves act as mixing zones for fresh and salt water rather than as water conduits. Figure 3.1-3 shows the locations of sinkholes and caves found across the island.

Karst geology for each of the proposed project areas is described in further detail below.

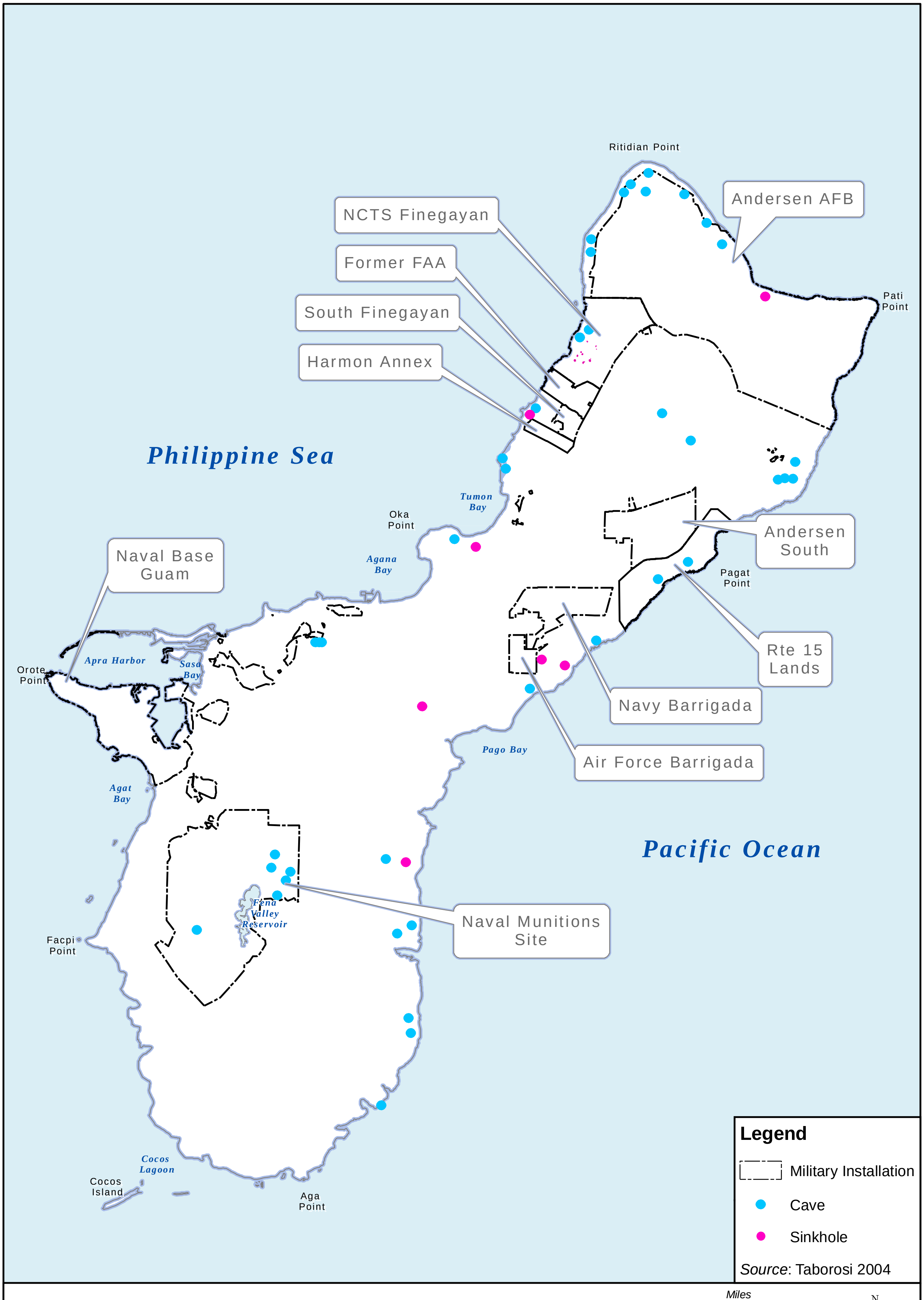

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Figure 3.1-3
Guam Major Sinkholes & Caves

3.1.1.4 Soils

Major soil types found on Guam include laterite (volcanic), riverine mud, coral rock, coral sand, and argillaceous (mixtures of coral and laterite soil). Other minor soil types are also found throughout the island (Figure 3.1-4). Soils on Guam are categorized as: bottomland, volcanic upland, or limestone upland. Soils developed on volcanic rock tend to be poorly drained clays, while soils developed on limestone are usually shallow and highly porous. Soil classes across Guam were identified by the United States (U.S.) Department of Agriculture (USDA) Soil Conservation Service in 1985 (Young 1988) and the descriptions of each soil type are summarized in Table 3.1-1.

Soil types and characteristics dictate the potential for soils to erode. The USDA defines soil erosion as the removal of material from the surface soil that is the part of the soil having an abundance of nutrients and organic matter vital to plant growth. Natural causes of erosion include wind and water, but humans can exacerbate erosion particularly by construction projects (Muckel 2004). During construction, grading and filling are often required; this may reduce soil quality that in turn may affect plant growth and runoff. When topsoil is removed, biological activity decreases, as does the presence of organic matter and plant nutrients, thereby affecting plant nutrition, control of pests and disease, water infiltration, and resistance to erosion. Compaction also typically occurs at construction sites and can also increase erosion potential. Compaction occurs when vehicles drive on and off a construction site and compact the soil beneath it. Compaction can lower rates of water infiltration and inhibit plant growth, both increasing runoff. Typically, construction vehicle tires track mud onto streets and roadways, thereby increasing runoff. It has been reported that erosion potential on construction sites are approximately 100 times greater than on agricultural land (Muckel 2004).

Table 3.1-1 shows soil erodibility factors for soils found across Guam. A soil’s erodibility factor (K) represents both its susceptibility to erosion and it’s runoff rate, and is determined using a standard plot 72.6 ft (22.1 m) long on a 9% slope (USDA1978, 1996). K denotes the vulnerability of a soil to sheet and rill erosion and is a factor of the Universal Soil Loss Equation (USLE). The value is based on percentage of silt, fine sand, sand, and organic matter, soil structure and permeability. The higher the K value, the more susceptible the soil is to sheet and rill erosion (Young 1988).

Table 3.1-1. Soils Across Guam

Soil Class	*Soil Description*	*Runoff Rate*	*Permeability*	*Erodibility Factor (K)*	*Soil Category*
Inarajan - Inarajan Varient	Deep and very deep, somewhat poorly drained and poorly drained, level and nearly level soils; on valley bottoms and coastal plains	Medium	0.02 – 0.5	0.24	Bottom Lands
Akina	Very shallow to very deep, well drained, moderately steep to extremely steep soils; on strongly dissected mountains and plateaus	Slow	1.5 – 5.0	0.20	Volcanic Uplands
Agfayan	Very shallow to very deep, well drained, moderately steep to extremely steep soils; on strongly dissected mountains and plateaus	Slow	0.5 – 1.5	0.20	Volcanic Uplands
Togcha	Very deep, somewhat poorly drained and well drained, gently sloping soils, on plateaus and in basins	Slow	0.5 – 1.5	0.15	Volcanic Uplands
Chacha – Chacha Varient	Shallow, deep and poorly drained, and found on steep slopes: plateaus and hills	Medium	0.02 – 0.5	0.15	Limestone Uplands

Soil Class	*Soil Description*	*Runoff Rate*	*Permeability*	*Erodibility Factor (K)*	*Soil Category*
Guam Cobbly Clay Loam	Very shallow, well drained, nearly level to moderately sloping soils; on plateaus	Slow	5.0 – 15.0	0.05	Limestone Uplands
Guam Urban Land	Very shallow and shallow, well drained, level to gently sloping soils, and Urban land; on plateaus	Slow	5.0 – 15.0	0.05	Limestone Uplands
Ritidian - Rock outcrop	Very shallow, well drained, gently sloping to extremely steep soils, and rock outcrop; on plateaus, mountains, and escarpments	Very slow	5.0 – 15.0	0.02	Limestone Uplands
Pulantat	Shallow, well drained, gently sloping to steep soils; on dissected plateaus and hills	Medium	0.02 – 0.5	0.24	Limestone Uplands
Pulantat – Kagman - Clay	Shallow, deep, and very deep, somewhat poorly drained and well drained, nearly level to strongly sloping soils; on plateaus and hills	Medium	0.02 – 0.5	0.15	Limestone Uplands
Ylig	Very deep, somewhat poorly drained and well drained, gently sloping soils, on plateaus and in basins	Medium	0.5 – 1.5	0.24	Volcanic Uplands
Shioya Loamy Sand	Deep, rapidly permeable, well drained soil on coastal strands.	Slow	15.0-50	0.15	Coastal Limestone Sands

Source: Young 1988.

Table 3.1-1 shows that Inarajan Variant and Pulantat soils have the highest K values (0.28, 0.24, 0.28) and are the most vulnerable to sheet and rill erosion. These soil types are found in southern Guam near Naval Base Guam and the Naval Munitions Site (NMS). Young (1988) uses USLE to describe physical and chemical properties of soils. The equation was created to predict the long term average annual rate of erosion on a field slope based on rainfall patterns, soil type, topography, crop system, and management practices. USLE predicts the amount of soil loss that results from sheet or rill erosion on a single slope. Sheet erosion describes uniform removal of soil in thin layers, while rill erosion is the removal of soil by condensed water running through small streams.

Fire

Wildfire is a significant cause of increased soil erosion on Guam. Prior to the arrival of humans, Guam seldom experienced wildfire due to environmental conditions unfavorable to fire ignition. The introduction of anthropogenic fire has lead to the expansion of savanna vegetation (Athens and Ward 2004) and may be aiding the spread of invasive species, particular grasses that are tolerant of and promote further burning. The presence of savanna vegetation instead of forest contributes to elevated soil loss, as erosion in savanna areas may be 100 times higher than in scrub forest.

Even 18 months following a burn, after vegetation had returned to pre-burn levels of biomass, soil loss from burned savanna was twice as high compared to unburned savanna because of changes in species during revegetation (Minton 2005).

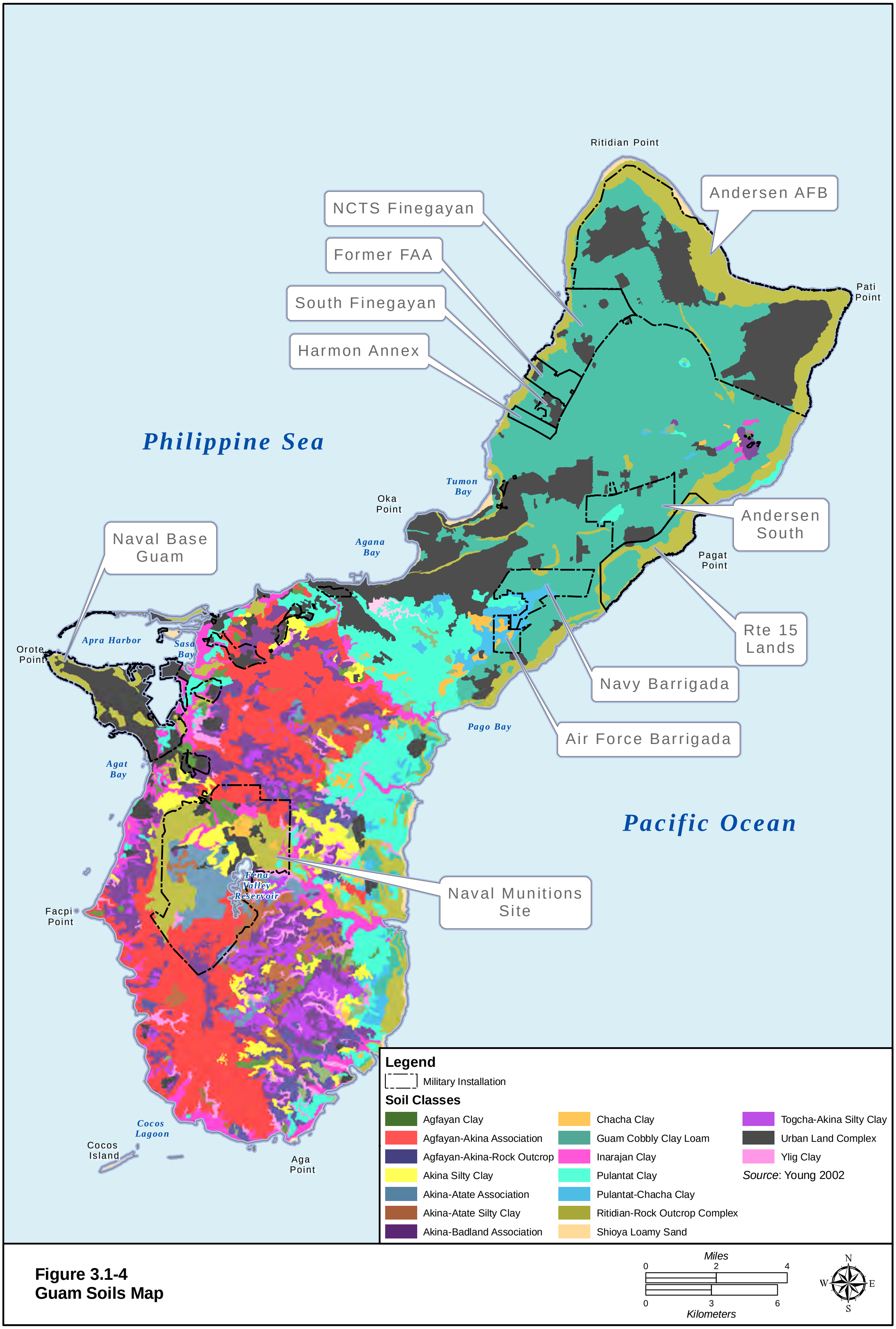

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Figure 3.1-4
Guam Soils Map

Fire history records available from 1979 – 2002 indicate that over this 23-year period more than 16,000 fires have occurred in Guam (averaging more than 700 per year) that have burned in excess of 100,000 acres (ac) (40,469 hectares [ha]). For the same period on Naval Base Guam, primarily at Apra Harbor and NMS, the number of fires was 477 (just over 21 per year) burning more than 9,800 ac (3,966 ha) (Brooke 2008).

Fire has become an integral part of the local culture, particularly among game hunters. Hunters set fires because deer are attracted to new vegetation that occurs during succession. While local laws exist criminalizing wildland arson (9 Guam Code Annotated §34.20), fire use has not slowed. Enforcement and prosecution are sporadic at best.

3.1.1.5 Geologic Hazards and Seismicity

Seismic Activity

Many geological phenomena, such as earthquakes, tsunamis, and volcanic eruptions, originate in areas where plates meet (U.S. Geological Survey [USGS] 2008). The Marianas are positioned where the Philippine and Pacific Plates converge.

Earthquake activity is common on Guam and across the entire Mariana Island chain (Lander et al. 2002). Earthquake is a term used to describe the sudden slip of a fault that results in ground shaking and radiated seismic energy caused by the slip, volcanic or magmatic activity, or other sudden stress changes in the earth (USGS 2008).

Faults, the cause of seismic activity, zigzag across Guam and are the result of collisional stresses and rock failure, where the Philippine Plate and the Pacific Plate converge (Siegrist et al. 1998). A fault is defined as a bedrock fracture along which opposite sides have moved. Fault activity on Guam can be inconsistent and unpredictable, and ultimately dependent on the angle that the Philippine Plate collides with the Pacific Plate, the rate of subduction, and the dip in the Benioff Zone (Siegrist et al. 1998). The USGS defines the Benioff Zone as a dipping flat zone of earthquakes produced by the interaction of a downgoing oceanic crustal plate with a continental plate. These earthquakes can be produced by: (1) a slip along the subduction thrust fault, or (2) a slip on faults within the downgoing plate as a result of bending and extension as the plate, is pulled down.

Fault types differ across Guam. Normal faults, or dip-slip faults, are inclined fractures where the blocks have mostly shifted vertically. If the rock mass above an inclined fault descends, the fault is termed normal; however, if the rock above the fault ascends, the fault is termed reverse (USGS 2008). Strike-slip faults are vertical (or nearly vertical) fractures where the blocks have mostly moved horizontally. Figure 3.1-5 shows the fault lines that run across Guam. The figure shows that the Adelup Fault Zone separates southern Guam from the limestone plateau of northern Guam. The Tamuning-Yigo Fault runs south-southwest from the Mount Santa Rosa Fault Zone to the Tamuning-East Agana boundary. The Talofofo Fault Zone is made up of multiple parallel normal faults, and runs from the Pacific Ocean at Talofofo embayment west-northwest past the NMS, and is assumed to continue along the southern coast of Orote Peninsula. The Cocos Fault strikes along the southern coast.

Landslides

The effects of an earthquake are typically local, but they can also affect areas beyond its origin. Local effects may include slope failures and landslides, predominantly in limestone terrain. The tropical weather on Guam, which includes high precipitation and annual storms, rapidly weathers and easily erodes the volcanic rock found on the island. Slope destabilization and landslides often occur from a combination of

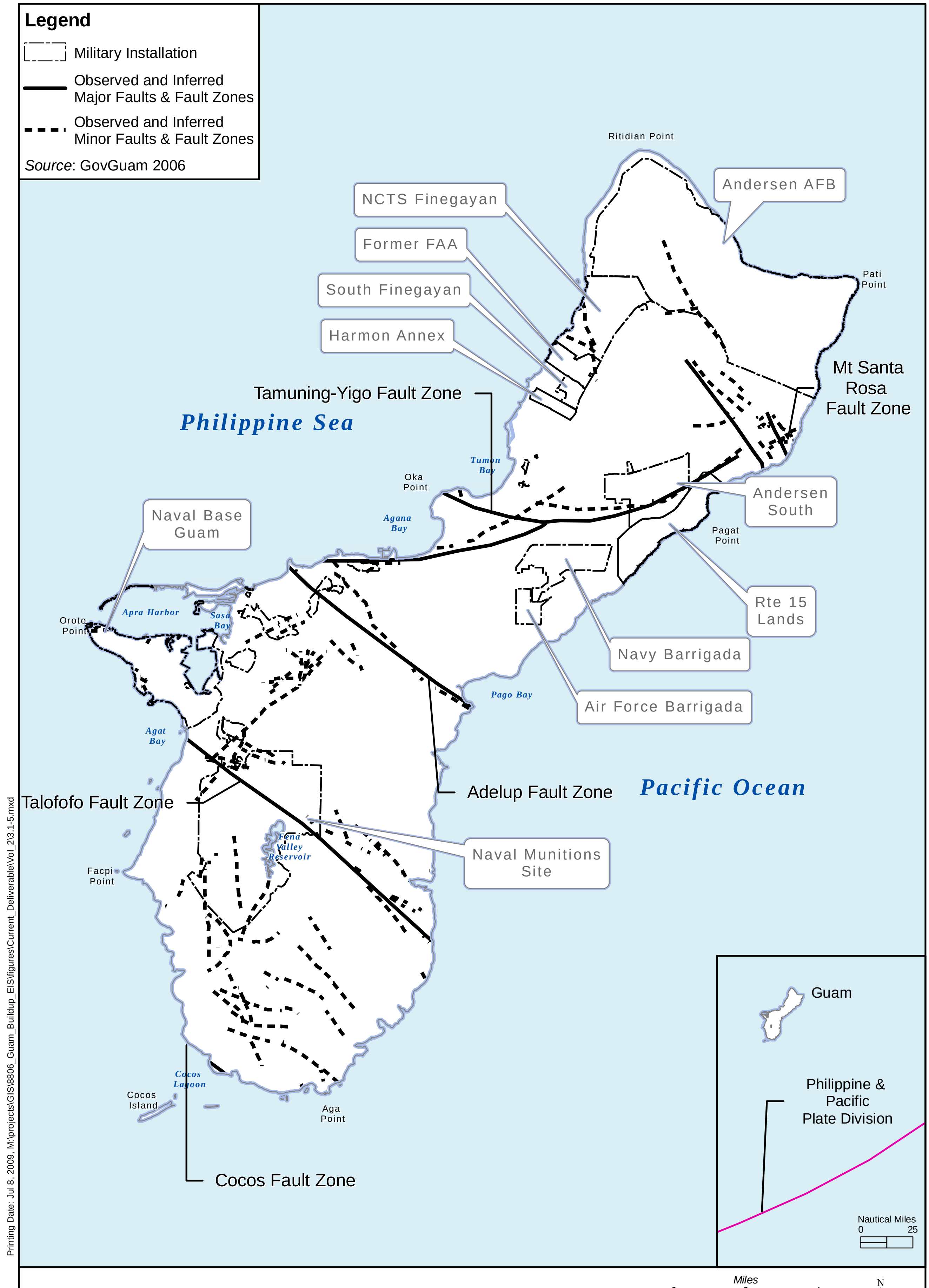


Figure 3.1-5
Guam Fault Lines

natural events, and seismic activity usually destabilizes a slope. When destabilization is followed by heavy rainfall, the destabilized slope is saturated, and slides result.

Limestone boulders commonly slide and tumble down steep inclines and fall off fault cliffs in northern Guam. Several localized rockfalls, rockslides, and boulder slides occurred on the plateau following a quake on August 8, 1993, and several others have occurred within earthquake weakened rock sections during heavy rains. On Marine Drive in East Agana, a small rockslide destroyed several parked vehicles. One large fall-slide combination destroyed the coastal spring at Janum on the northeast coast. Additionally, a major rockfall at Mergagan Point on the north coast closed a large popular sea cave on the edge of Andersen Air Force Base (AFB) (Siegrist et al. 1998).

Potential landslide occurrence depends on thegeology, the angle of a slope, groundwater depths, rainfall, and local geologic structures (e.g., faults and joints). According to the Guam Hazard Mitigation Plan (GHMP) (GovGuam 2008), the most appropriate approach to defining landslide hazard risks on Guam involves determining the vulnerability of an area based on geologic units mapped at the surface (see Section 3.1.2). Vulnerability has been determined by the geology and the slope angle of the various specific areas on the island (Table 3.1-2). The GHMP uses these two factors to develop a qualitative rating of the potential of an area for a landslide to occur. The potential ratings in the GHMP are expressed as high, moderate to high, moderate, and low (Table 3.1-2).

Table 3.1-2. Risk Potential for Landslides to Occur

Slope Angle	*Potential Risk of Landslide*
Less than 5%	Low potential regardless of geologic deposits
30% or more	Moderate to high

Source: GovGuam 2008.

Approximately 47.2 square mi (mi^2) (122.25 square km [km^2]), or 22.5%, of Guam have a very high potential for landslides. About 9.3 mi^2 (24 km^2), or 4.4% of the island, have a high potential. 37.6 mi^2 (97.4 km^2), or 17.9 % have a moderate potential and 116.3 mi^2 (301 km^2), or 55.4%, have a low potential (GovGuam 2008).

The overall likelihood for landslides to occur on northern Guam is generally low, and the landslide potential for southern Guam is mostly moderate to high. The sea cliffs and cliff faces at the coastline along the perimeter of northern Guam have a high potential for landslides. Aside from these cliff faces and a moderate to high potential along the flanks of Mount Santa Rosa, the remainder of northern Guam is primarily flat. In general, the limestone geology of this area has a low potential for landslides.

The relatively flat areas along the east coast of northern Guam and the flat areas of Apra Harbor have a low potential for landslides.

Liquefaction

Another effect of seismic activity is liquefaction, a process where water-saturated sediment temporarily loses strength and acts as a fluid (USGS 2008).

Due to the high potential for strong seismic events to occur in and around Guam, there is a relatively consistent probability of occurrence for liquefaction and lateral spreading throughout the island (GovGuam 2008). However, certain conditions and geological units are more susceptible to liquefaction than others. Geologic information and historical occurrences are the only data available to determine susceptibility to liquefaction.

GHMP reports that 14 mi^2 (36 km^2) of Guam have a potential risk for liquefaction. About 0.5 mi^2 (1.3 km^2), or 0.3% of Guam, mainly located around parts of Apra Harbor, have a very high risk of liquefaction. This is the area with the greatest historical record of liquefaction. Large areas of Apra Harbor contain widespread areas of fill. Areas with a high risk of liquefaction include parts of Tumon Bay and the northern portion of Andersen AFB. Approximately 2.8 mi^2 (7.3 km^2), 1.3% of Guam, is at high risk of liquefaction (GovGuam 2008). Approximately 7.3 mi^2 (18.9 km^2), or 3.5% of Guam, have moderate risk of liquefaction (GovGuam 2008).

The only known incidence of liquefaction on Guam is from the 7.8 magnitude earthquake of August 1993, when liquefaction occurred at Apra Harbor and in downtown Agana (GovGuam 2008). Liquefaction occurred in areas where coral fill overlaid fine-grain estuarine deposits. At the commercial port at Apra Harbor, horizontal displacement of up to 24 inches (in) (61 centimeters) occurred and cracks measuring up to 8 ft (2.4 m) deep and up to 300 ft (91.4 m) long (GovGuam 2008). At Navy port facilities at Apra Harbor, most wharves were damaged by liquefaction, and the damage was estimated at $25.15 million (GovGuam 2008). Liquefaction at Piti Power Plant caused up to 4 ft (1.2 m) of settlement (GovGuam 2008).

Tsunamis

Earthquakes and landslides can cause big wave events called tsunamis. A tsunami is a sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine slides, or exploding volcanic islands (USGS 2008). Table 3.1-3 shows a history of tsunamis on Guam, their location, the vertical run-up of the wave, the location of the earthquake that caused the event, and the magnitude of the earthquake. According to Lander et al. (2002), the impacts of a local tsunami would most likely occur on Guam's east coast, due to the eastern location of the Mariana Trench, the origin of many local earthquakes. If a tsunami has a southern origin it can impact both the west and east coast of Guam (Lander et al. 2002).

Table 3.1-3. Historic Tsunamis on Guam

Date	*Tsunami Location*	*Vertical Run-up ft (m)*	*Earthquake Location*	*Magnitude (Modified Mercalli Scale [MM])*
1819	Guam, Mariana Islands	-	Mariana Islands	-
24 June 1849	Guam, Mariana Islands	11.5 (3.5)	Mariana Islands	7.5
16 May 1892	Agana, Guam	-	Guam, Mariana Islands	7.5
Feb 1903	Guam, Mariana Islands	-	Philippines	-
9 Dec 1909	Guam, Mariana Islands	-	Guam, Mariana Islands	8.1
4 Mar 1952	Apra Harbor, Guam	0.03 (0.1)	SE. Hokkaido Island, Japan	8.1
4 Nov 1952	Guam, Mariana Islands	0.03 (0.1)	Kamchaka, Russia	8.2
9 Mar 1957	Guam, Mariana Islands	0.03 (0.1)	Central Aleutian Islands, Alaska	8.3
22 May 1960	Guam, Mariana Islands	0.07 (0.2)	Central Chile	8.6
13 Oct 1963	Guam, Mariana Islands	0.03 (0.1)	Kuril Islands, Russia	8.1
28 Mar 1964	Guam, Mariana Islands	0.03 (0.1)	Gulf of Alaska-Alaska Pen.	8.5
8 Aug 1993	Pago Bay, Guam	-	Guam, Mariana Islands	8.2

Note: MM = Modified Mercalli scale that measures earthquake intensity.
Source: National Geophysical Data Center as reported in GovGuam 2008.

The band of coral reef that surrounds Guam provides protection from tsunamis, and the steep slope of the ocean floor surrounding the island lowers the risk of significant wave run-up. Therefore, the possibility of a large tsunami causing extensive damage on Guam is generally low (GovGuam 2008).

The maximum reported vertical run-up on Guam was approximately 11.5 ft (3.5 m) in an 1849 tsunami event. GHMP reports that the area most prone to large tsunamis are landmasses below 16.4 ft (5 m) in mean sea elevation, which encompasses 10.8 mi^2 (28 km^2), 5.2% of the island. The project area most vulnerable to potential tsunami impacts is Apra Harbor (GovGuam 2008).

The Pacific Tsunami Warning Center considers the tsunami evacuation safety zone to be above 30 ft (9 m) elevation and over 100 ft (30 m) inland. Guam is recognized as Tsunami Ready and Storm Ready by the National Weather Service. To qualify as a Tsunami Ready community, a community must:

- Establish a 24-hour warning point and emergency operations center
- Create a system that monitors local weather and ocean conditions
- Develop multiple ways to receive tsunami and severe weather warnings, and alert the public in a timely manner
- Develop a formal hazard plan and conduct emergency exercises
- Promote public readiness through community education

3.1.2 North

3.1.2.1 Andersen AFB

Topography

Total area of Andersen AFB measures 15,423 ac (6,241.5 ha). Andersen AFB is located on the limestone formations of the northern plateau, underlain by massive limestone formations (see Figure 3.1-1). The limestone plateau's elevation ranges from 295 to 590 ft (90 to 180 m) above mean sea level (msl). Steep cliffs surround the plateau on the north, east, and west with a narrow coastal lowland terrace at the bottom of these cliffs. This coastal terrace is 300 to 900 ft (90 to 270 m) wide from the base of the cliff to the ocean. The underlying limestone subtypes range from brittle to well-cemented (Pacific Air Force [PACAF] 2006). All proposed project areas are on the limestone plateau that is relatively flat with gradual changes in elevation.

Geology

Andersen AFB overlies limestone rock, primarily of younger age rocks (Pliocene to Pleistocene, 1.5-5 million years ago) (refer to Figure 3.1-1). A large sinkhole (IRP Site 66), approximately 700 ft by 900 ft (213 m by 274 m), is located on the northeast portion of the base, near the coastline (refer to Figure 3.1-3). The upper few hundred feet of the plateau are composed of basalt and andesite, sedimentary rock, and limestone (COMNAV Marianas 2008). The area is karst, containing cavities and sinkholes in the porous limestone. Rainwater easily percolates through the porous limestone (Gingerich 2003). The Mount Santa Rosa Fault Line is located just south of Andersen AFB and smaller lines are located throughout.

Soil

Soil formation on northern Guam is the result of intense weathering of the permeable limestone to form the silica-poor soils that are rich in iron oxides and gibbsite clays (Young 1988). Soil at Andersen AFB is classified as limestone upland (refer to Figure 3.1-4). This soil exhibits moderately rapid permeability and low water capacity (Young 1988). A thin layer (from 4 to 10 in [10 to 25 centimeters]) of Guam Cobbly Clay Loam overlies the northern limestone substrate, contributing to a shallow vegetation root structure (PACAF 2006). Erosion does not present a significant problem in this project area because it is generally located on a broad limestone reef plateau underlain by volcanic rocks.

The South Ramp, North Ramp, and much of Northwest Field and the Munitions Storage Area (MSA) are in areas classified as Guam-Urban Land Complex, 0% to 3% slopes. This soil type is described by Young (1988) as 55% Guam Cobbly Clay Loam and 45% urban land. Urban land consists of land developed with roads, buildings, parking lots, and airstrips. A small part of the North Ramp and the North Gate

Access Road are in Guam Cobbly Clay Loam, 3% to 7% slopes. This soil is described previously in Table 3.1-1.

Geologic Hazards

Andersen AFB overlies a minor fault line and is susceptible to earthquake events. However, the overall likelihood for landslides to occur on northern Guam is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events.

GHMP reports that the northern portion of Andersen AFB has a high risk of liquefaction.

The maximum reported tsunami waves height reached on Guam was approximately 11.5 ft (3.5 m) in an 1849 tsunami event. GHMP reports that the area most prone to large tsunamis are landmasses below 16.4 ft (5 m) in mean sea elevation. The sites considered under the proposed action are at higher elevation and not at susceptible to tsunami inundation.

3.1.2.2 Finegayan

Topography

Naval Computer and Telecommunications Station (NCTS) Finegayan encompasses 2,700 ac (1,092.7 ha). NCTS Finegayan lies in the northern limestone structural province (refer to Figure 3.1-1). Elevations at the top of the plateau range from 500 to 600 ft (152 to 183 m) above msl. At the edge of the plateau to the north, west and east, steep cliffs drop down to an intermittent narrow coastal lowland terrace. The coastal areas range from 200 to 900 ft (61 to 274 m) stretching from the base of the cliffs to the shore. The substrate comprises a heterogeneous mixture of limestone subtypes ranging from highly friable to well-cemented depending on the depositional source (COMNAV Marianas 2001).

The coastline in this area includes two small, localized but important reef flats: one off Haputo Beach and the second reef flat is inshore of Double Reef (also known as Pugua Patch Reef). The Haputo area is established as an Ecological Reserve Area. This Ecological Reserve Area has a diverse assemblage of marine habitats, including Double Reef. Double Reef is the most striking offshore feature along the entire northwest coast of Guam because it is the beginning of a young barrier reef that breaks the ocean surface (Paulay et al. 2002). It lies on a shallow shelf that extends considerably further from the coast than adjacent areas. The area around Double Reef is topographically heterogeneous because of variation created by reef growth and the erosive action of the large quantities of freshwater discharge from the islands freshwater aquifer (Paulay et al. 2002).

Geology

At Finegayan, the ground surface elevation of the site generally grades downward from east-northeast to west-southwest. A north-south trending fault pattern may control formation of the karst topography. Both the southwest and southeast portions of Finegayan have evidence of sinkhole formation and clay filling of sinkhole depressions (GovGuam 2008). The small valley oriented perpendicular to the cliff line in the northwest area may be enhancing the erosion of the Mariana Limestone along the cliff line that could affect surface drainage patterns (GovGuam 2008). Numerous solution cavities and caves exist within the porous limestone bedrock. As previously discussed, collapses of these subterranean cavities often form sinkholes (COMNAV Marianas 2001).

Soils

The majority of the soils at Finegayan are shallow, well-drained soils on the limestone plateaus (Figure 3.1-4). The cliff line areas are primarily rock outcrops and very shallow and well drained coralline limestone soils (COMNAV Marianas 2001). Nearly all of the plateau area is Guam Cobbly Clay Loam, 3% to 7% slopes. This soil is described in Table 3.1-1. Erosion does not present a significant problem in Finegayan because it is located on a broad limestone reef plateau underlain by volcanic rocks.

Geologic Hazards

Finegayan overlies a minor fault line and is susceptible to earthquake events, although the overall likelihood for landslides to occur is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events. Finegayan has a low risk of liquefaction and tsunami inundation.

3.1.2.3 Non-Department of Defense (DoD) Land

Former Federal Aviation Administration (FAA) Parcel

Topography

The Former FAA Parcel lies in the northern limestone structural province (refer to Figure 3.1-1). Elevations at the top of the plateau range from 500 to 600 ft (152 to 183 m) above msl. At the edge of the plateau to the north, west, and east, steep cliffs drop down to an intermittent narrow coastal lowland terrace. The coastal areas range from 200 to 900 ft (61 to 274 m) stretching from the base of the cliffs to the shore. The substrate comprises a heterogeneous mixture of limestone subtypes ranging from highly friable to well-cemented depending on the depositional source (COMNAV Marianas 2001).

Geology

At the Former FAA Parcel, the ground surface elevation of the site generally grades downward from east-northeast to west-southwest. A north-south trending fault pattern may control formation of the karst topography. Numerous solution cavities and caves exist within the porous limestone bedrock. As previously discussed, collapses of these subterranean cavities often form sinkholes (refer to Figure 3.1-1) (COMNAV Marianas 2001).

Soils

The majority of the soils at the Former FAA Parcel are shallow, well-drained soils on the limestone plateaus (refer to Figure 3.1-4). The cliff line areas are primarily rock outcrops and very shallow and well drained coralline limestone soils (COMNAV Marianas 2001). Nearly all of the plateau area is Guam Cobbly Clay Loam, 3% to 7% slopes. This soil is described in Table 3.1-1. Erosion does not present a significant problem at the Former FAA Parcel because it is located on a broad limestone reef plateau underlain by volcanic rocks.

Geologic Hazards

The Former FAA Parcel overlies a minor fault line and is susceptible to earthquake events, although the overall likelihood for landslides to occur is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events. The Former FAA Parcel has a low risk of liquefaction and tsunami inundation.

Harmon Annex

Topography

Harmon Annex lies in the northern limestone structural province (refer to Figure 3.1-1). Elevations at the top of the plateau range from 500 to 600 ft (152 to 183 m) above msl. At the edge of the plateau to the north, west, and east, steep cliffs drop down to an intermittent narrow coastal lowland terrace. The coastal areas range from 200 to 900 ft (61 to 274 m) stretching from the base of the cliffs to the shore. The substrate comprises a heterogeneous mixture of limestone subtypes ranging from highly friable to well-cemented depending on the depositional source (COMNAV Marianas 2001).

Geology

At Harmon Annex, the ground surface elevation of the site generally grades downward from east-northeast to west-southwest. A north-south trending fault pattern may control formation of the karst topography. Numerous solution cavities and caves exist within the porous limestone bedrock. As previously discussed, collapses of these subterranean cavities often form sinkholes (refer to Figure 3.1-3) (COMNAV Marianas 2001).

Soils

The majority of the soils at Harmon Annex are shallow, well-drained soils on the limestone plateaus (refer to Figure 3.1-4). The cliff line areas are primarily rock outcrops and very shallow and well drained coralline limestone soils (COMNAV Marianas 2001). Nearly all of the plateau area is Guam Cobbly Clay Loam, 3% to 7% slopes. This soil is described in Table 3.1-1. Erosion does not present a significant problem at Harmon Annex because it is located on a broad limestone reef plateau underlain by volcanic rocks.

Geologic Hazards

Harmon Annex overlies a minor fault line and is susceptible to earthquake events, although the overall likelihood for landslides to occur is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events. Harmon Annex has a low risk of liquefaction and tsunami inundation.

3.1.2.4 Off Base Roadways

The proposed action includes on base roadway construction projects that would be implemented by the DoD. An affected environment description for on base roadway construction projects is included beneath the appropriate subheadings in other sections of this chapter. The following section describes the affected environment for off base roadway construction projects that would be implemented by the Federal Highway Administration (FHWA).

Roadway projects in the northern portion of Guam include pavement strengthening, road widening, and construction of a new road, as well as military access point construction for facilitating access to Finegayan and Andersen AFB. The roadway project action alternatives, which are described in detail in the Proposed Action and Alternatives chapter, Roadway Projects section in Volume 6, comprise 13 projects proposed for the North Region of Guam.

<u>Topography</u>

A limestone plateau covers the northern half of Guam. The Guam Road Network (GRN) projects that would occur along Routes 1, 3, 9, 15, and 28, as well as the new Finegayan Connection within the North Region, would be located on the limestone plateau with elevations that range from 295 ft (90 m) to 590 ft (180 m) above msl. These project areas on the limestone plateau are relatively flat with gradual changes in elevation.

<u>Geology</u>

The GRN projects that would occur along Routes 1, 3, 9, 15, and 28, as well as the new Finegayan Connection within the North Region, would be located on limestone rock of younger and old age, as shown in Figure 3.1-6. Rock, and limestone comprise the upper few hundred feet of the plateau.

Soils

Soils beneath Routes 1, 3, 9, 15, and 28, as well as the new Finegayan Connection within the North Region are classified as Limestone Uplands, which are very shallow, well-drained, and nearly level to moderately sloping soils on plateaus. Intense weathering of the permeable limestone form silica-poor soils rich in iron oxides and gibbsite clays (Young 1988). Guam Cobbly Clay Loam is the predominant soil class found along the GRN project locations in the North Region. This soil type has a slow rate of runoff and a relatively low rate of erosion.

Soils and geologic hazards within the study area for the roadway projects in the North Region are shown in Figure 3.1-6.

One cave is located in the vicinity of Route 1 north of Andersen South.

3.1.3 Central

3.1.3.1 Andersen South

Topography

The elevation of the Andersen South site gently rises from approximately 300 ft (91 m) msl in the northwestern portion to 500 ft (152 m) above msl at the southeastern corner of the site (refer to Figure 3.1-2).

Geology

The geology of Andersen South is characterized by a broad limestone reef plateau underlain by volcanic rocks (Figure 3.1-1). The southern portion of the site consists of young limestone rock (Pliocene to Pleistocene, 1.5-5 million years ago) and the northern portion is old limestone rock (Miocene to Pliocene, 5-25 million years ago). Numerous caves are located at Andersen South.

Soils

Soil types at Andersen South include: (1) Guam Cobbly Clay Loam, covering the majority of the area, and in smaller amounts; (2) Guam Urban Land Complex and Pulantat Clay in the western portion of the project area; (3) Pulantat-Kagman Clay in a small section in the center of the western border of the project area; and (4) Ritidian-Rock Outcrop Complex at the southeastern corner of Andersen South (refer to Figure 3.1-4). In general, erosion risks at Andersen South are slight to moderate, but do not present a major problem because the area is located on a broad limestone reef plateau. Soil characteristics are further summarized in Table 3.1-1.

Geologic Hazards

Andersen South overlies both a major and minor fault line and is susceptible to earthquake events.The overall likelihood for landslides to occur on northern Guam is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events. Andersen South is not an area of high risk for liquefaction or tsunami inundation.

3.1.3.2 Barrigada

Topography

Navy and Air Force Barrigada lie in the northern limestone structural province (refer to Figure 3.1-1). The substrate comprises a heterogeneous mixture of limestone subtypes ranging from highly friable to well-cemented depending on the depositional source. Elevations at the site range from approximately 240 ft (73 m) to 500 ft (152 m) above msl (refer to Figure 3.1-2). The most prominent feature is Barrigada Hill

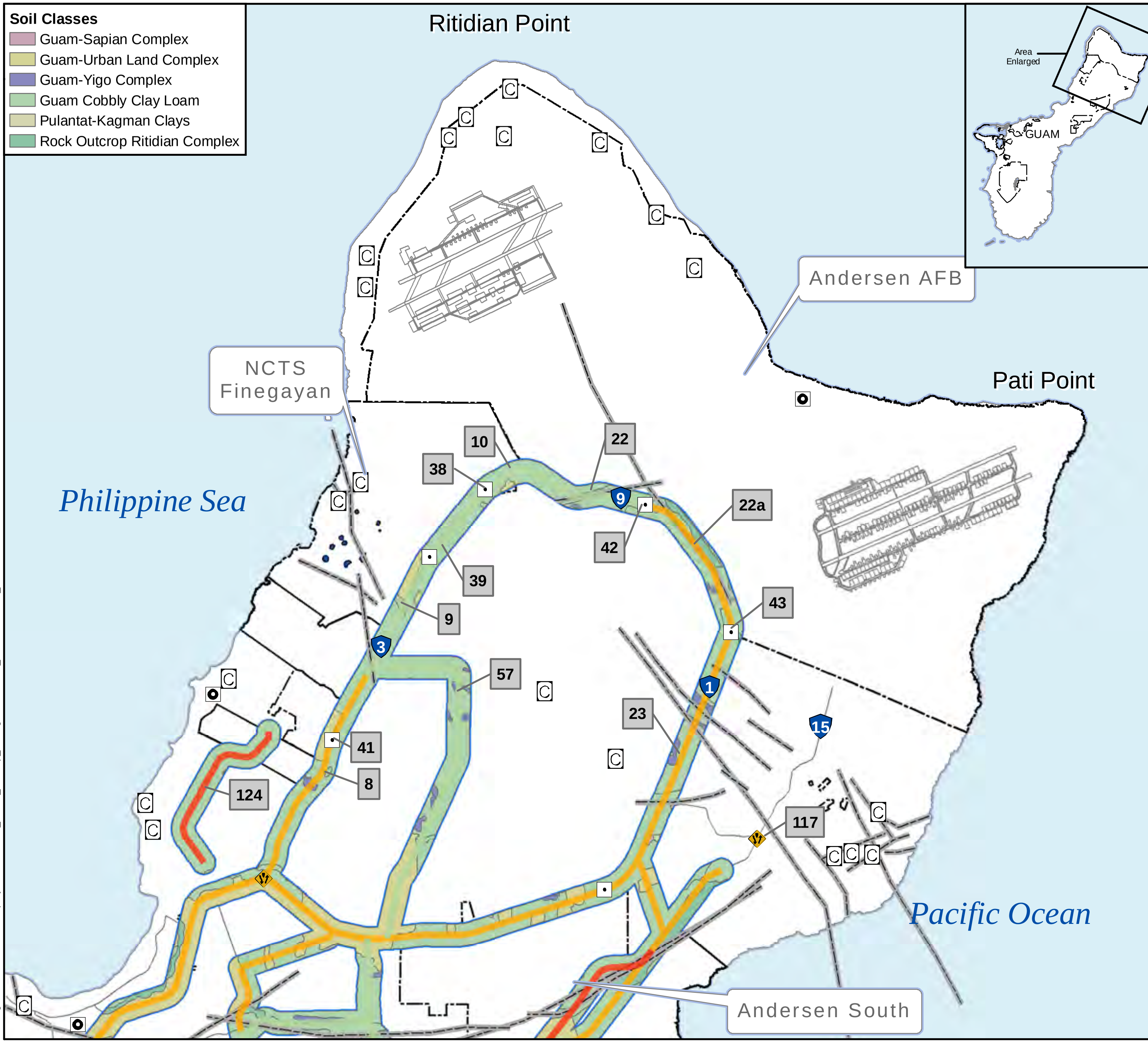


Figure 3.1-6
Soils and Geologic Hazards for GRN Projects in the North Region

Printing Date: Jul 8, 2009; M:\projects\GIS\8806_Guam_Buildup_EIS\figures\Current_Deliverable\Vol_2\3.1-6.mxd that rises in the north-central part of the area with a maximum height of roughly 600 ft (183 m) just north of the site boundary.

Geology

The geology of Navy and Air Force Barrigada is characterized by a broad limestone reef plateau underlain by volcanic rocks (refer to Figure 3.1-1). Most of the site consists of young limestone rock (Pliocene to Pleistocene, 1.5-5 million years ago) but the central-northern portion of Navy Barrigada is old limestone rock (Miocene to Pliocene, 5-25 million years ago). Numerous cavities and caves exist within the porous limestone bedrock in the general area and collapses of these subterranean cavities form sinkholes (COMNAV Marianas 2001).

Soils

Soil formation on northern and most of central Guam is the result of intense weathering of the permeable limestone to form silica-poor soils rich in iron oxides and gibbsite clays (Young 1988). The soil survey results for this area show the following soil types: (1) Guam Cobbly Clay Loam 3% to 7% slopes, covering the majority of the area, and in smaller amounts; (2) Guam Urban Land Complex; (3) Pulantat Clay; (4) Pulantat-Kagman, Chacha Clay 0% to 5% slopes; and (5) Ritidian-Rock Outcrop Complex (refer to Figure 3.1-4). In general, erosion risks at Navy and Air Force Barrigada are slight to moderate, but do not present a major problem because the area is located on a broad limestone reef plateau. Soil characteristics are further summarized in Table 3.1-1.

Geologic Hazards

While Navy and Air Force Barrigada do not directly overlie any fault lines, like all of Guam, the areas are susceptible to earthquake events.The overall likelihood for landslides to occur at Navy or Air Force Barrigada is low due to the lack of steep areas with soil vulnerable to slipping in seismic events. Navy and Air Force Barrigada are not in an area vulnerable to liquefaction, nor are they in danger of tsunami inundation.

3.1.3.3 Non-DoD Land

Non-DoD land in Central Guam proposed for DoD use is limited to the Route 15 Parcel (Alternatives A and B).

Topography

The Route 15 Parcel lies in the northern limestone structural province (refer to Figure 3.1-1). The substrate comprises a heterogeneous mixture of limestone subtypes ranging from highly friable to well-cemented, depending on the depositional source. Elevations at the top of the plateau range from 500 to 600 ft (152 to 183 m) to the west and steep cliffs drop down to a narrow coastal lowland terrace (refer to Figure 3.1-2). The coastal areas range from 200 to 900 ft (61 to 274 m) wide stretching from the base of the cliffs to the sea (COMNAV Marianas 2001).

Geology

The geology of the Route 15 Parcel is characterized by a broad limestone reef plateau underlain by volcanic rocks (refer to Figure 3.1-1). Most of the site consists of young limestone rock (Pliocene to Pleistocene, 1.5-5 million years ago). Karst features are present throughout the area. Cockpit karst (a term for the sharp and jagged mature tropical karst topography) is present in areas near the cliff line and in the lowland terrace. Marbo Cave, a flank margin cave, is located on the northeast coast (Taborosi 2002).

Soils

Intense weathering of permeable limestone in the north and most of central Guam forms silica-poor soils rich in iron oxides and gibbsite clays (Young 1988). The soil survey results for this area show the following soil types for the site: (1) Guam Cobbly Clay Loam 3% to 7% slopes, covering the majority of the area, and in smaller amounts; (2) Guam Urban Land Complex; (3) Pulantat Clay; (4) Pulantat-Kagman; (5) Chacha Clay 0% to 5% slopes; and (6) Ritidian-Rock Outcrop Complex (refer to Figure 3.1-4). In general, erosion risks at the Route 15 Parcel are slight to moderate, but do not present a major problem because the area is located on a broad limestone reef plateau. Soil permeability, runoff, and erosion hazards are summarized in Table 3.1-1.

Geologic Hazards

The Route 15 Parcel overlies both a major and minor fault line and is susceptible to earthquake events. The overall likelihood for landslides to occur on the Route 15 Parcel is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events and it is not vulnerable to liquefaction. The Route 15 Parcel is located on the east coast of Guam and is at risk of tsunami inundation.

3.1.3.4 Off Base Roadways

The proposed action includes on base roadway construction projects that would be implemented by the DoD. An affected environment description for on base roadway construction projects is included beneath the appropriate subheadings in other sections of this chapter. The following section describes the affected environment for off base roadway construction projects that would be implemented by the FHWA.

Topography

GRN project locations near Navy Barrigada, Air Force Barrigada, and Andersen South in the central region of Guam are located on a broad limestone reef plateau underlain by volcanic rocks. Elevations range from 300 ft (91 m) to 500 ft (152 m) above msl.

Geology

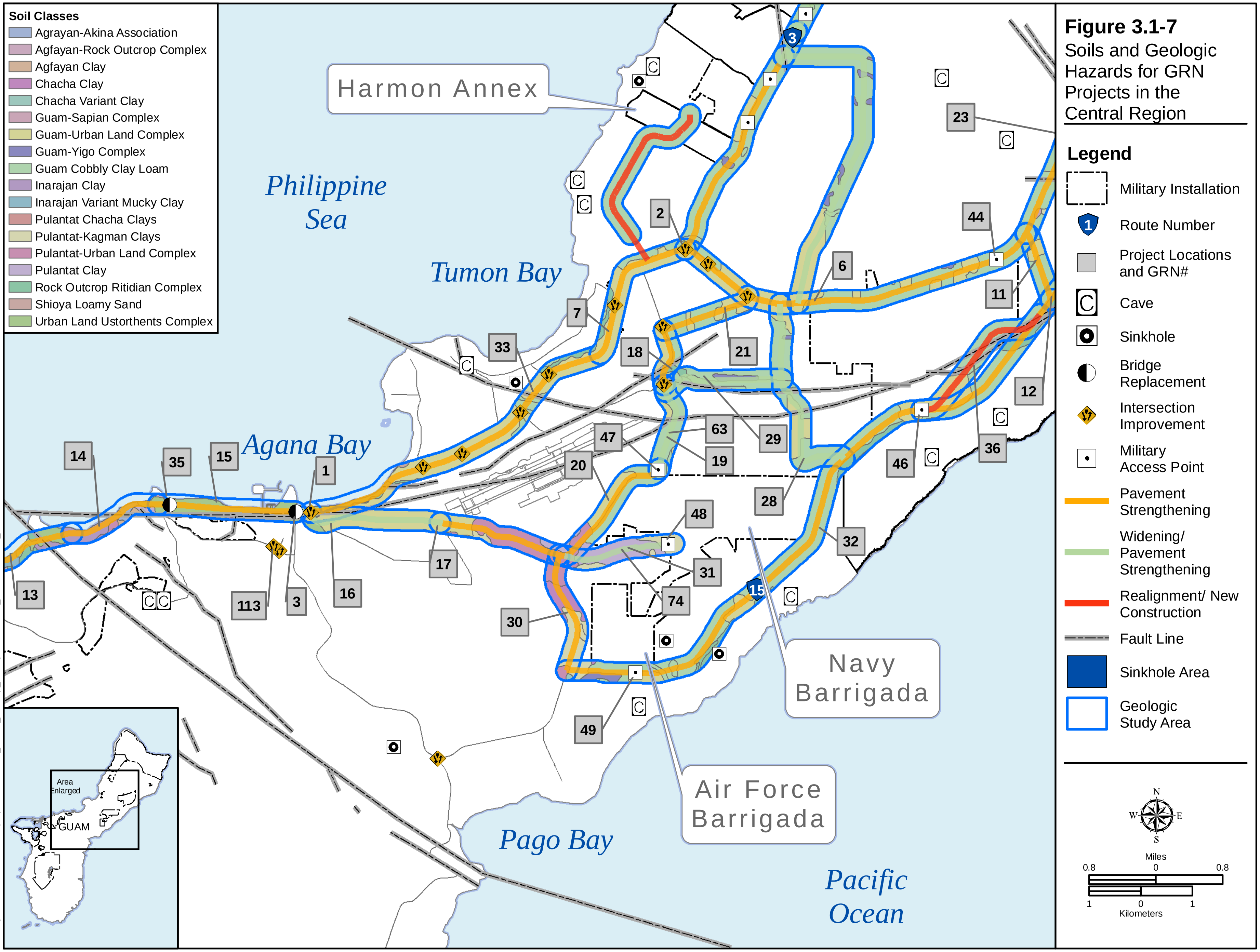
The GRN projects within the central region would be located on limestone rock of younger and old age, as shown in Figure 3.1-7. Caves formed from collapsed sinkholes in limestone forest are found along the coastline near Routes 1 and 15. Four known sinkholes are located in this region. The Tamuning-Yigo Fault Zone is situated in an east-west direction through Andersen South and extends across the center of the island. This fault zone connects to the Adelup Fault Zone bisecting the island at Pago Bay (Figure 3.1-7). Observed and inferred minor fault zones are found within the central region of the island. The potential for landslides in the central region of Guam is generally low. Roadways in the Tumon Bay area, such as Route 1, would have a high potential for liquefaction. The central region of Guam has low vulnerability for tsunami damage.

Soils

Soils beneath roadways in the central region of Guam are classified as Limestone Uplands, which are very shallow, well-drained, and nearly level to moderately sloping soils on plateaus. The primary soil classes found in the central region are Guam Cobbly Clay Loam; Guam Urban Land Complex and Pulantat Clay; Pulantat-Kagman Clay; and Ritidian-Rock Outcrop Complex. These soil types have slow to medium rates of runoff rates. With the exception of the Pulantat soils, which are more vulnerable to sheet and rill erosion, soils beneath roadways in the central region have a relatively low rate of erosion.

Soils and geologic hazards within the study area for the roadway projects in the central region are shown in Figure 3.1-7.

Figure 3.1-7
Soils and Geologic Hazards for GRN Projects in the Central Region



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3.1.4 Apra Harbor

3.1.4.1 Apra Harbor

Topography

Apra Harbor is a natural deep water harbor measuring 3 mi (5 km) by 0.5 mi (0.8 km). Inner Apra Harbor ranges in depth from 15 to 46 ft (5 to 14 m) and Outer Apra Harbor ranges in depth from 100 to 150 ft (30 to 46 m). The Orote Peninsula, the southern boundary of Apra Harbor, consists of a raised limestone plateau (refer to Figure 3.1-2). The manmade Glass Breakwater extends from Cabras Island, making up the northern boundary to the harbor (U.S. Fish and Wildlife Service [USFWS] 2006).

Geology

Apra Harbor's shoreline consists of large areas of basaltic and calcareous fill (USFWS 2006) (refer to Figure 3.1-1). The fill makes the area susceptible to liquefaction; GovGuam 2008 reports that 0.5 mi^2 (1.3 km^2) at Apra Harbor have a very high risk of liquefaction. This is the area with the greatest historical record of liquefaction. There is no karst geology in the project area.

Soils

Permeability of the soil is moderately rapid and runoff is slow; however, the majority of the onshore area is paved, resulting in rapid runoff. Extensive areas along Apra Harbor consist of coastal fill covered by roads, buildings, and parking lots. Soil consists of urban land coastal fill that is quarried fill material consisting of crushed coral gravel and cobbles, and few areas of very gravelly clay and clay loam (refer to Figure 3.1-4) (COMNAV Marianas 2006). Sediment from Inner Apra Harbor is primarily fine-grained and classified as clay, sandy clay, and silty clay. While silty soils are prone to erosion, the lack of slope lessens erosion hazards. Soil characteristics are summarized in Table 3.1-1.

Geologic Hazards

Apra Harbor lies near a major fault line and is susceptible to earthquake events. The overall likelihood for landslides to occur at Apra Harbor is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events. About 0.5 mi^2 (1.3 km^2) of Apra Harbor has a very high risk of liquefaction. This is the area with the greatest historical record of liquefaction. Apra Harbor has the highest likelihood of being affected by tsunamis near Guam (GovGuam 2008).

3.1.4.2 Naval Base Guam

Topography

Naval Base Guam consists of relatively low and flat land surrounding the harbor and Orote Peninsula, a raised limestone plateau reaching 190 ft (58 m) elevation. The plateau slopes eastward towards the sea (COMNAV Marianas 2001). Much of the land has been substantially altered by shaping, dredging, and filling (COMNAV Marianas 2008).

Geology

The geology of the project area is much like that of northern Guam (refer to Section 3.1.8.1 for additional discussion). The coastline is composed of a relatively narrow margin of beach interspersed with basalt or limestone rock formations. There is no Karst geology in the proposed project areas.

Soils

Large areas of Orote Peninsula have highly disturbed soils classified as Guam Urban Land Complex (refer to Figure 3.1-4 and Table 3.1-1 for soil description). Extensive areas along Apra Harbor consist of coastal fill covered by roads, buildings, and parking lots. The Naval Base Guam area is dominated by shallow, well-drained limestone soils; however, areas of soil formed on bottomlands and volcanic plateaus are also present in specific areas. The Dry Dock Island Peninsula, Polaris Point, and sections of the shoreline are the result of dredging and filling. Beach deposits consist of beach sand and gravel, beach rock in the intertidal zone, and patches of recently emerged detrital limestone (COMNAV Marianas 2001). Erosion hazards are slight in these areas.

Geologic Hazards

Naval Base Guam lies near a major fault line and is susceptible to earthquake events. The overall likelihood for landslides to occur at Naval Base Guam is generally low due to the lack of steep areas with soil vulnerable to slipping in seismic events. About 0.5 mi^2 (1.3 km^2), or 0.3% of Guam, mainly located around parts of Apra Harbor, have a very high risk of liquefaction. This is the area with the greatest historical record of liquefaction. Naval Base Guam is included in the area considered most vulnerable to potential tsunami impacts (GovGuam 2008).

3.1.4.3 Off Base Roadways

The proposed action includes on base roadway construction projects that would be implemented by the DoD. An affected environment description for on base roadway construction projects is included beneath the appropriate subheadings in other sections of this chapter. The following section describes the affected environment for off base roadway construction projects that would be implemented by the FHWA.

Topography

Roadways in the Apra Harbor Region consist of Routes 1, 2A, 5, and 11. These roadways are located at relatively flat terrain at elevations that are less than 100 ft (30 m) above msl.

Geology

The GRN projects that would occur along Routes 1, 2A, 5, and 11 within the Apra Harbor Region would be located in areas of older limestone rock, artificial fill, and volcanic units, as shown in Figure 3.1-8. There are no karst geologic formations in the Apra Harbor Region, so sinkholes and caves are not present. There are no major faults or fault zones in the Apra Harbor Region of Guam, although there are areas of observed or inferred minor faults in this region (Figure 3.1-8). The potential for landslides in the Apra Harbor Region of Guam is low. The Apra Harbor Region, including areas of artificial fill, has a very high risk of liquefaction. Although impacts of a tsunami would most likely occur on Guam's east coast, the area most prone to potential tsunami impact is Apra Harbor, based on the elevation of its landmass.

Soils

Soils beneath Routes 1, 2A, 5, and 11 within the Apra Harbor Region consist of Urban Land coastal fill, gravelly clay, and clay loam. These soils have slow runoff rates, although rapid runoff occurs due to paving over most areas. Soils in the Apra Harbor Region exhibit a low rate of erosion.

Soils and geologic hazards within the study area for the roadway projects in the Apra Harbor Region are shown in Figure 3.1-8.

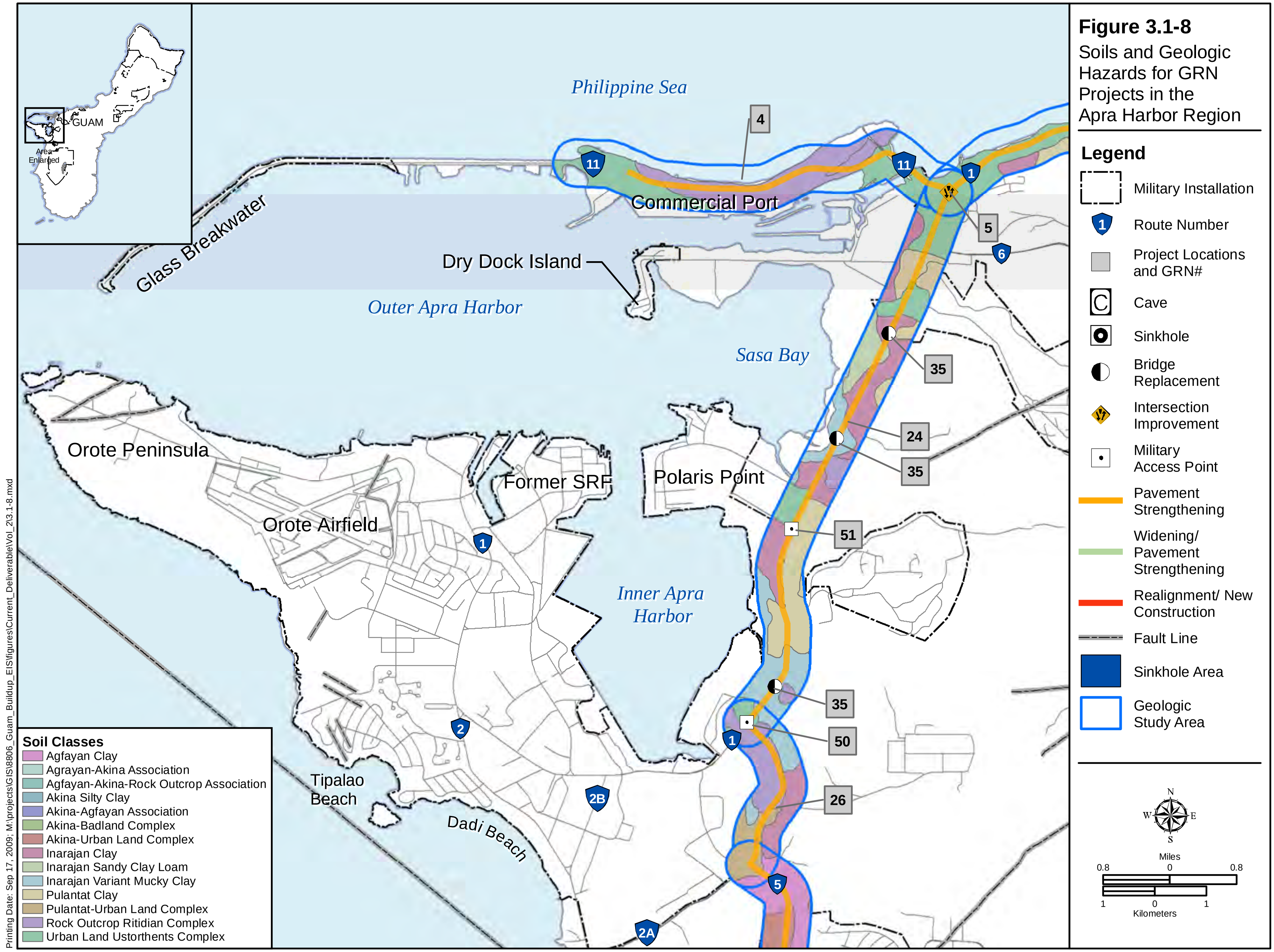

Figure 3.1-8
Soils and Geologic Hazards for GRN Projects in the Apra Harbor Region
Legend
Military Installation
Route Number
Project Locations and GRN#
Cave
Sinkhole
Bridge Replacement
Intersection Improvement
Military Access Point
Pavement Strengthening
Widening/ Pavement Strengthening
Realignment/ New Construction
Fault Line
Sinkhole Area
Geologic Study Area
Miles
Kilometers
Soil Classes
Agfayan Clay
Agrayan-Akina Association
Agfayan-Akina-Rock Outcrop Association
Akina Silty Clay
Akina-Agfayan Association
Akina-Badland Complex
Akina-Urban Land Complex
Inarajan Clay
Inarajan Sandy Clay Loam
Inarajan Variant Mucky Clay
Pulantat Clay
Pulantat-Urban Land Complex
Rock Outcrop Ritidian Complex
Urban Land Ustorthents Complex
GUAM
Area Enlarged
Philippine Sea
Commercial Port
Glass Breakwater
Dry Dock Island
Outer Apra Harbor
Sasa Bay
Orote Peninsula
Former SRF
Polaris Point
Orote Airfield
Inner Apra Harbor
Tipalao Beach
Dadi Beach
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3.1.5 South

3.1.5.1 Naval Munitions Site

Topography

Southern Guam is a mountainous upland with many rivers that form wide valleys and plains near the coast (refer to Figure 3.1-2). The western boundary of Naval Munitions Site (NMS) coincides with a range of low mountains orientated on a north to south axis. This range includes Mount Alifan, Mount Almagosa, Mount Lamlam, and Mount Humuyong (COMNAV Marianas 2001).

Geology

NMS is located in the southern structural provinces of Guam. Most of the areas in southern Guam are volcanic in origin, but limestone may be found near the coast and surrounding Mount Lamlam and Mount Alifan (Young 1988). Southern Guam is underlain by weathered basalt and tuff-derived sedimentary rocks (COMNAV Marianas 2008).

The mountain range at the western boundary lies on the Bolanos structural block that consists of rock from the Miocene-aged Umatac Formation. The Umatac Formation is composed of east-dipping volcanic rocks, including flow basalts and tuff, breccia, sandstone, and shale. The tuff is consolidated volcanic ash that was marine deposited and uplifted. Breccia refers to the angular fragments of the conglomerate. Portions of the range have alternated between periods of submergence and emergence as evidence from the presence of Alifan Limestone (COMNAV Marianas 2001).

Southern Guam is an uplifted volcanic highland containing a karst terrain on limestone remnants (Mylroie et al. 1999). These units are positioned above the influence of the fresh water lens, sea water mixing, and sea level change; therefore, the karst is classic tropical continental. Its characteristics include contact springs issuing from well-developed caves, sinking streams with resurgences, and conical cockpit karst. The NMS area includes numerous caves and karst features (Taborosi 2004) including Almagosa Cave/Spring and Bonya Spring that serve as water sources for the Navy.

Soils

The NMS area contains soils formed on bottomland, volcanic plateaus, and limestone plateaus. The soils found at higher elevations along the mountain range from Mount Alifan to Mount Lamlam are made up of shallow, well-drained, limestone soils (refer to Figure 3.1-4 and Table 3.1-1). Extensive areas of highly weathered volcanic soils are present in the central and southern portions of the site. River bottoms tend to consist of poorly drained soils formed by erosion of upland limestone and volcanic soils (COMNAV Marianas 2001).

Soils within the Fena Watershed, part of NMS, are either volcanic in origin or were formed from old limestone parent material. The limestone soils within the Fena Watershed are distinguished from the volcanic soils on the basis of parent material and associated properties. According to Young (1988), parent material is the single most important soil-forming factor used to explain the differences between the soils of Guam.

The limestone soils formed mainly in the residue from coralline limestone, whereas the volcanic soils formed from volcanic sediments or deposition. The pH is slightly to moderately alkaline (pH 7.4 to 8.4) throughout the profile. Soils formed over limestone are typically very shallow, well drained, and have low water-holding capacity. Permeability is very rapid and these soils are not highly erosive. Moderate and steep soils are rated as having very slow runoff and are a slight erosion hazard.

Volcanic soils range from deep to very deep with minor inclusions of shallow to very shallow volcanic soils. In general, the volcanic soils have high water holding capacity and high potential for runoff. Permeability is generally slow throughout all horizons of volcanic soils and on moderate slopes volcanic soils have a medium runoff and moderate erosion hazard. The pH of volcanic soils ranges from neutral to strongly acid. The lower horizons are typically moderately to strongly acid.

Erosion in the Fena Watershed (approximately 3,600 ac [1,457 ha]) measures 120,000 tons (108,862 metric tons) per year or 34 tons (31 metric tons) per acre annually (COMNAV Marianas 2004). This erosion is responsible for the majority of the sediment into Fena Reservoir. The steep ravine forests and savannas contribute to the severe erosion, as do bare badlands that have lost topsoil due to water and wind erosion. Badland erosion contributes the greatest to erosion on a per acre basis (COMNAV Marianas 2004). The exposed subsoil usually has a very low pH, and lacks organic matter and many essential plant nutrients (COMNAV Marianas 2001). Steep savanna, steep ravine forest, and badlands near the Fena Reservoir have higher sediment delivery rates and contribute greater amounts of sediment than similar cover with similar slopes in other parts of the watershed.

Within the Fena Watershed, the Imong Subwatershed erodes at an average rate of 51 tons/ac/year, Sadog Gago at 47, East Fena at 35, West Fena at 31, Maulap at 26, Almagosa at 24, and Almagosa Sink at 7 tons/ac/year. The high rates for the first two basins are explained by the fact that nearly 94% of both Imong and Sadog Gago Subwatersheds consist of steeply sloping savanna, steeply sloping ravine forest, or badlands (COMNAV Marianas 2004).

<u>Geologic Hazards</u>

NMS overlies a major fault line and four minor fault lines and is susceptible to earthquake events. The overall likelihood for landslides to occur in southern Guam is high due to steep areas with soil vulnerable to slipping in seismic events. NMS has a low risk of liquefaction and tsunami inundation.

3.1.5.2 Off Base Roadways

The proposed action includes on base roadway construction projects that would be implemented by the DoD. An affected environment description for on base roadway construction projects is included beneath the appropriate subheadings in other sections of this chapter. The following section describes the affected environment for off base roadway construction projects that would be implemented by the FHWA.

<u>Topography</u>

The topography of roadway locations in the south region (Routes 5 and 12) varies in elevation from below 100 ft (30 m) to 300 ft (91 m) above msl.

<u>Geology</u>

The GRN projects that would occur along Routes 5 and 12 within the south region would be located on older limestone rock and volcanic units, as shown in Figure 3.1-9. Sinkholes and caves are not known from these GRN project locations. The Talofofo Fault Zones runs in a northwest direction in the south region (refer to Figure 3.1-6). Observed and inferred minor fault zones are located along portions of the Navy Housing and the NMS. The potential for landslides in the south region of Guam is moderate to high. This area has a low potential for liquefaction and a low vulnerability for tsunami damage.

<u>Soils</u>

Soils beneath Routes 5 and 12 within the south region are classified as Urban Land Complex and Guam Cobbly Clay Loam. These soils are very shallow, well-drained, and nearly level to moderately sloping soils on plateaus. These soil types have a slow rate of runoff and a relatively low rate of erosion.

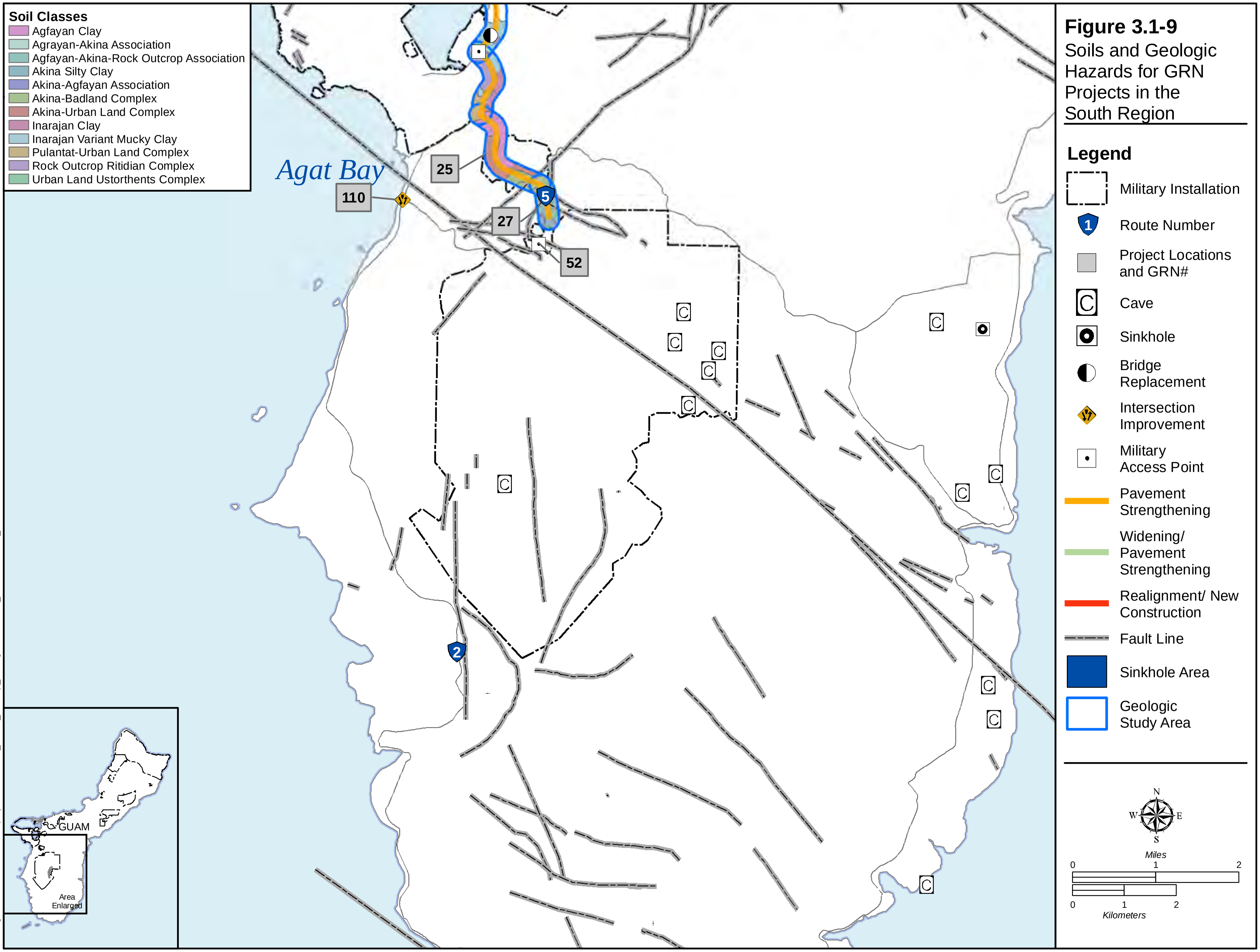

Figure 3.1-9
Soils and Geologic Hazards for GRN Projects in the South Region

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Soils and geologic hazards within the study area for the roadway projects in the south region are shown in Figure 3.1-9.

3.2 ENVIRONMENTAL CONSEQUENCES

This description of environmental consequences addresses all components of the proposed action for the Marine Corps on Guam. The components addressed include: Main Cantonment, Training, Airfield, and Waterfront. There are multiple alternatives for the Main Cantonment, Training-Firing Range, Training-Ammunition Storage, and Training-NMS Access Road. Airfield and Waterfront do not have alternatives. Although organized by the Main Cantonment alternatives, a full analysis of each alternative, Airfield, and Waterfront is presented beneath the respective headings. A summary of impacts specific to each alternative, Airfield, and Waterfront is presented at the end of this chapter. An analysis of the impacts associated with the off base roadways is discussed in Volume 6.

3.2.1 Approach to Analysis

3.2.1.1 Methodology

The methodology for identifying, evaluating, and mitigating impacts to geology and soil resources was established through geologic and soil studies and reports, along with federal laws and regulations, including state and local building codes and grading ordinances. The assessment of geological and soils impacts was conducted, in part, by reviewing available literature such as previously published National Environmental Policy Act (NEPA) documents for actions in the Mariana Islands Range Complex (MIRC) and surrounding area. A site-specific geotechnical investigation was not undertaken for all of the areas covered in this Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS), although one was completed for Naval Computer and Telecommunications Station (NCTS) Finegayan to identify geologic features. The impact analyses presented in this section discuss each alternative (Main Cantonment, Training, Airfields and Waterfront) of the proposed action with geologic and soil impacts by geographic area, as described in the previous affected environment section. Geology and soils also affect the placement or location of a land use; where such constraints occur, they are discussed. In master planning, topography and geological features were assessed and buildings were sited to avoid steep slopes, karst features, and geologic hazards. The geology and soils ROI includes all the geologic resources on Guam that are subject to construction and operation activities.

LIDAR Contour Data were used to identify potential sinkholes on proposed sites. Proposed road alignments were adjusted to avoid these potential sinkhole locations, and buffer areas of 100 ft (30 m) or more were implemented around the potential sinkhole sites. These buffer areas would be maintained in their current natural state and would not be used for any facility development. Analysis of topography, soil, and vegetation was completed during site characterization using LIDAR Contour Data, geotechnical reports, and site visits to ensure minimal impacts to geological and soil resources.

Project effects and constraints that can take place during construction and operations or may limit activities may include:

<u>Construction</u>

- Cut and fill activities leading to soil erosion
- Removal of vegetation and landscaping leading to soil erosion
- Use of heavy equipment resulting in soil compaction
- Identification and avoidance of karst geological features, such as caves and sinkholes
- Increased risk of damage from liquefaction, landslides, tsunamis

Operation

- Impervious surface increase resulting in increased runoff and soil erosion
- Vehicle movements resulting in increased soil erosion and compaction
- Troop movements resulting in increased soil erosion
- Munitions impacts resulting in soil and subsurface contamination
- Explosive detonations resulting in soil and subsurface contamination
- Fires resulting in reduced vegetation and increased soil erosion

Potential geology and soils impacts are limited to elements of current and proposed activities that could affect onshore land forms or that could be affected by geologic hazards. Aircraft training activities are not expected to have substantial effects on geology and soils. Potential soil contamination issues are addressed in Volume 2, Chapter 17, Hazardous Materials and Waste. Increased soil erosion also may indirectly impact water quality and aquatic ecosystems. Potential impacts to these resources are described in Volume 2, Chapter 4, Water Resources; Chapter 10, Terrestrial Biological Resources; and Chapter 11, Marine Biological Resources.

Actions with potential impacts to soil and geology resources include:

- Construction and operation activities at Andersen Air Force Base (AFB)
- Main Cantonment construction and operation activities
- Waterfront and Naval Base Guam improvements at Apra Harbor
- Range operations at Navy Barrigada and NMS
- Training activities at Andersen South and Route 15 Parcel

Applicable Regulatory Standards

The United States (U.S.) Environmental Protection Agency (USEPA) Region 9 gives the Guam Environmental Protection Agency (GEPA) the authority to enforce portions of federal statutes via a Memorandum of Agreement.

Under this agreement, the Safe Drinking Water Program, Water Resources Management Program, and the Water Pollution Control Program are administered by GEPA. GEPA Water Pollution Control Program is responsible for protecting Guam's resources from point and non-point source pollution, including administration of the National Pollutant Discharge Elimination System (NPDES) program. NPDES Construction General Permits are required for large and small construction activities. Requirements include a Notice of Intent, a Notice of Termination and a construction site Storm Water Pollution Prevention Plan (SWPPP). Permits are required for projects that disturb greater than one acre of soil, including lay-down, ingress and egress areas. Phase I regulates construction activity disturbing 5 ac (2 ha) or more of total land area and Phase II regulates small construction activity disturbing between 1 and 5 ac (0.4 and 2 ha) of total land area.

An Environmental Protection Plan (EPP) is required for projects at the discretion of the GEPA Administrator**.** EPPs are specifically identified in 22 Guam Annotated Regulations, Division II, Chapter 10, Section 10103.C.5(d). EPPs would include nonpoint source control management measures including erosion and sedimentation control, vegetation, wildlife and coral/marine resource protection measures, fugitive dust control, solid and hazardous waste management and disposal procedures, nutrient management plan, integrated pest management strategy/plan, confined animal facilities management plan, irrigation water management plan, personnel safety procedures, work site maintenance, and typhoon contingency plans, as necessary, depending on the work, project, activity and facility function.

Seismic, liquefaction and ground shaking effects would be reduced by following Unified Facility Code (UFC) 3-310-04 Seismic Design for Buildings (U.S. Army Corps of Engineers [USACE] 2007).

3.2.1.2 Determination of Significance

standards, as well as by subjective criteria. To be considered a significant impact, the additional factors would be considered for each project area:

- Any increase in rate of erosion and soil loss from physical disturbance
- Reduced amounts of productive soils
- Alteration of surrounding landscape and effect on important geologic features (including soil or rock removal and filling of sinkholes)
- Diminished slope stability
- Increased vulnerability to a geologic hazard (e.g., seismic activity, tsunami, liquefaction), and the probability that such an event could result in injury

3.2.1.3 Issues Identified During Public Scoping Process

The following analysis focuses on potential affects to geology and soils resources that would be impacted by the proposed action. As part of the analysis, concerns relating to geology and soils resources that were mentioned by the public, including regulatory stakeholders, during scoping meetings were addressed. These included:

- Implementing erosion control measures for construction and post construction phases
- Ensuring that proper permitting and local government clearances are sought where applicable

3.2.2 Alternative 1

3.2.2.1 North

Andersen AFB

The proposed activities at Andersen AFB include construction at North Ramp, building new embarkation facilities at South Ramp, ammunition storage at MSA1, and constructing the North Gate and Access Road; using an existing demolition range at Northwest Field (NWF) and conducting aviation training at North Ramp and NWF.

The majority of the North Ramp at Andersen AFB is undeveloped, but has been previously disturbed. The Air Combat Element Beddown project area is approximately 69 ac (27 ha) on an inactive, previously disturbed area north of the existing Andersen AFB airfield.

The total project area for Air Mobility Command at the South Ramp is 28 ac (11.33 ha). The site currently includes paved airfield parking and disturbed, unused land adjacent to the airfield.

The North Gate and Access Road project includes a 12-ft (3.66-m) wide access road to intersect Route 9 and extend into Andersen AFB approximately 6,561 ft (2,000 m) until it terminates at 5th Avenue. A new Entry Control Point facility is also proposed. Roadway paving, street lighting, and drainage would be constructed the entire length of the alignment. Other associated construction totals 1,014 ft^2 (94 m^2) in area.

Construction

Development under Alternative 1 would disturb soil during construction. There is a risk of increased rate of erosion, compaction and soil loss from physical disturbance whenever there is construction activity, but Standard Operating Procedures (SOPs) and a SWPPP (required by the NPDES Construction General

Permit) would be implemented to minimize impacts. Soil found at Andersen AFB and other locations potentially affected by Alternative 1 are shown in Table 3.2-1. Soil at Andersen AFB does not have a high erodibility factor and construction is not proposed on steep slopes. Erodibility factors for each soil type can be found in Table 3.2-1.

Table 3.2-1. Soil Types at Proposed Sites

Soil Type	*Location*
Guam Cobbly Clay Loam at 3-7% slope	Andersen AFB
Guam Cobbly Clay Loam at 7-15% slope	Andersen AFB
Guam Urban Land Complex at 0-3% slope	Andersen AFB
Guam Urban Land Complex at 0-3% slope	NCTS Finegayan
Guam Cobbly Clay Loam at 3-7% slope	NCTS Finegayan
Guam-Yigo Complex at 0-7% slope	South Finegayan
Guam Cobbly Clay Loam at 3-7% slope	South Finegayan
Guam Urban Land Complex at 0-3% slope	South Finegayan
Guam Cobbly Clay Loam at 3-7% slope	FAA Parcel
Guam Urban Land Complex at 0-3% slope	FAA Parcel
Guam Cobbly Clay Loam at 3-7% slope	Harmon Annex
Guam Cobbly Clay Loam at 7-15% slope	Andersen South
Guam Cobbly Clay Loam at 7-15% slope	Andersen South
Guam Urban Land Complex at 0-3% slope	Andersen South
Guam Cobbly Clay Loam at 7-15% slope	Navy Barrigada
Pulantat Clay at 3-7% slope	Navy Barrigada
Pulantat Clay at 7-10% slope	Navy Barrigada
Urban Land Coastal Fill at 0 -3% slope	Navy Barrigada
Guam Cobbly Clay Loam at 3-7% slope	Air Force Barrigada
Chacha Clay at 0-5% slope	Air Force Barrigada
Pulantat-Kagman Clays at 0-7% slope	Air Force Barrigada
Guam Urban Land Complex at 0-3% slope	Apra Harbor
Ritidian Rock Outcrop Complex 3-15% slope	Apra Harbor
Urban Land-Ustorthents Complex, nearly level	Apra Harbor
Inaranjan Clay at 0-4% slope	NMS
Akina Silty Clay at 7-15% slope	NMS
Akina-Atate at steep slope	NMS
Akina-Urban Land Complex at 0-7% slope	NMS

Source: Young 1988.

The construction SOPs would include requirements for stormwater compliance, with Best Management Practices (BMPs), including the SWPPP to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A list of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction. Construction SOPs would be followed to prevent soil erosion. Therefore, Alternative 1 would not result in significant impacts to geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

Construction activities under Alternative 1 for the Main Cantonment and alternatives associated with training and waterfront activities would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscape around previously disturbed areas, such as buildings and base entrance. Temporary, rather than permanent loss of vegetation would occur. Therefore, these alternatives would result in minimal impacts to unique geologic resources with little change to the landscape of the affected area.

There is a sinkhole in the vicinity of the North Ramp approximately 700 ft by 900 ft (213 m by 274 m) in area, just east of the project site. The sinkhole would be avoided and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. The sinkhole would not be affected by construction activities. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

Under these alternatives, proposed developments would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). Therefore, construction relating to Alternative 1 and training and waterfront alternatives would not result in significant impacts associated with geologic hazards.

Operation

Alternative 1 operations activities would not disturb or compact soil or cause an increase in erosion. There is a sinkhole in the vicinity of the North Ramp approximately 700 ft by 900 ft (213 m by 274 m) in area, just east of the project site. The sinkhole would be avoided during operations and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. If deemed hazardous, this sinkhole, along with any others found, could be fenced off and signs put in place to warn of the potential danger. Less than significant impacts are expected.

The potential for wildfire that might impact soil and geological resources would be minimal since proposed training exercises under Alternative 1 are non-firing. A Marine Corps fire station with alert force facilities (45 people) would be located at the Main Cantonment. That unit would help to ensure fire safety procedures and, along with the Andersen AFB fire department, would be responsible for controlling any fires that could be started during training exercises. There would be an Aircraft Fire and Rescue Station at the main cantonment at NCTS Finegayan which would respond to air-ground training incidents, and would be present during some training exercises as a precautionary measure. Based on a low fire potential and fire response capabilities, impacts to soil and geological resources would be less than significant.

<u>Finegayan</u>

A total of 1,090 ac (441 ha) at NCTS Finegayan and 290 ac (117 ha) at South Finegayan would be developed under Alternative 1 as the Main Cantonment. Although DoD property encompasses an area down to the waterline, the proposed Alternative 1 Main Cantonment would be situated on the upper area of NCTS Finegayan and would not encroach on the cliff line leading to the ocean. Table 3.2-2 shows the ground area that would be disturbed by development of each area of the proposed Main Cantonment.

Table 3.2-2. Alternative 1 Main Cantonment Footprint Area

Area Number	*Facility*	*Total Area Affected ac (ha)*
Area 1	Marine Expeditionary Force (MEF) Command Element, 12th Marine Regiment, and 3d Marine Division Headquarters	19.6 (7.9)
Area 2	No construction proposed	0
Area 3	III MEF Admin. & Operations	34.5 (14.0)
Area 4	3d Marine Div. Admin. & Operations	81.7 (33.1)
Area 5	Marine Logistics Group (MLG) and Admin. & Operations	101.0 (40.9)
Area 6	MLG and Base Industrial Area	173.0 (70.0)
Area 7	Bachelor's Enlisted Quarters Campus	125.7 (50.9)
Area 8	No construction proposed	0
Area 9	Provost Marshall's Office	33.0 (13.4)
Area 10	Main Entry Control Point Gate and Base Operations Area	18.4 (7.4)
Area 11	Bachelor's Officer's Quarters, Campus & Officer's Club	18.3 (7.3)
Area 12	administrative, legal services, family services, and Morale, Welfare, and Recreation support facilities	9.9 (4.0)
Area 13	temporary lodging facilities	8.0 (3.2)
Area 14	Main Community Center	69.3 (28.0)
Area 15	fire station and alert force facilities	3.7 (1.5)
Area 16	applied instruction and auditorium facilities	3.4 (1.4)
Area 17	Marine Air Wing	38.6 (15.6)
Area 18	administrative areas, warehousing, dental clinic, and gate house facilities	20.7 (8.4)
Area 19	religious ministry facility, youth center, and swimming pool	10.0 (4.0)
Area 20	Child Development Center	2.4 (1.0)
Area 21	elementary school	5.0 (2.0)
Area 22	middle and high school	12.1 (4.0)
Area 23	Child Development Center	2.7 (1.1)
Area 24	elementary schools	9.9 (4.0)
Area 25	indoor fitness, swimming pool, and youth center facilities	9.9 (4.0)
Area 26	Child Development Center	2.7 (1.1)
Area 27	elementary and middle school	12.2 (4.9)
Area 28	restaurant, location exchange, bank, gas station, and gate house	10.0 (4.0)
Family Housing	Area A	181.2 (73.3)
Family Housing	Area B	76.8 (31.1)
	Total Impervious Area for Main Cantonment:	**1,093.9 ac (442.7 ha)**

Hazardous materials storage would occur in Areas 3, 4, 5, 6, 17 and 18. Hazardous materials storage areas present the potential to impact soil resources if the materials are not properly handled. BMPs and mitigation measures are discussed in Volume 2, Chapter 17, Hazardous Materials and Waste.

Construction

The proposed Alternative 1 Main Cantonment development would disturb soil during construction. Construction activities under Alternative 1 would include building of facilities, infrastructure, utilities, and roadways, which would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscaping. There is a risk of increased rate of erosion, compaction, and soil loss from physical disturbance caused by construction activity, but stormwater BMPs would serve to provide erosion and sediment control. Erosion potential for soils found at Finegayan is shown in Table 3.1-1.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction.

Construction SOPs and a SWPPP required by the NPDES permit would be followed to prevent soil erosion. Therefore, Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed description of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

There are at least ten sinkholes in the vicinity of the proposed Main Cantonment area. The sinkholes would be avoided and a buffer zone of vegetation would be left around all sinkholes to prevent further erosion or expansion. The sinkholes would not be affected by construction activities. If deemed hazardous, this sinkhole, along with any others found, could be fenced off and signs put in place to warn of the potential danger. Less than significant impacts are expected.

Finegayan is located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, slope instability and liquefaction would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

Operation

Although Finegayan is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, slope instability and liquefaction are minimal. The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Operations activities would not disturb or compact soil or cause an increase in erosion. The predominant limestone bedrock is not vulnerable to liquefaction. If deemed hazardous, any sinkholes found in the area could be fenced off and signs put in place to warn of the potential danger. Less than significant impacts are expected.

<u>Non-DoD Land</u>

Under Alternative 1, 326 ac (132 ha) of Harmon Annex would be developed as Military Family Housing. An additional 680 ac (2755 ha) of the former FAA parcel would be developed as part of the proposed Main Cantonment.

Construction

The proposed Alternative 1 Main Cantonment and Family Housing development would disturb soil during construction. There is a risk of increased rate of erosion, compaction, and soil loss from physical disturbance caused by construction activity; however, stormwater BMPs would provide erosion and sediment control. Erosion potential for soils found at Harmon Annex and the Former FAA Parcel are shown in Table 3.1-1.

The soil types that would be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction. Construction SOPs and a SWPPP (required by the NPDES permit) would be followed to prevent soil erosion. Therefore, Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed description of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Construction activities under Alternative 1 would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 1 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

There is at least one sinkhole in the Harmon Annex, and none found at the Former FAA Parcel. The sinkhole would be avoided and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. The sinkhole would not be affected by construction activities. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

Harmon Annex and the Former FAA Parcel are located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, slope instability and liquefaction would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

Operation

Although Harmon Annex and the Former FAA Parcel are located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, slope instability and liquefaction are minimized during construction. The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Operations activities would not disturb or compact soil or cause an increase in erosion. The predominant limestone bedrock is not vulnerable to liquefaction. Therefore, Alternative 1 would not result in significant impacts associated with geologic resources or hazards.

3.2.2.2 Central

<u>Andersen South</u>

Andersen South would be developed as a non-firing training range complex under Alternative 1. Maneuver training would would be conducted within the 2,000 acre (809 ha) area with two landing zones (LZ). It would also include hand grenade training and a grenade house. The majority of the site is currently vacant. The abandoned buildings and vacant lands are currently used for non-firing training, thus very little change to land use for training and limited construction of access roads would occur. A perimeter fence would be constructed around Andersen South with a main gate and three range gates for access. Erosion potential for soil found at Andersen South can be found in Table 3.1-1.

Construction

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed description of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Construction activities under Alternative 1 would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscape. Temporary loss of vegetation would occur. Therefore, Alternative 1 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

There are no known sinkholes at Andersen South. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

The Alternative 1 proposed developments would be located on a relatively flat, broad limestone reef plateau that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Due to the limited duration of construction activities, potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

Operation

Training activities are conducted with established procedures aimed at minimizing topsoil loss, compaction, and erosion. Therefore, Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

Although Andersen South is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, slope instability and liquefaction are minimal. The Alternative 1 proposed range complex is to be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

<u>Non-DoD Land</u>

The proposed range complex on the Route 15 parcel would encompass approximately 1,000 ac (405 ha). The land disturbance required for firing ranges is concentrated at the firing points and targets. The majority of the site would remain naturally vegetated open space and encompass the Surface Danger Zones (SDZs). Establishment of Special Use Airspace (SUA) would not have any impact on geological and soil resources.

The two alternatives for the proposed firing range are Alternative A and Alternative B. If firing range Alternative A is selected, then Route 15 would be relocated to Andersen South, where it would be constructed below grade for the 1.2 mi (1.9 km) of its 1.7 mi (2.8 km) length. The relocation would require soil moving and grading for proper highway grade. Its average distance below grade would be approximately 15 ft (5 m). Roadway cut would measure 323,509 cubic yards (cy) (247,340 m^3), and fill would be 34,837 cy (26,635 m^3).

Firing range Alternative B would require construction of a frontage road adjacent to Route 15 to serve range traffic crossing Route 15 in either one or two locations. In this alternative, a machine gun range of the same size, 58 ac (23 ha), 3,280 ft (1,000 m) maximum gun-target distance, would require 121,602 cy (92,971 m^3) of cut and 1,670,000 cy (1,276,659 m^3) of fill.

Alternative A and Alternative B would both require relocation of the International Raceway Park and residences. Demolition would temporarily disturb soil. The majority of the 1,000-ac (405-ha) site is undeveloped.

Construction

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner that would minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed description of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Construction activities under Alternative 1 would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 1 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

There are no known sinkholes at the Route 15 Parcel. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

The Alternative 1 proposed developments would be located on a relatively flat, broad limestone reef plateau that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

Operation

Military training activities at the Route 15 parcel would result in localized disturbances to soil. Training activities are conducted with established procedures aimed at minimizing topsoil loss, compaction, and erosion and would not result in significant impacts to geological and soil resources. Soil types that could be disturbed would not be agriculturally productive soils. Erosion potential for soils found at the Route 15 Parcel is shown in Table 3.1-1.

Munitions and explosive detonations could potentially result in soil contamination. However, the unexploded ordnance management policies require containment and frequent disposal of these munitions in firing ranges. Proposed activities for range maintenance include removing expended rounds from the ranges periodically and transporting them to an appropriate recycling contractor or smelter in accordance with appropriate regulations. Therefore, there would be minimal potential for soil or subsurface contamination and no significant impacts are expected.

There is potential for ordnance-ignited wildfires that could impact soil and geological resources. The potential for erosion would depend on how much land area is burned. To minimize impacts, a fire management plan would be developed for use in this area which would include prevention, planning, and suppression methods. It would include protocols for monitoring fire conditions and adjusting training as needed (e.g., firing or tracers may be disallowed under certain fire conditions); location and management of fire breaks, fire fighting roads, a fire fighting water system; protocols for using units to be briefed by range control on requirements suitable to the conditions of the day; and protocols should a fire occur (e.g., specifying how the range would shut down and fire suppression action would be taken). With implementation of standard fire management measures, impacts from wildfire on soil and geological resources would be less than significant.

Barrigada

Construction

There would be no construction in Navy Barrigada or Air Force Barrigada under the proposed alternative.

Operation

There would be no operation in Navy Barrigada or Air Force Barrigada under the proposed alternative.

3.2.2.3 Apra Harbor

Apra Harbor

Renovation and construction at Apra Harbor would support an increase in traffic to the harbor resulting from the proposed action. The support facilities at Victor Wharf, Oscar/Papa Wharves and the cargo staging area would be on areas that have been disturbed by previous construction and activities. Landing craft air cushion and the amphibious assault vehicle would each have a dedicated ramp to access their respective lay down areas that are adjacent to each other. Each vehicle would be rinsed on arrival to remove sand and salt spray to deter corrosion and increase vessel efficiency. U.S. Coast Guard facilities would be relocated to the Former SRF.

Dredged material may be disposed at a USEPA-designated Ocean Dredged Material Disposal Site; the potential impacts of the site use are being addressed in a separate EIS (USEPA 2009). When the material is dry it can be reused or stockpiled. Dredging activities are addressed in Volume 2, Chapter 4, Water Resources.

For upland placement, the dredged material is unloaded into a shoreside containment area or directly into sealed-end dump trucks at a designated wharf (e.g., Uniform Wharf has been used in the past). No free water is anticipated to drain back into Apra Harbor. The retention area would be constructed in accordance with Navy specifications for Temporary Environmental Control that requires a filter fabric liner. The trucks haul the dredged material to a pre-designated upland placement site for potential subsequent beneficial use.

The upland placement sites are enclosed by earthen berms approximately 16 to 30 ft (5 to 9 m) in height. The dredged material would be at or below the berm height. The berms would have an exterior horizontal to vertical slope of 2:1. No soil or fill would be brought to the site for construction. Vegetation would be cleared and soil compacted. No effluent is anticipated. Non-hazardous dredged material water is allowed to evaporate or percolate through the ground. Utilities at the site would be realigned outside of the enclosure. No closure plan or environmental monitoring is proposed. The exterior slopes would be seeded to discourage erosion and minimize visual impact. The drying material is unlikely to generate dust, but once dry, there would be dust associated with relocating the dry materials. No ponding water is anticipated that might attract migrating birds. In the event a site becomes an attractive site for migrating birds, they could be easily discouraged by decoys and noise makers. Once the dredged material is removed, the site could be re-leveled for alternative use, or re-used for future dredged material placement.

Construction

Alternative 1 would disturb soil during construction at Apra Harbor. There is a risk of increased rate of erosion and soil loss from physical disturbance and compaction caused by construction activity, but stormwater BMPs would provide erosion and sediment control. Erosion potential for soils found at Apra Harbor is shown in Table 3.1-1.

Soil types that could be disturbed would not be agriculturally productive soils. Construction SOPs and a SWPPP (required by the NPDES permit) would be followed to prevent soil erosion. Therefore, Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impact. A more detailed description of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

There are no known sinkholes in the vicinity. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

Apra Harbor is located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, and slope instability would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at the Apra Harbor is vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

Operation

Operations under Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

Although Apra Harbor is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, and liquefaction would be minimized during construction. The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

Naval Base Guam

The proposed Alternative 1 at Naval Base Guam includes the Military Working Dog Kennel, U.S. Coast Guard relocations, and a New Medical Clinic. Aviation training at Orote Point is proposed as well, on existing paved surfaces. Proposed activities would disturb soil during construction. There is a risk of increased rate of erosion and soil loss from physical disturbance caused by construction activity, however stormwater BMPs would be implemented to prevent impacts. Erosion potential for soils found at Naval Base Guam is shown in Table 3.1-1.

The feasible upland disposal sites are described in Volume 2, Chapter 4 (Water Resources) of this EIS/OEIS. The disposal sites are considered temporary (3 to 4 years). The sites are all vacant and would be developed with bermed perimeters approximately 13 ft (4 m) in height.

Military Working Dog Kennel

The Military Working Dog Facility would include a 2,040 ft^2 (190 m^2) single-story building. The locker would generate a 20-ft (1.9-m) radius explosive safety quantity distance arc. There would be an outdoor obedience/training course (22,500 ft^2 [2,090 m^2]), exercise area (800 ft^2 [74 m^2]) and break area (200 ft^2 [19 m^2]), all with self closing/self-latching gates.

Site improvements include an 8ft (2.4 m) high chain link fence with three strands of straight wire along the perimeter of the working dog site with a 20 ft (6.1 m) wide service gate for vehicular access. Low levels of polychlorinated biphenyls contaminants have been identified approximately 400 ft (121.92 m) north of the site. Soil testing would be conducted prior to construction. No trees would be cleared. Access to the site would be from existing roads, and utilities would tie into the utilities along the roadways. Area of grading/grubbing is approximately 85,301.84 ft^2 (26,000 m^2) and landscaping would be required for 65,617 ft^2 (20,000 m^2).

Medical Clinic

The new Naval Base Guam clinic project consists of constructing one single-level outpatient facility. It is assumed that the entire site (334,000 ft^2 [31,029.62 m^2]) would be graded during construction. The facility would be constructed of reinforced concrete with slab on grade foundations.

Construction

Soil types that could be disturbed would not be agriculturally productive soils. Construction SOPs and a SWPPP (required by the NPDES permit) would be followed to prevent soil erosion. Therefore, Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

There are no known sinkholes in the vicinity of any of the proposed projects. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

Naval Base Guam is located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, and liquefaction would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Naval Base Guam is vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

Operation

Operations under Alternative 1 would not result in significant impacts to unique geologic resources or result in significant soil erosion or compaction or loss of agriculturally productive soil.

Although Naval Base Guam is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, and liquefaction would be minimized during construction. The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

3.2.2.4 South

Training activities, including aviation training, non-firing operations training, and storage of munitions, would occur at NMS. Eleven new magazines are proposed for the area that would require concrete slab foundations. The footprint of each magazine would be 80 ft (24 m) long and no wider than 30 ft (9.1 m). Each earth covered magazine (ECM) is covered in a minimum of 24 inches (61 centimeters) of soil. Non-firing maneuver training facilities that already exist would be subject to greater use in Southern NMS. The proposed unimproved helicopter landing zone would be sited on vacant land. No improvements would be made that would increase erosion or runoff into Fena Reservoir.

Construction

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Construction activities under Alternative 1 would include clearing, grading and grubbing, demolition of existing earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 1 would result in minimal impacts to geologic resources by changing the landscape of the affected area.

There are no known sinkholes at NMS. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

The Alternative 1 proposed developments would be located in an area subject to slope instability. SOPs would be implemented to avoid geologic hazards from slope instability, such as landslides. The area is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

Operation

An increase in military training activities would result in localized disturbances to topographic features and soil. Training activities are conducted with established procedures aimed at minimizing topsoil loss, compaction, and erosion. Erosion potential for soil found at NMS can be found in Table 3.1-1. There would be minimal impact to soil and geological resources from training activities and short-term impacts on soil and geological resources during construction of munitions magazines. No significant impacts are expected.

Fire potential would be increased due to the presence of Marines during ground training exercises, especially through the use of such pyrotechnics such as smoke for marking. Potentially greater access to trespassers including hunters due to the development of the proposed NMS training access road would be prevented by installation of fencing and gates at the access road entrance. A fire management plan would be developed for use in this area which would include prevention, planning, and suppression methods (see Section 10.2.2.5). Fire-related geological impacts resulting from the proposed action would be less than significant.

3.2.2.5 Summary of Impacts

Construction Impacts

At Finegayan, construction activities under Alternative 1 would include building of facilities, infrastructure, utilities, and roadways, which would include clearing, grading and grubbing, demolition of existing road pavement, earthwork, and landscaping. Permanent loss of vegetation would occur. Therefore, Alternative 1 would result in adverse but not significant impacts to topography at Finegayan by changing the landscape of the affected area.

Construction activities at all other locations under Alternative 1 would include clearing, grading and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 1 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

The construction SOPs would include requirements for stormwater compliance and BMPs to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal impacts from soil erosion. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction, except for at Apra Harbor, where BMPs would be used to prevent significant soil erosion.

NMS encompasses areas of soil with high erodibility factors, including Akina and Atate soils. BMPs to manage erosion and stormwater during the construction process (refer to Table 3.1-2) would be implemented to control erosion.

There is a sinkhole in the vicinity of the North Ramp approximately 700 ft by 900 ft (213 m by 274 m) in the area just east of the project site, at least ten in the vicinity of the proposed Main Cantonment Area, and one found at Harmon Annex. The sinkholes would be avoided and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. A survey by a licensed geologist is required prior to construction to ensure that all sinkholes have been identified. The sinkholes would not be affected by construction activities. Therefore, Alternative 1 would not result in significant impacts to a unique geologic resource.

The Alternative 1 proposed developments in north and central Guam would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 1 proposed developments at NMS would be located in an area subject to slope instability. SOPs would be implemented to avoid geologic hazards from slope instability, such as landslides. The area is not vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards.

Although Apra Harbor and Naval Base Guam are located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, and liquefaction would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

Operation Impacts

Training activities at Andersen South, NMS, and at the Route 15 parcel would be conducted with established procedures aimed at minimizing topsoil loss and erosion. Vehicle movements and troop movements would occur on paved routes and would not increase erosion and compaction. Erosion potential for soils found at NMS is shown in Table 3.1-1.

The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability during operations. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 1 would not result in significant impacts associated with geologic hazards at Andersen AFB, NCTS Finegayan, Finegayan South, and nearby non-DoD lands.

Although Apra Harbor is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, and liquefaction would be minimized during construction. The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Apra Harbor is vulnerable to liquefaction. Adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007) during construction would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact operations. Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

If deemed hazardous, any sinkholes found in the area could be fenced off and signs put in place to warn of the potential danger. No significant impacts are expected.

There is potential for ordnance-ignited wildfires that might impact soil and geological resources in central Guam, where live-fire training would occur. A fire management plan would be developed for use in this area which would include prevention, planning, and suppression methods (see Section 3.2.2.7). It would include protocols for monitoring fire conditions and adjusting training as needed (e.g., firing or tracers may be disallowed under certain fire conditions); location and management of fire breaks, fire fighting roads, and a fire fighting water system; protocols for using units to be briefed by range control on requirements suitable to the conditions of the day; and protocols should a fire occur (e.g., specifying how the range would shut down and fire suppression action would be taken). With implementation of these measures, impacts from wildfire would be less than significant.

3.2.2.6 Potential Mitigation Measures

A fire management plan would be developed to include burn hazard assessment (fire danger rating system), fire fighting water systems, on-call helicopter fire suppression,Since implementation of the proposed action and alternatives would not result in any significant impacts, no mitigation measures would be required.

3.2.3 Alternative 2 (Preferred Alternative)

3.2.3.1 North

Andersen AFB

Construction and operation impacts are the same as for Alternative 1.

Finegayan

A total of 1,610 ac (652 ha) at NCTS Finegayan and 290 ac (117 ha) at South Finegayan would be developed under Alternative 1. Construction and operation impacts are the same as for Alternative 1.

Non-DoD Land

Harmon Annex would not be developed under Alternative 2, thus there would be no impact to soil and geological resources at Harmon Annex under Alternative 2.

Construction and operation impacts to the Former FAA Parcel are the same as for Alternative 1.

3.2.3.2 Central

Andersen South

Construction and operation impacts are the same as for Alternative 1.

Non-DoD Land

Construction and operation impacts are the same as for Alternative 1.

Barrigada

Construction Impacts

There would be no construction in Navy Barrigada or Air Force Barrigada under the proposed alternative.

Operation Impacts

There would be no operation in Navy Barrigada or Air Force Barrigada under the proposed alternative.

3.2.3.3 Apra Harbor

Harbor

Construction and operation impacts are the same as for Alternative 1.

Naval Base Guam

Construction and operation impacts are the same as for Alternative 1.

3.2.3.4 South

Construction and operation impacts are the same as for Alternative 1.

3.2.3.5 Summary of Impacts

Construction Impacts

Construction activities under Alternative 2 would include clearing, grading and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 2 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

The construction SOPs would include requirements for stormwater compliance with stormwater Best BMPs, including the SWPPP, to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion, thus there would be minimal soil erosion impacts. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction, except for at Apra Harbor, where BMPs would be used to prevent significant soil erosion. Construction SOPs and a SWPPP (required by the NPDES permit) would be followed to prevent soil erosion. Therefore, Alternative 2 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

NMS encompasses areas of soil with high erodibility factors including Akina and Atate soils. BMPs to manage erosion and stormwater during the construction process would be implemented to control erosion. There is a sinkhole in the vicinity of the North Ramp approximately 700 ft by 900 ft (213 m by 274 m) in area, just east of the project site. There are at least ten sinkholes in the vicinity of the proposed Main Cantonment area. The sinkholes would be avoided and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. A survey by a licensed geologist is required prior to construction to ensure that all sinkholes have been identified. The sinkholes would not be affected by construction activities. Therefore, Alternative 2 would not result in significant impacts to a unique geologic resource.

The Alternative 2 proposed developments in northern and central Guam would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 2 proposed developments at NMS would be located in an area subject to slope instability. SOPs would be implemented to avoid geologic hazards from slope instability, such as landslides. The area is not vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 2 would not result in significant impacts associated with geologic hazards.

Apra Harbor and Naval Base Guam are located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, and slope instability would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 2 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Apra Harbor and Naval Base Guam is vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Alternative 2 would result in adverse but not significant impacts associated with geologic hazards.

Operation Impacts

Training activities at Andersen South and at the Route 15 parcel would be conducted with established procedures aimed at minimizing topsoil loss, compaction, and erosion. Vehicle movements and troop movements would occur on paved routes and would not increase erosion and compaction.

Military training activities at NMS would result in localized disturbances to soil. Training activities are conducted with established procedures aimed at minimizing topsoil loss and erosion. Soil types that could be disturbed would not be agriculturally productive soils. Erosion potential for soils found at NMS is shown in Table 3.1-1.

The Alternative 2 proposed developments would be located on a relatively flat area that would not be subject to slope instability during operations. Exposure potential to seismic ground shaking and fault rupture would be minimized during construction. Therefore, Alternative 2 would not result in significant impacts associated with geologic hazards at Andersen AFB, Finegayan, Finegayan South,

Although Apra Harbor is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, and slope instability are minimal. The underlying fill at Apra Harbor is vulnerable to liquefaction. Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact operations. Alternative 2 would result in adverse but not significant impacts associated with geologic hazards.

Sinkholes would be fenced off and educational signs would be put in place to warn of their potential danger. Alternative 2 would not result in impacts associated with geologic resources or hazards that would require mitigation.

There is potential for ordnance-ignited wildfires that might impact soil and geological resources in central Guam, where live-fire training would occur. As mitigation, a fire management plan would be developed for use in this area which would include prevention, planning, and suppression methods (see Section 3.2). It would include protocols for monitoring fire conditions and adjusting training as needed (e.g., firing or tracers may be disallowed under certain fire conditions); location and management of fire breaks, fire fighting roads, and a fire fighting water system; protocols for using units to be briefed by range control on requirements suitable to the conditions of the day; and protocols should a fire occur (e.g., specifying how the range would shut down and fire suppression action would be taken). With implementation of these measures, impacts from wildfire would be less than significant.

3.2.3.6 Potential Mitigation Measures

Since implementation of Alternative 2 would not result in significant impacts to soils and geological resources, no mitigation measures would be required.

3.2.4 Alternative 3

3.2.4.1 North

Andersen AFB

Construction and operation impacts would not differ from those of Alternative 1.

Finegayan

Impacts to Finegayan would not differ from those of Alternative 2.

Non-DoD Land

There would be no impact to Non-DoD land under Alternative 3; neither Harmon Annex nor the Former FAA Parcel would be developed.

3.2.4.2 Central

Andersen South

Construction and operation impacts would not differ from those of Alternative 1.

Non-DoD Land

Construction and operation impacts would not differ from those of Alternative 1.

Barrigada

Construction

Three hundred seventy-seven ac (153 ha) of Navy Barrigada and 430 ac (174 ha) of Air Force Barrigada would be developed as family housing/community support under Alternative 3.

The proposed Alternative 3 at Navy and Air Force Barrigada would disturb soil during construction. There is a risk of increased rate of erosion, compaction, and soil loss from physical disturbance caused by construction activity, but construction SOPs and a SWPPP (required by the NPDES permit) would be followed to prevent soil erosion. The construction SOPs would include requirements for stormwater compliance with stormwater BMPs, including the SWPPP, to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. Erosion potential for soils found at Barrigada is shown in Table 3.1-1.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction. Construction SOPs would be followed to prevent soil erosion. Therefore, Alternative 3 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

Construction activities under Alternative 3 would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 3 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

There are no known sinkholes at Navy and Air Force Barrigada. Therefore, Alternative 3 would not result in significant impacts to a unique geologic resource.

Navy and Air Force Barrigada are located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, slope instability and liquefaction would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). No fault lines run directly through the Barrigada area. The Alternative 3 proposed developments would be located on a relatively flat plateau that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Due to the limited duration and amount of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 3 would not result in significant impacts associated with geologic hazards.

Operation

Although Finegayan is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, slope instability and liquefaction would be minimized during construction. The Alternative 3 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Operations activities would not disturb soil or cause an increase in erosion. The predominant limestone bedrock is not vulnerable to liquefaction. Therefore, Alternative 3 would not result in significant impacts associated with geologic resources or hazards.

3.2.4.3 Apra Harbor

Harbor

Construction and operation impacts would not differ from those of Alternative 1.

Naval Base Guam

Construction and operation impacts would not differ from those of Alternative 1.

3.2.4.4 South

Construction and operation impacts would not differ from those of Alternative 1.

3.2.4.5 Summary of Impacts

Construction Impacts

Construction activities under Alternative 3 would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 3 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

The construction SOPs would include requirements for stormwater compliance with stormwater BMPs, including the SWPPP, to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent significant erosion and compaction, thus there would be minimal soil erosion impacts. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction, except for at Apra Harbor, where BMPs would be used to prevent significant soil erosion. Construction SOPs would be followed at all proposed sites to prevent soil erosion. Therefore, Alternative 3 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

NMS encompasses areas of soil with high erodibility factors, including Akina and Atate soils. BMPs to manage erosion and stormwater during the construction process would be implemented to control erosion.

There is a sinkhole in the vicinity of the North Ramp approximately 700 ft by 900 ft (213 m by 274 m) in area, just east of the project site. There are at least ten sinkholes in the vicinity of the proposed Main Cantonment area. The sinkholes would be avoided and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. A survey by a licensed geologist is required prior to construction to ensure that all sinkholes have been identified. The sinkholes would not be affected by construction activities. Therefore, Alternative 3 would not result in significant impacts to a unique geologic resource.

The Alternative 3 proposed developments in North and Central Guam would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 3 proposed developments at NMS would be located in an area subject to slope instability. SOPs would be implemented to avoid geologic hazards from slope instability, such as landslides. The area is not vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 3 would not result in significant impacts associated with geologic hazards.

Apra Harbor and Naval Base Guam are located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, and slope instability would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 3 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Apra Harbor and Naval Base Guam is vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Alternative 3 would result in adverse but not significant impacts associated with geologic hazards.

Operation Impacts

Military training activities at Andersen South, NMS, and at the Route 15 parcel would result in localized disturbances to topographic features. Training activities would be conducted with established procedures aimed at minimizing topsoil loss, compaction, and erosion. Vehicle movements and troop movements would occur on paved routes and would not increase erosion and compaction. Erosion potential for soil found at training sites can be found in Table 3.1-1. There would be minimal impact to soil and geological resources from training activities and short-term impacts on soil and geological resources during construction of munitions magazines.

The Alternative 3 proposed developments would be located on a relatively flat area that would not be subject to slope instability. Potential damage from seismic ground shaking and fault rupture would be minimized during construction. Therefore, Alternative 3 would not result in significant impacts associated with geologic hazards at Andersen AFB, Finegayan, and Finegayan South.

Apra Harbor is located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, and slope instability would be minimized during construction. The Alternative 1 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Apra Harbor is vulnerable to liquefaction. Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact operations. Alternative 3 would result in adverse but not significant impacts associated with geologic hazards.

Sinkholes would be fenced off and educational signs would be put in place to warn residents of their potential danger. Alternative 3 would result in impacts associated with geologic resources or hazards that would require mitigation.

There is potential for ordnance-ignited wildfires that might impact soil and geological resources in central Guam, where live-fire training would occur. A fire management plan would be developed for use in this area which would include prevention, planning, and suppression methods (see Section 3.2.4.7). It would include protocols for monitoring fire conditions and adjusting training as needed (e.g., firing or tracers may be disallowed under certain fire conditions); location and management of fire breaks, fire fighting roads, and a fire fighting water system; protocols for using units to be briefed by range control on requirements suitable to the conditions of the day; and protocols should a fire occur (e.g., specifying how the range would shut down and fire suppression action would be taken). With implementation of these measures, impacts from wildfire would be less than significant.

3.2.4.6 Potential Mitigation Measures

Since implementation of Alternative 3 would not result in significant impacts to soils and geological resources, no mitigation measures would be required.

3.2.5 Alternative 8

3.2.5.1 North

Andersen AFB

Construction and operation impacts would not differ from those of Alternative 1.

Finegayan

Construction and operation impacts would not differ from those of Alternative 1.

Non-DoD Land

There would be no impact to Harmon Annex under Alternative 8. Impacts to Former FAA Parcel would not differ from those of Alternative 1.

3.2.5.2 Central

Andersen South

Construction and operation impacts would not differ from those of Alternative 1.

Non-DoD Land

Construction and operation impacts would not differ from those of Alternative 1.

Barrigada

There is no action at Navy Barrigada under Alternative 8, thus there are no construction or operation impacts to soil or geological resources at Navy Barrigada.

Construction and operation impacts to soil and geological resources at Air Force Barrigada would not differ from those of Alternative 3.

3.2.5.3 Apra Harbor

Harbor

Construction and operation impacts would not differ from those of Alternative 1.

Naval Base Guam

Construction and operation impacts would not differ from those of Alternative 1.

3.2.5.4 South

Construction and operation impacts would not differ from those of Alternative 1.

3.2.5.5 Summary of Impacts

Construction Impacts

Construction activities under Alternative 1 would include clearing, grading, and grubbing, demolition of existing road pavement, earthwork, and landscaping. Temporary loss of vegetation would occur. Therefore, Alternative 8 would result in minimal impacts to unique geologic resources by changing the landscape of the affected area.

The construction SOPs would include requirements for stormwater compliance, with BMPs, including the SWPPP, to ensure that all aspects of the project construction would be performed in a manner to minimize impacts during construction activity. A description of the standard BMPs and resource protection measures required by regulatory mandates can be found in Volume 7 of this EIS/OEIS. Implementation of measures such as revegetation as soon as possible after any ground disturbance or grading and minimizing construction and grading during times of inclement weather would prevent erosion and compaction, thus there would be minimal soil erosion impacts. A more detailed explanation of regulatory permitting requirements can be found in Volume 8 of this EIS/OEIS.

Soil types that could be disturbed would not be agriculturally productive soils. Soil erosion is primarily a concern for discharge into surface or nearshore waters that are not located near the proposed construction, except for at Apra Harbor, where BMPs would be used to prevent significant soil erosion. Construction SOPs would be followed at all proposed sites to prevent soil erosion. Therefore, Alternative 8 would not result in significant impacts to unique geologic resources or result in significant soil erosion or loss of agriculturally productive soil.

NMS encompasses areas of soil with high erodibility factors, including Akina and Atate soils. BMPs to manage erosion and stormwater during the construction process would be implemented to control erosion.

There is a sinkhole in the vicinity of the North Ramp approximately 700 ft by 900 ft (213 m by 274 m) in area, just east of the project site., as well as ten sinkholes at the proposed Main Cantonment area. The sinkholes would be avoided and a buffer zone of vegetation would be left around it to prevent further erosion or expansion. A survey by a licensed geologist is required prior to construction to ensure that all sinkholes have been identified. The sinkholes would not be affected by construction activities. Therefore, Alternative 8 would not result in significant impacts to a unique geologic resource.

The Alternative 8 proposed developments in north and central Guam would be located on a relatively flat area that would not be subject to slope instability. The predominant limestone bedrock is not vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 8 proposed developments at NMS would be located in an area subject to slope instability. SOPs would be implemented to avoid geologic hazards from slope instability, such as landslides. The area is not vulnerable to liquefaction. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 8 would not result in significant impacts associated with geologic hazards.

Apra Harbor and Naval Base Guam are located in a potentially active seismic zone. Hazards associated with earthquakes, fault rupture, and slope instability would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). The Alternative 8 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Apra Harbor is vulnerable to liquefaction. Potential damage from seismic ground shaking and fault rupture would be minimized by adherence to UFC 3-310-04 Seismic Design for Buildings (USACE 2007). Alternative 8 would result in adverse but not significant impacts associated with geologic hazards.

Operation Impacts

Military training activities would result in localized disturbances to topographic features. Training activities are conducted with established procedures aimed at minimizing topsoil loss, compaction, and erosion. Erosion potential for soils affected is shown in Table 3.1-1. There would be minimal impact to soil and geological resources from training activities and short-term impacts on soil and geological resources during construction of munitions magazines.

Training activities at Andersen South, NMS, and at the Route 15 parcel would be conducted with established procedures aimed at minimizing topsoil loss and erosion. Vehicle movements and troop movements would occur on paved routes and would not increase erosion and compaction.

The Alternative 8 proposed developments at Andersen AFB, Finegayan, Finegayan South, and Barrigada would be located on a relatively flat area that would not be subject to slope instability. Due to the limited duration of construction activities, exposure potential to seismic ground shaking and fault rupture would be minimal. Therefore, Alternative 8 would not result in significant impacts associated with geologic hazards.

Although Apra Harbor is located in a potentially active seismic zone, the hazards associated with earthquakes, fault rupture, and slope instability are minimal. The Alternative 8 proposed developments would be located on a relatively flat area that would not be subject to slope instability. The underlying fill at Apra Harbor is vulnerable to liquefaction. Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact operations. Alternative 1 would result in adverse but not significant impacts associated with geologic hazards.

Sinkholes would be fenced off and educational signs would be put in place to warn of their potential danger. Alternative 8 would not result in impacts associated with geologic resources or hazards that would require mitigation.

There is potential for ordnance-ignited wildfires that might impact soil and geological resources in central Guam, where live-fire training would occur. A fire management plan would be developed for use in this area which would include prevention, planning, and suppression methods (see Section 3.2.5.7). It would include protocols for monitoring fire conditions and adjusting training as needed (e.g., firing or tracers may be disallowed under certain fire conditions); location and management of fire breaks, fire fighting roads, and a fire fighting water system; protocols for using units to be briefed by range control on requirements suitable to the conditions of the day; and protocols should a fire occur (e.g., specifying how the range would shut down and fire suppression action would be taken). With implementation of these measures, impacts from wildfire would be less than significant.

3.2.5.6 Potential Mitigation Measures

Since implementation of Alternative 8 would not result in significant impacts to soils and geological resources, no mitigation measures would be required.

3.2.6 No-Action Alternative

Under the no-action alternative, Marine Corps units would not relocate to Guam. No construction, dredging, training, or operations associated with the military relocation would occur. Existing DoD operations on Guam would continue. Therefore, implementation of the no-action alternative would maintain existing conditions and there would be no impact to geological resources and soils. Implementation of the no-action alternative would not meet the mission, readiness, national security and international treaty obligations of the Marine Corps.

3.2.7 Summary of Impacts

Tables 3.2-3, 3.2-4, 3.2-5, and 3.2-6 summarize the potential impacts of each action alternative associated with the Main Cantonment, firing range training, ammunition storage, and NMS access roads. Table 3.2-7 summarizes the potential impacts of other training, airfield, and waterfront components of the proposed action. A text summary is provided below.

Relocation of Marine Corps personnel from Okinawa to Guam would require construction and renovation that would potentially disturb soil, increase erosion, and change the landscape of Guam in multiple areas.

Temporarily increased rates of erosion and soil loss from physical disturbance of construction would occur during construction. With the implementation of protective measures, there would be no significant impacts from soil erosion. Soil types lost would not be agriculturally productive soils. Topographic or landscape features would not be changed substantively by the proposed action and it is not located in a seismically-active zone. The action area is located in areas with karst geologic features that are of concern for the construction and operation of these facilities. Careful construction planning would be required to minimize changes to geological features like Guam's unique karst caves and sinkholes. Construction on previously disturbed land is less likely to impact soil and geological resources. Liquefaction is a risk at Apra Harbor, but impacts to development are not significant.

Table 3.2-3. Summary of Main Cantonment Impacts – Alternatives 1, 2, 3 and 8

Main Cantonment Alternative 1 (North)	*Main Cantonment Alternative 2 (North)*	*Main Cantonment Alternative 3 (North/Central)*	*Main Cantonment Alternative 8 (North/Central)*
Construction			
LSI • Alternative 1 would result in adverse but not significant impacts to topography at Finegayan, where 1,093 ac (442 ha) of land would be permanently altered.	LSI • Alternative 2 would result in adverse but not significant impacts to topography at Finegayan, where 1,093 ac (422 ha) of land would be permanently altered.	LSI • Alternative 3 would result in adverse but not significant impacts to topography at Finegayan, where 1,093 ac (422 ha) of land would be permanently altered.	LSI • Alternative 8 would result in adverse but not significant impacts to topography at Finegayan, where 1,093 ac (422 ha) of land would be permanently altered.
LSI • Alternative 1 would result in minimal impacts to topography by changing the landscape at Andersen AFB, Andersen South, Harmon Annex, Former FAA, Route 15, Apra Harbor, and NMS. • Alternative 1 would result in minimal impacts to topography as a result of training activities at Andersen South, NMS, and Route 15.	LSI • Alternative 2 would result in minimal impacts to topography by changing the landscape at Andersen AFB, Andersen South, Former FAA, Route 15, Apra Harbor, and NMS. • Alternative 2 would result in minimal impacts to topography as a result of training activities at Andersen South, NMS, and Route 15.	LSI • Alternative 3 would result in minimal impacts to topography by changing the landscape at Andersen AFB, Andersen South, Barrigada, Route 15, Apra Harbor, and NMS. • Alternative 3 would result in minimal impacts to topography as a result of training activities at Andersen South, Route 15 and NMS.	LSI • Alternative 8 would result in minimal impacts to topography by changing the landscape at Andersen AFB, Andersen South, Former FAA, Route 15, Barrigada, Apra Harbor, and NMS. • Alternative 8 would result in minimal impacts to topography as a result of training activities at Andersen South, Route 15 and NMS.
LSI • During construction, sinkholes would be avoided and a buffer zone of vegetation would be left around them to prevent further erosion or expansion at Andersen AFB, Finegayan, and Harmon Annex. Minimal impacts to sinkholes would occur under Alternative 1. • Sinkholes would not be adversely impacted by operations.	LSI • During construction, sinkholes would be avoided and a buffer zone of vegetation would be left around them to prevent further erosion or expansion at Andersen AFB and Finegayan. Minimal impacts to sinkholes would occur under Alternative 2. • Sinkholes would not be adversely impacted by operations.	LSI • During construction, sinkholes would be avoided and a buffer zone of vegetation would be left around them to prevent further erosion or expansion at Andersen AFB. Minimal impacts to sinkholes would occur under Alternative 3. • Sinkholes would not be adversely impacted by operations.	LSI • During construction, sinkholes would be avoided and a buffer zone of vegetation would be left around them to prevent further erosion or expansion at Andersen AFB. Minimal impacts to sinkholes would occur under Alternative 8. • Sinkholes would not be adversely impacted by operations.

Main Cantonment Alternative 1 (North)	*Main Cantonment Alternative 2 (North)*	*Main Cantonment Alternative 3 (North/Central)*	*Main Cantonment Alternative 8 (North/Central)*
Operation			
LSI • Alternative 1 operations would not result in significant soil erosion or loss of agriculturally productive soil. • Slope stability would not be altered, thus minimal impacts to soil resources would occur.	LSI • Alternative 2 operations would not result in significant soil erosion or loss of agriculturally productive soil. • Slope stability would not be altered, thus minimal impacts to soil resources would occur.	LSI • Alternative 3 operations would not result in significant soil erosion or loss of agriculturally productive soil. • Slope stability would not be altered, thus minimal impacts to soil resources would occur.	LSI • Alternative 8 operations would not result in significant soil erosion or loss of agriculturally productive soil. • Slope stability would not be altered, thus minimal impacts to soil resources would occur.

Table 3.2-4. Summary of Training Impacts – Firing Range Alternatives

Firing Range Alternative A (Central)	*Firing Range Alternative B (Central)*
Construction	
LSI • Alternative A would result in minimal impacts to topography by changing the landscape at Route 15. • Slope stability would not be altered, thus minimal impacts to soil resources would occur. • Risk of damage to structures from seismic, liquefaction and ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.	LSI • Alternative B would result in minimal impacts to topography by changing the landscape at Route 15. • Slope stability would not be altered, thus minimal impacts to soil resources would occur. • Risk of damage to structures from seismic, liquefaction and ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.
Operation	
LSI • Alternative A would result in minimal impacts to topography as a result of firing range training activities at Route 15. • Alternative A operations would not result in significant soil erosion or loss of agriculturally productive soil. • Risk of damage to structures from seismic, liquefaction and ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.	LSI • Alternative B would result in minimal impacts to topography as a result of firing range training activities at Route 15. • Alternative B operations would not result in significant soil erosion or loss of agriculturally productive soil. • Risk of damage to structures from seismic, liquefaction and ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.

Legend: SI = Significant impact, SI-M = Significant impact mitigable to less than significant, LSI = Less than significant impact, NI = No impact.

Table 3.2-5. Summary of Training Impacts – Ammunition Storage Alternatives

Ammunition Storage Alternative A (South)	*Ammunition Storage Alternative B (South)*
Construction	
LSI • Alternative A would result in minimal impacts to topography by changing the landscape at Andersen AFB and NMS. • Alternative A construction would not result in significant soil erosion or loss of agriculturally productive soil. • Slope stability would not be altered, thus minimal impacts to soil resources would occur. • Risk of damage to structures from seismic, ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.	LSI • Alternative B would result in minimal impacts to topography by changing the landscape at Andersen AFB and NMS. • Alternative B construction would not result in significant soil erosion or loss of agriculturally productive soil. • Slope stability would not be altered, thus minimal impacts to soil resources would occur. • Risk of damage to structures from seismic, and ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.
Operation	
LSI • Alternative A would result in minimal impacts to topography as a result of training activities at Andersen South and NMS. • Alternative A operations would not result in significant soil erosion or loss of agriculturally productive soil. • Risk of damage to structures from seismic, ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.	LSI • Alternative B would result in minimal impacts to topography as a result of training activities at Andersen South and NMS. • Alternative B operations would not result in significant soil erosion or loss of agriculturally productive soil. • Risk of damage to structures from seismic, liquefaction and ground shaking hazards would be minimized by adherence to required building safety codes and design guidelines.

Legend: SI = Significant impact, SI-M = Significant impact mitigable to less than significant, LSI = Less than significant impact, NI = No impact.

Table 3.2-6. Summary of Training Impacts – NMS Access Roads Alternatives

Access Road Alternative A (South)	*Access Road Alternative B (South)*
Construction	
LSI • Alternative A would result in minimal impacts to topography by changing the landscape at NMS.	LSI • Alternative B would result in minimal impacts to topography by changing the landscape at NMS.
Operation	
LSI • Alternative A would result in minimal impacts to topography as a result of training activities at NMS.	LSI • Alternative B would result in minimal impacts to topography as a result of training activities at NMS.

Legend: SI = Significant impact, SI-M = Significant impact mitigable to less than significant, LSI = Less than significant impact, NI = No impact.

Table 3.2-7. Summary of Other Training, Airfield, and Waterfront Component Impacts

Other Training (North/Central/South)	*Airfield (North)*	*Waterfront (Apra Harbor)*
Construction		
LSI • Alternatives would result in minimal impacts to topography by changing the landscape at Andersen AFB, Andersen South, Harmon Annex, Former FAA, Route 15, Apra Harbor, and NMS. • Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact construction; minimal impacts would occur. • Presence of sinkholes near construction areas poses safety hazard for construction and installation personnel, sinkholes would be fenced off as needed with warning signs. Minimal impacts would occur.	LSI • Alternatives would result in minimal impacts to topography by changing the landscape at Andersen AFB. • Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, ground shaking hazards that could potentially impact construction; minimal impacts would occur. • Presence of sinkholes near construction areas poses safety hazard for construction and installation personnel, sinkholes would be fenced off as needed with warning signs. Minimal impacts would occur.	LSI • Alternatives would result in minimal impacts to topography by changing the landscape at Apra Harbor. • Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact construction; minimal impacts would occur.
Operation		
LSI • Alternatives would result in minimal impacts to topography as a result of training activities at Andersen South, NMS, and Route 15. • Adherence to UFC 3-310-04 Seismic Design for Buildings during construction would reduce risk of damage to structures from seismic, ground shaking hazards that could potentially impact operations; minimal impacts would occur. • Presence of sinkholes near construction areas poses safety hazard for construction and installation personnel, sinkholes would be fenced off as needed with warning signs. Minimal impacts would occur.	LSI • Alternatives would result in minimal impacts to topography as a result of training activities at Andersen AFB. • Presence of sinkholes near operation areas poses safety hazard for construction and installation personnel; sinkholes would be fenced off as needed with warning signs. Minimal impacts would occur.	LSI • Alternatives would result in minimal impacts to topography as a result of training activities at Apra Harbor. • High risk of liquefaction at Apra Harbor and risk of damage to structures from seismic, liquefaction and ground shaking hazards exists. Adherence to UFC 3-310-04 Seismic Design for Buildings would reduce risk of damage to structures from seismic, liquefaction and ground shaking hazards that could potentially impact operations; minimal impacts would occur.

Legend: SI = Significant impact, SI-M = Significant impact mitigable to less than significant, LSI = Less than significant impact, NI = No impact.

3.2.8 Summary of Potential Mitigation Measures

Implementation of alternatives 1, 2, 3 and 8 and associated specific project components would not result in significant impacts to soils and geological resources. No mitigation measures are required.

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