GUAM
SHORELINE ATLAS
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U.S. ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT

THE GUAM BUREAU OF STATISTICS AND PLANS
GUAM COASTAL MANAGEMENT PROGRAM

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1

INTRODUCTION

1.1 Objective

The objective of the Guam Shoreline Atlas is to describe the physical characteristics of the Guam shoreline, with emphasis on shorelines experiencing erosional problems, containing at-risk infrastructure, or needing shore protection. This Atlas comprehensively documents current shoreline conditions throughout Guam, providing shoreline managers with baseline information and a tool for future planning efforts.

1.2 Scope

This study was conducted by the U.S. Army Corps of Engineers, Honolulu District under the Planning Assistance to the States program for the non-Federal sponsor, the government of Guam (GovGuam) Bureau of Statistics and Plans, Guam Coastal Management Program (GCMP). The Guam Shoreline Atlas was completed in two phases. The first phase consisted of field investigations including ground photography and shoreline assessments, and the second phase consisted of the preparation of this Atlas. The field investigations were conducted to identify, photograph, document, and map existing shoreline features, conditions, and problem areas. Ground level digital photographs captured the site characteristics and documented the shoreline condition for inclusion in this Atlas. Global Positioning System (GPS) units were used to accurately map the shoreline features. The data collected from the field investigations were used to create this interactive Portable Document Format (PDF) for the user to easily view and access the data. Additionally, a Geographic Information System (GIS) geodatabase containing compatible spatial data from the study is also provided.

1.3 Study Area

Guam is the largest and southernmost island of the Mariana Islands located South-Southwest of Saipan, as shown in Figure 1. Located 3,950 miles west of Hawaii, Guam is the westernmost point of the United States. The island is approximately 30 miles long, 4 to 12 miles wide with an area of 210 square miles and 110 miles of shoreline. Guam is composed of volcanic material, partly covered by coralline limestone. The geologic and topographic features of Guam divide the island into a northern and southern section.

The northern half of Guam is a broad limestone plateau with an elevation of 100 to 600 ft. Three prominent peaks, two of which are volcanic, protrude above the limestone plateau, with a maximum elevation of 860 ft. The plateau is fringed by coastal cliffs, with intermittent beaches and narrow coastal plains. The northern limestone plateau is permeable with no existing permanent streams.

The southern half of Guam is mountainous with areas of relatively impervious volcanic rock. Several mountain peaks exceed 1,000 ft in height. The volcanic rock has been weathered and eroded by surface water runoff creating deep valleys and streams. There are more than 40 streams in the southern half of Guam. The largest is the Talo'fo'fo' River and its tributaries, which drain a 28-square mile area. There are two prominent limestone masses along the southern coastline, Cabras Island and Orote Peninsula.

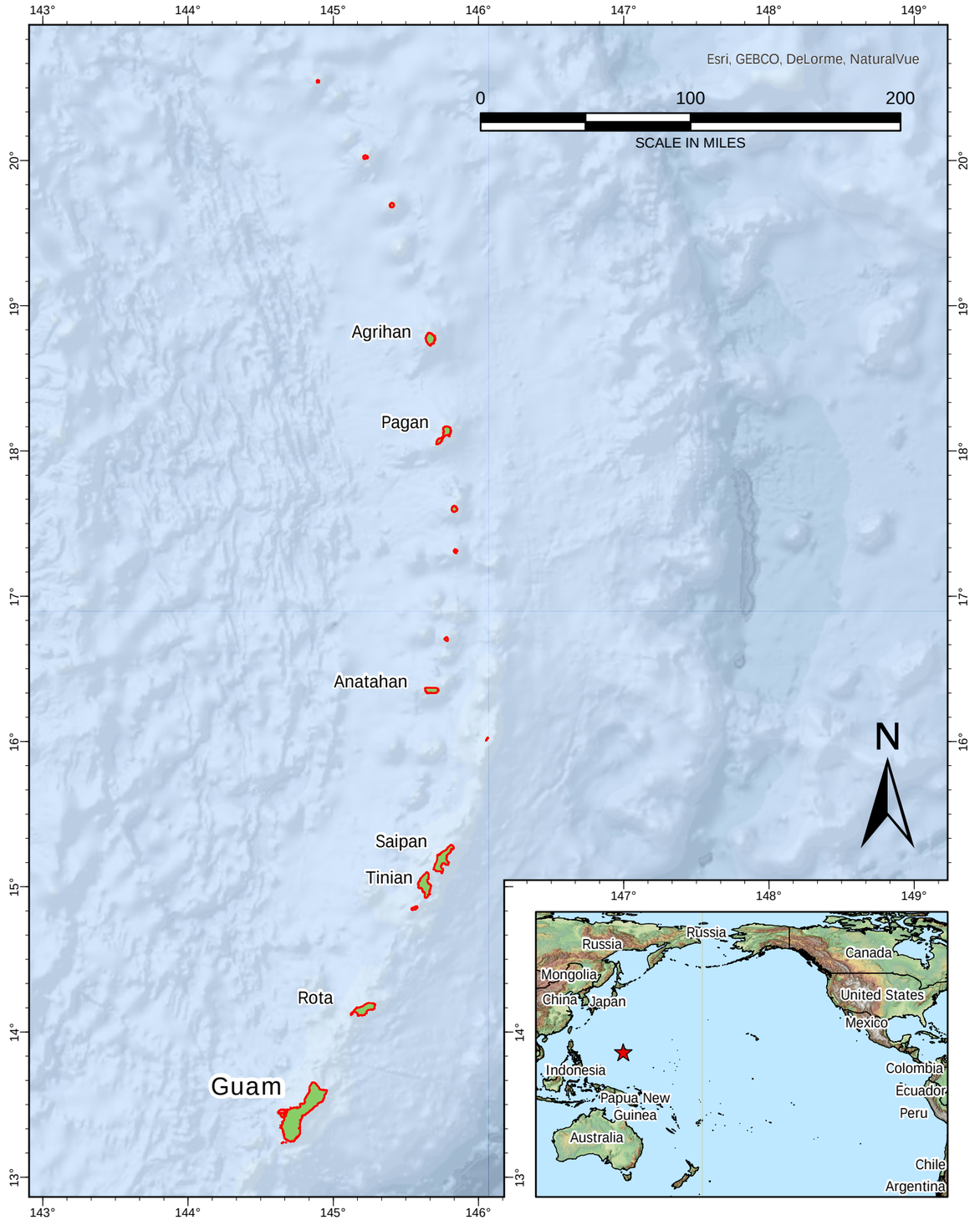


Figure 1. Regional Map of Guam

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1.3 Study Area Continued

The coastline of Guam was divided into 16 sections, shown in Figure 2, as agreed to by the Government of Guam (GovGuam) at the initiation of this study for investigation. These shorelines were chosen based on several criteria including presence of sand, accessibility, infrastructure present in the backshore, population, or recreational usage close to the shoreline, and importance to the Guam economy. Since the focus of this investigation was on evaluating shoreline conditions and the potential need for shore protection, shorelines with rocky cliffs, headlands, or no backshore infrastructure were not included in this study. Within each of these sections, the coastline was further divided into separate reaches. Reaches were designated by either a change in coastline type, shoreline protection, or other defining characteristics.

1.4 Methodology

This shoreline inventory included a review of available pertinent information in conjunction with detailed field investigations to verify and supplement the available information.

1.4.1 Literature Review

- **Guam Shoreline Inventory by the U.S. Army Corps of Engineers Honolulu District, and prepared by Sea Engineering Services Inc. and R.M. Towill Corporation (1980)**
  - ➢ This inventory focused on the southern region of Guam and gives detailed information on the fringing reefs, shorelines, and immediate backshore areas. It also provides analysis of coastal processes and shoreline condition. Due to the overlap between this inventory and this Atlas, descriptions and reach definitions were kept consistent where it was applicable and appropriate.

- **Coastal Survey of Guam by Randall and Holloman (1974)**
  - ➢ This study was intended for use as a planning document. The report includes an extensive literature review of all previously published information and includes an extensive discussion of the geology and hydrology of Guam.

- **Atlas of the Reefs and Beaches of Guam by Randall and Eldredge (1976)**
  - ➢ This study was strictly a physical inventory of the shoreline and fringing reef flats of Guam. No mention was made of backshore development, coastal erosion or nearshore processes.

- **Supplemental Guam Coastal Atlas by Burdick (November 2005)**
  - ➢ This updated Guam Coastal Atlas focuses on the benthic habitat data around Guam and does not include information about shoreline features.

- **Guam Shoreline Inventory: Vicinity of Piti, Agat, and Merizo (October 2007)**
  - ➢ This report gives a detailed assessment of storm wave vulnerable road sections and determines high priority areas and prepares recommendations for shore protection.

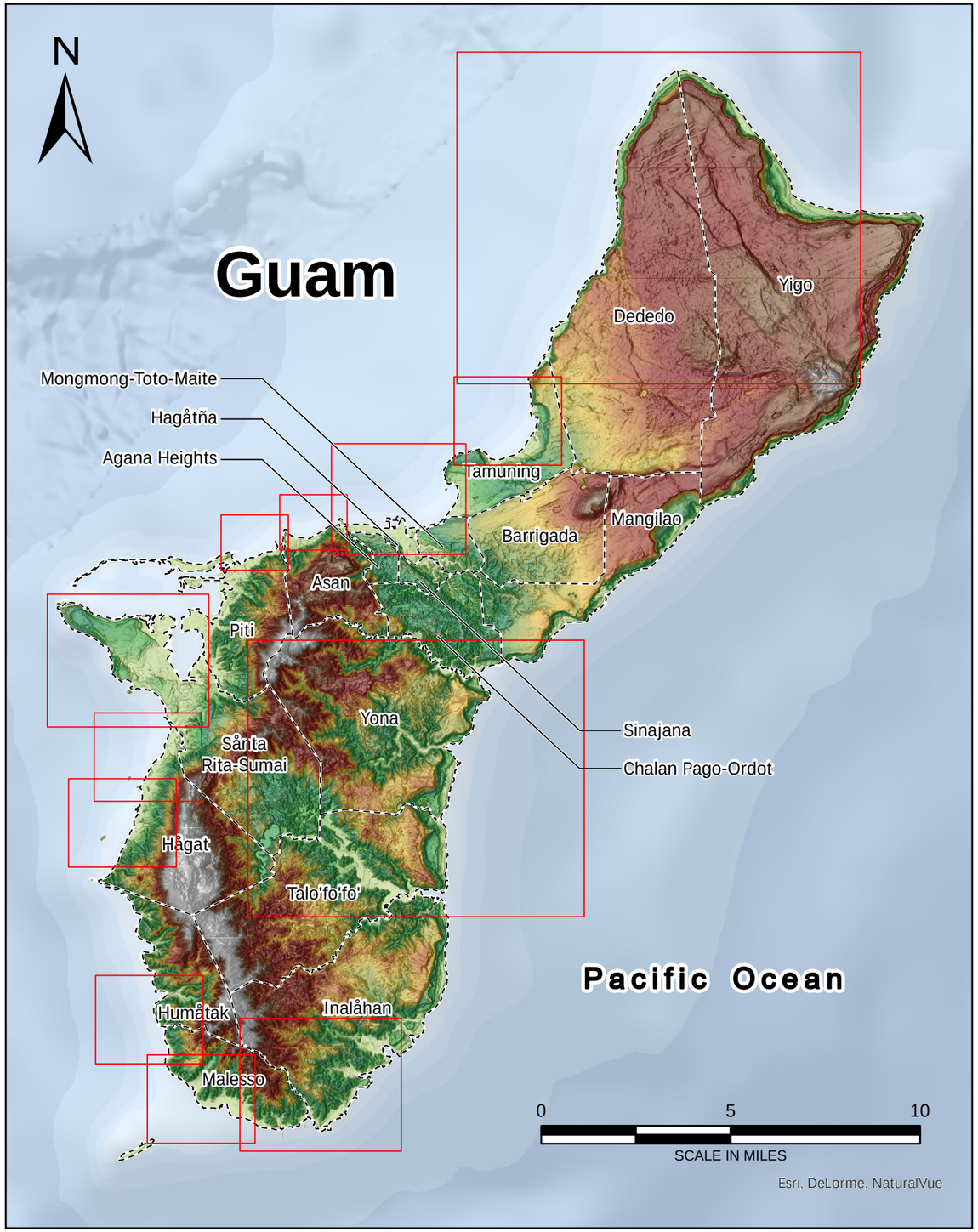


Figure 2. Guam Shoreline Atlas study areas

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1.4.2 Field Investigations

Field investigations for this Atlas were conducted in two site visits by USACE coastal engineers in April 2019 and September 2019. During the April 2019 site visit, the western shorelines of the island were documented. During the September 2019 site visit, the shorelines along the south, east and north of Guam were documented, except Ritidian Point since the Fish and Wildlife Service had closed access to the Guam National Wildlife Refuge due to high waves. The data collected during each of these site visits included: GPS collection of the mean-high-water shoreline, photographs and assessments of the shoreline condition and sediment type as well as documenting the existence of drainage outfalls and coastal structures. Where possible, the estimates were checked against existing data. During the site visits the wave climate was mild (with the exception of Ritidian Point) and in most instances the effects of erosion were easily seen. Since access to Ritidian Point was restricted during the site visits, photographs of the shoreline are included from a separate USACE study performed in March of 2018.

1.4.3 Geospatial Data

All field GPS data was processed, analyzed, and compiled into a geodatabase. Additional GIS layers were provided by GCMP. The main sources of these layers are the Digital Atlas of Guam (hydroguam.net) and the Digital Coast by NOAA (www.coast.noaa.gov/digitalcoast). More information about these datasets can be found in the metadata of the individual layers in the geodatabase.

1.4.4 Shoreline Classification

The existence of shoreline erosion was determined from direct observation of the available physical evidence along with comparison to previous descriptions and photographs. The maps of each shoreline segment show the coastline type, shore protection type, and shoreline status.

Coastline Type - Shorelines were classified into 4 types, based on data provided by GovGuam and verified with field observations: **sandy, rocky, muddy, and artificial**. The shoreline type is listed in the summary table for each Reach.

Shoreline Protection - Shoreline protection was classified into 4 types: engineered, marginal, natural, or none, and is illustrated using the symbols shown in the map legend.



Figure 3. Example of an engineered shoreline protection (revetment at Inalåhan)

- **Engineered** shore protection included well-constructed structures, such as rock revetments, seawalls, groins and grouted rock or concrete walls in good condition. An example of engineered shore protection is shown in Figure 3.
- **Marginal** shore protection included failing engineered structures or inadequate types of protection used along the shoreline, such as: randomly dumped rocks and boulders, loose rock walls, or grout covered loose boulders. An example of marginal shore protection is shown in Figure 4.
- **Natural** shore protection included natural features that provide some protection to the shoreline, such as the presence of trees, mangroves, vegetation, or wide sandy beaches. An example of a natural shore protection (mangroves) is shown in Figure 5.
- Shoreline protection was classified as **None** if there were no natural features or structures, but there was something that may be impacted by shoreline erosion.

1.4.4 Shoreline Classification Continued

Shoreline Status - Shoreline status was classified into 3 types: Critical, Potentially Critical, and Non-Critical. These classifications are shown on the maps using the symbols indicated in the Map Legend.

- **Critical** is defined as existing and/or continuing shoreline erosion, protective structure failure, or storm damage vulnerability that is an **immediate threat** to existing structures or public facilities, and thereby justifies protective action.
- **Potentially Critical** is defined as existing and/or continuing shoreline erosion, protective structure failure, or storm damage vulnerability that is a **potential threat**, and justifies protective action. However, protective action is not as urgent as for critical status.
- **Non-critical** is defined as shoreline erosion, protective structure failure, or storm damage vulnerability that is either **not currently a threat** or **does not exist**, and does not justify protective action. These areas could become potentially critical or critical if erosion begins to threaten existing structures or public facilities.



Figure 4. Example of marginal shore protection at Hågat



Figure 5. Example of natural protection (mangroves)

2

SHORELINE AND OCEANOGRAPHIC CHARACTERISTICS

2.1 Reefs

The island of Guam is encircled by approximately 108 square kilometers of fringing reef, which varies from narrow cut benches around limestone headlands, to reef flats more than 3,000 feet wide containing a variety of corals and algae. Small bays are common in the southern half of Guam where freshwater outflow from river mouths has prevented or slowed reef development. In two places barrier reefs have developed which fully or partially enclose small lagoons: at Apra Harbor on the west coast and at Cocos Island to the southwest.

This study is concerned only with the reef area between shoreline and the start of the reef margin. Reef zones seaward of the reef flat are not discussed. For the purposes of coastal description and classification, the reef platform may be divided into three zones suggested by Tracey, et al. (1964). All fringing reefs of Guam do not necessarily have all the zones discussed.

The supratidal bench zone consists of narrow platforms cut into elevated rocky shorelines. The average elevation is slightly higher than mean high tide level. The benches on Guam are generally restricted to coastal regions without a fringing reef platform.

The intertidal shoreline zone is that portion of the shore covered at high tide and exposed at low tide. In exposed areas, where the intertidal zone consists of limestone, wave-cut indentations called “nips” usually develop.

The most common zone is the reef flat. There are two types of reef flats that exist on Guam. The first type of reef flat is composed of a flat limestone platform that extends from the intertidal shoreline to the wave washed reef margin. Generally, the outer seaward part of the platform is slightly elevated with respect to the inner shoreward section and is often exposed at low tide. Because of this, the reef flat can be divided into two subzones--an outer reef flat which is exposed at low tide, and an inner reef flat, covered at low tide. The inner reef flat which retains water at low tide is referred to as the “moat”.

Table 1: Percent of total reef area by biological cover type

Biological Cover Type	% of Total Reef Area
Coral	29.8
Uncolonized	27.8
Macroalgae	19.7
Turf	17.3
Seagrass	2.8
Coralline Algae	2.3
Emergent Vegetation	0.2



Figure 6: Example of supratidal bench zone at Talo'fo'fo' Bay. Photo source: The Guam Daily Post

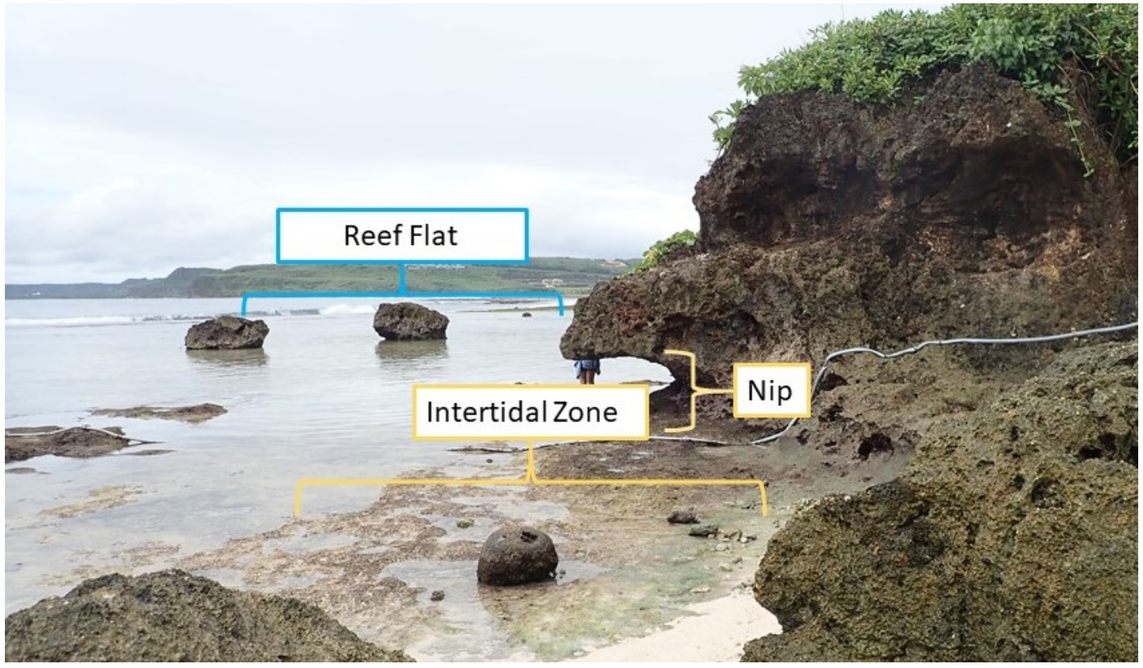


Figure 7: Example of a reef flat and intertidal zone at Pago Bay

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2.1 Reefs Continued

Unconsolidated sediments coat the platforms at some locations. These sediments range from a few inches to a foot or more in thickness. The outer reef flats are generally devoid of sediments because wave and surf action tend to keep unconsolidated material swept away. Boulder tracts are a common feature where the outer reef flat grades into the inner reef flat.

The second type of reef flat is the fringing coastal platform composed of volcanic rocks which have been cut down to sea level by marine erosion. In some instances, the inner part of a platform may consist of truncated volcanic rock, while the outer part consists of reef limestone accretion. This type of platform occurs in small isolated stretches along the southwest coast of Guam. The surfaces of these volcanic platforms, like those of limestone platforms, may contain thin patches of unconsolidated sediments.

In addition to categorizing the reefs according to their zones, the reef platforms may also be categorized based on their structural and biological cover types. The Coastal Guam Atlas (Burdick 2005) contains a benthic summary of the percent of the reef covered by each type.

The biological cover types are categorized based on the predominant biological component colonizing the surface of the benthic feature. Nine types of coverage were considered including: coral, macroalgae, turf algae, seagrass, coralline algae, emergent vegetation, and uncolonized. The percent of total reef area by biological cover type is displayed in Table 1.

The structural coverage types are broken into two categories. The first category is Coral Reef and Hardbottom and the second is Unconsolidated Sediments. Coral Reef and Hardbottom include hardened substrate of unspecified relief, composed of bedrock, volcanic rock, or formed by reef building organisms. Unconsolidated Sediment includes areas with less than 10% of any hardbottom structure type, such as areas composed of mud or sand. The percent of reef area by structure type is displayed in Table 2.

Table 2: Percent of total reef area by structure type

Geomorphological Structure Type	% of Total Reef Area
Total Coral Reef and Hardbottom	**68.8**
Pavement	44.6
Aggregate Reef	15.7
Spur and Groove	5.0
Rubble	1.4
Aggregated Patch Reef	0.8
Rock/Boulder	0.4
Individual Patch Reef	0.4
Scattered Coral/Rock	0.3
Total Unconsolidated Sediment	**31.2**
Sand	30.7
Mud	0.5

2.2 Beach Materials

The primary beach sands of Guam can be categorized into two main types (Emery, 1962): white or buff sands, which consist of calcareous organic remains and comprise more than 75 percent of the beaches in Guam, and sands that are light brown to black because of the presence of detrital volcanic minerals. From these two primary sand types three beach environments can be described.

The first beach environment encompasses virtually all the northern half of the island and is composed of calcareous sands, as shown in Figure 8. These beaches are of calcareous origin due to the lack of stream development on the northern limestone plateau.

A more complex environment exists in the southern half of Guam where surface rocks are of volcanic types. A network of streams drains this area and transports alluvial and volcanic sediments to the heads of coastal embayments. In this beach environment the sands contain large percentages of alluvial or volcanic grains, as shown in Figure 9. The regions between these embayments have beaches composed of calcareous sands. Little of the calcareous sand enters the embayments, and likewise, the volcanic sands carried by the streams are contained in the embayment regions, with little transport of stream carried sands to the adjacent beaches.

A third and intermediate type of beach environment exists on the west coast between Humåtak and Hågat, where volcanic rocks at the coast are subject to wave erosion. In this area, the beach is supplied with sediments from both land and the reef flat, resulting in a mixture of calcareous and volcanic sediments, as shown in Figure 10.



Figure 8: Calcareous sand from Tumon Bay

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Figure 9: Alluvial and volcanic sediments at Inalåhan

2.3 Climate

The Guam climate is tropical, with warm and humid conditions throughout the year. The surrounding ocean has a year-round temperature of 81 degrees and is largely responsible for the island's climate. There are two distinct seasons, defined by variations in wind and rainfall. A dry season extends from January through May, and a wet season from July through November. December and June are transitional months. Annual rainfall averages are typically above 80 inches. Easterly trade winds occur throughout the year but are dominant during the dry season. From July to October the winds become variable and the occurrence of typhoons increases. Annual temperatures are stable and fall within 86-90 °F during the day and 75-77 °F at night.

2.4 Winds

The dominant winds in Guam are the easterly trade winds, which approach from the sector northeast through east-southeast. They occur approximately 70 percent of the time throughout the year, but are particularly pronounced during the dry season, January through April, when they occur more than 90 percent of the time. Typical trade wind speeds fall in the 7 to 16 knot range. Wind speeds greater than 21 knots only occur 0.4 percent of the time.

Wind directions are variable with frequent calms during the main typhoon season from July to December. Trade winds, although they occur less frequently than during the dry season, are still the most common winds during this period. The highest percentage of strong winds come from the northeast.



Figure 10: Mixture of calcareous and volcanic sediments at Utamac

From 1999 to 2020, the average yearly max wind speed recorded at NOAA Station 630000 located in Apra Harbor, was 50 mph. The average wind speed was 12 mph, with a modal wind speed of 3 mph. During this twenty-one-year record there were three incidences of recorded sustained wind speeds with typhoon intensities - in December 1999 (142 mph), November 2000 (169 mph), and December 2001 (142 mph). This indicates that while Guam is affected by one or more typhoons almost every year, they often do not pass directly over Guam, and/or that high winds can be very localized. Data records can also be limited by failure of the measurement equipment during high winds.

2.5 Typhoons

Typhoons are tropical storms with winds of 75 mph or greater with associated intense rainfall. Although severe typhoons occur in the western Pacific throughout the year, the period from July to December is characterized as the primary typhoon season. From 1900 to 1941 Guam was affected by 23 typhoons, and from 1945 to 1990 Guam was affected by 37 typhoons. Gaps in the data exist from 1942-1944 when Guam was occupied by Japanese forces (Weir, 1983). In 1962, Typhoon Karen destroyed 90% of the homes on Guam, with estimated peak sustained wind of 135 knots (Rupp and Lander, 1996). Typhoon Pamela in 1976, with sustained winds of 120 knots, stalled off the west coast of Guam for several days, resulting in extensive damage to coastal facilities. Typhoon Omar devastated the island in 1992, with sustained winds of 170 knots. Then in 1997, Typhoon Paka, with an estimated maximum sustained wind speed of 123 mph at Apra Harbor, destroyed roughly 1,500 buildings, leaving an estimated 5,000 people homeless (EQE International 1998 and NCDC 1997). Typhoon Pongsona in 2002, left more than 60% of the island's water wells inoperable and destroyed approximately 1,300 homes (FEMA 2003 and Gillespie 2002). The most recent typhoon to affect Guam was Typhoon Wutip in February 2019, with sustained winds of 130 knots.

2.6 Tsunamis and Earthquakes

An earthquake is seismic waves created by the sudden release of stored energy in the Earth's crust. A tsunami is a large open ocean wave or series of waves typically caused by an earthquake or underwater landslide. There have been 12 major earthquakes and 4 tsunamis recorded in Guam. The most significant earthquake event occurred in August 1993, with an 8.1 magnitude. No deaths were reported, but approximately 50 people were injured and more than $200 million in property damage were reported (Brunsdon, 1993). The 1993 earthquake caused land subsidence, affecting Guam's local relative sea level change rates (see Section 2.10.1). This earthquake also generated a minor tsunami. A report from Lander et al. (2002) that considered the risk of destructive tsunamis in Guam, notes that locally generated tsunamis are most likely to affect the less populated east coast due to the location of the Marianas Trench, which is the main origin of Guam's earthquakes. The most recent tsunami event to affect Guam occurred in February 2010. The tsunami was generated from an 8.8 magnitude earthquake near Chile and measured 0.5 ft at Apra Harbor.

Table 3: Tide Elevations in Apra Harbor (in ft. relative to MLLW)

Mean Higher High Water, MHHW	2.34
Mean High Water, MHW	2.22
Guam Vertical Datum of 2004, GUVD04	1.38
Mean Sea Level, MSL	1.37
Mean Low Water, MLW	0.60
Mean Lower Low Water, MLLW	0.00

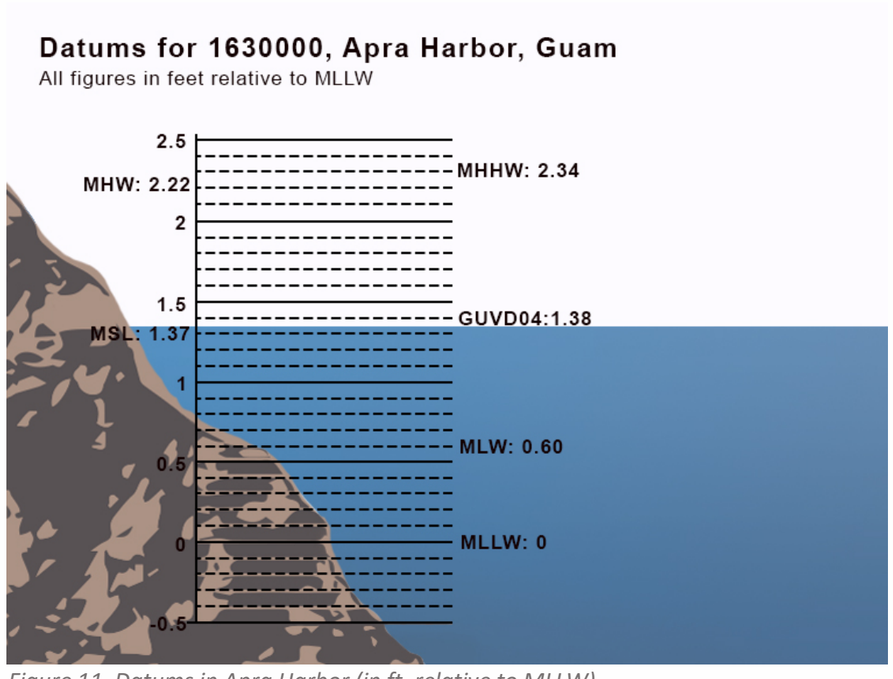


Figure 11. Datums in Apra Harbor (in ft. relative to MLLW)

2.7 Tides

Tides at Guam are semi-diurnal, with two high and two low tides each day. The National Oceanographic and Atmospheric Administration (NOAA) maintains a tide station at Apra Harbor, Guam (Station 1630000). The station has been recording water levels since 1948 (over 70 years). The mean tide range is 1.6 ft and the diurnal range is 2.4 ft. The extreme tides observed in Apra Harbor are a high tide of 4.29 ft mean lower low water (MLLW) and a low tide of -2.34 ft MLLW. The tidal datum for Guam is MLLW and is used as the datum for elevations in this report. Tidal datums for Guam relative to MLLW for the tidal epoch spanning 1983-2001 are shown in Table 3 and Figure 11.

2.8 Currents

Inshore current patterns around Guam are poorly known, except at specific locations where small studies have been conducted for projects.

The North Equatorial Current caused by the northeast trades generally sets in a westerly direction near Guam, with a speed of 1/2 to 1 knot. According to Emergy (1962) the North Equatorial Current diverges off Pati Point on the northeast side of the island. The two separate components then move down the northwest and southeast coasts of Guam, converging in the vicinity of Orote Point.

Current patterns on the reef flats are dependent on the reef flat topography and the wave-induced mass transport of water over the shallow outer reef flat. Where well developed inner reef flat moats exist, longshore currents are generated which then exit through depressed outer reef flat areas, which in effect act as rip channels. The same current regime is present during ebbing tide.

Recent studies conducted on the surface currents in Guam include:

- **Eddies around Guam, an island in the Mariana Islands group by E. Wolanskia, R.H. Richmond, G. Davis, E. Deleersnijder, R.R. Leben (2002).**
  This study estimated the near-surface currents around Guam, from current meters, satellite-derived surface topography, and a numerical model. The authors findings indicated that a dominant northwestward-flowing North Equatorial Current, which prevailed from June to December 2000, with speeds of ~0.1–0.2m/s, generated unsteady eddies in the lee of Guam. Eddies were also noted off the tips of the island. The smallest eddies identified were at the scale of local topographic features such as headlands and embayment. Other notable eddies observed was a large cyclonic eddy that impinged on the island and generated counterclockwise currents around the island of up to 0.5m/s.

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2.8 Currents Continued

- **Ocean Current Study Ocean Dredged Material Disposal Site Apra Harbor, Guam Final Report by Weston Solutions, Inc. and Prepared For the Department of the Navy (2007).**
  This study utilized the global Navy Coastal Ocean Model (NCOM), an assimilative ocean model nowcast/forecast system to generate oceanographic current data. The model found that during the dry season, surface currents tended to be quite uniform, having a significant west-northwesterly component across much of the study area. In the wet season, surface currents are slightly more variable on a month-to-month basis and the net current direction tends to flow in a more southwesterly direction. Under both seasons, that area in the lee of the island, experienced a variable current pattern.

- **Coastal Circulation and Water-Column Properties in the War in the Pacific National Historical Park, Guam—Measurements and Modeling of Waves, Currents, Temperature, Salinity, and Turbidity, April–August 2012 by Curt D. Storlazzi, Olivia M. Cheriton, Jamie M.R. Lescinski, and Joshua B. Logan (2014).**
  The U.S. Geological Survey (USGS) Pacific Coastal and Marine Science Center initiated an investigation in the National Park Service's War in the Pacific National Historical Park (WAPA) to provide baseline coastal circulation and water-column properties along west-central Guam, focusing on WAPA's Agat Unit. The oceanographic data and numerical circulation modeling results from this study demonstrate that circulation in Agat Bay was strongly driven by winds and waves at longer (>1 day) timescales and by the tides at shorter (<1 day) timescales. The near-surface currents in deep water were primarily controlled by the winds, whereas currents on the shallow reef flats were dominated by wave-driven motions.

Forecasts of currents around Guam and the other Mariana Islands is produced by the Pacific Islands Ocean Observing System (PacIOOS). These forecasts are produced as a part of the Regional Ocean Modeling System (ROMS), which is a mesoscale numerical ocean prediction model that provides 7-day, daily average forecasts at various depth levels of water temperature, currents, salinity, and sea surface height. The model at Guam simulates these forecasts at an approximate 2-km resolution. The model simulations are produced by Dr. Brian Powell of the Department of Oceanography in the School of Ocean and Earth Science and Technology (SOEST) at the University of Hawai'i at Mānoa and are available on the PacIOOS website (https://www.pacioos.hawaii.edu/currents/model-mariana/).

2.9 Waves

The island of Guam is exposed to three distinct wave types: waves generated by the prevailing local winds, swell waves generated by distant storms, and waves from tropical cyclones passing near Guam. Trade wind waves are typically from northeast through east-southeast, with wave heights in the range of 1 to 6 feet (0.3 to 2m) and wave periods between 5 to 10 seconds. Swell waves from distant storms (usually in the north Pacific) can range from 6 to 18 feet (2 to 6 m) in height and have wave periods from 10 to 16 seconds. Tropical storm and typhoon waves can approach from almost any direction (though the storms typically track east to west or southeast to northwest), resulting in waves to 40+ feet (13+ m) in deep water and wave periods in the 8 to 14 second range.

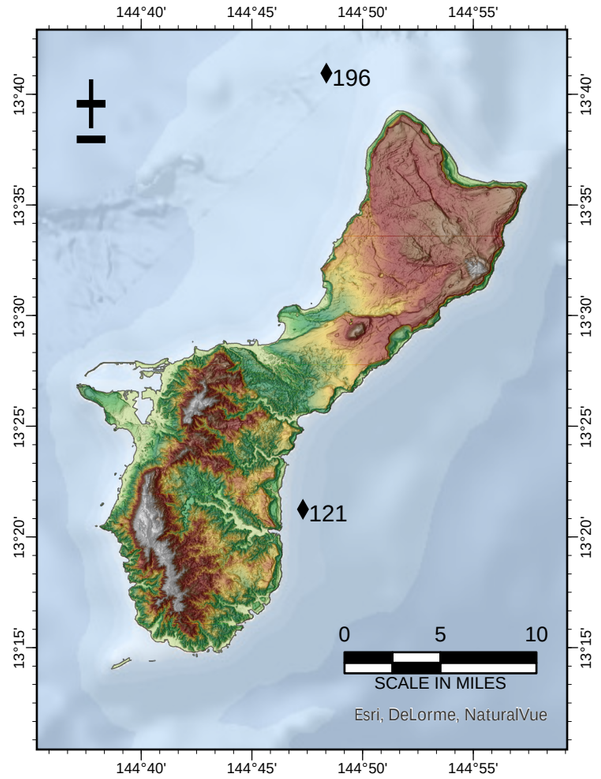


Figure 12: Location of CDIP Buoys around Guam

Typical wave conditions are illustrated by wave rose and period rose from wave buoy data. The Coastal Data Information Program (CDIP) has two buoys, stations 196 and 121, deployed on the northwest and southeast sides of the island, as shown in Figure 12. These two buoys provide a time series of wave parameters including wave height, peak period, peak direction, and average period.

Station 196 is located at 13.6825° N, 144.806° E, approximately 3.25 nautical miles northwest of Ritidian Point in a water depth of 1,640 feet. Station 196 contains wave parameters from 2015 to 2019. Figure 13 shows the wave rose of wave heights and directions, and Figure 14 shows the wave period rose.

Station 121 is located at 13.3542° N, 144.7883° E, approximately 1 nautical mile offshore of Ipan Beach Park in a water depth of 656 feet. Station 121 contains wave parameters from 2003 to 2019. Figure 15 shows the wave rose of wave heights and directions, and Figure 16 shows the wave period rose.

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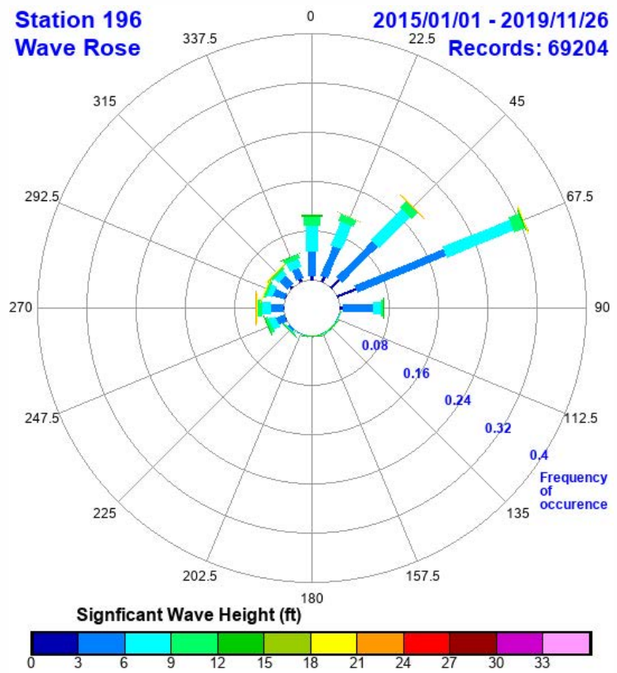


Figure 13. Wave Rose of Wave Heights and Wave Directions for CDIP station 196

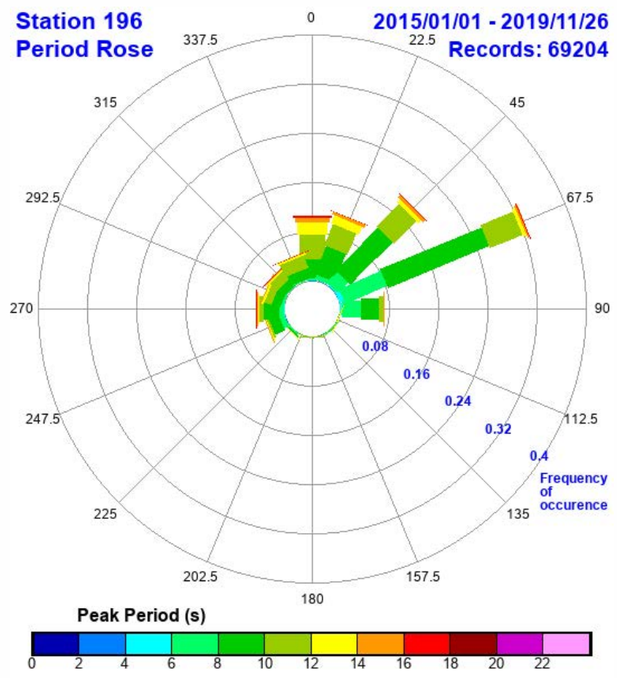


Figure 14. Period Rose for CDIP station 196

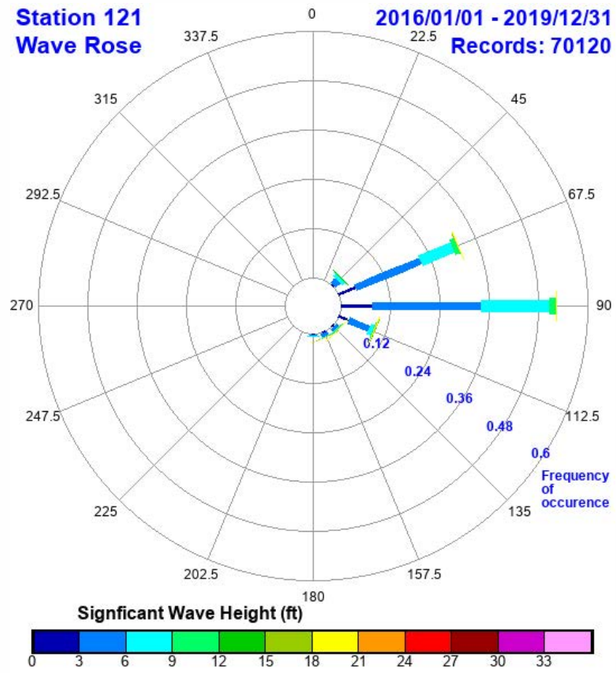


Figure 15.Wave Rose of Wave Heights and Wave Directions for CDIP station 121

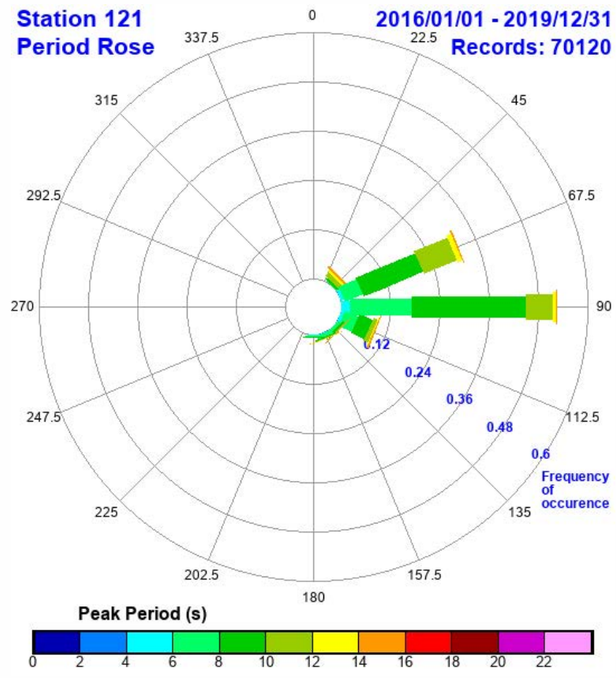


Figure 16.Period Rose for CDIP station 121

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2.10 Sea Level Rise

Many of Guam's shorelines are protected by wide fringing reefs, which results in a relatively mild wave climate along the shoreline, except during infrequent typhoon events. This results in narrow and mildly sloped beaches, often backed by vegetated beach berms. These areas are not as vulnerable to erosion, but will be affected by rising sea levels, as larger waves may be able to transform across the reef and reach the shoreline. The primary areas of concern are those in which buildings and roadways exist very close to the shoreline. In these areas, as sea levels rise, homeowners, businesses, and the Government of Guam will be required to adapt by using protective structures, elevating smaller infrastructure, or by retreat from the shoreline.

2.10.1 Potential Impacts of Sea Level Change

Relative sea level change (SLC) is the local change in sea level relative to the elevation of the land at a specific point on the coast, including the lowering or rising of land through geologic processes such as subsidence and glacial rebound. Relative SLC is a combination of both global and local SLC caused by changes in estuarine and shelf hydrodynamics, regional oceanographic circulation patterns (often caused by changes in regional atmospheric patterns), hydrologic cycles (river flow), and local and/or regional vertical land motion (subsidence or uplift). Thus, relative SLC is variable along the coast.

To incorporate the direct and indirect physical effects of projected future sea level change on design, construction, operation, and maintenance of coastal projects, USACE has provided guidance in the form of Engineering Regulation, ER 1110-2-8162 (USACE 2013). ER 1110-2-8162 provides both a methodology and a procedure for determining a range of sea level change estimates based on global sea level change rates, the local historic sea level change rate, the construction (base) year of the project, and the design life of the project. Three estimates are required by the guidance, a Baseline (or "Low") estimate, which is based on historic sea level change and represents the minimum expected sea level change, an Intermediate estimate (NRC Curve I), and a High estimate (NRC Curve III) representing the maximum expected sea level change.

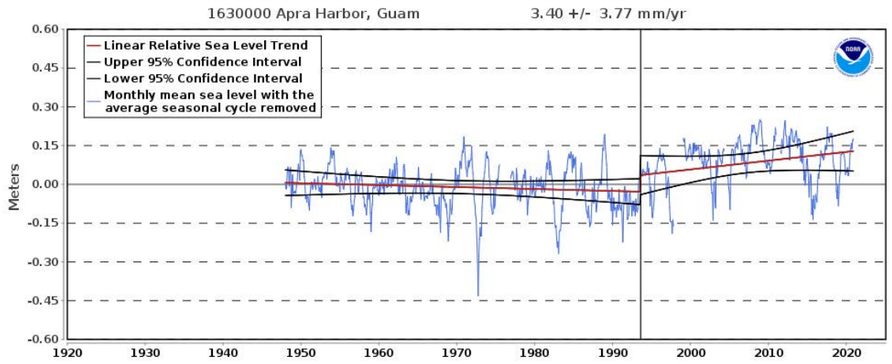


Figure 17: Mean Sea Level Trend from NOAA Tide Gage 1630000 – Apra Harbor, Guam

Local sea level rise accounts for the eustatic change (e) (1.7mm/year or 0.0056 ft/year) as well as uplift, subsidence, and other effects (M) and is generally available from the nearest tide station. The tide station for Guam is the National Oceanic and Atmospheric Administration (NOAA) Station 1630000 at Apra Harbor, which has a tidal record of approximately 40 years.

Over the past two decades, sea level trends have increased in the western tropical Pacific Ocean with rates that are approximately three times the global average. Several papers including Merrifield and Maltrud (Merrifield 2011) have shown that the high rates of SLC recorded are caused by a gradual intensification of Pacific trade winds since the early 1990s. Multi-decadal tradewind shifts in the Pacific (1950-1990 had weak tradewinds, while 1990-present have shown strong tradewinds) are likely related to the Pacific Decadal Oscillation (Merrifield et al. 2012), a recurring pattern of ocean-atmosphere climate variability centered over the mid-latitude Pacific basin. These low frequency tradewind changes can contribute on the order of 1 cm variations in sea level in western tropical Pacific. Multi-decadal variations such as these can lead to linear trend changes over 20 year time scales that are as large as the global SLC rate, and even higher at individual tide gauges, such as Apra Harbor, Guam (Merrifield 2011, Merrifield et al. 2012).

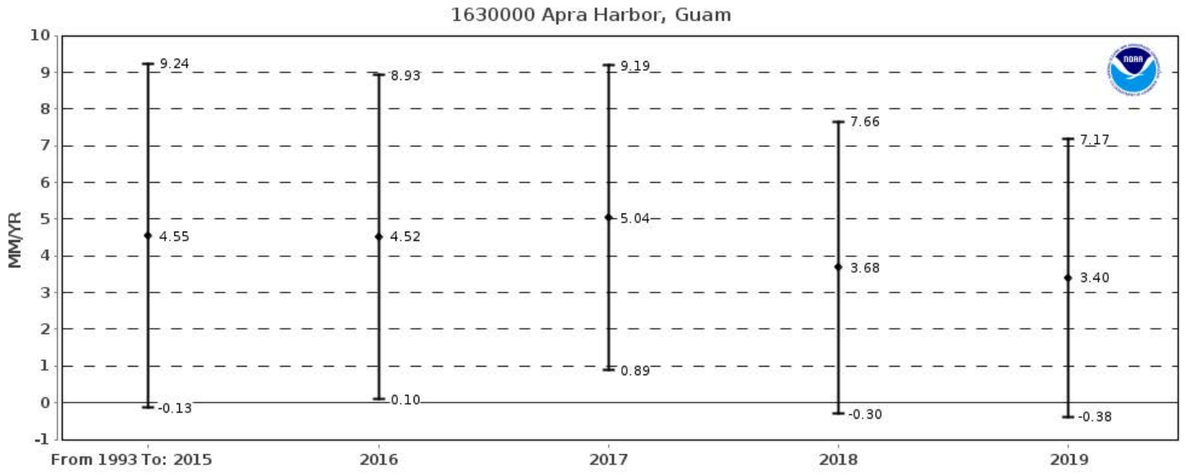


Figure 18: Previous Mean Sea Level Trends from NOAA Tide GAGE 1630000 – Apra Harbor, Guam

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2.10.1 Potential Impacts of Sea Level Change Continued

In addition, higher frequency inter-annual variations in Pacific water levels can be caused by the effect of the El Nino Southern Oscillation; the climate phenomenon in the Pacific evidenced by alternating periods of ocean warming and high air pressure in the western Pacific (El Nino) and cooler sea temperatures accompanied by lower air pressure in the western Pacific (La Nina). In fact, it is known that the largest inter-annual variability of sea level around the globe occurs in the tropical Pacific, due to these climate patterns (Widlansky 2015). During El Nino years, sea level in the western tropical Pacific is known to drop by 20 to 30 cm, while La Nina phases cause an average sea level rise of about 10 cm. Additionally, and throughout the tropical Pacific, prolonged inter-annual sea level inundations are also found to become more likely with greenhouse warming and increased frequency of extreme La Niña events, thus exacerbating the coastal impacts of the projected global mean sea level rise (Widlansky 2015).

Anecdotal reports have suggested a possible recent reversal in the 20+ year trend of dramatically rising sea levels in the western tropical Pacific, possibly due in part to the strong El Nino cycle documented in 2015/2016; however, analysis and published research supporting this change in trend is not yet available. These phenomena are documented here to emphasize the large variability in sea level that is experienced in the western tropical Pacific, and to indicate that sea level trends reported by the nearest NOAA tide gage at Apra Harbor, Guam are likely affected by this variability.

The mean sea level trend reported by NOAA at Apra Harbor Station 1630000 is 3.4 mm/year (+/- 3.77 mm/year 95% confidence interval), as shown in Figure 17. The two trend lines in the figure are indicative of rates prior to and following the 1993 earthquake in Guam. The land elevation experienced an approximately 10 cm drop during the earthquake and is now slowly subsiding, which affects the local relative SLC rate. In addition, the division of the MSL trend into pre- and post-earthquake results in a shorter period of record of approximately 24 years (1993 – present), which is less than the suggested 40-year period of record required by ER 1110-2-8162.

NOAA also provides information on the historical Mean Sea Level trend, shown in Figure 18. This figure gives additional information on the variability of the average rate of change, as it is basically a look at the historical “trend of the trend”. The figure shows that as recently as 2017, the MSL trend was as high as 9.19 mm/year, over 2 mm/year higher than its present rate, a significant difference that would be amplified when calculating the “intermediate” and “high” curves of potential accelerated SLC.

Due to the variability in MSL trends in the western Pacific over recent years outlined above, in addition to the short post-earthquake trend at Apra Harbor, Guam, a different approach was taken for determination of the rate of relative SLC in Guam. The rate for Guam is estimated by using the global eustatic rate of SLC, +1.7 mm/year added to a measured rate of Vertical Land Movement (VLM) rate of -1.0 mm/year (as reported by the NASA Jet Propulsion Laboratory website https://sideshow.jpl.nasa.gov/post/series.html – an average of two monitoring stations on Guam and one on Saipan). Since eustatic sea level is rising, and the land is subsiding, this results in a relative SLC rate of 2.7 mm/year (= +1.7 mm/year – (-1.0 mm/year)) or 0.0089 feet/year for Guam. As an example, the USACE SLC calculator was used to plot the three potential curves based on this rate, shown in Figure 19. The curves show that by 2030 relative SLC in the study area will be between 0.3 ft or 0.09 m (low curve) and 0.9 ft or 0.27 m (high curve). By 2070, sea level will have risen between 0.7 ft and 2.9 ft (0.23 m to 0.9 m); and by 2120, sea level will have risen between 1.1 ft and 7.2 ft (0.33 m and 2.2 m) relative to the existing MSL datum.

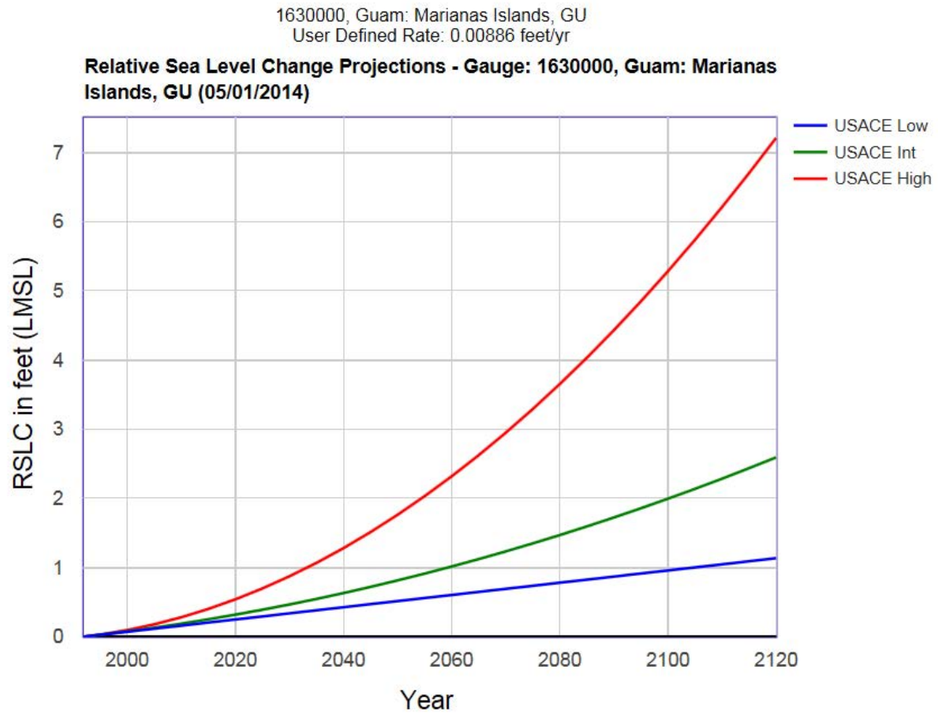


Figure 19: Relative Sea Level Change curves for Guam, based on SLC rate of 2.7 mm/YEAR

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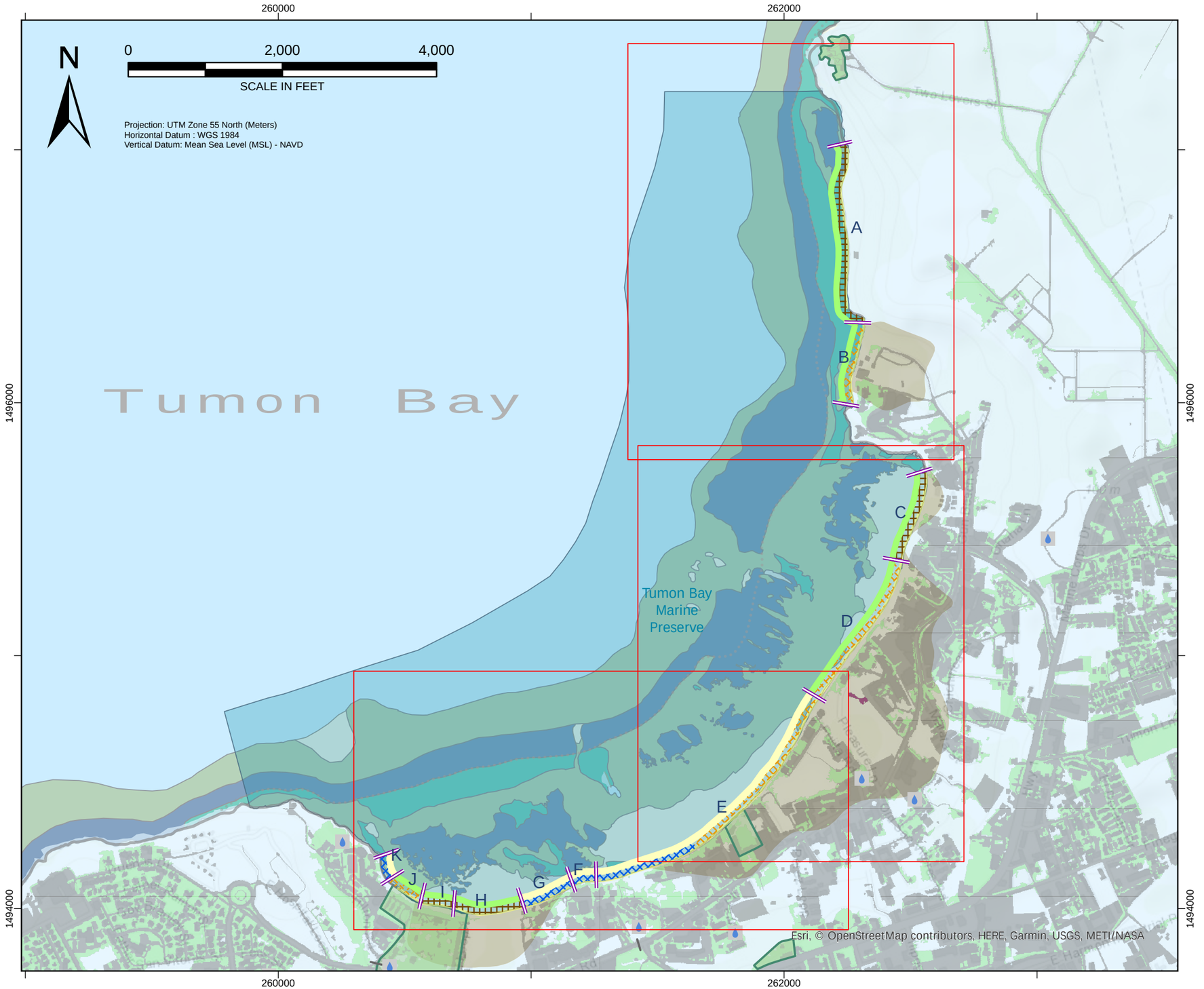
3

SHORELINE DESCRIPTION TUMON BAY

3.1 Tumon Bay Overview

The two-mile long coastline between Ypao Point and Gun Beach forms a broad concave embayment known as Tumon Bay. The bay is bordered at both ends by limestone cliffs. Ypao Point, the south boundary, is a prominent headland more than 200 feet high. There are no streams discharging into the Tumon Bay area, but several storm drain culverts discharge across the shoreline.

Beaches extend along most of the Tumon Bay shoreline, the principal ones being Fafai, Gun, Gogna, Naton and Ypao Beaches. They are among the most heavily used recreational beaches on Guam. Much of Guam's hotel development is concentrated along the Tumon Bay shoreline and backshore terrace, with associated residential and commercial development. Tumon Bay is a popular region for net fishing, spear fishing, snorkeling, shelling, reef walking, outrigger canoe paddling, stand up paddle boarding, kayaking, diving and spear fishing. Tumon Bay is one of five marine preserves on Guam.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

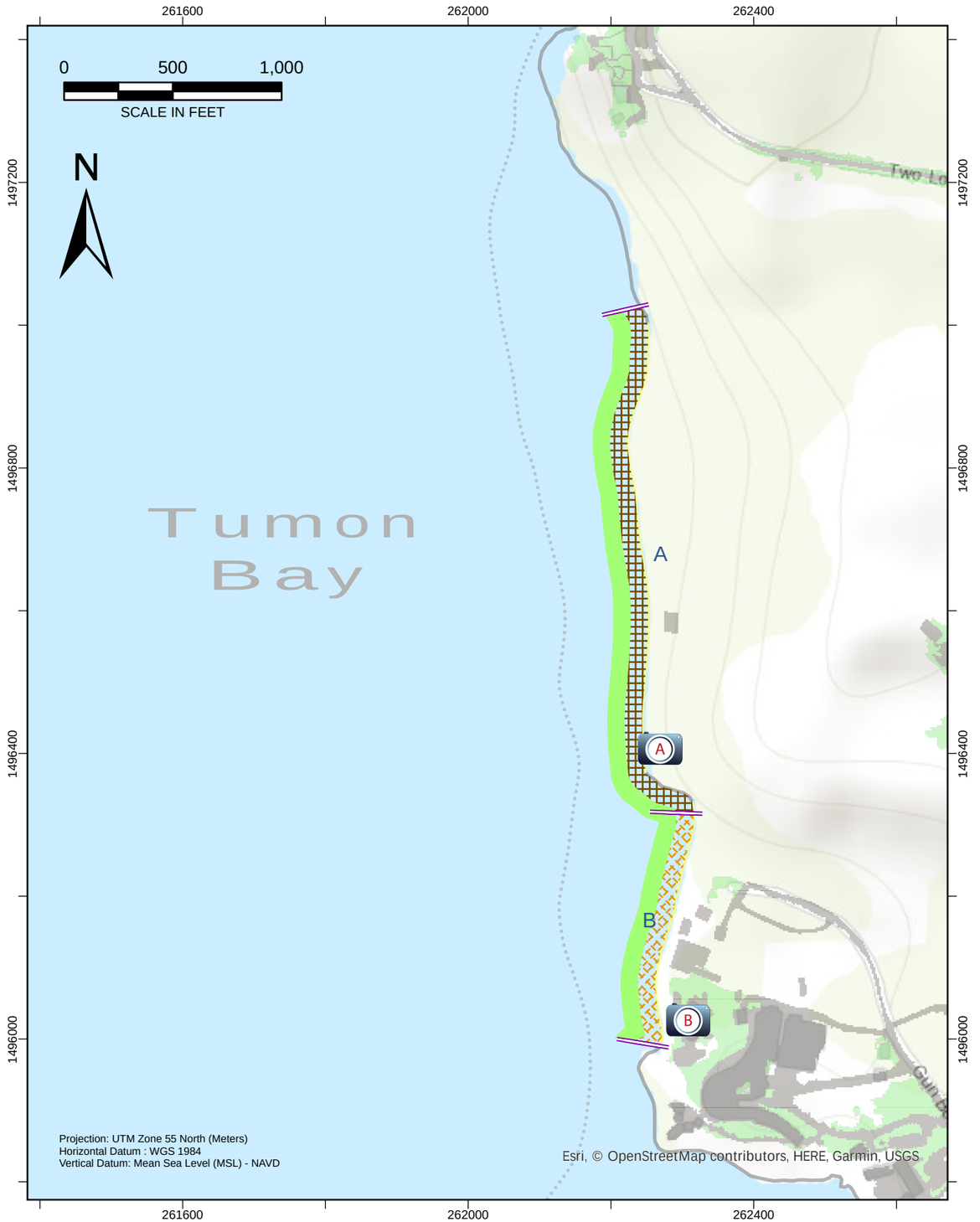
Stream

Reef Line

Reach Extents

3.2 Tumon Bay Reaches A-B

Reach	Reach A: FaiFai Beach	Reach B: Gun Beach
Beach Width	30-50 feet	30 feet
Reach Length	2,300 feet	1,150 feet
Forshore Slope	1 on 5	1 on 5
Coastline Type	Sandy	Sandy
Shoreline Protection	Natural	None
Backshore	Undeveloped No Infrastructure Vegetation	Developed No Infrastructure Vegetation
Notes	---	---
Shoreline Status	Non-Critical	Non-critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

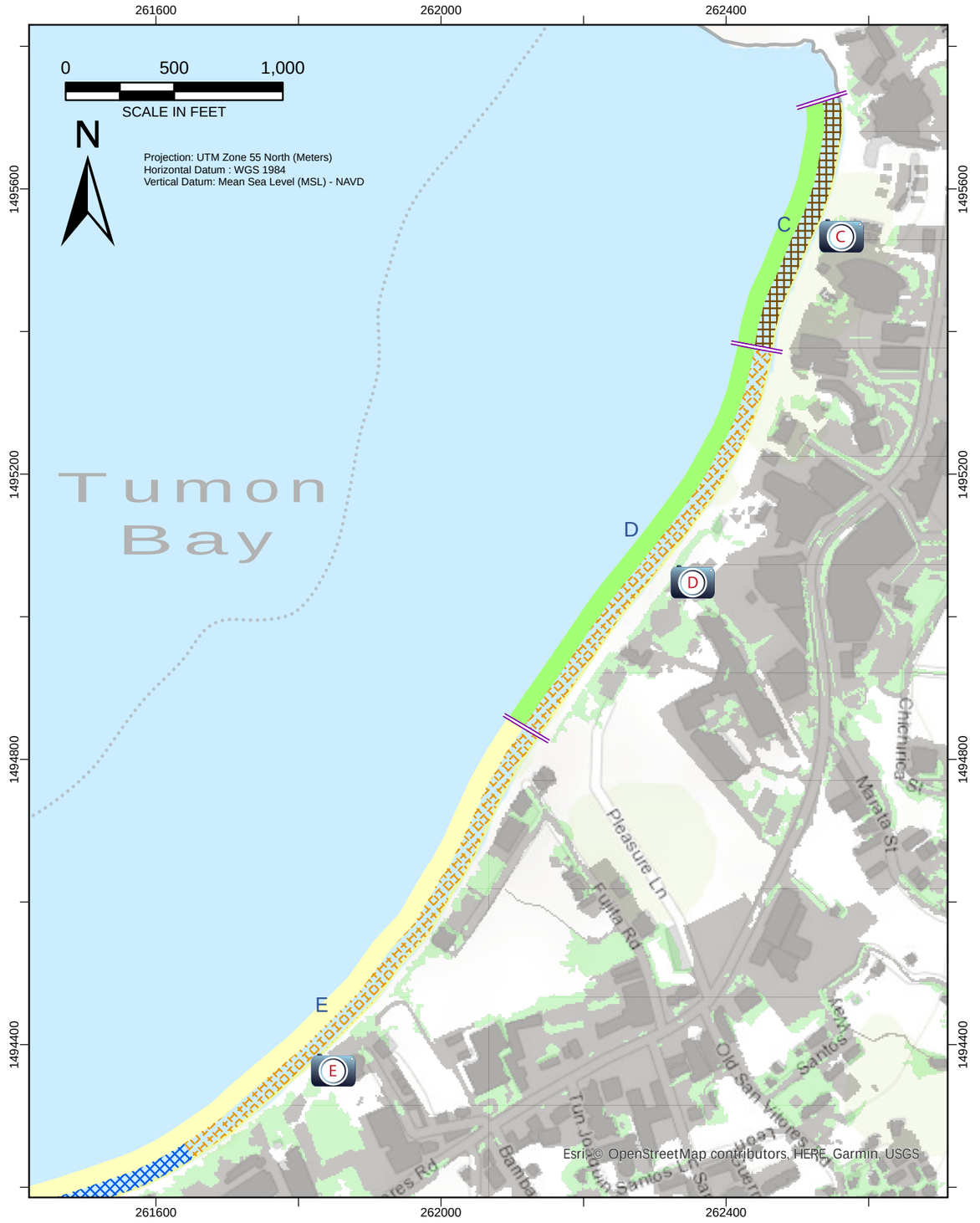
Reef Line

Stream

Reach Extents

3.2 Tumon Bay Reaches C-E

Reach	Reach C: Gogna Beach	*Reach D: Naton Beach, North End*	*Reach E: Naton Beach, South End*
Beach Width	30 feet	40 feet	20-30 feet
Reach Length	700 feet	2,000 feet	3,500 feet
Forshore Slope	1 on 10	1 on 10	1 on 9
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Natural	None	Engineered, None
Backshore	Partially Developed No Infrastructure Partially Vegetated	Developed No Infrastructure Vegetation	Developed No Infrastructure Vegetation
Notes	---	A WW2 Pillbox is present	Retaining walls undermined
Shoreline Status	Non-critical	Non-critical	Potentially Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

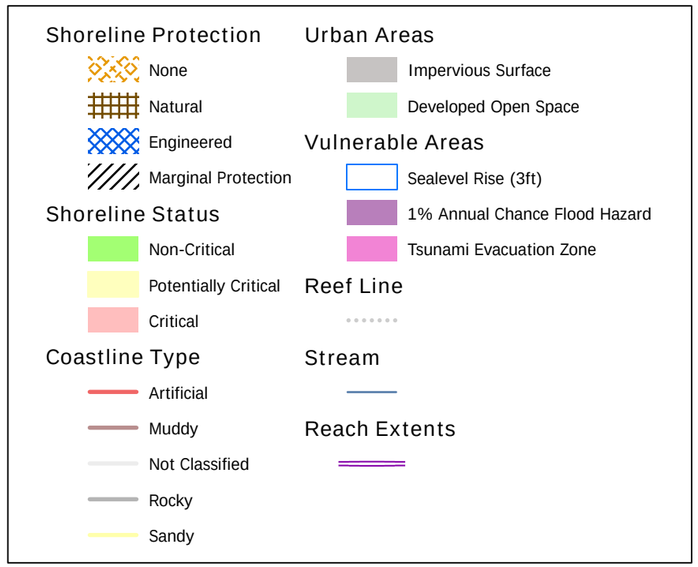
Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

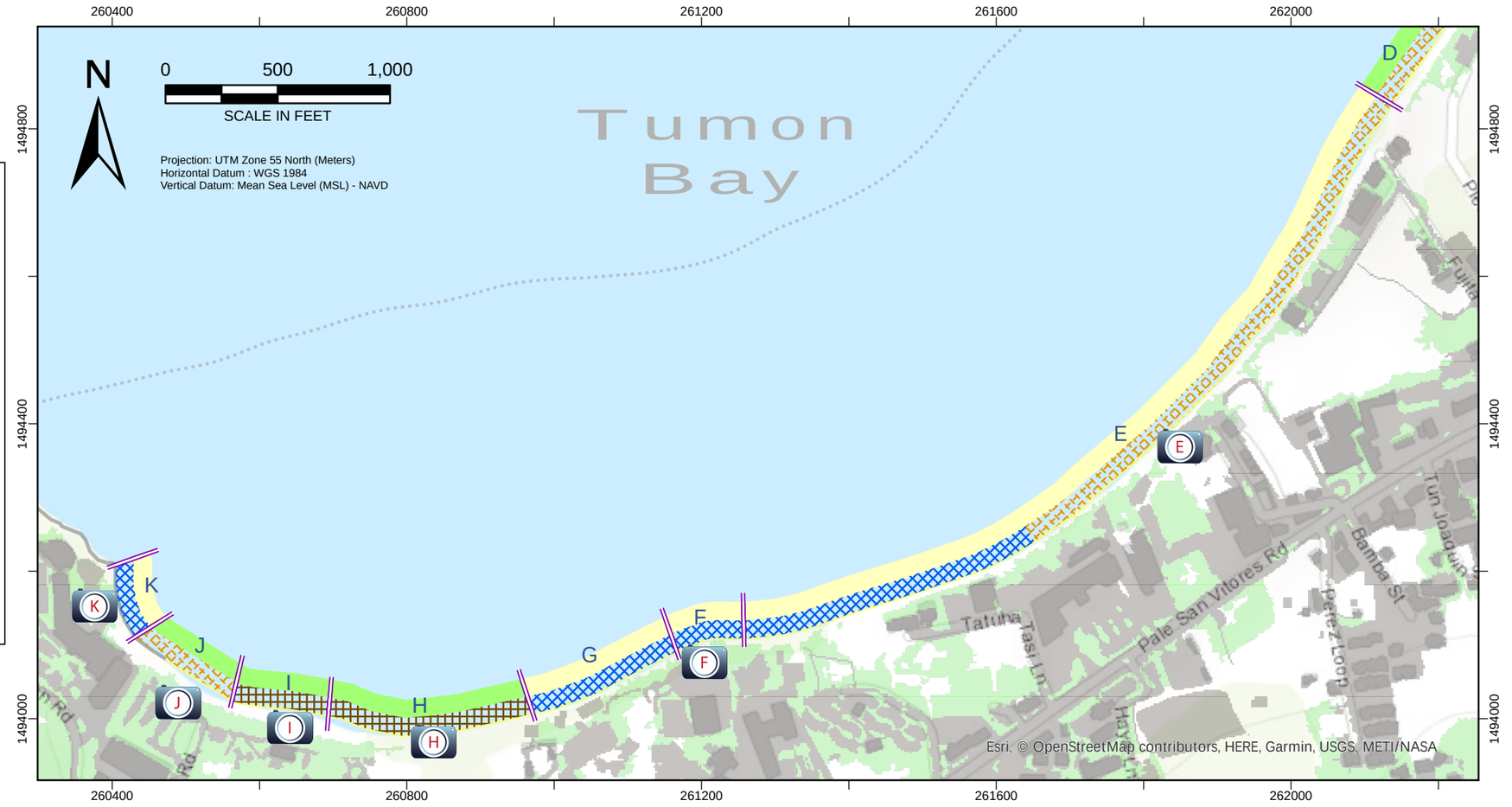
Reef Line

Stream

Reach Extents

3.2 Tumon Bay Reaches E-K





Reach	Reach F: WW2 Fortification	Reach G: Ypao Beach, Northeast End	Reach H: Central Portion, Ypao Beach	Reach I: Ypao Beach, Southwest End	Reach J	Reach K: Hilton Hotel Beach
Beach Width	<20 feet	20 feet	40 feet	70 feet	30 feet	No Beach
Reach Length	200 Feet	620 feet	700 feet	600 feet	480 feet	420 feet
Forshore Slope	No Data	1 on 8	No Data	1 on 11	No Data	No Beach
Coastline Type	Sandy	Sandy	Sandy	Sandy	Rocky	Rocky
Shoreline Protection	Engineered	Engineered	Natural	Natural	None	Engineered
Backshore	Undeveloped No Infrastructure No Vegetation	Developed Infrastructure No Vegetation	Developed No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure No Vegetation	Developed No Infrastructure No Vegetation
Notes	WW2 fortification is present, stairs undermined	Narrow beach fronting retaining wall	Dredged swimming area	---	---	Revetment damaged
Shoreline Status	Potentially Critical	Potentially Critical	Non-Critical	Non-Critical	Non-Critical	Potentially Critical

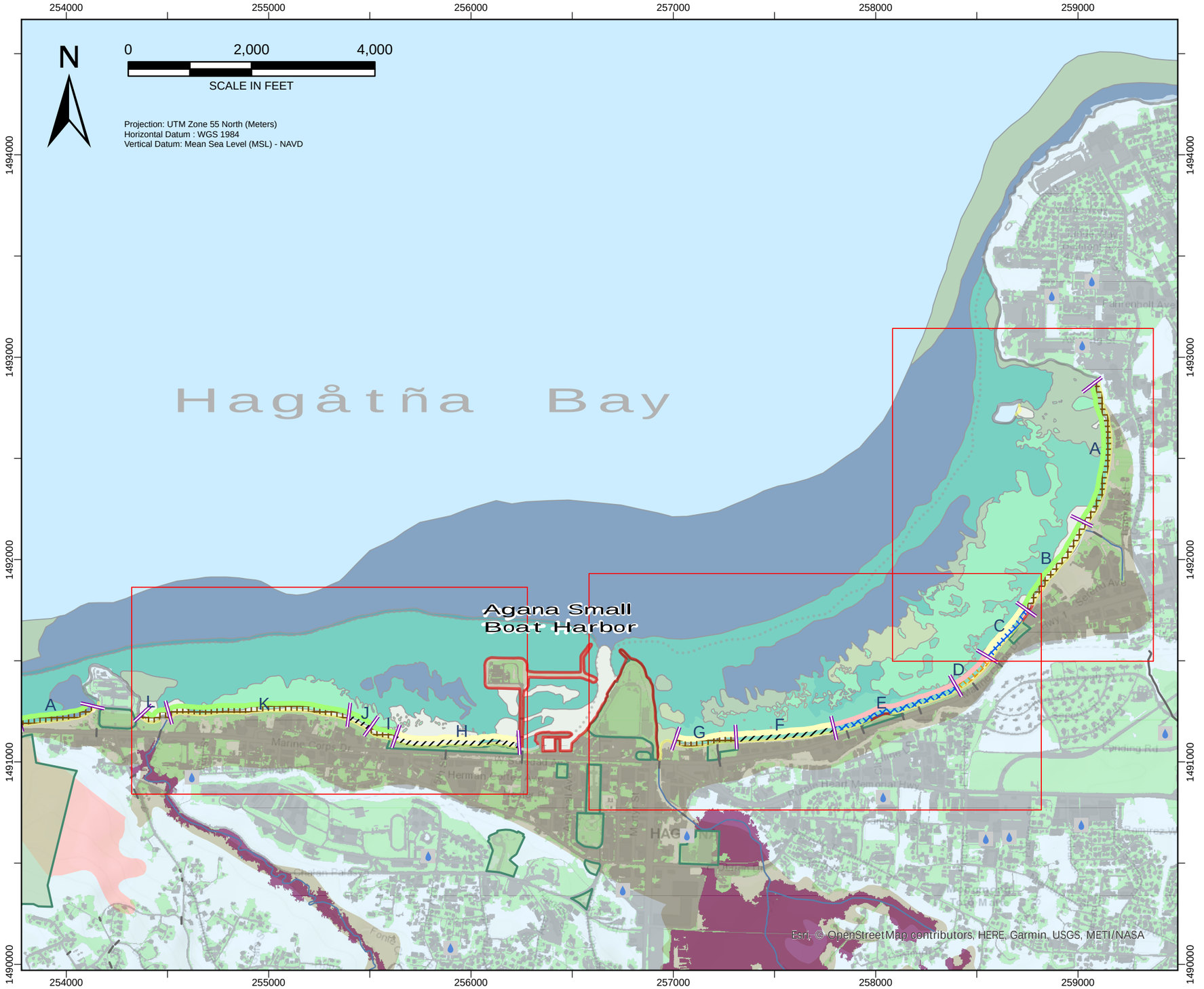
4

SHORELINE DESCRIPTION HAGÅTÑA BAY

4.1 Hagåtña Bay Overview

Hagåtña Bay is a broad embayment between Oka Point and Adelup Point. The Paseo de Susana Park, a man-made peninsula constructed on the reef flat, is centrally located within Hagåtña Bay. Adelup Point, the south boundary, is a small limestone peninsula approximately 40 feet high.

The coast of Hagåtña Bay is bordered by a wide fringing reef flat. A drainage channel for the Hagåtña River is cut across the reef flat east of Alupat Island. Hagåtña Channel, on the west side, provides passage for boats moored in the federally authorized Agana Small Boat Harbor.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

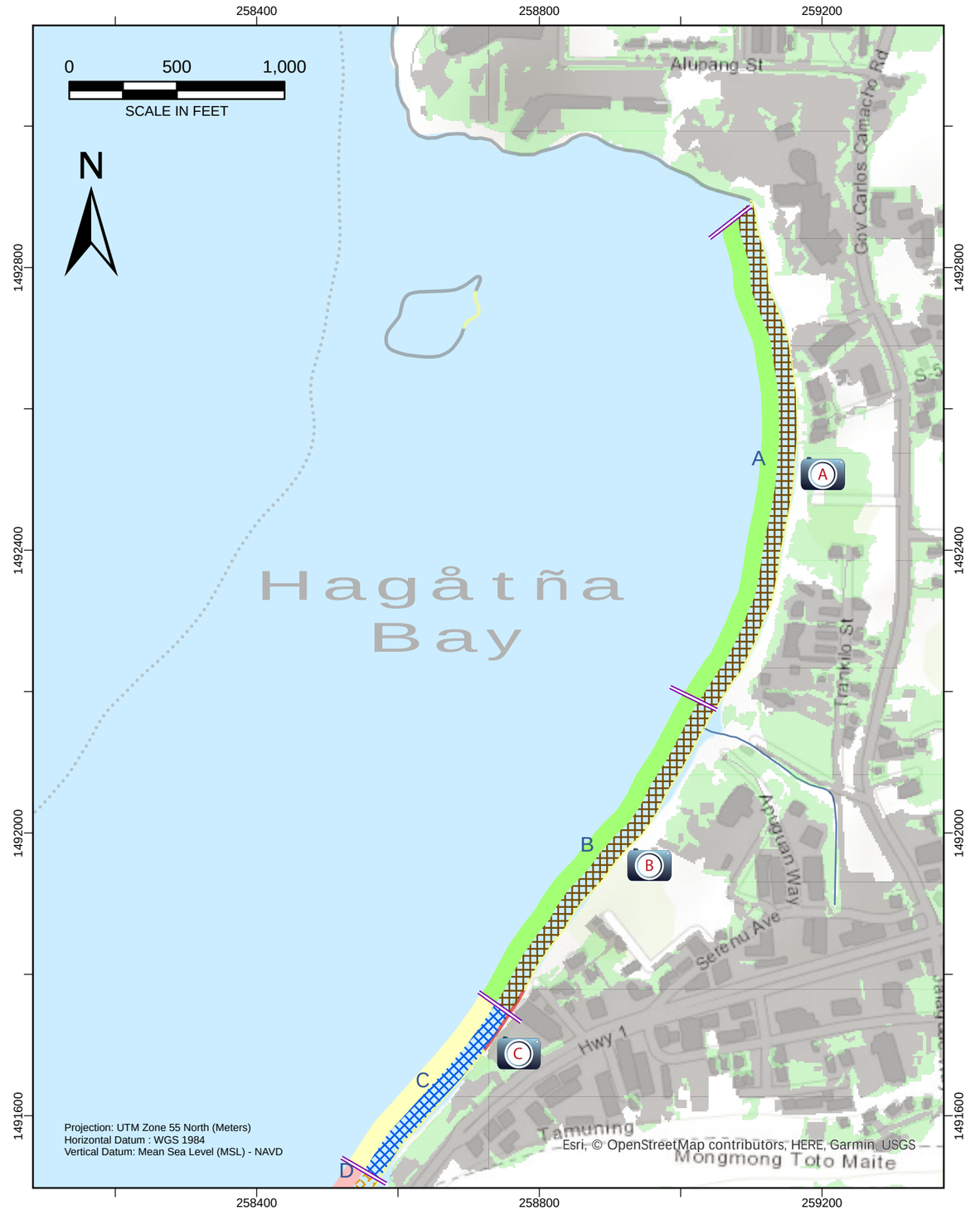
Stream

Reef Line

Reach Extents

4.2 Hagåtña Bay Reaches A-C

Reach	Reach A: Dungcas Beach, North End	Reach B: Dungcas Beach, South End	Reach C
Beach Width	25 to 35 feet	30 to 35 feet	20 feet
Reach Length	2,400 feet	1,500 feet	900 feet
Forshore Slope	1 on 9	1 on 10	No Data
Coastline Type	Sandy	Sandy	Artificial
Shoreline Protection	Natural	Natural	Engineered
Backshore	Partially Developed No Infrastructure Partially Vegetated	Developed No Infrastructure Partially Vegetated	Developed No Infrastructure No Vegetation
Notes	---	Stream contributes sediment	Narrow shoreline, seawalls at risk of undermining
Shoreline Status	Non-Critical	Non-Critical	Potentially Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

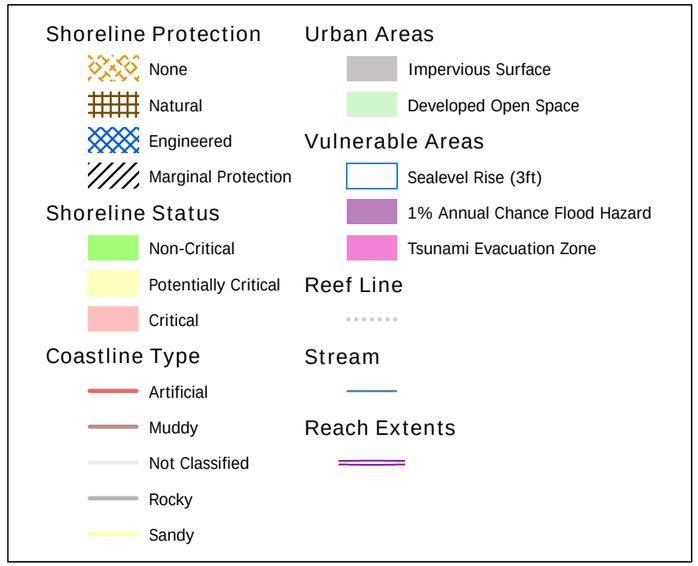
Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

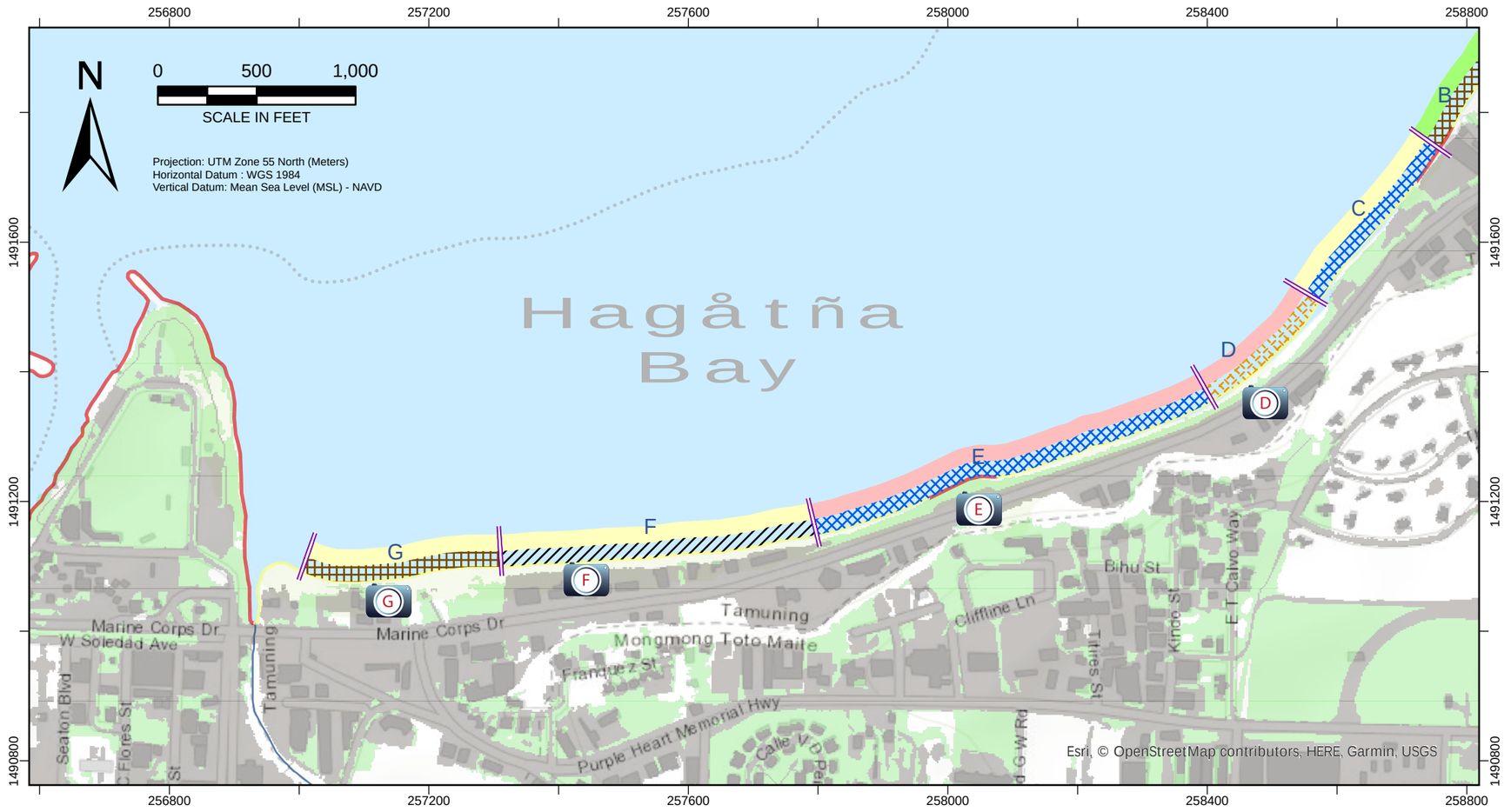
Reef Line

Stream

Reach Extents

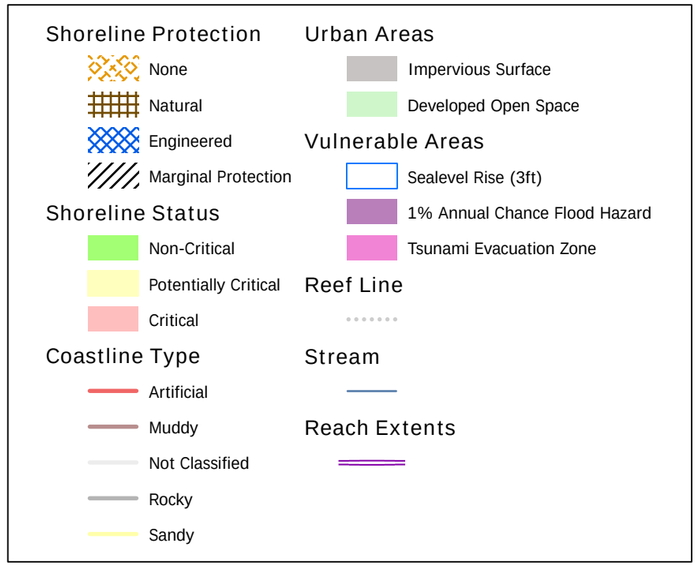
4.2 Hagåtña Bay Reaches D-G

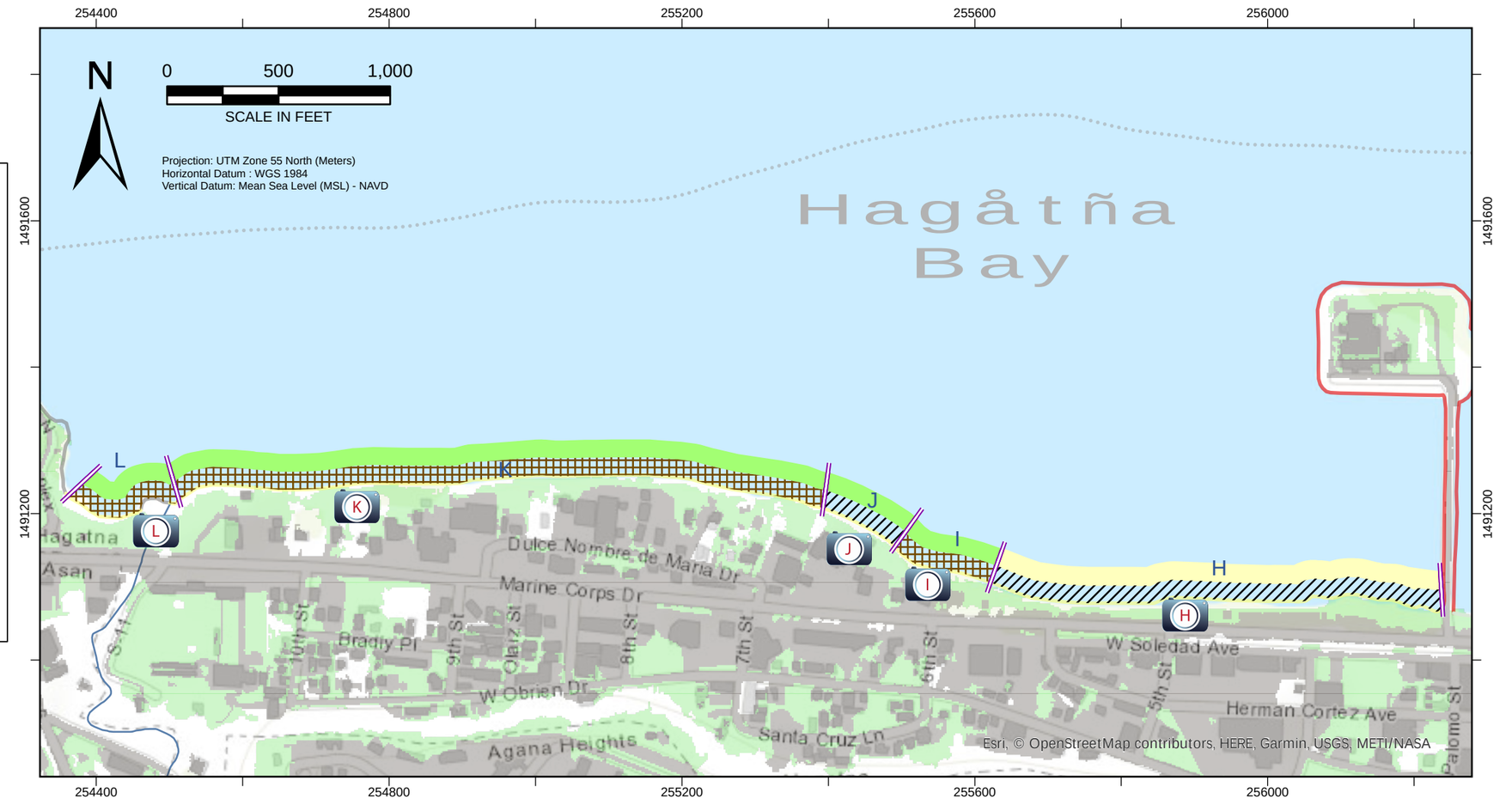




Reach	Reach D: Trinchera Beach, East End	Reach E: Trinchera Beach, Central Part	Reach F: Trinchera Beach, West End	Reach G
Beach Width	20 feet	< 20 feet	< 20 feet	< 20 feet
Reach Length	800 feet	2,000 feet	1,750 feet	1,000 feet
Forshore Slope	1 on 9	No Data	No Data	No Data
Coastline Type	Sandy	Sandy, Artificial	Sandy	Sandy
Shoreline Protection	None	Engineered	Marginal	Natural
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Developed Infrastructure Partially Vegetated	Developed Infrastructure Vegetation
Notes	Route 1 in backshore with no shoreline protection	Seawall is undermined	Unprotected development close to shoreline	Unprotected development close to shoreline
Shoreline Status	Critical	Critical	Potentially Critical	Potentially Critical

4.2 Hagåtña Bay Reaches H-L





Reach	Reach H	Reach I	Reach J	Reach K	Reach L
Beach Width	< 20 feet	< 20 feet	< 20 feet	20 to 30 feet	20 to 30 feet
Reach Length	2,800-foot	400 feet	400 feet	2,200-foot	350 feet
Forshore Slope	No Data	No Data	No Data	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy	Sandy	Sandy
Shoreline Protection	Marginal	Natural	Marginal	Natural	Natural
Backshore	Undeveloped Infrastructure Vegetation	Developed Infrastructure No Vegetation	Developed No Infrastructure No Vegetation	Developed No Infrastructure Partially Vegetated	Undeveloped No Infrastructure Vegetation
Notes	Two drainage culverts contribute sediment Seawall is undermined	Drainage outfall and stream discharge sediment	Revetment in poor condition	---	---
Shoreline Status	Potentially Critical	Non-Critical	Non-Critical	Non-Critical	Non-Critical

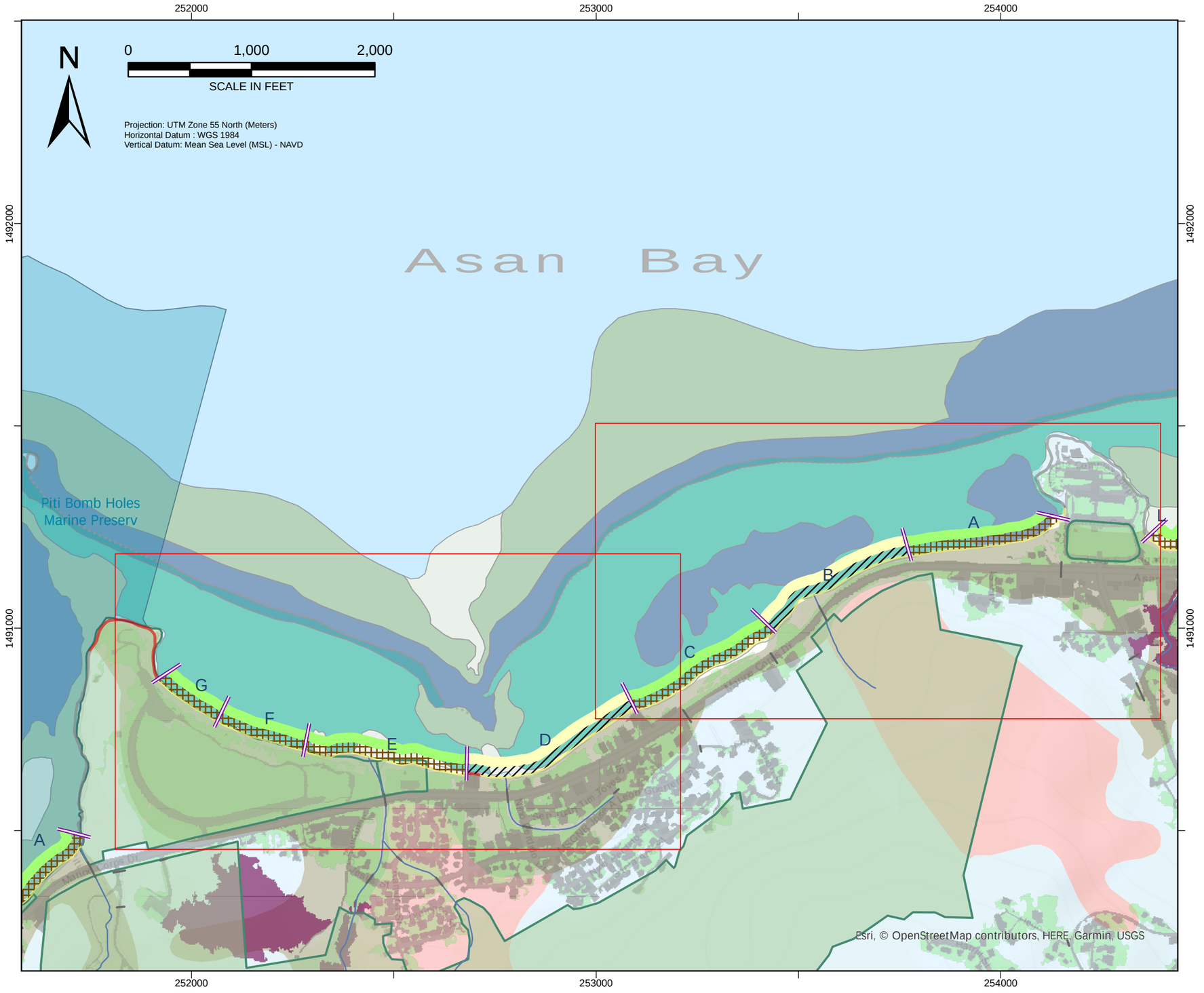
5

SHORELINE DESCRIPTION ASAN BAY

5.1 Asan Bay Overview

Asan Bay is a shallow embayment with a shoreline length of ~1.5 miles, bounded by Adelup Point on the north and Asan Point on the south. Asan Point is a protruding limestone ridge with a maximum elevation of 120 feet.

Only the Asan River discharges into Asan Bay. It drains the volcanic highlands shoreward of the bay, and the beaches along the bay contain more non-carbonate material than those in Hagåtña Bay. The fringing reef flat in the area has a broad channel cut partially across the reef fronting the Asan River. The Asan Bay Channel divides the reef into two sectors.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

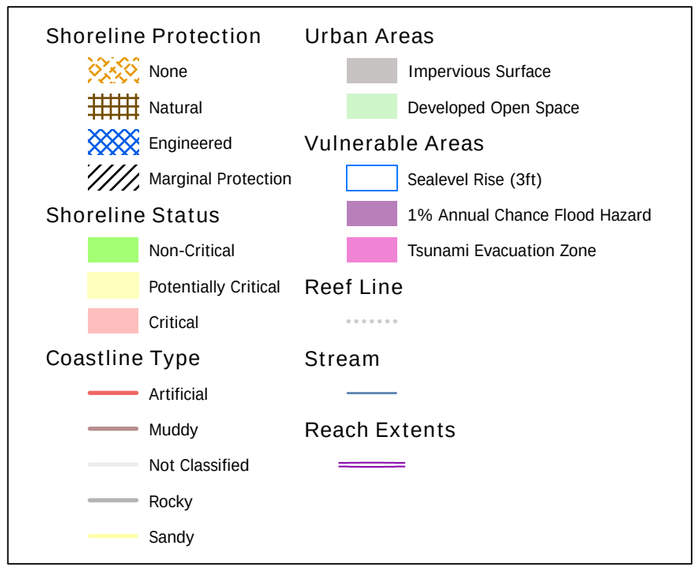
Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

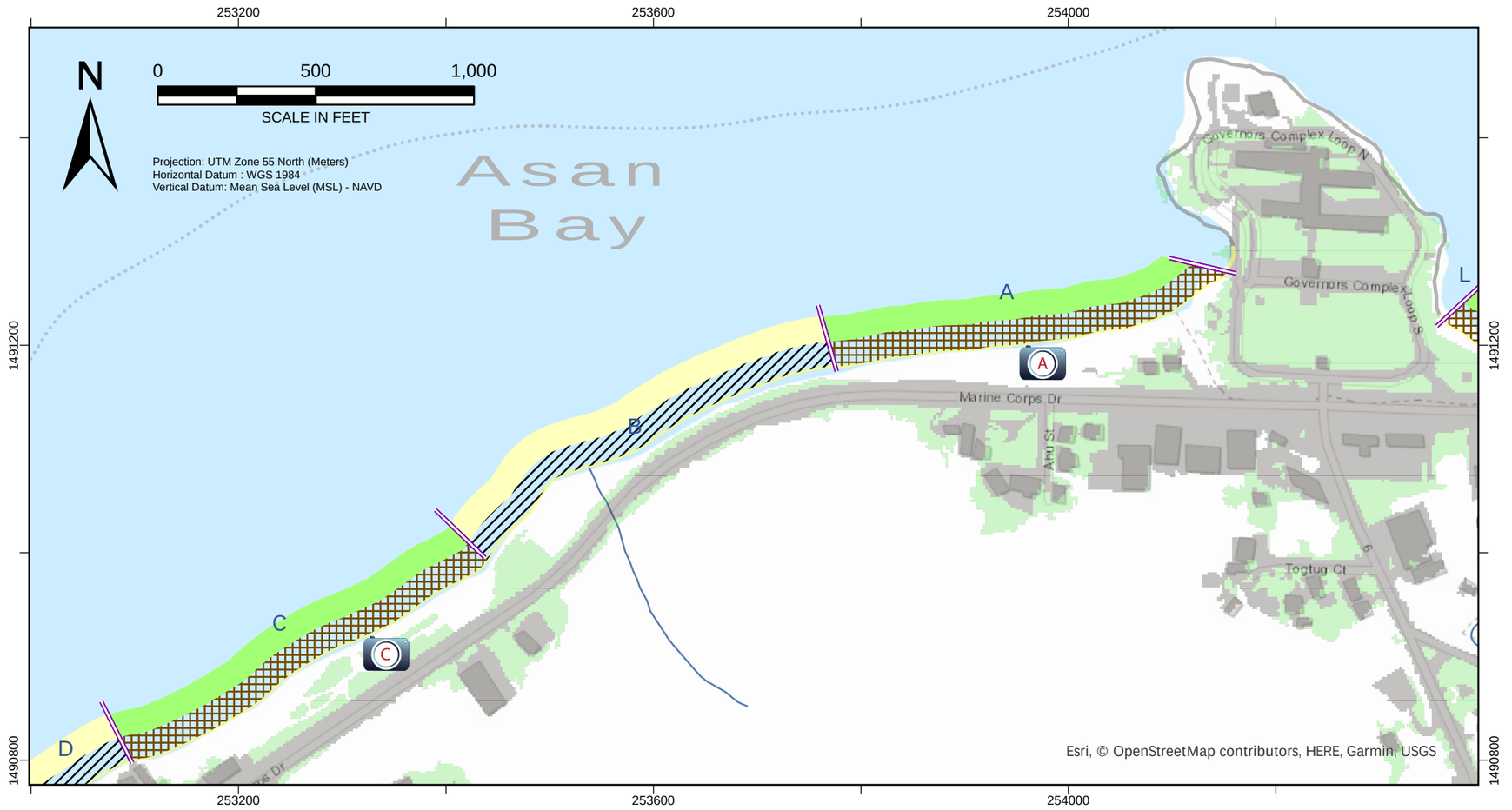
Stream

Reef Line

Reach Extents

5.2 Asan Bay Reaches A-C





Reach	Reach A	Reach B	Reach C
Beach Width	20-30 feet	< 20 feet	20-30 feet
Reach Length	1,300 feet	1,300 feet	1,300 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy	Sandy, Rocky	Sandy
Shoreline Protection	Natural	Marginal	Natural
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	---	Route 1 and power lines in backshore, grouted boulder revetment	Two drainage culverts contribute sediment
Shoreline Status	Non-Critical	Potentially Critical	Non-Critical

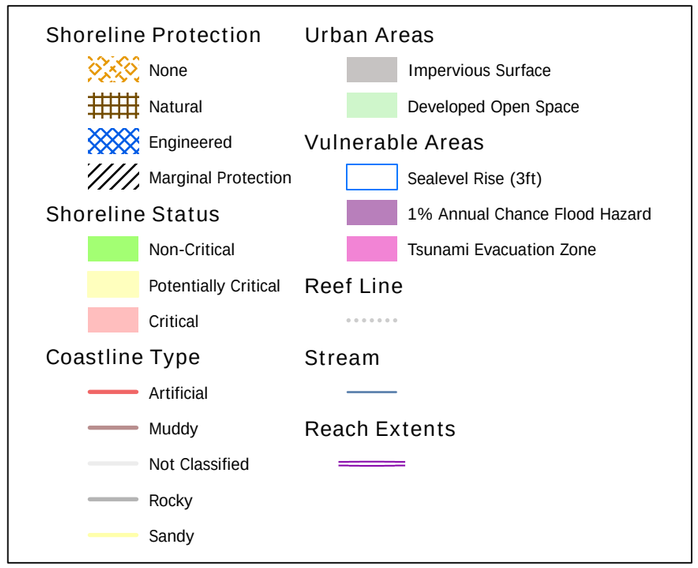
Go To Photo Appendix– Asan Bay

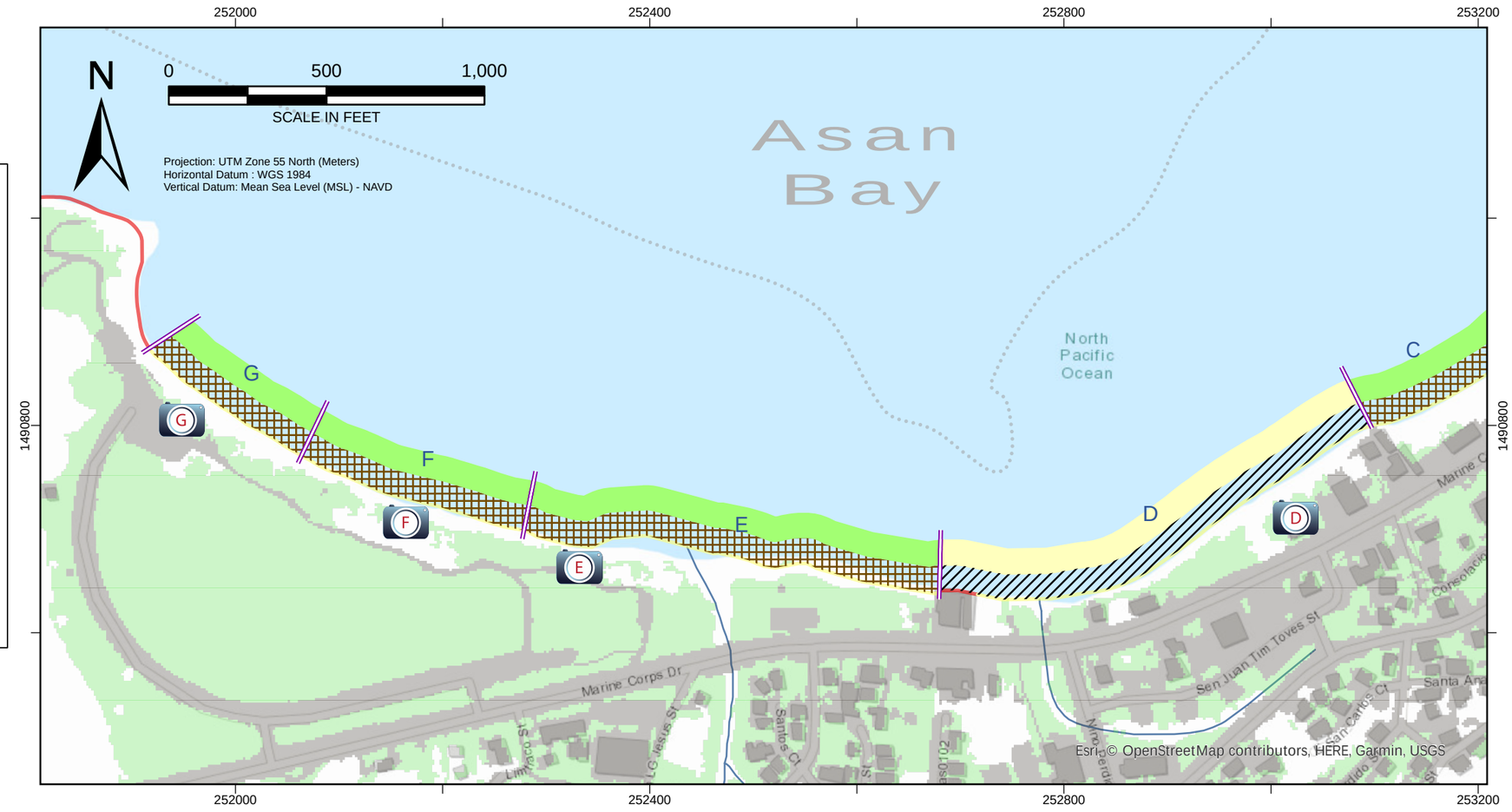
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5.2 Asan Bay Reaches D-G





Reach	Reach D	Reach E	Reach F	Reach G
Beach Width	20-30 feet	25 feet	25 feet	25 feet
Reach Length	1,400 feet	1,400 feet	700 feet	600 feet
Forshore Slope	No Data	1 on 9	No Data	No Data
Coastline Type	Sandy, Artificial	Sandy	Sandy	Sandy
Shoreline Protection	Marginal	Natural	Natural	Natural
Backshore	Developed Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	Existing seawalls in poor to fair condition	The Asan River contributes sediment	---	---
Shoreline Status	Potentially Critical	Non-Critical	Non-Critical	Non-Critical

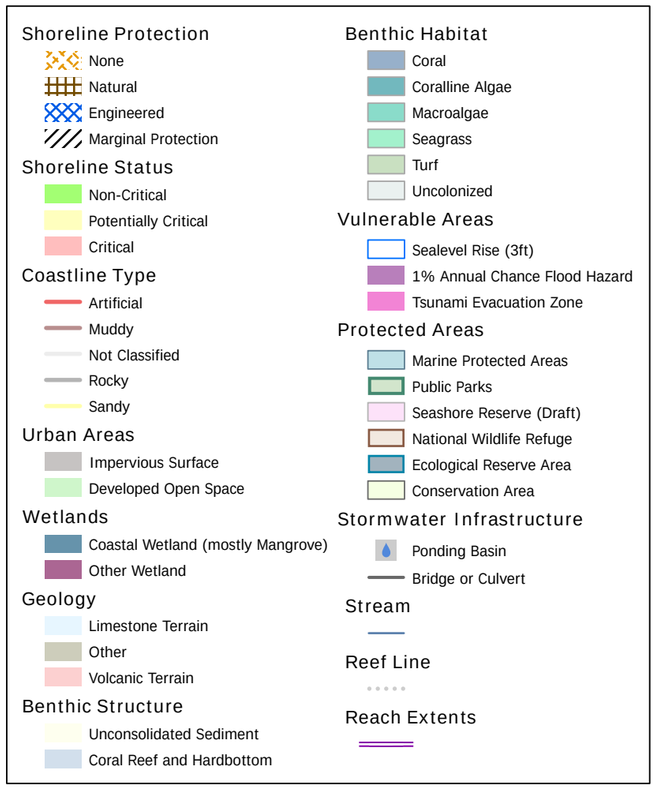
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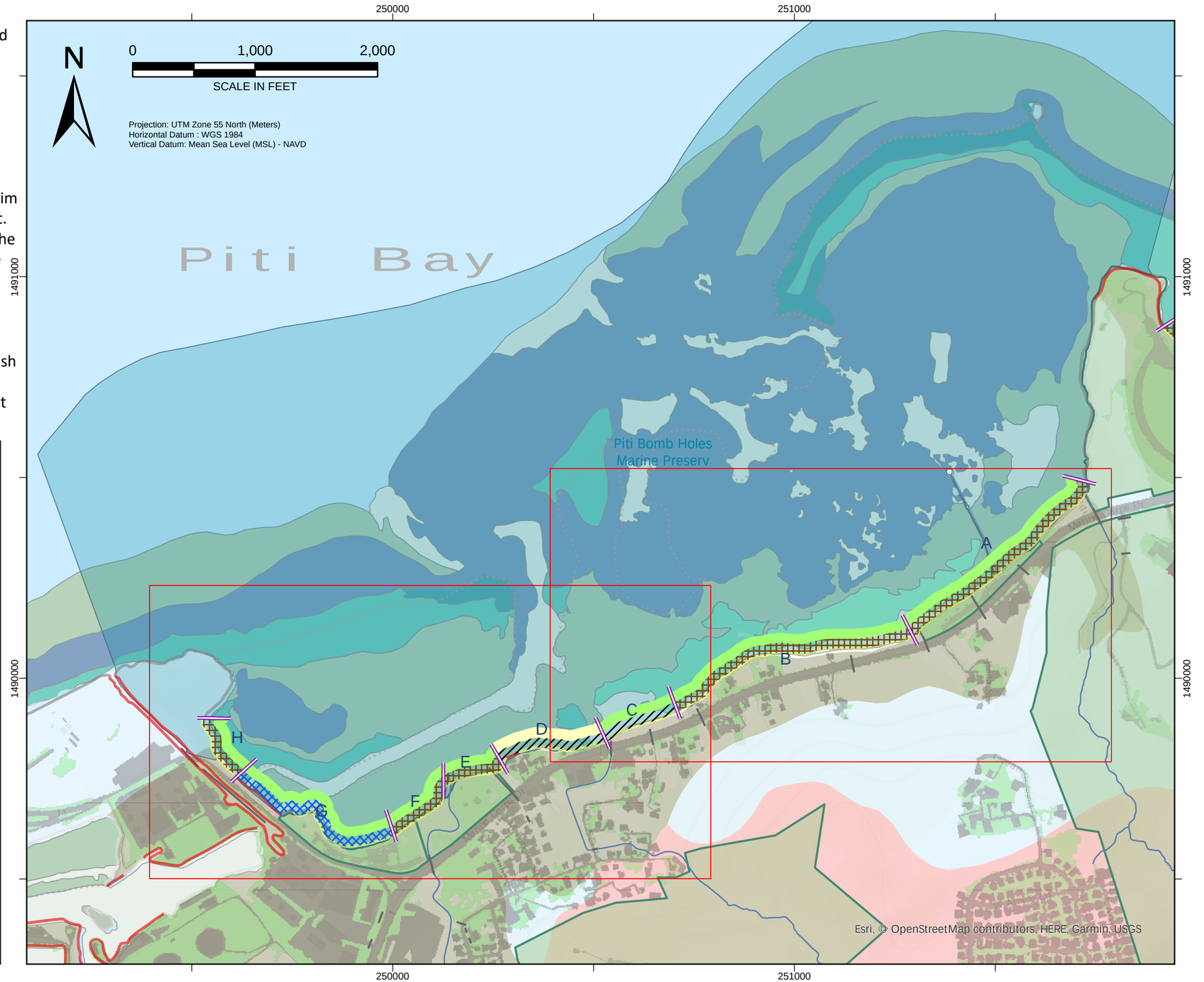
SHORELINE DESCRIPTION PITI BAY

6.1 Piti Bay Overview

Piti Bay is bounded by Asan Point on the east and Cabras Island on the west. Cabras Island is a narrow limestone island with a maximum elevation of 60 feet. The Piti Power Plant is located on the east end and the commercial port occupies the remainder of the island. The island is connected to the main body of Guam by a man-made causeway.

Three rivers draining the volcanic highlands discharge into Piti Bay; the Matgue, Toguan and Masso Rivers. Narrow beaches rim the shoreline, backed by intermittent residential development. The Piti Bay reef margin is irregular cut by several channels. The Tepungan Channel cuts completely across the reef flat. Before the causeway to Cabras Island and the Piti Power Plant were built, Tepungan Channel and Piti Channel connected the east end of Apra Harbor with the open ocean. Camel Rock, a small limestone islet, is located at the reef margin just west of Asan Point. Piti Bay is one of five marine preserves on Guam. The Fish Eye Marine Park is a popular destination with an underwater observatory of the marine preserve. Piti Bay is one of the most popular SCUBA diving areas in Guam.



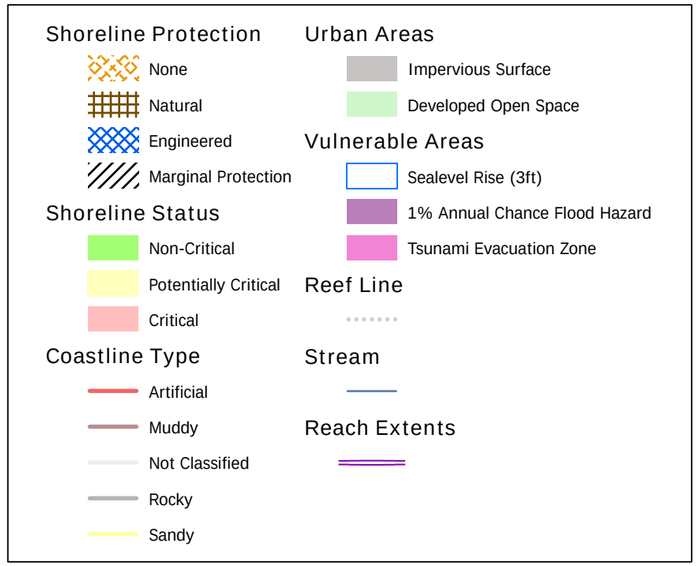


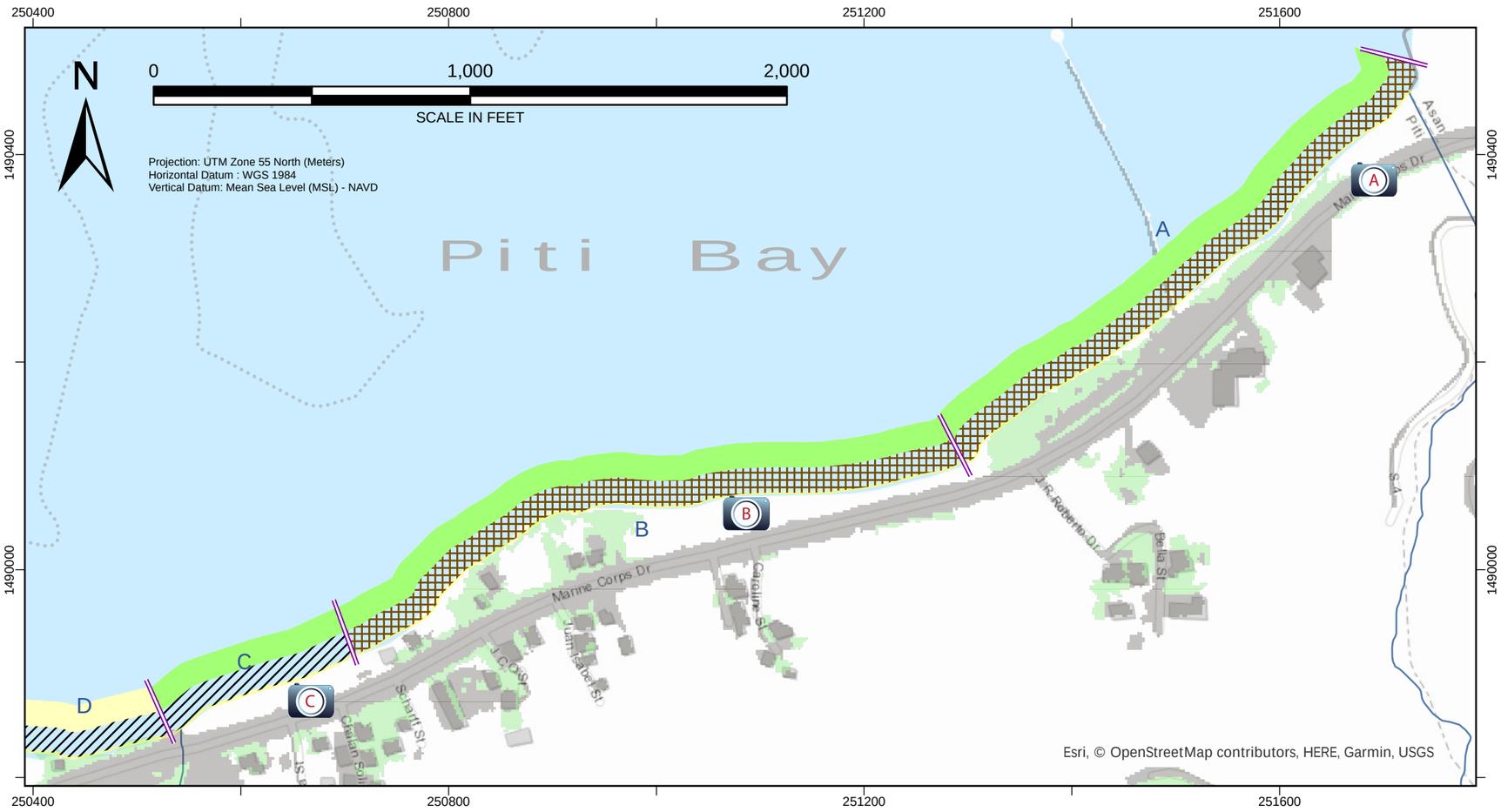
Go To Photo Appendix– Piti Bay

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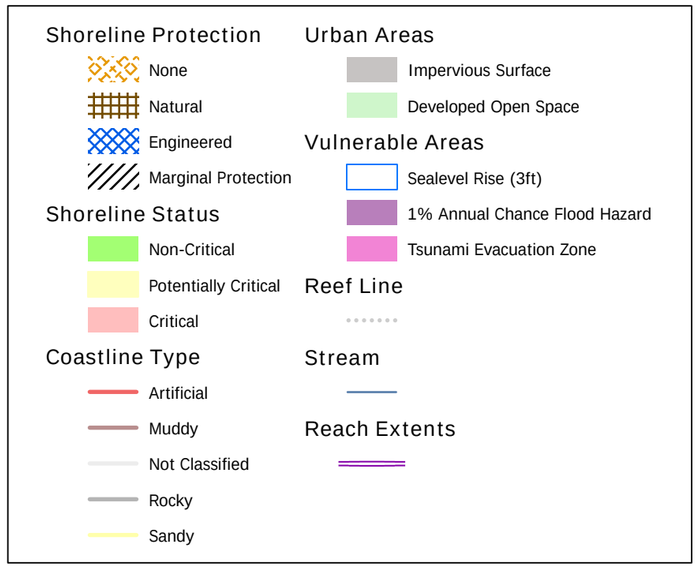
6.2 Piti Bay Reaches A-C

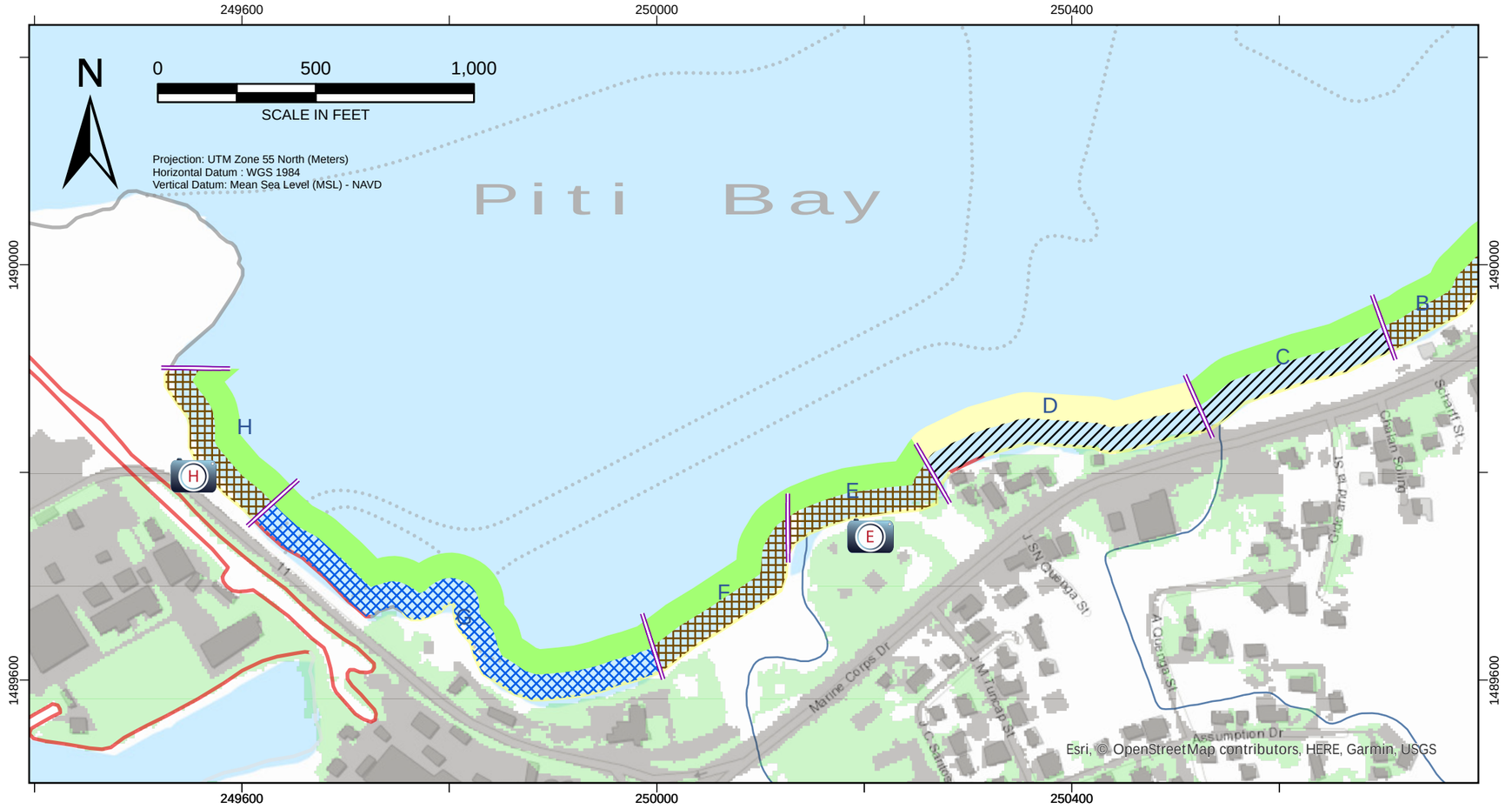




Reach	Reach A	Reach B	Reach C
Beach Width	20 feet	20 feet	< 20 feet
Reach Length	1,600 feet	2,200 feet	900 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Natural, Marginal	Natural, Marginal	Marginal
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	---	Drainage culvert contributes sediment	---
Shoreline Status	Non-Critical	Non-Critical	Non-Critical

6.2 Piti Bay Reaches D-H





Reach	Reach D	Reach E	Reach F	Reach G	Reach H
Beach Width	No beach	20 feet	20 feet	No beach	30-50 feet
Reach Length	600 feet	400 feet	600 feet	1,500 feet	500
Forshore Slope	No Data	1 on 9	No Data	No Data	No Data
Coastline Type	Sandy, Artifical	Sandy	Sandy	Sandy, Rocky, Artificial	Sandy
Shoreline Protection	Marginal	Natural	Natural	Engineered	Natural
Backshore	Developed No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	Unprotected developed area Marginal revetment protecting Route 1	Stream mouth	---	---	---
Shoreline Status	Potentially Critical	Non-Critical	Non-Critical	Non-Critical	Non-Critical

Go To Photo Appendix– Piti Bay

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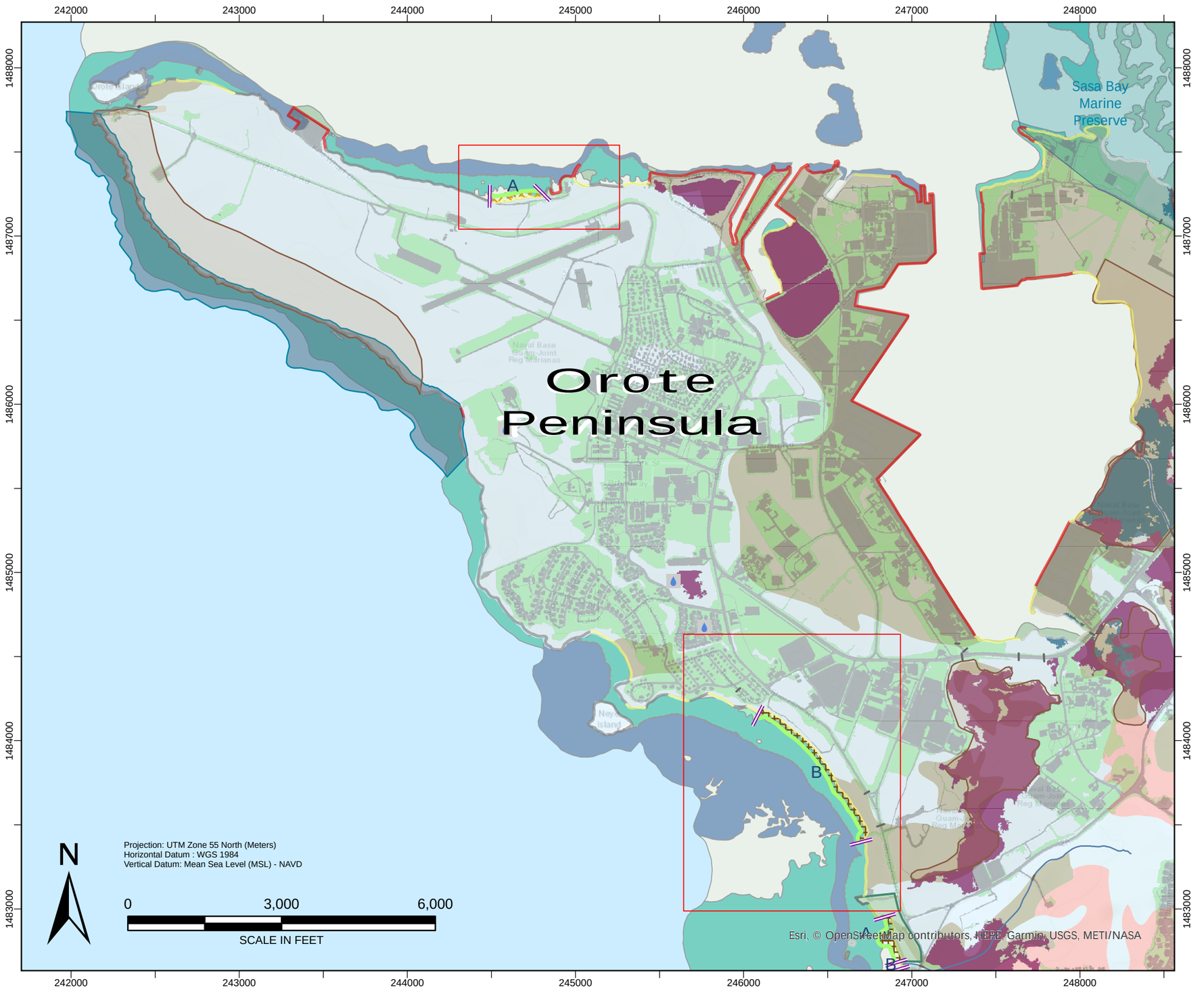
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SHORELINE DESCRIPTION OROTE PENINSULA

7.1 Orote Peninsula Overview

Orote Peninsula is a raised limestone plateau with elevations up to 190 feet. It is comprised of Mariana limestone, in contrast to the volcanic highlands immediately inland. Most of the shoreline is high, steep cliffs, with a few pocket beaches. The entire peninsula is used by Naval Base Guam, providing access to Apra Harbor along the northern shoreline. Beach deposits consist of beach sand and gravel, beach rock in the intertidal zone, and patches of recently emerged detrital limestone (COMNAV Marianas 2001). The Sasa Bay Marine Preserve, in Outer Apra Harbor, is one of five marine preserves on Guam.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

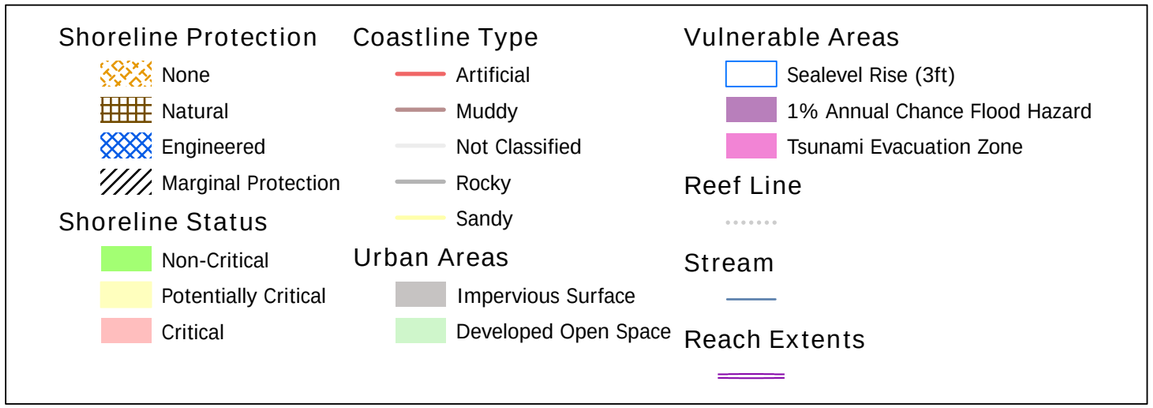
Stream

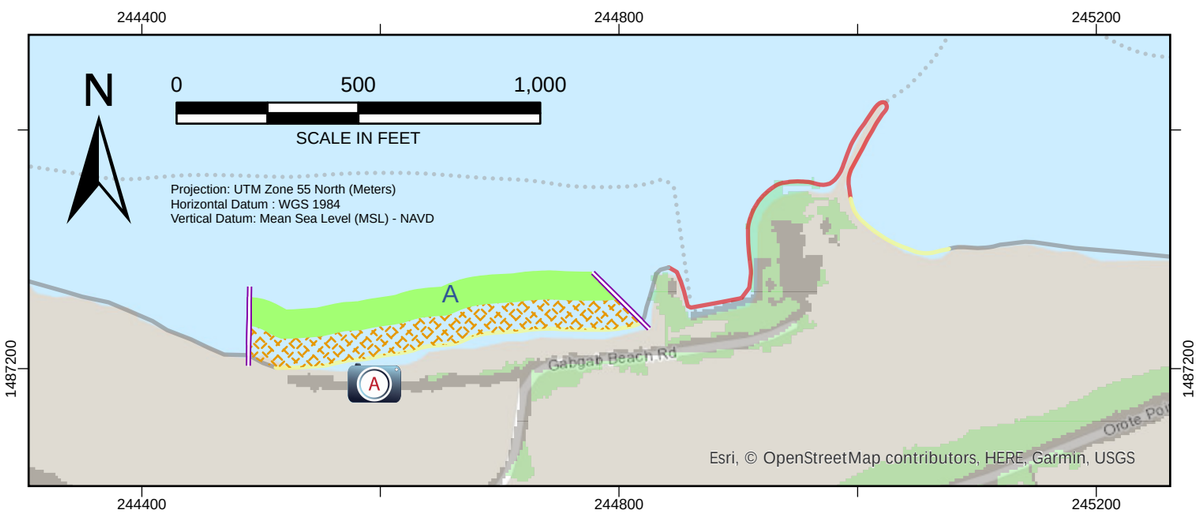
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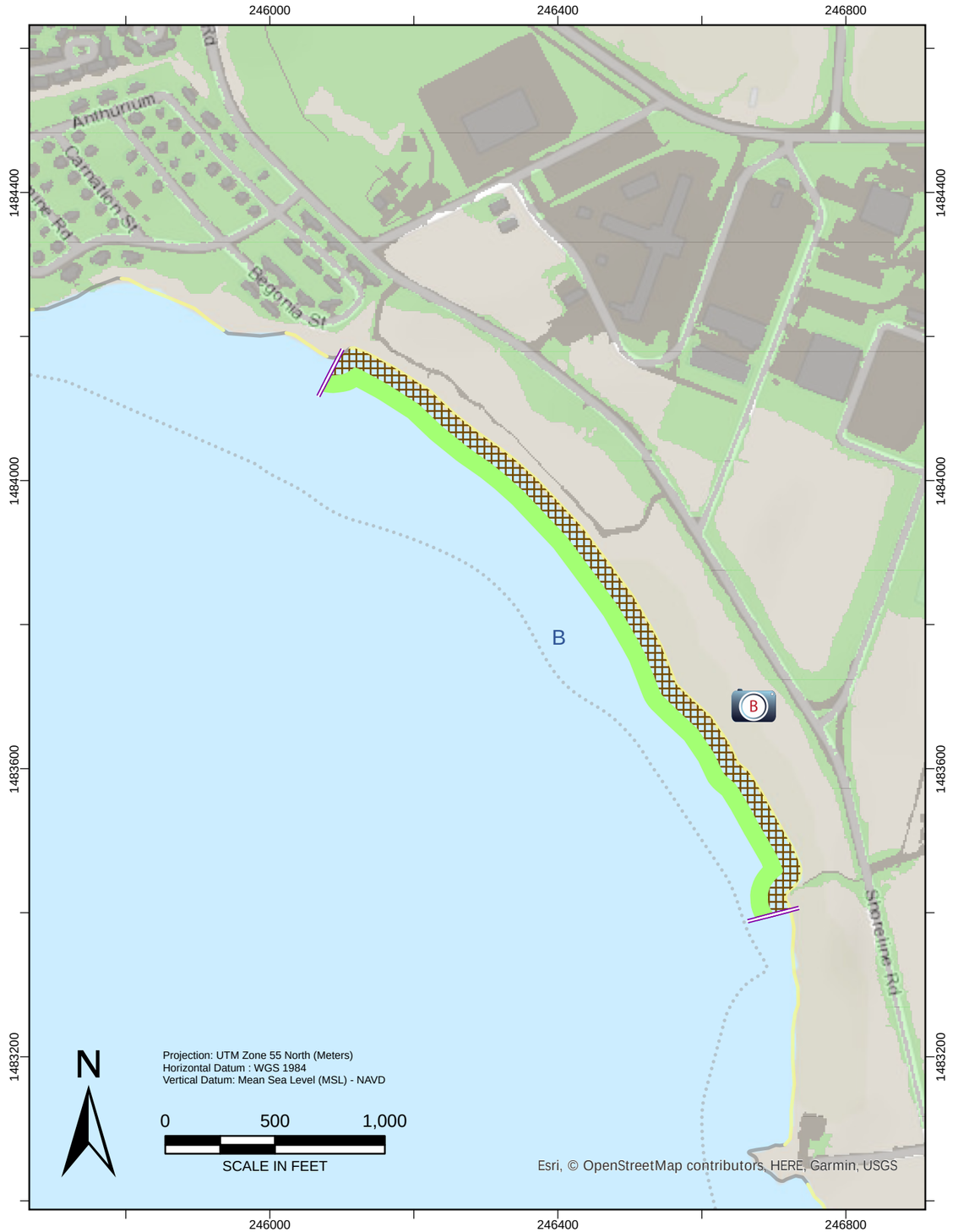
Reach Extents

7.2 Orote Peninsula Reaches A-B

Reach	Reach A: Gab Gab Beach	Reach B: Dadi Beach
Beach Width	30 feet	20-30 feet
Reach Length	1,000 feet	3,200 feet
Forshore Slope	No Data	No Data
Coastline Type	Sandy	Sandy
Shoreline Protection	None	Natural
Backshore	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	---	---
Shoreline Status	Non-Critical	Non-Critical







Go To Photo Appendix– Orote Peninsula

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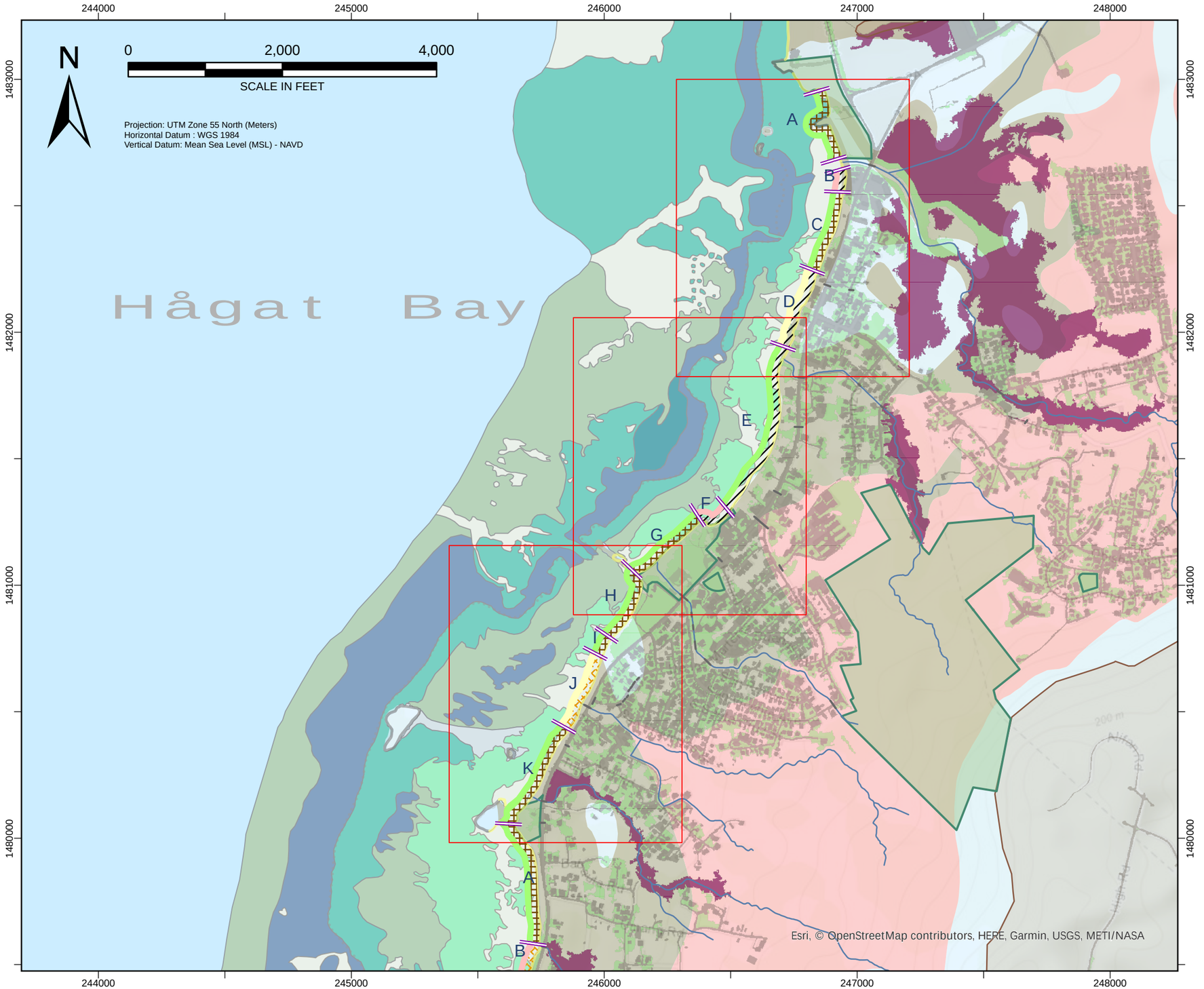
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SHORELINE DESCRIPTION HÅGAT BAY

8.1 Hågat Bay Overview

This coastal area comprises the northern half of Hågat Bay. There are two major beaches, Togcha Beach and Salinas Beach, in the sector. There is also a third, unnamed beach extending from Gaan Point to Bangi Island.

Five streams discharge into the area; the Namo River, Togcha River, Finile Creek, Gaan River and Auau Creek. The reef is indented by partial channels off Togcha Beach and just south of Gaan Point. There are small islets located on the reef flat at the north and south ends of the sector. Pelagi Islets, two small limestone islands, are located on the seaward edge of the reef flat off Apaca Point.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

Stream

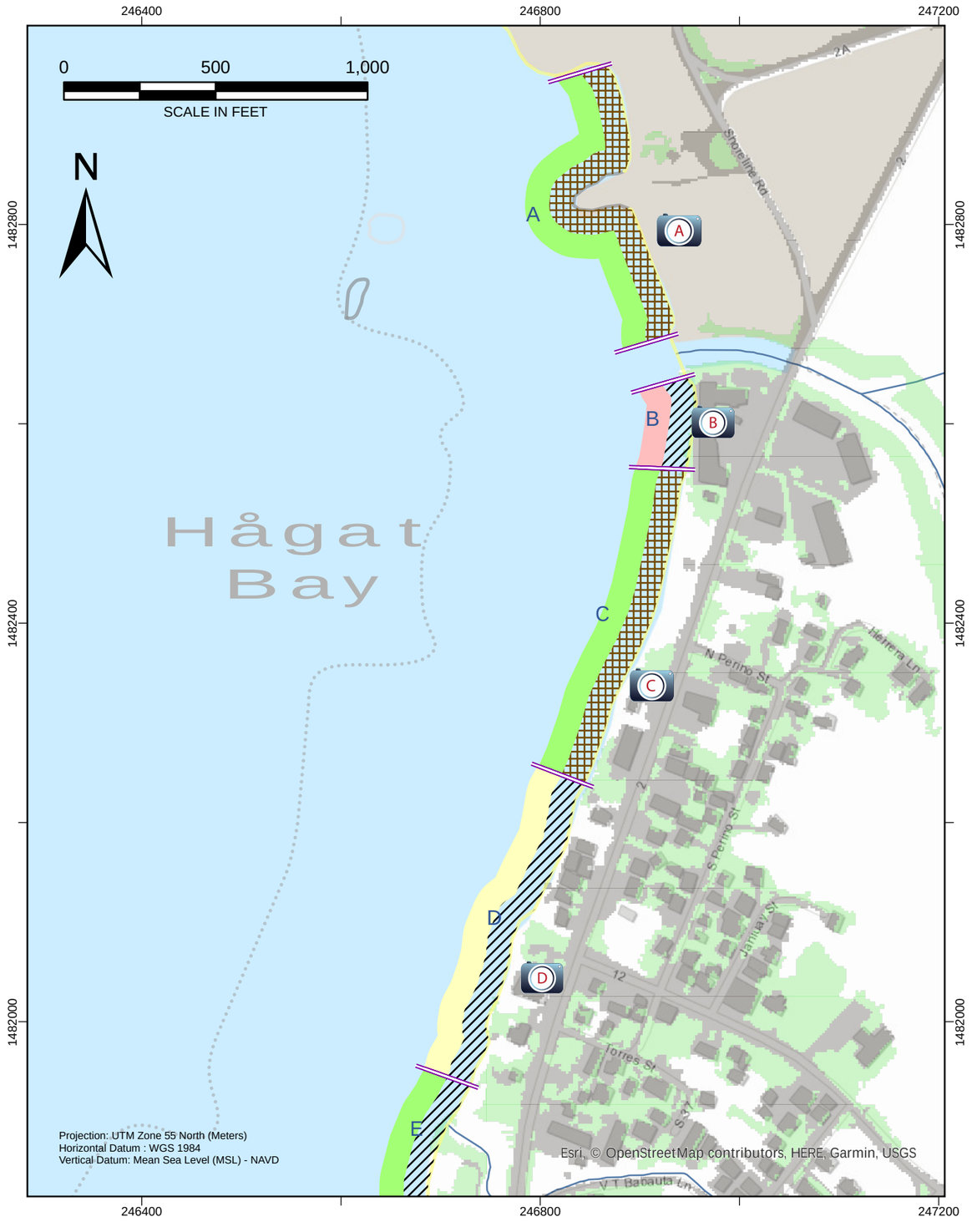
Reef Line

Reach Extents

8.2 Hågat Bay Reaches A-D

Reach	Reach A: Apaca Point	Reach B: Inn on the Bay	Reach C: Togcha Beach, North End
Beach Width	15-30 feet	No Beach	25 feet
Reach Length	900 ft	300 feet	1,000 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy	Artificial	Sandy
Shoreline Protection	Natural	Marginal	Natural
Backshore	Undeveloped No Infrastructure Vegetation	Developed No Infrastructure No Vegetation	Developed Infrastructure Vegetation
Notes	Two pocket beaches	Seawall in poor condition Erosion hotspot	---
Shoreline Status	Non-Critical	Critical	Non-Critical

Reach	Reach D: Togcha Beach, South End
Beach Width	< 20 feet
Reach Length	1,000 feet
Forshore Slope	No Data
Coastline Type	Sandy
Shoreline Protection	Marginal
Backshore	Developed Infrastructure Partially Vegetated
Notes	Seawalls and revetments in poor condition
Shoreline Status	Potentially Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

Go To Photo Appendix– Hågat Bay

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8.2 Hågat Bay Reaches E-G

Reach	Reach E: Salinas Beach	Reach F: Hågat Mayor's Office	Reach G: War Memorial
Beach Width	25 feet	20 feet	30 feet
Reach Length	2,300 feet	300 feet	1,100 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Marginal	Marginal	Natural
Backshore	Partially Developed Infrastructure Vegetation	Developed No Infrastructure No Vegetation	Undeveloped No Infrastructure Vegetation
Notes	2 stream mouths and 1 drainage outfall contribute sediment	Seawall in fair condition Erosion hot spot	War Memorial Park, dumped limestone boulders at north end, abondoned outfall pipeline at south end
Shoreline Status	Non-Critical	Critical	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

Go To Photo Appendix– Hågat Bay

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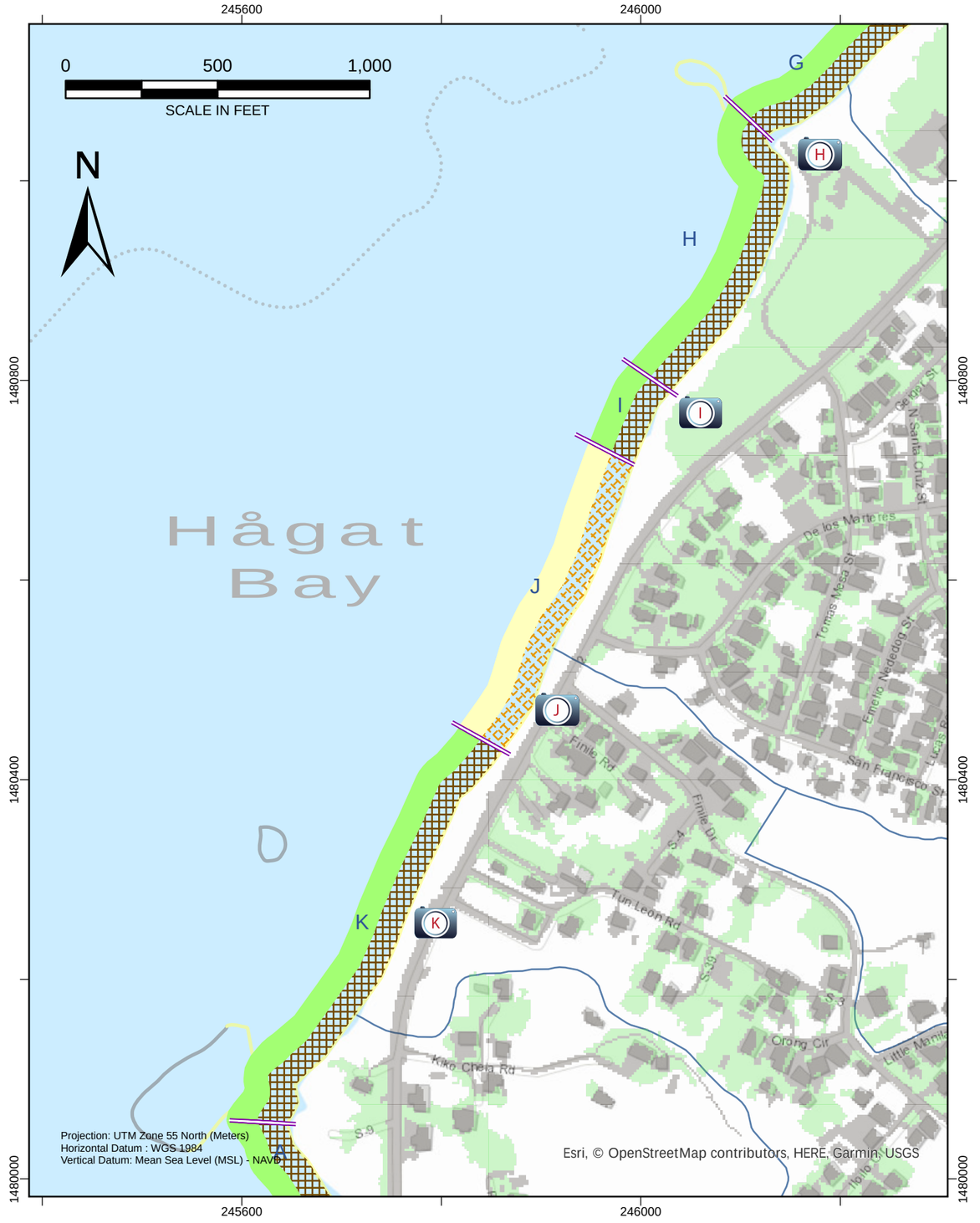
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8.2 Hågat Bay Reaches H-K

Reach	Reach H	Reach I	Reach J
Beach Width	25 feet	< 20 feet	30 feet
Reach Length	900 feet	300 feet	1,000 feet
Forshore Slope	1 on 12	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Natural	Natural	None
Backshore	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	Cemetery located between shoreline and Route 2	Basalt boulder outcropping	Powerlines and Route 2 in backshore, no shore protection
Shoreline Status	Non-Critical	Non-Critical	Potentially Critical

Reach	Reach K
Beach Width	20 feet
Reach Length	1,300 feet
Forshore Slope	No Data
Coastline Type	Sandy
Shoreline Protection	Natural
Backshore	Undeveloped No Infrastructure Vegetation
Notes	Stream mouth and culvert contribute sediment
Shoreline Status	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

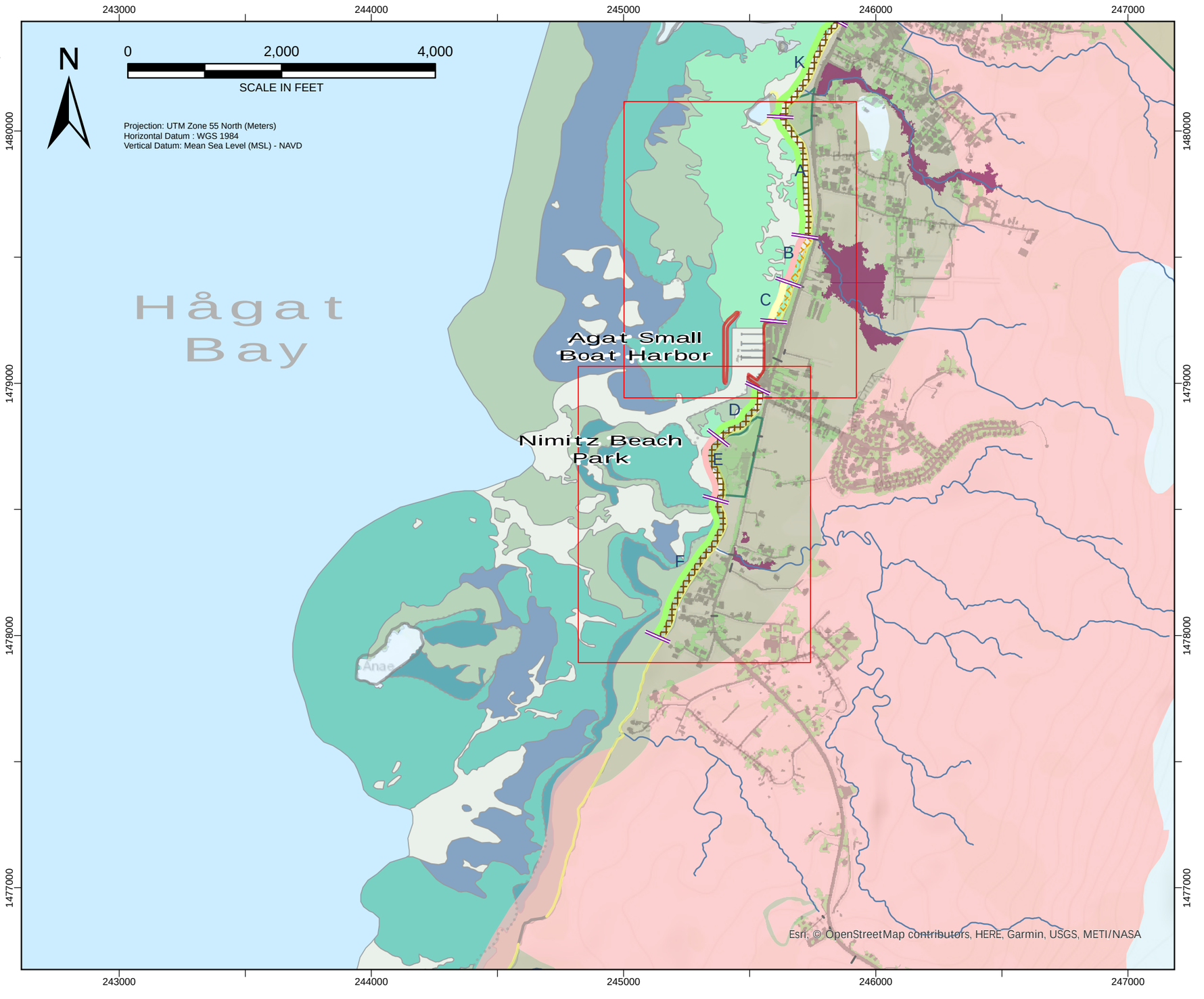
SHORELINE DESCRIPTION NIMITZ BEACH

9.1 Nimitz Beach Overview

This coastal area extends 1-1/2 miles from Bangi Point to Taelayag Creek. Nimitz Beach Park and Agat Small Boat Harbor are located in the center of the sector. The beach park is heavily used for recreation. The Nimitz Channel is used for small boat access to the open ocean, and by snorkelers and divers. The backshore is mostly undeveloped, except for a few houses. Route 2 parallels the shoreline along the north half of the sector, then swings inland south of the beach park.

At Agat Small Boat Harbor, the shoreline was built out as a revetted mole and is protected by a rock revetment. The harbor basin and channel were dredged from the reef and are protected by a detached breakwater.

There is a well-developed inner reef flat moat. The reef is mainly intertidal reef flat consisting of reef rock pavement. Two major channels cut through the reef flat, located at Nimitz Beach Park and off the Taleyfac River. South of the Taleyfac River, the reef flat is narrow.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

Stream

Reef Line

Reach Extents

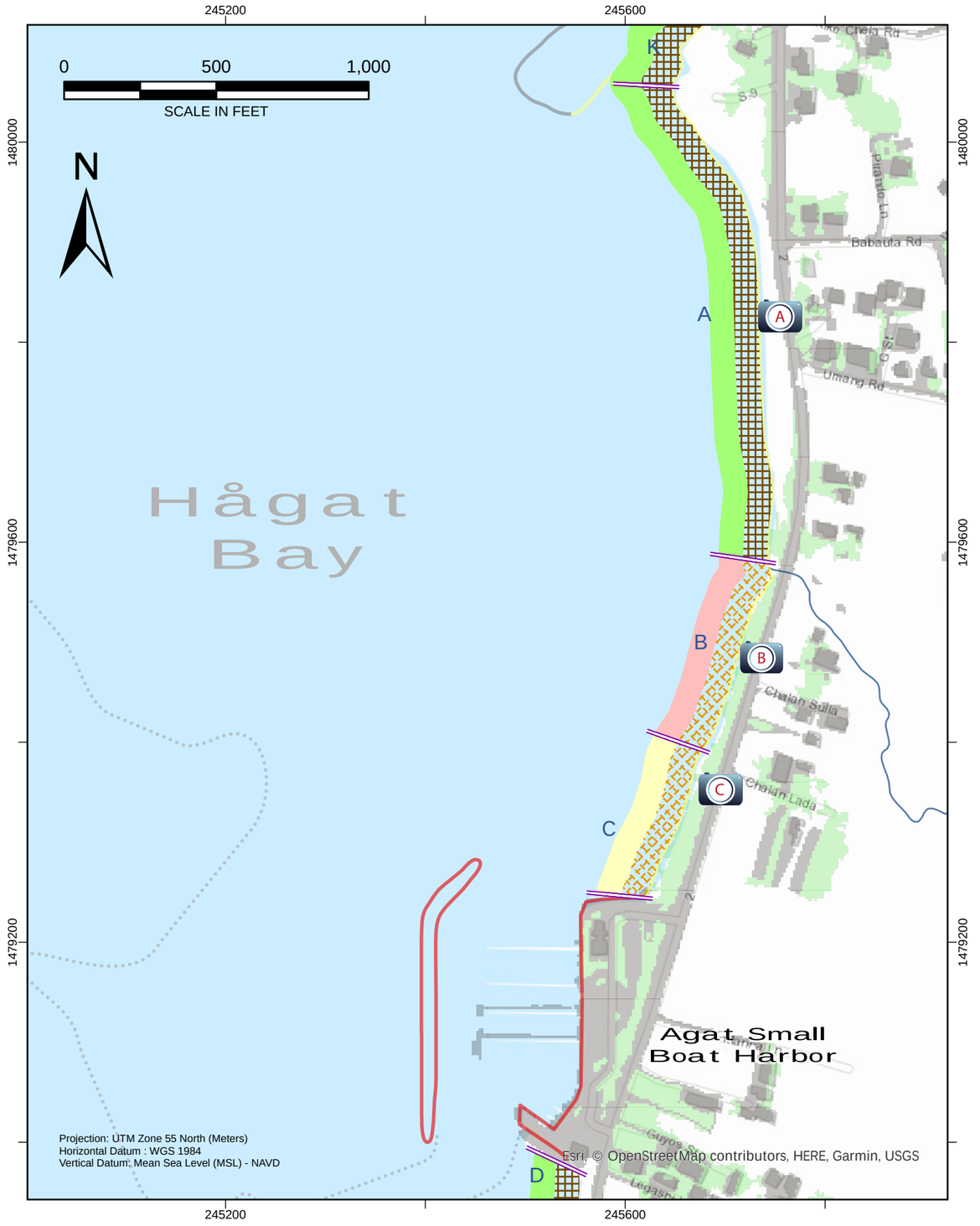
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9.2 Nimitz Beach Reaches A-C

Reach	Reach A	Reach B	Reach C
Beach Width	< 20 feet	< 20 feet	< 20 feet
Reach Length	1,600 feet	600 feet	500 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Natural	None	None
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	Chaligan River at southern extent contributes sediment	Powerlines on shoreline side of Route 2 are undermined	Powerlines on shoreline side of Route 2
Shoreline Status	Non-Critical	Critical	Potentially Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

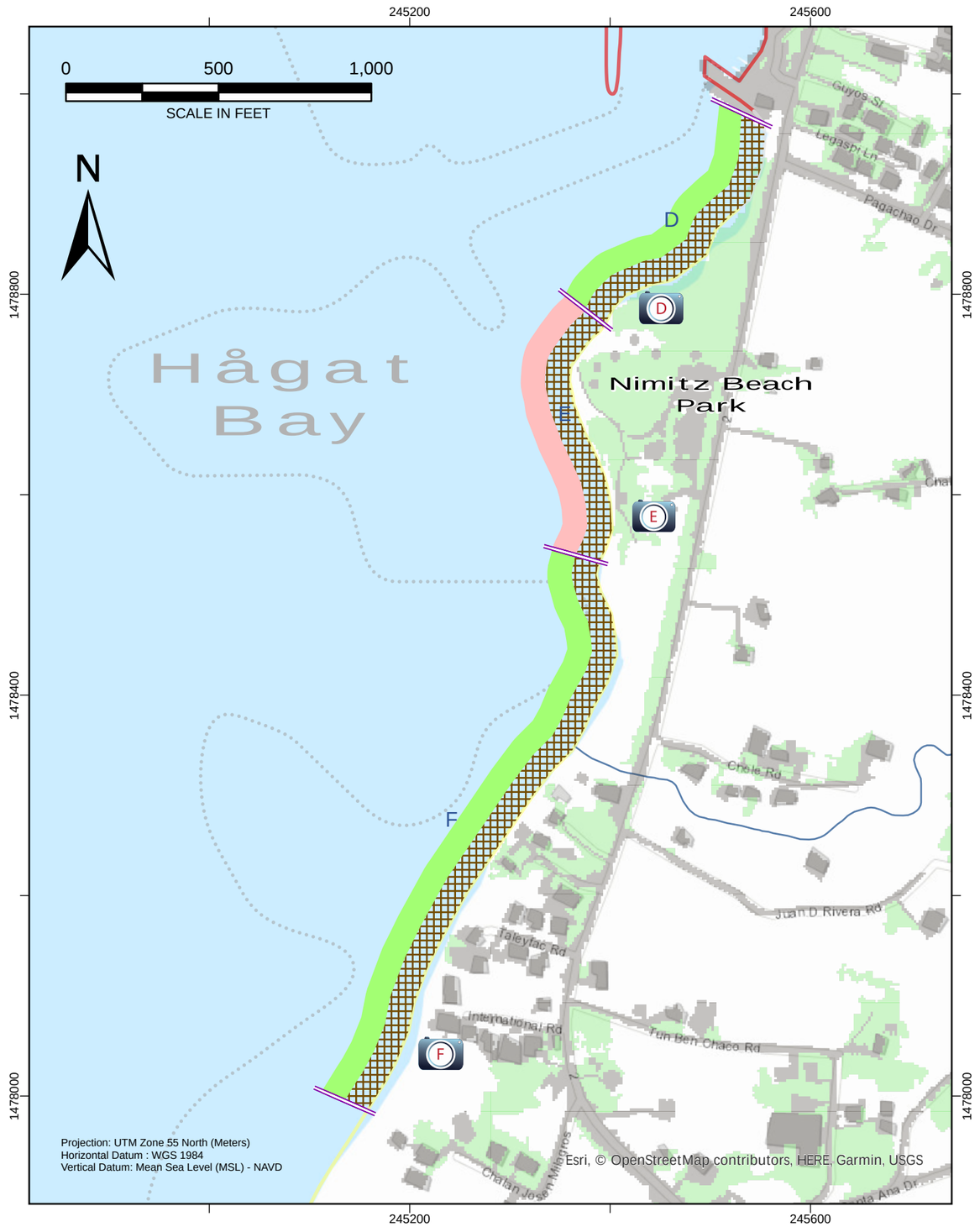
Reef Line

Stream

Reach Extents

9.2 Nimitz Beach Reaches D-F

Reach	Reach D	Reach E	Reach F
Beach Width	20 feet	20 feet	20 feet
Reach Length	800 feet	900 feet	2,000 feet
Forshore Slope	No Data	1 on 8	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Natural	Natural	Natural
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Partially Developed No Infrastructure Vegetation
Notes	Two drainage outfalls contribute sediment	Undermining of Nimitz Beach Park facilities	---
Shoreline Status	Non-Critical	Critical	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

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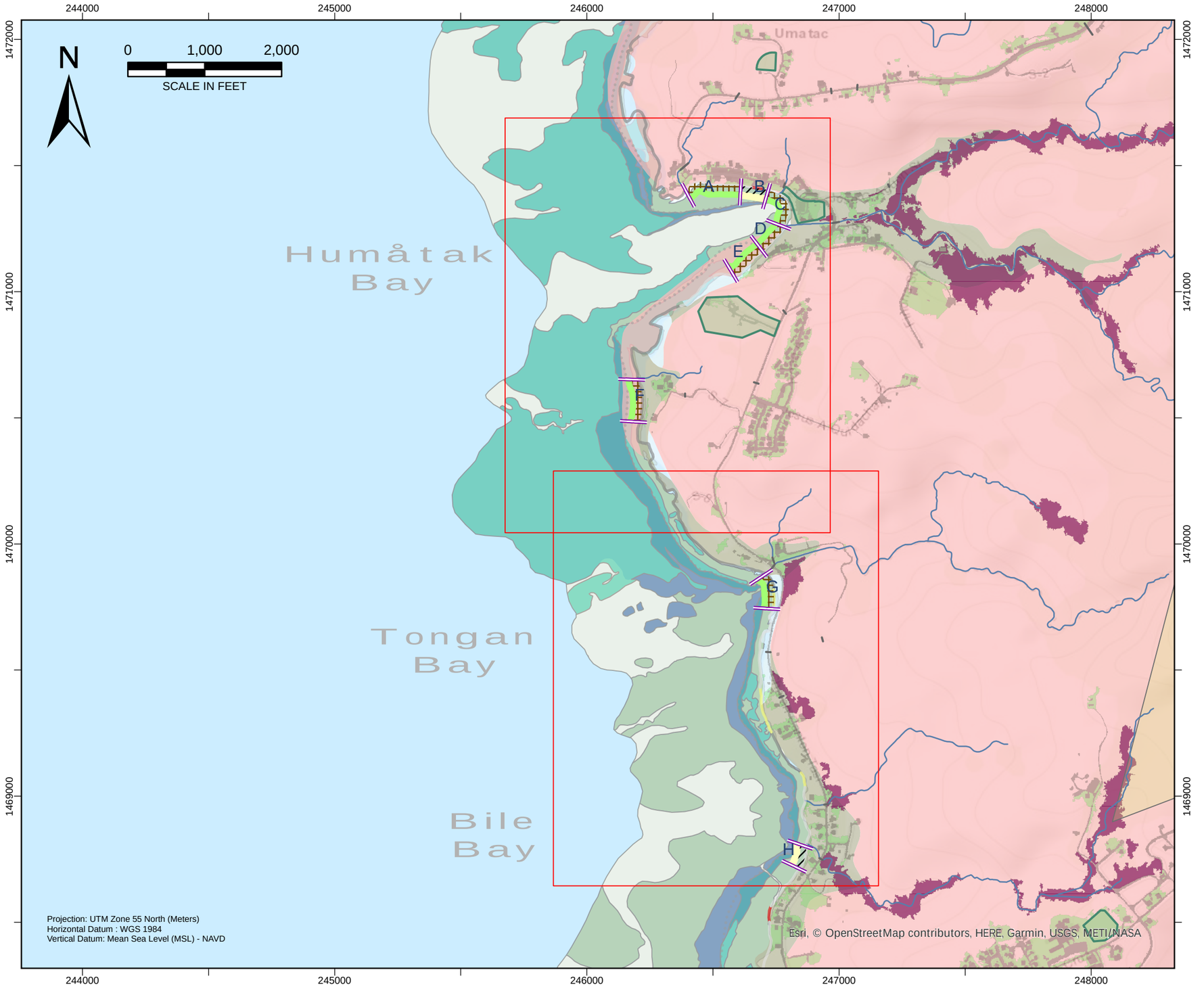
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SHORELINE DESCRIPTION HUMÅTAK BAY

10.1 Humåtak Bay Overview

The shoreline from Taelayag Beach to the start of the Cocos Barrier Reef consists of rocky volcanic headlands, shorelines, and small pocket beaches. The coastline forms several prominent embayments; Sella Bay, Cetti Bay, Fouha Bay Humåtak Bay, Tongan Bay, and Bile Bay. The only development is at the village of Humåtak. Several historical sites are located in the vicinity of Humåtak Bay. Fort San Jose (Ruins), Fort Santo Angel (Ruins) are on the bluff north of Humåtak Bay; Magellan Monument is at the head of the bay; Fort Soledad (Ruins) is located on the bluff south of Humåtak Bay.

The backshore area is the steep, mountainous volcanic land of southern Guam, and is drained by many rivers. The rivers are short and steep with no well-defined estuaries. Channels cut completely through the fringing reef at the mouths of the larger rivers. This coastal sector is in the lee of the predominant trade winds and the wave climate is generally mild, except during the approach of tropical storms or hurricanes.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

Stream

Reef Line

Reach Extents

10.2 Humåtak Bay Reaches A-F

Reach	Reach A	Reach B	Reach C
Beach Width	< 20 feet	< 20 feet	75 feet
Reach Length	700 feet	350 feet	600 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy Cobble	Artificial	Sandy
Shoreline Protection	Natural	Marginal	Natural
Backshore	Developed No Infrastructure Vegetation	Developed No Infrastructure No Vegetation	Undeveloped No Infrastructure Vegetation
Notes	---	Retaining wall undermined; Building foundation undermined	Some scarping near boat ramp River contributes sediment
Shoreline Status	Non-Critical	Potentially Critical	Non-Critical

Reach	Reach D	Reach E	Reach F - Mamatgun Point
Beach Width	30 feet	30 feet	30 feet
Reach Length	400 feet	450 feet	500 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Natural	Natural	Natural
Backshore	Developed No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation	Developed No Infrastructure Vegetation
Notes	Failing seawall	Humåtak Cemetery on erosive buff	Private property
Shoreline Status	Non-Critical	Non-Critical	Non-Critical

Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

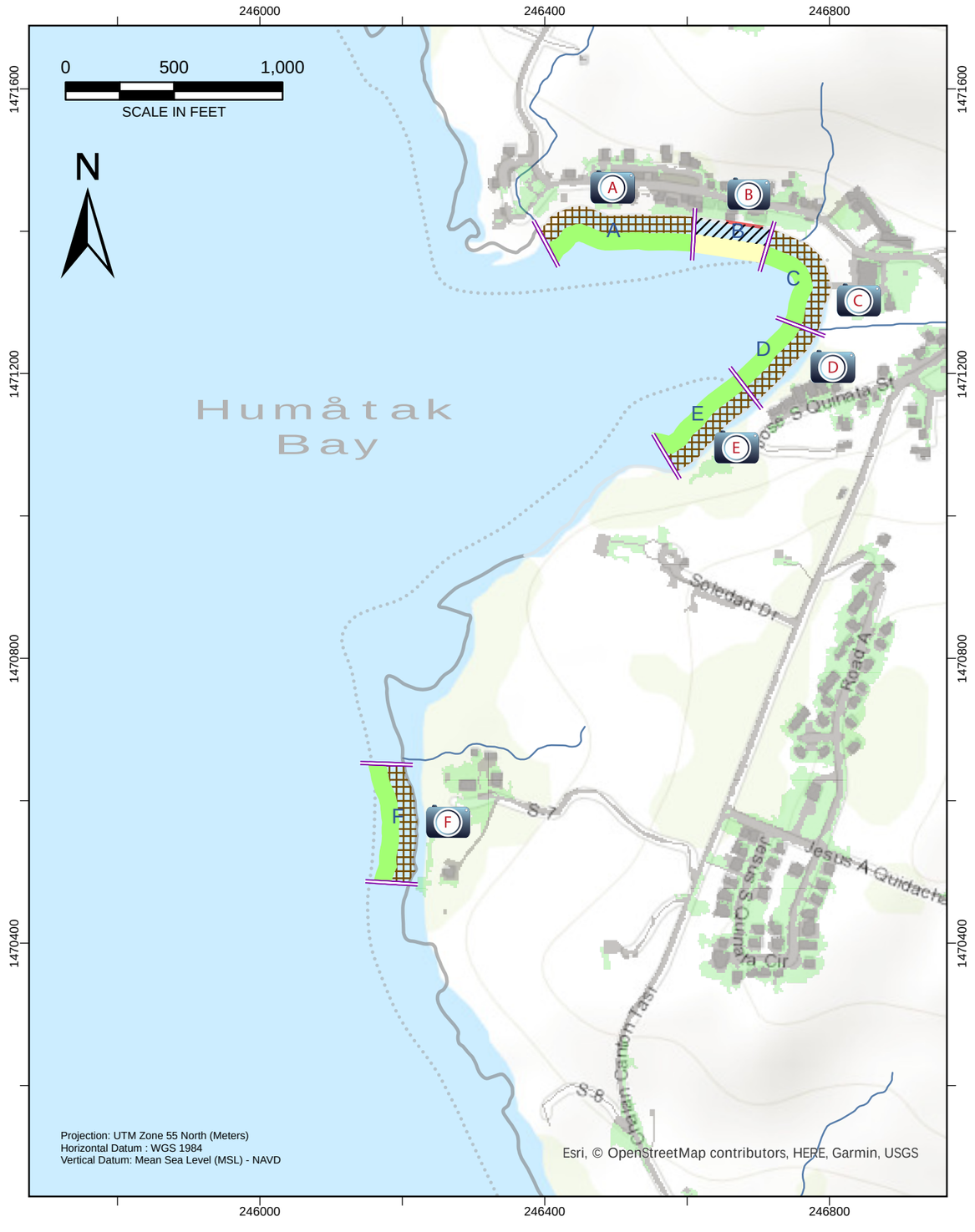
Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

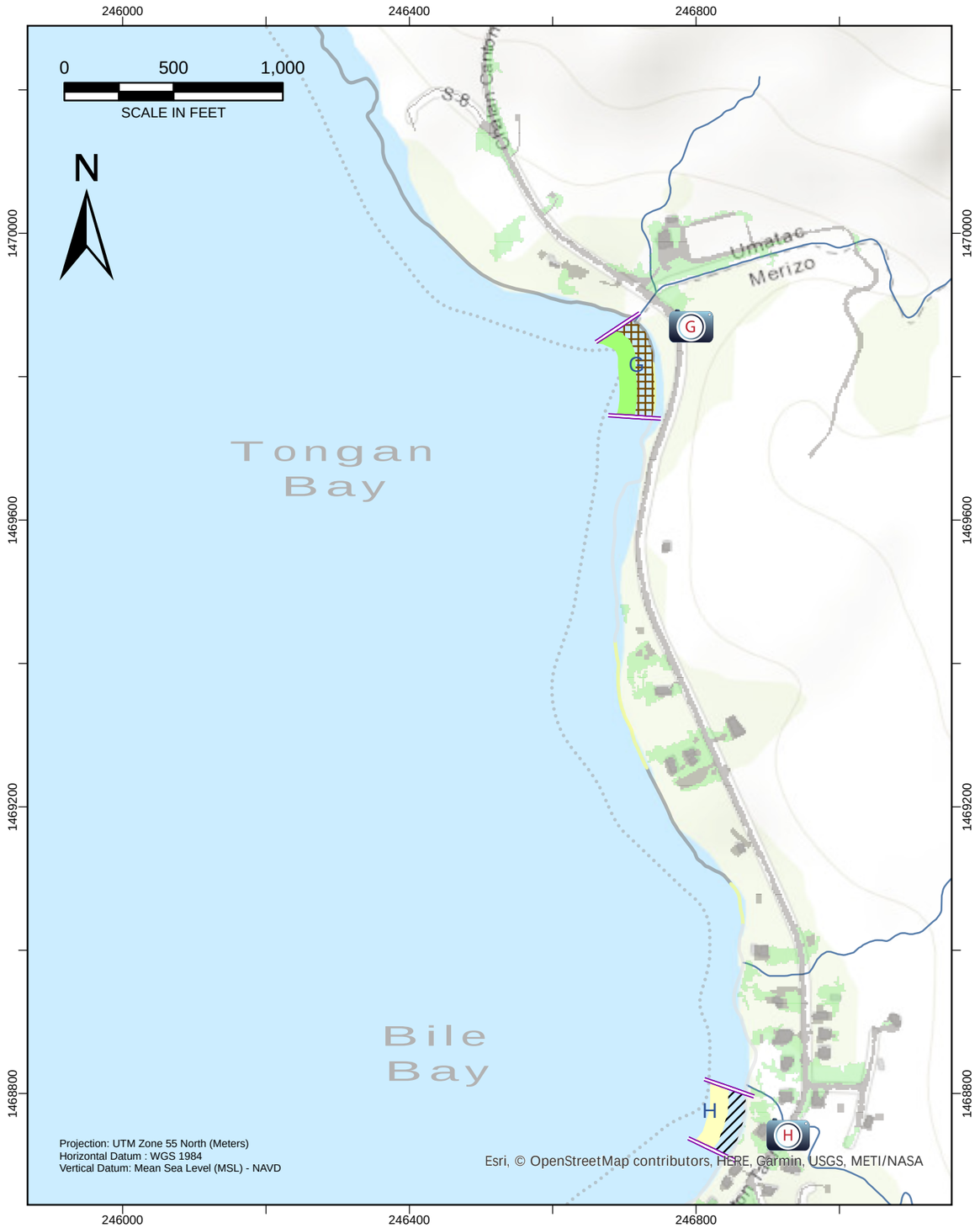
Stream

Reach Extents



10.2 Humåtak Bay Reaches G-H

Reach	Reach G - Tongan Bay	Reach H - Bile Bay
Beach Width	30 feet	20 feet
Reach Length	450 feet	250 feet
Forshore Slope	No Data	No Data
Coastline Type	Sandy	Sandy
Shoreline Protection	Natural	Marginal
Backshore	Undeveloped Infrastructure Vegetation	Developed No Infrastructure Vegetation
Notes	Tongan Creek discharges at the north end of the bay	Marginal revetment Stream delta and boat ramp
Shoreline Status	Non-Critical	Potentially Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

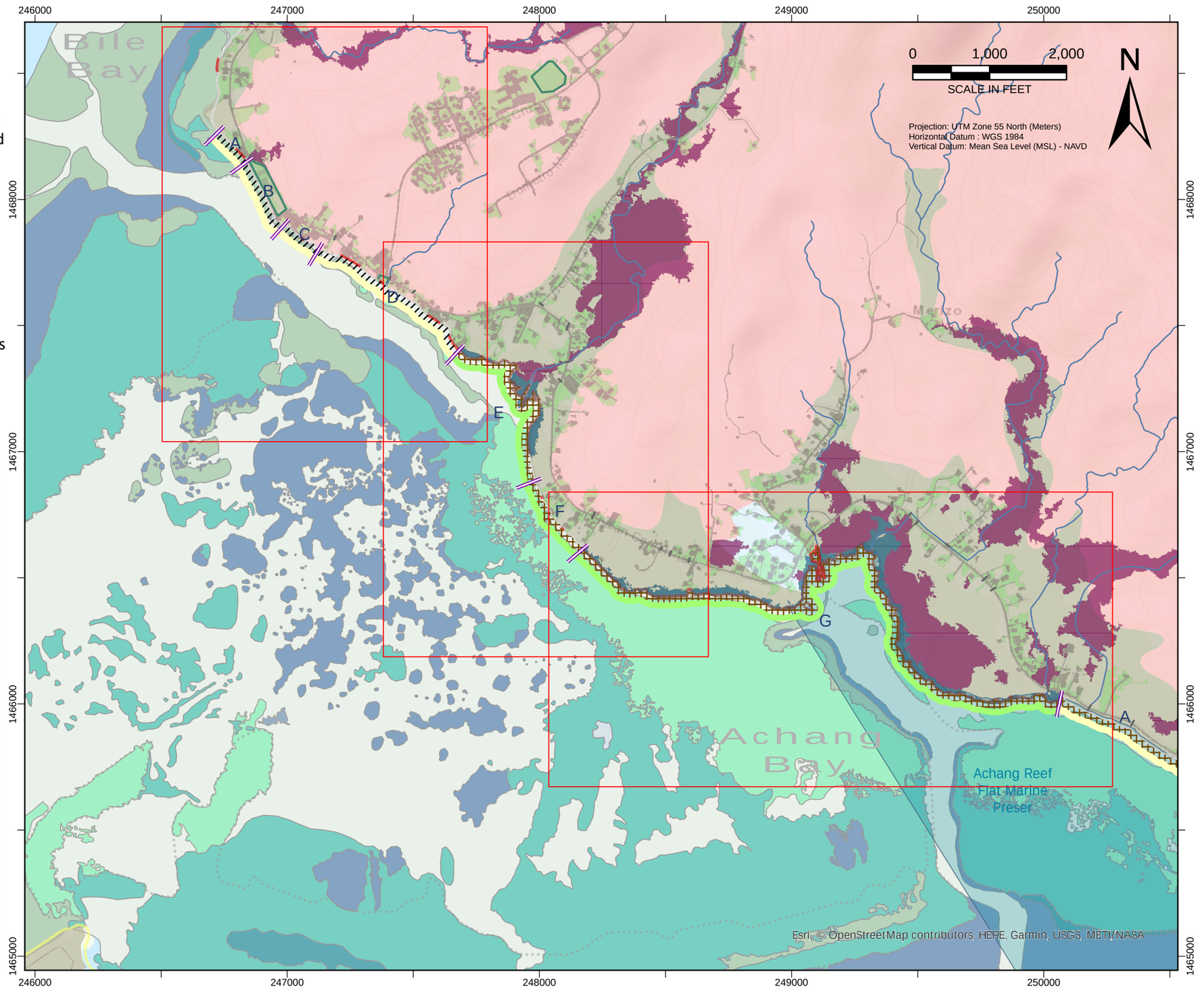
11

SHORELINE DESCRIPTION MALESSO

11.1 Malesso Overview

Malesso includes the coastal region between the mouth of Mamaon and Manell Channels. The predominant feature is Cocos Lagoon, enclosed by Cocos Island and the Cocos Barrier Reefs. Two deep channels connect the lagoon waters with the open sea: Mamaon Channel and Manell Channel. Several small rivers form alluvial valleys and a broad coastal plain at the head of Manell Channel. Near the mouth of the Geus River and at Achang Bay, the shores are mud flats and mangrove swamps.

The shoreline is extensively developed and altered from its natural condition. The village of Malesso occupies most of the shoreline, with residential and commercial development concentrated along the coastline bordered by Mamaon Channel. Several marinas and piers are located along the narrow fringing reef shelf between the shoreline and Mamaon Channel. The density of development diminishes from the Geus River to Achang Bay and Route 4 is located slightly inland. The protected waters of Cocos Lagoon are widely used for recreation, including boating, sailing, glass bottom boat tours, water skiing, snorkeling, diving and shell collecting.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

Stream

Reef Line

Reach Extents

11.2 Malesso Reaches A-D

Reach	Reach A	Reach B
Beach Width	No Beach	< 20 feet
Reach Length	400 feet	900 feet
Forshore Slope	No Data	No Data
Coastline Type	Artificial	Sandy
Shoreline Protection	Marginal	Marginal
Backshore	Developed Infrastructure Partially Vegetated	Developed Infrastructure Vegetation
Notes	Route 4 retaining wall in poor condition	Malesso Pier Park public boat ramp and pier; retaining wall in poor condition
Shoreline Status	Potentially Critical	Potentially Critical

Reach	Reach C	Reach D
Beach Width	< 20 feet	No Beach
Reach Length	500 feet	2,300 feet
Forshore Slope	No Data	No Data
Coastline Type	Sandy, Artificial	Sandy, Artificial
Shoreline Protection	Marginal	Marginal
Backshore	Developed No Infrastructure Partially Vegetated	Developed No Infrastructure Partially Vegetated
Notes	Minimal protection for marina and Cocos Crossing Ferry Line	Failed seawall Stream contributes sediment
Shoreline Status	Potentially Critical	Potentially Critical

Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

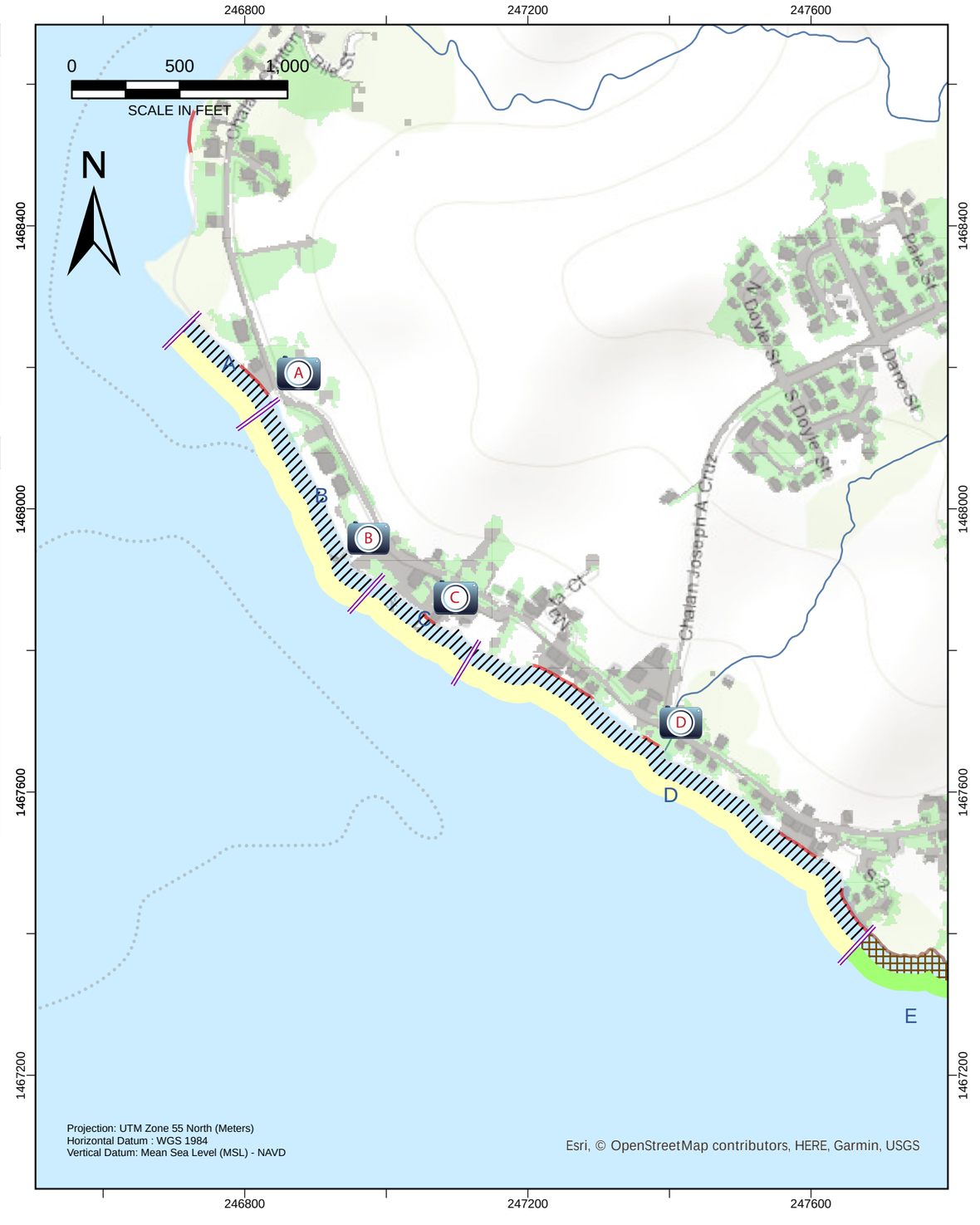
Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

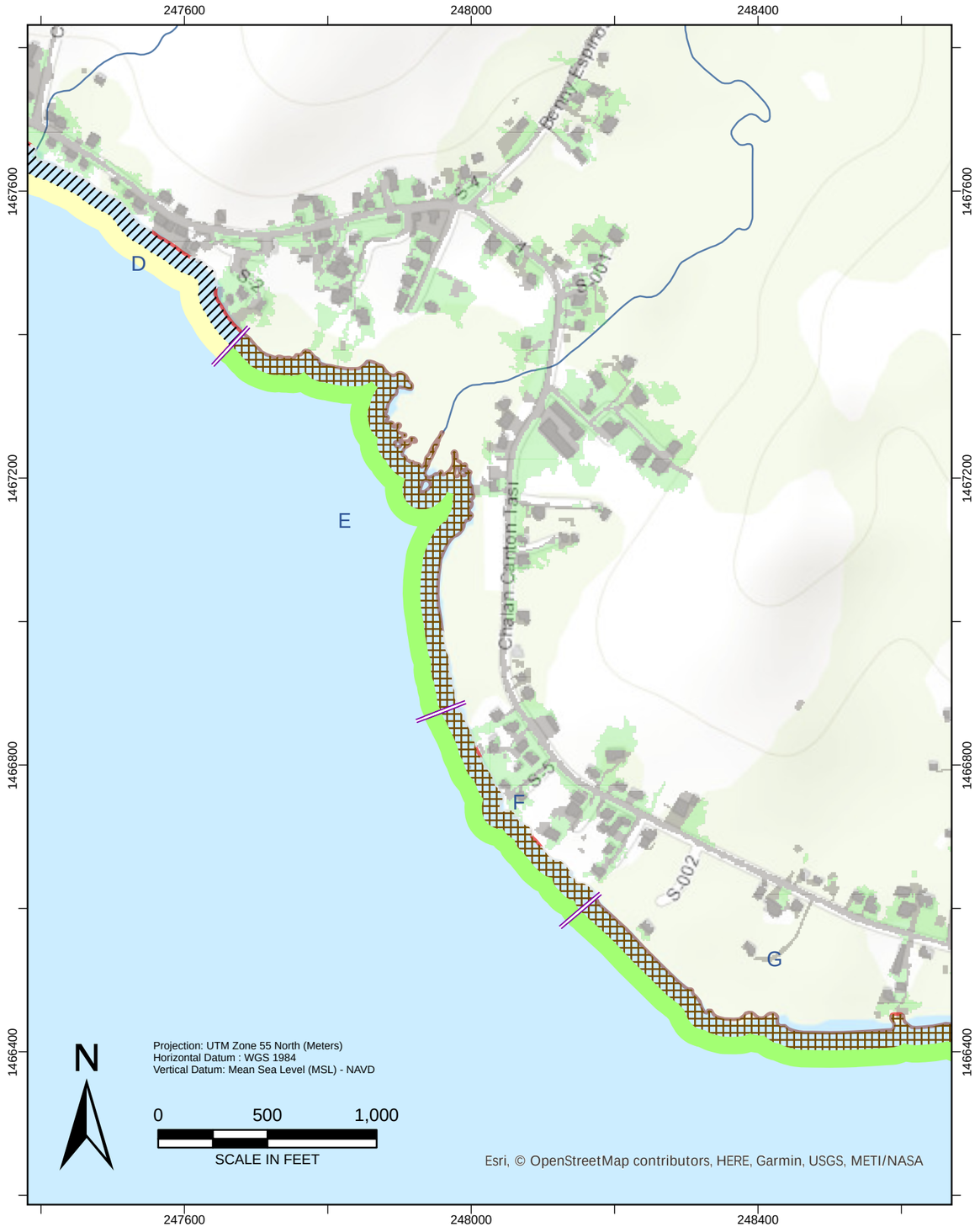
Stream

Reach Extents



11.2 Malesso Reaches E-F

Reach	Reach E	Reach F
Beach Width	No Data	No Data
Reach Length	2,300 feet	1,000 feet
Forshore Slope	No Data	No Data
Coastline Type	Muddy	Artificial, Not Classified
Shoreline Protection	Natural	Natural
Backshore	Undeveloped No Infrastructure Vegetation	Developed No Infrastructure Vegetation
Notes	River contributes sediment	---
Shoreline Status	Non-Critical	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

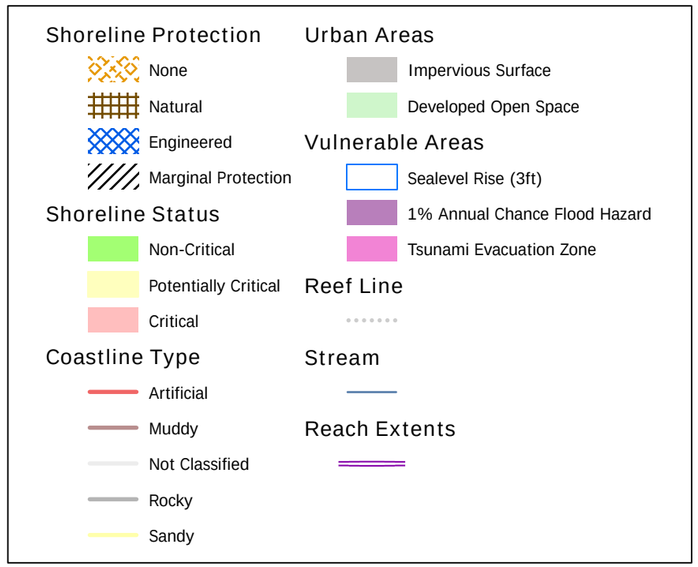
Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

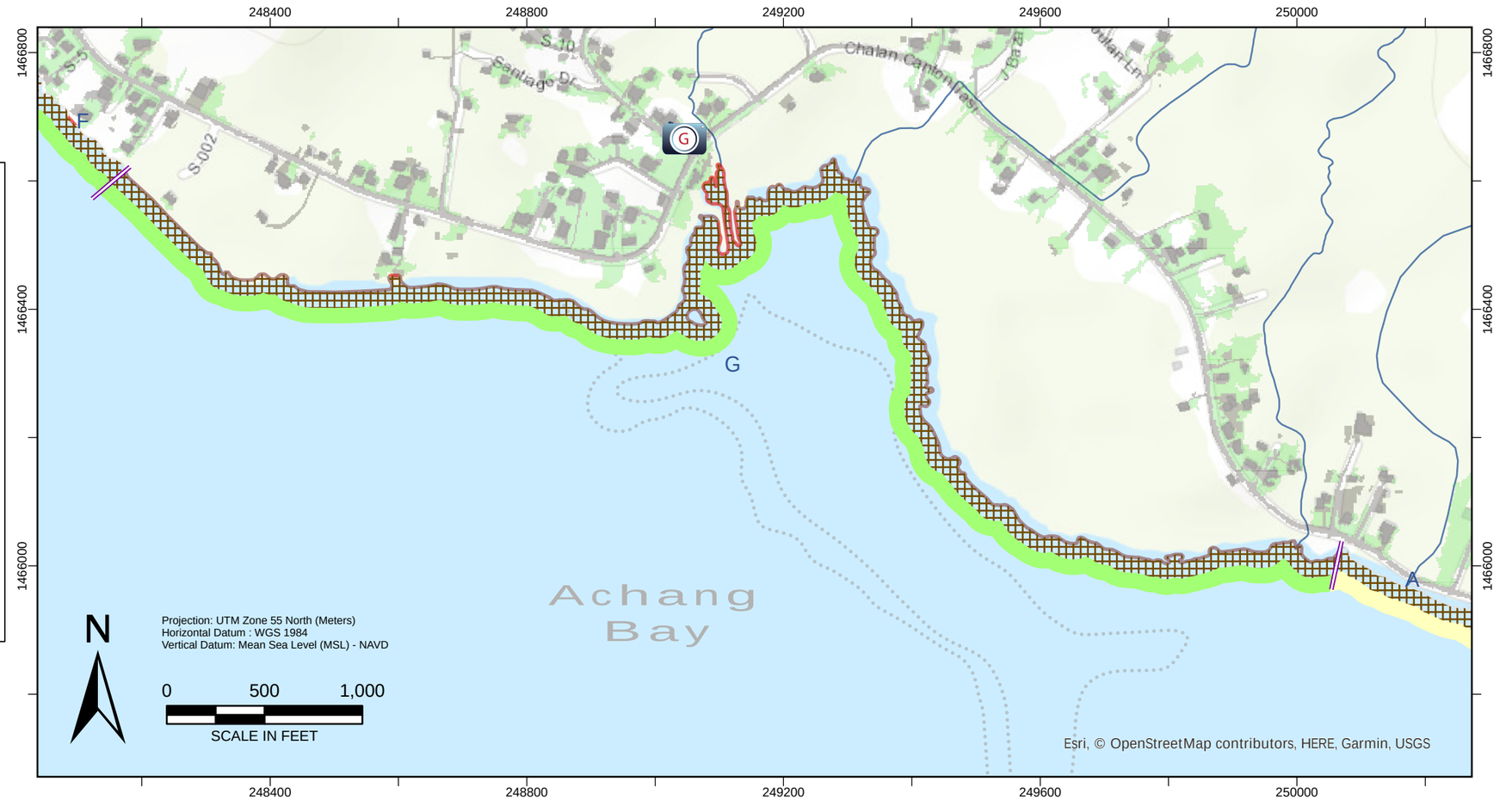
Reef Line

Stream

Reach Extents

11.2 Malesso Reaches G





Reach	Reach G
Beach Width	No Data
Reach Length	8,300 feet
Forshore Slope	No Data
Coastline Type	Muddy
Shoreline Protection	Natural
Backshore	Undeveloped Infrastructure Vegetation
Notes	Three streams contribute sediment. Small boat basin, jetties, boat ramp - poor condition.
Shoreline Status	Non-Critical

12

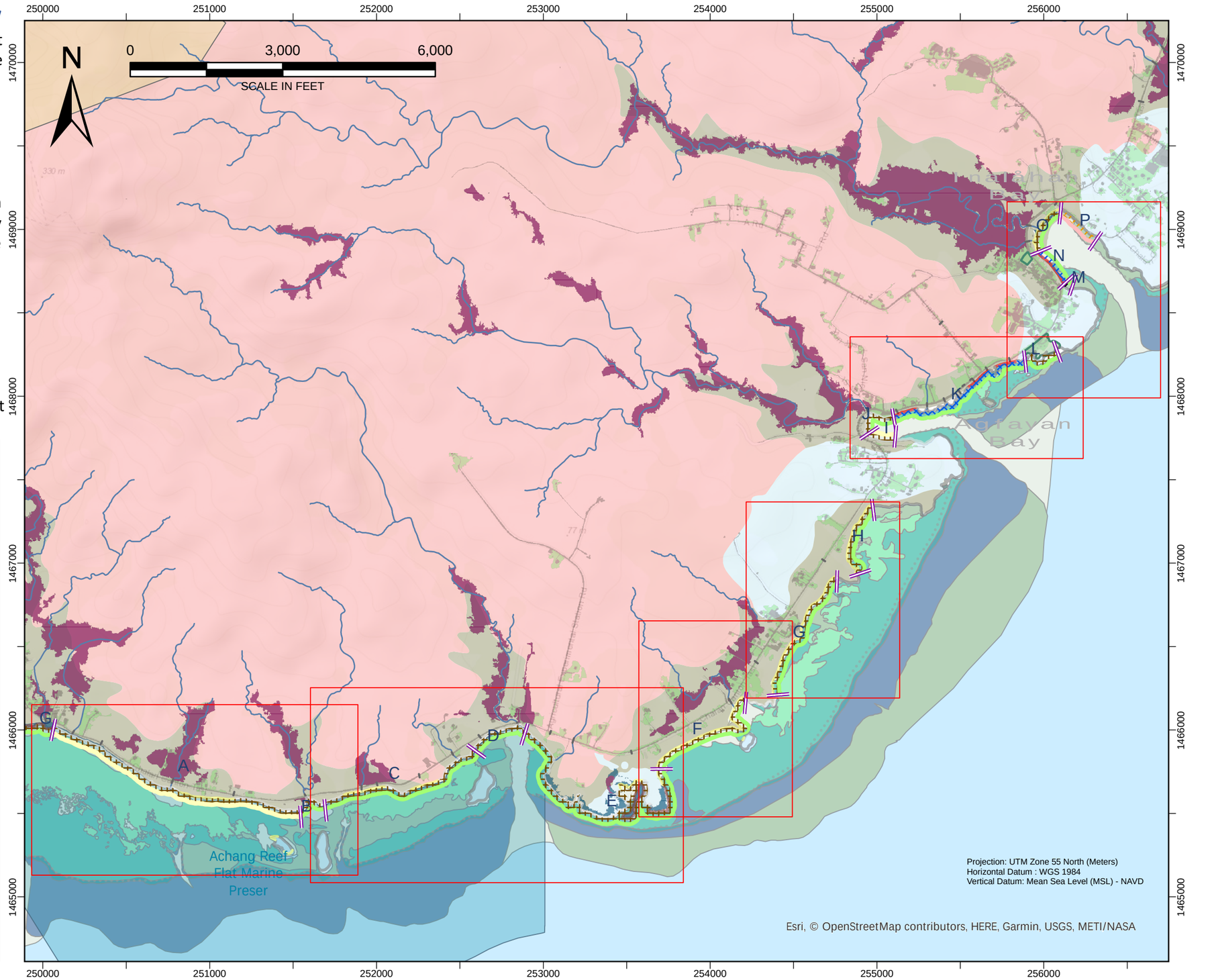
SHORELINE DESCRIPTION MANELL & INALÅHAN

12.1 Manell to Inalåhan Bay Overview

The Manell to Inalåhan area extends 6 miles along the southeast coast of Guam. Much of the southeast coast is bordered by wide fringing reef flats. Broad reef flats and prominent algal margins extend from Agfayan Point to the Manell Channel. Agrigan Island is a low limestone islet on the reef flat just east of Ajayan Bay.

Twelve rivers and streams drain the backshore area. River channels cut completely through the reef flat at Ajayan, Agfayan and Inalåhan Bays. Partial channels indent the reef flat at Sumay Bay, Asgadao Bay and Malilog Point. The Achang Reef Flat is one of five marine preserves on Guam and extends into the Malesso region also. Beaches have formed at the heads of all the bays in this sector.

Route 4 parallels the shoreline along the entire sector and provides easy access to the coast. Residences and small farms are widely scattered from the Manell Channel to Agfayan Bay. Inalåhan is the only village in the sector. This section of the coast is utilized by fishermen, snorkelers, divers and picnickers.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

Stream

Reef Line

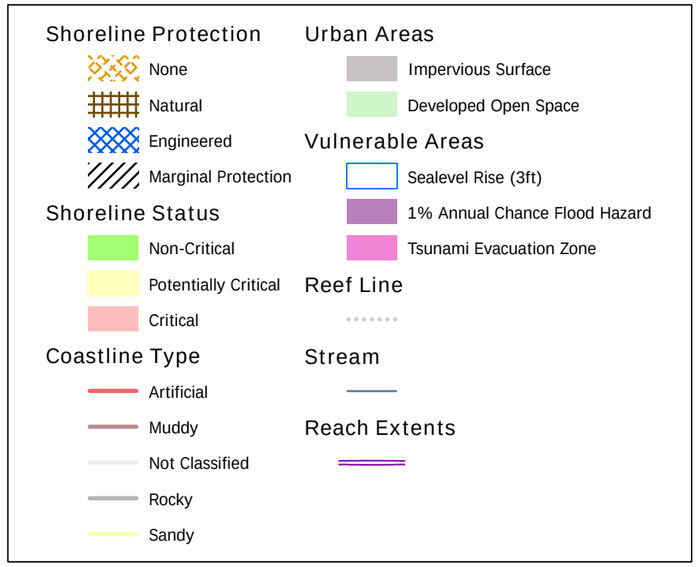
Reach Extents

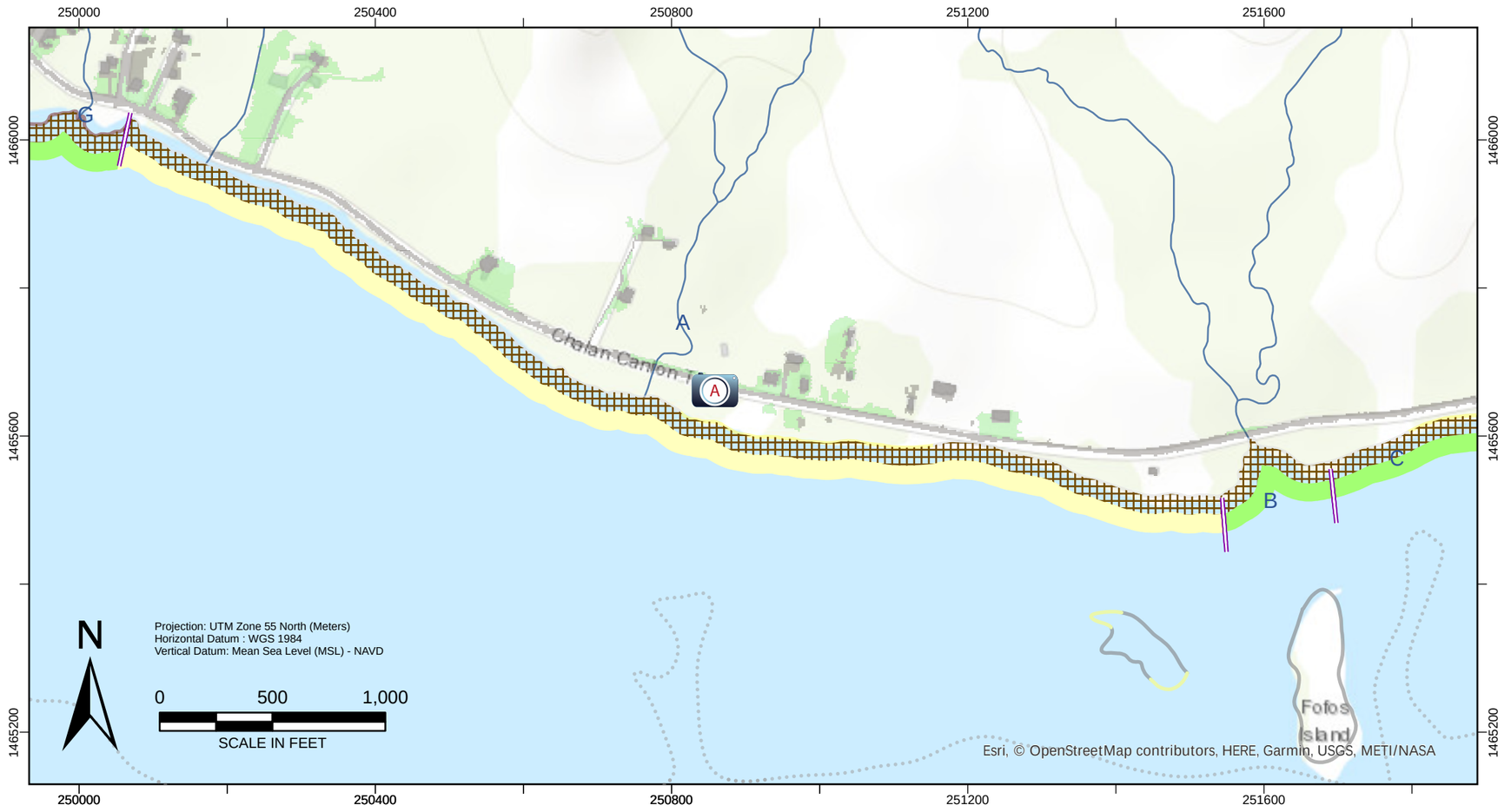
Go To Photo Appendix– Manell, Inalåhan

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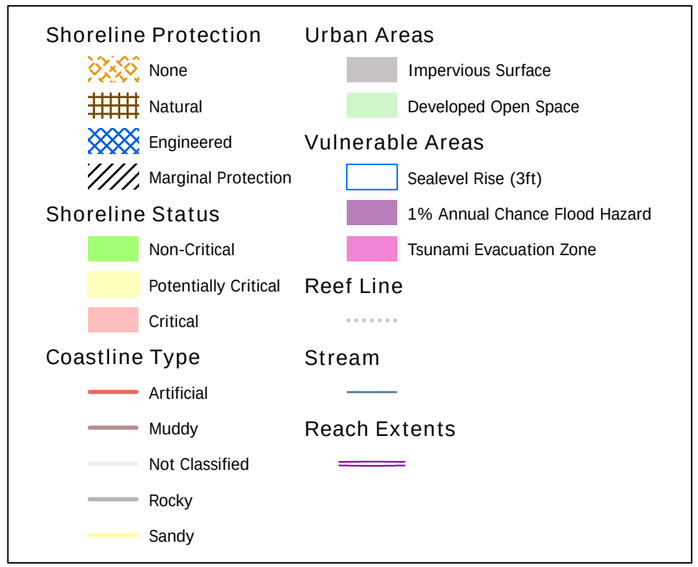
12.2 Manell and Inalåhan Reaches A-B

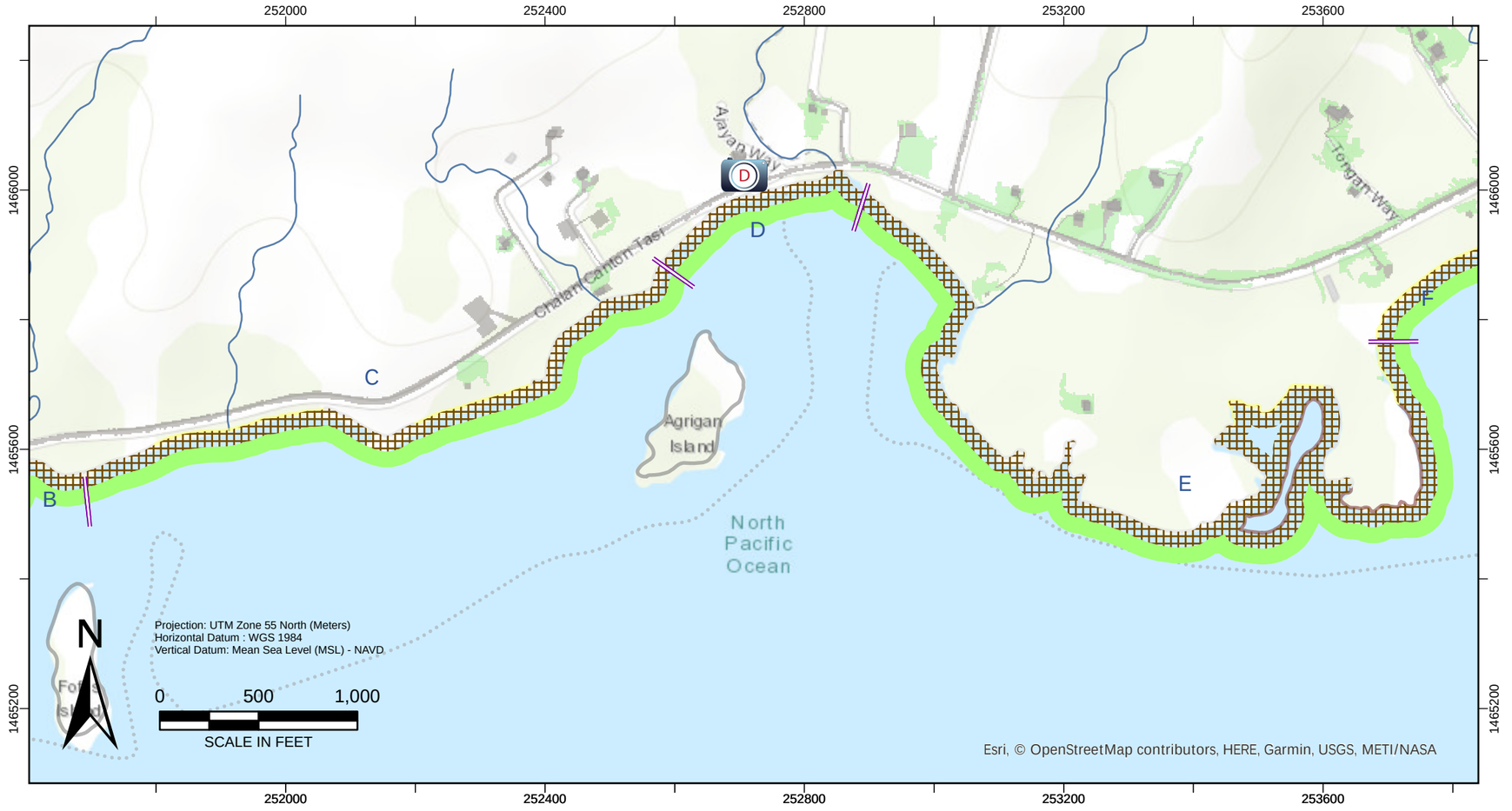




Reach	Reach A: Suyafe River to Liguan Point	Reach B: Liyog River
Beach Width	No Beach	No Beach
Reach Length	5,000 feet	500 feet
Forshore Slope	No Data	No Data
Coastline Type	Not Classified	Rocky
Shoreline Protection	Natural	Natural
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	Mangroves, no sand, narrow shoulder between road and shoreline	Two limestone islets offshore River contributetes sediment
Shoreline Status	Potentially Critical	Non-Critical

12.2 Manell and Inalåhan Reaches C-E





Reach	Reach C: Liyog River to Ajayan Bay	Reach D: Ajayan Bay	Reach E: Aga Bay
Beach Width	No Data	No Data	No Data
Reach Length	3,100 feet	1,200 feet	5,500 feet
Forshore Slope	No Data	No Data	No Data
Coastline Type	Sandy/Not Classified	Not classified	Muddy, Sandy
Shoreline Protection	Natural	Natural	Natural
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	Two streams contribute sediment	At narrowest section shoreline is 20-25ft from roadway Ajayan River contributes sediment	---
Shoreline Status	Non-Critical	Non-Critical	Non-Critical

Go To Photo Appendix– Manell, Inalåhan

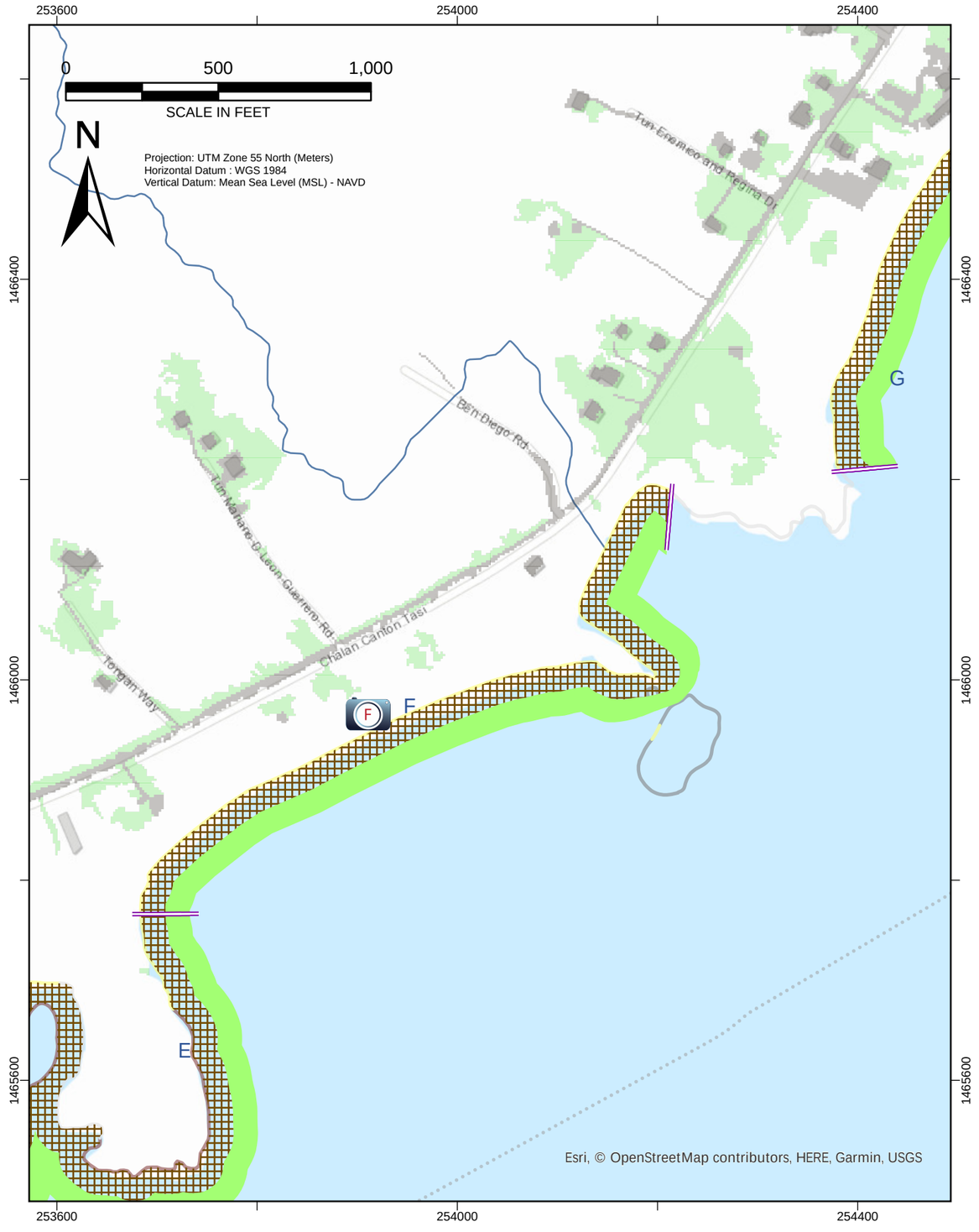
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12.2 Manell and Inalåhan Reaches F

Reach	Reach F: Aga Point to Dongua Point
Beach Width	30-50 feet
Reach Length	2,400 feet
Forshore Slope	No Data
Coastline Type	Sandy
Shoreline Protection	Natural
Backshore	Undeveloped Infrastructure Vegetation
Notes	Large drainage culvert contributes sediment
Shoreline Status	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

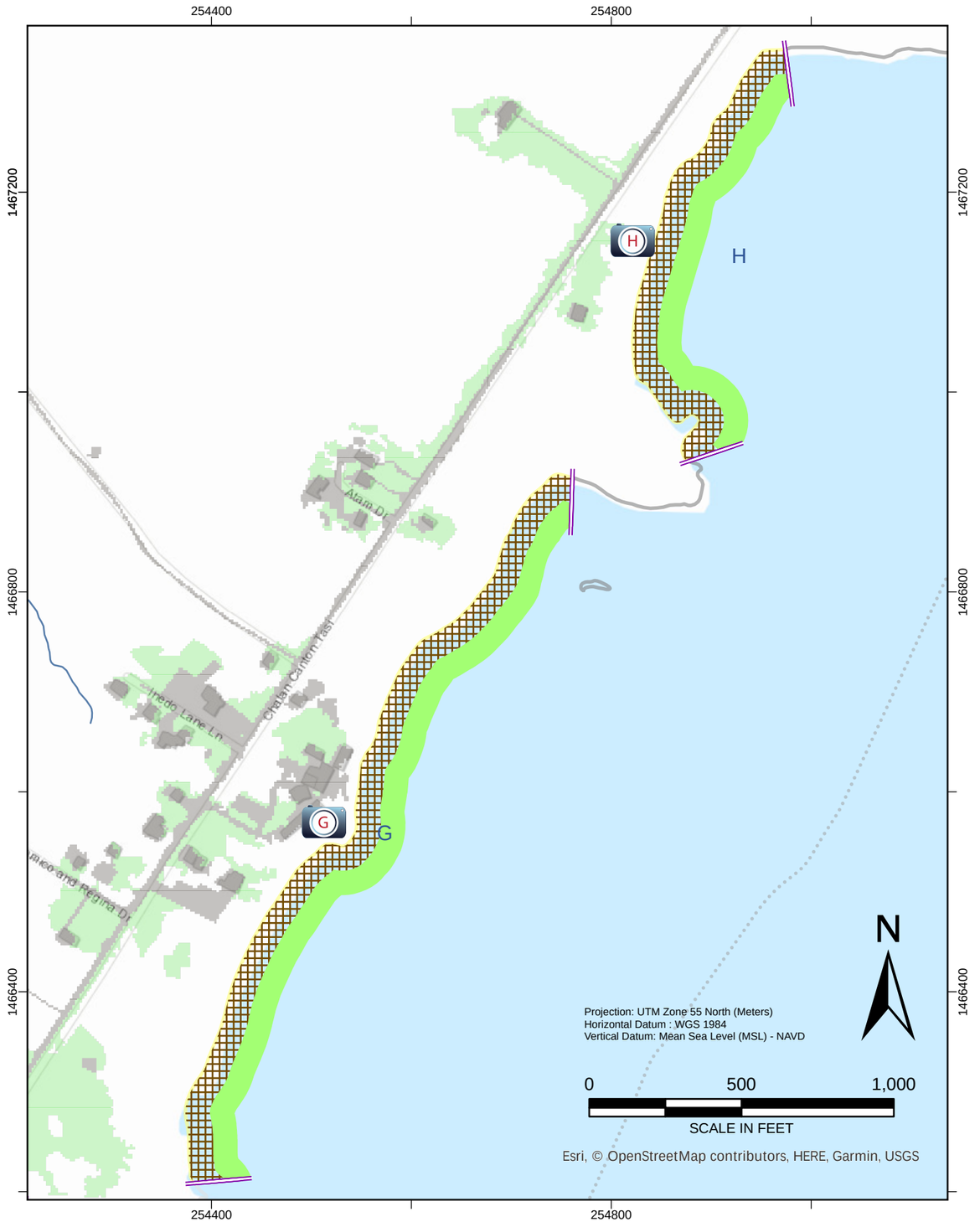
Reef Line

Stream

Reach Extents

12.2 Manell and Inalåhan Reaches G-H

Reach	Reach G: Atao Beach	Reach H
Beach Width	30-50 feet	20-50 feet
Reach Length	3,000 feet	1,500 feet
Forshore Slope	No Data	No Data
Coastline Type	Sandy	Sandy
Shoreline Protection	Natural	Natural
Backshore	Mostly Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	---	---
Shoreline Status	Non-Critical	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

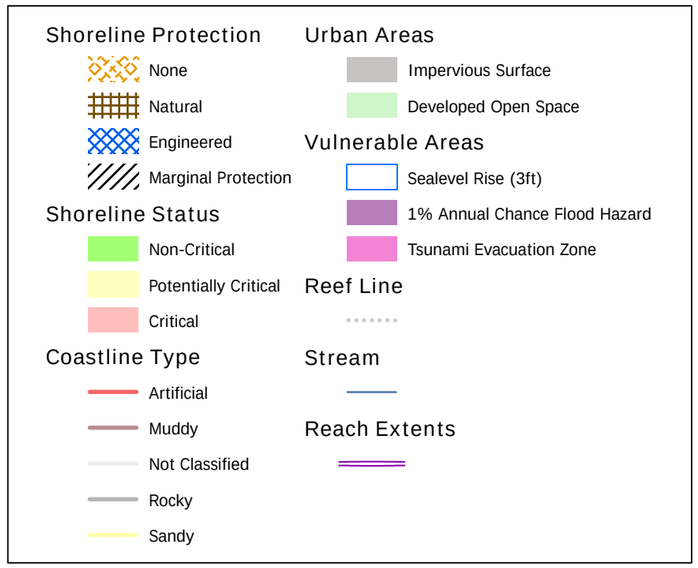
Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

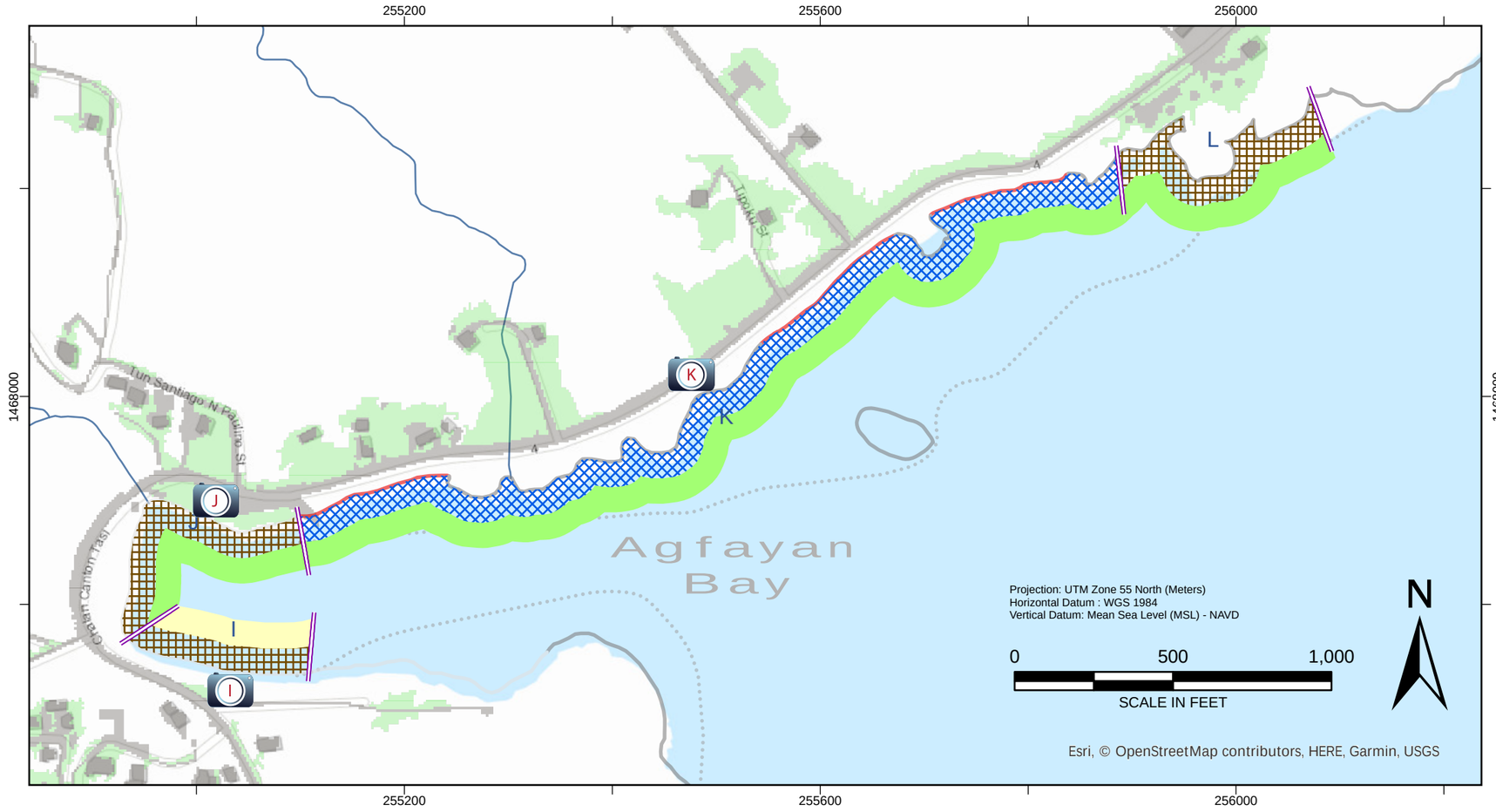
Reef Line

Stream

Reach Extents

12.2 Manell and Inalåhan Reaches I-L

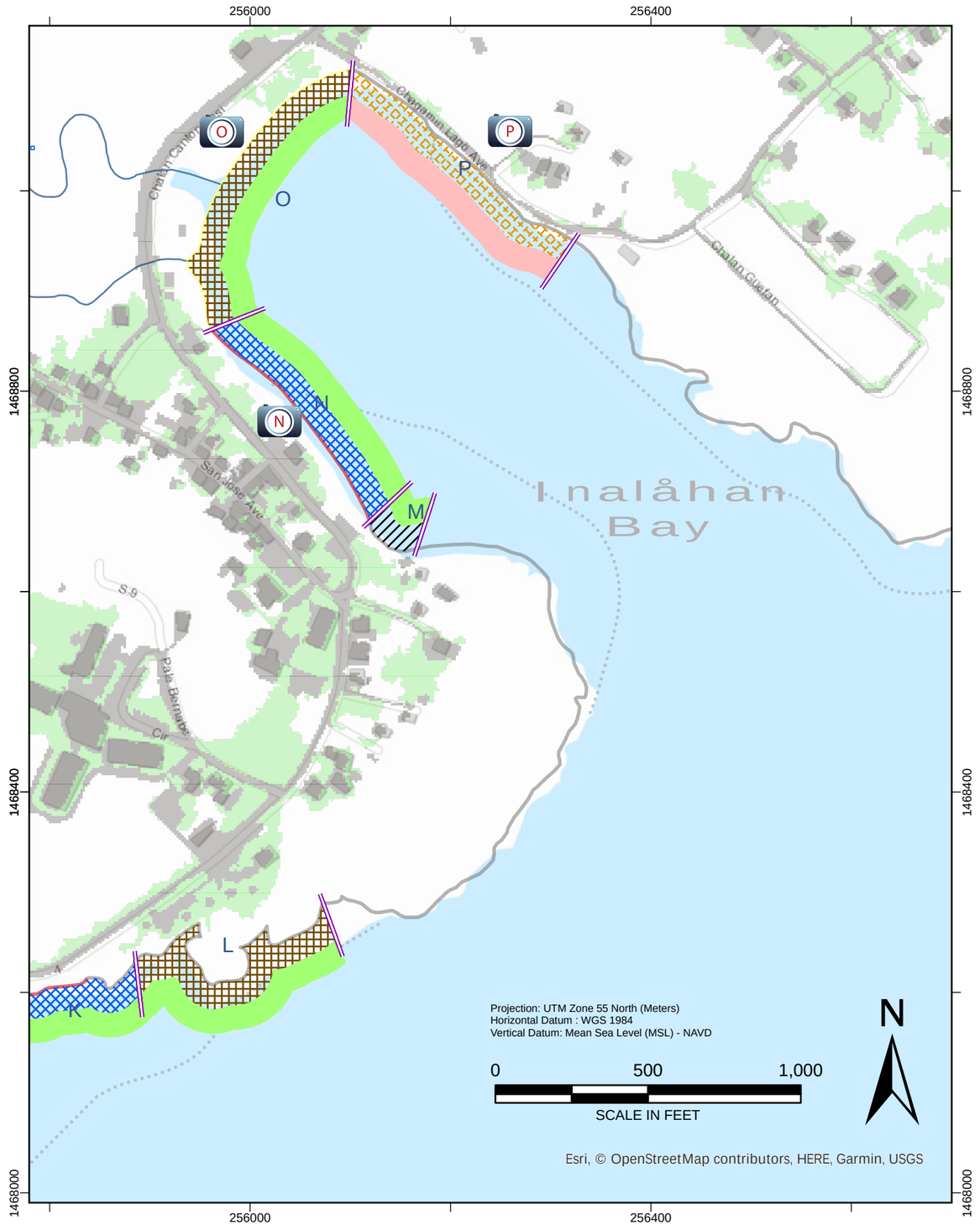




Reach	Reach I: Agfayan Bay	Reach J: Agfayan Bay	Reach K: Agfayan Bay to Inalåhan Pools	Reach L: Inalåhan Pools
Beach Width	< 20 feet	< 20 feet	No Data	No Data
Reach Length	500 feet	900 feet	2,900 feet	550 feet
Forshore Slope	No Data	No Data	No Data	No Data
Coastline Type	Boulders	Sandy	Artificial	Rocky
Shoreline Protection	Natural	Natural	Engineered	Natural
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	Small area of dumped rock where shoreline is about 25 ft from road	Agfayan River discharges Sheetpile retention wall & revetment adjacent to bridge - fair condition	Route 4 protected by a 4ft diameter rock revetment in good condition	Public park Small islets protect park area
Shoreline Status	Potentially Critical	Non-Critical	Non-Critical	Non-Critical

12.2 Manell and Inalåhan Reaches M-P

Reach	Reach M: Inalåhan Bay	Reach N: Inalåhan Bay
Beach Width	No Data	No Beach
Reach Length	150 feet	700 feet
Forshore Slope	No Data	No Data
Coastline Type	Rocky	Artificial
Shoreline Protection	Marginal	Engineered
Backshore	Developed Infrastructure No Vegetation	Developed Infrastructure Vegetation
Notes	Boat launch	Revetment in good condition
Shoreline Status	Non-Critical	Non-Critical
Reach	**Reach O: Inalåhan Bay**	**Reach P: Inalåhan Bay**
Beach Width	20-50 feet	< 20 feet
Reach Length	1,200 feet	750 feet
Forshore Slope	No Data	No Data
Coastline Type	Sandy	Rocky
Shoreline Protection	Natural	None
Backshore	Undeveloped No Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	Backshore flooding Wooden pile dike Two streams contribute sediment	Recent storm eroded bank to critical condition Two photos - 2019 original shoreline survey, 2021 recent site visit
Shoreline Status	Non-Critical	Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

Go To Photo Appendix– Manell, Inalåhan

Roll Over for Pop-up, Click for Full-size Photo

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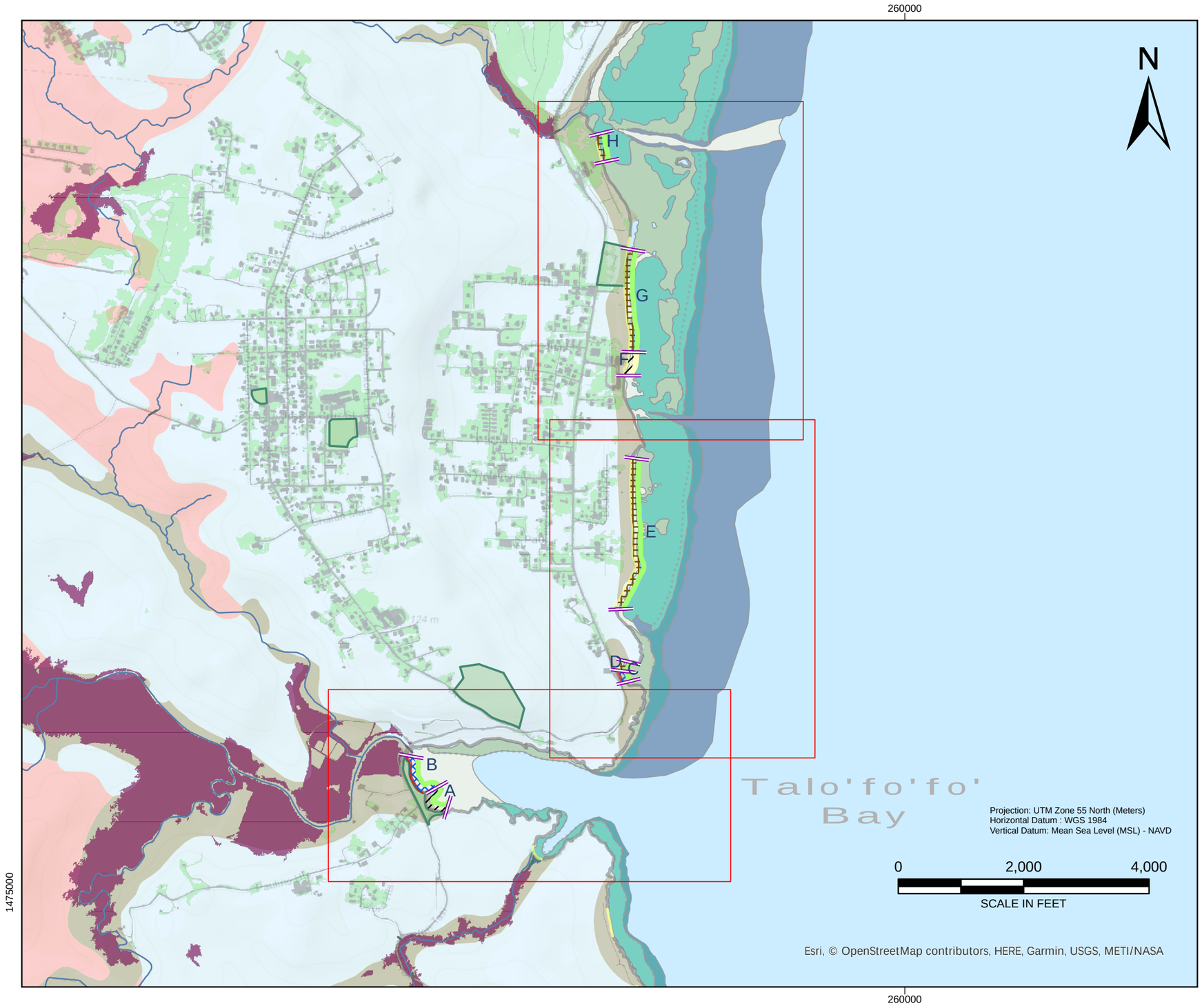
13

SHORELINE DESCRIPTION TALO'FO'FO' BAY & IPAN

13.1 Talo'fo'fo' Bay Overview

This area extends along the east coast of Guam. Prominent rocky headlands are found north and south of Talo'fo'fo' Bay. The fringing reef flat borders most of the shoreline and is composed primarily of reef rock pavement. There is a narrow partial channel cut across the reef flat at Togcha Bay. This channel is a popular snorkeling and diving spot. There are also four small limestone islets on the reef flat. Two rivers have cut through the limestone plateau; the Talo'fo'fo', and Togcha Rivers. The river channel cuts completely through the reef flat at Talo'fo'fo' Bay. A narrow, partial channel is cut through the reef flat at Togcha Bay.

Route 4 parallels the shoreline along this sector. There is little development with only scattered houses. The main village of Talo'fo'fo' is located approximately one mile inland.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

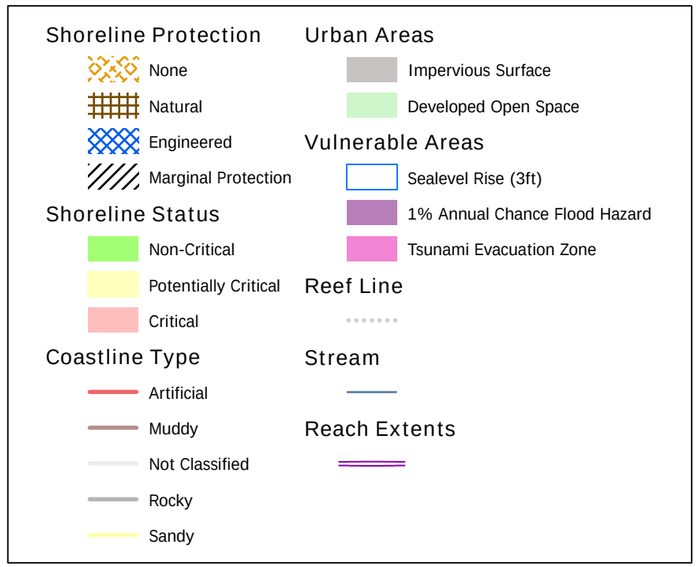
Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

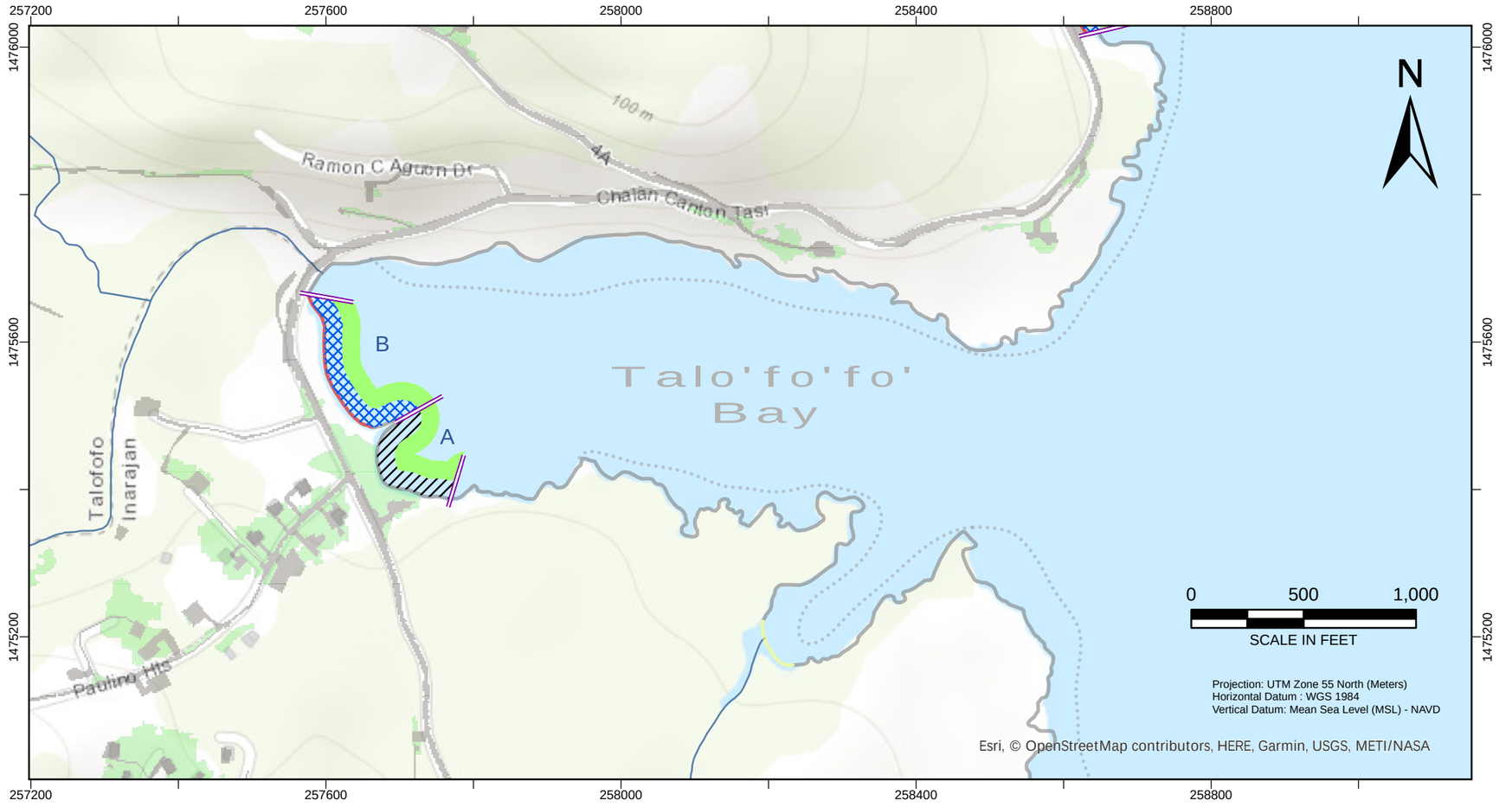
Stream

Reef Line

Reach Extents

13.2 Talo'fo'fo' Bay Reaches A-B

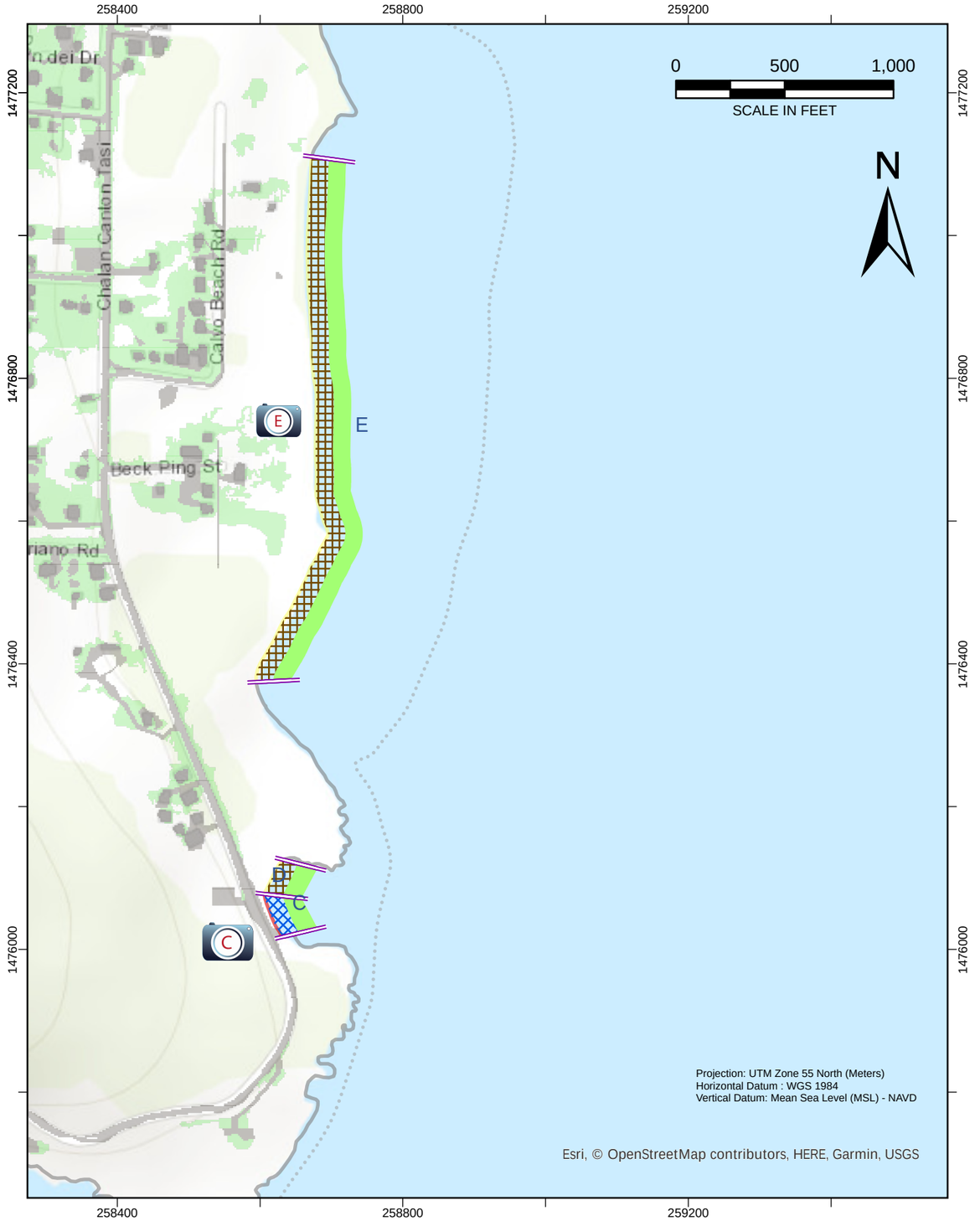




Reach	Reach A: Talo'fo'fo' Bay	Reach B: Talo'fo'fo' Bay
Beach Width	No Data	No Data
Reach Length	450 feet	650 feet
Forshore Slope	No Data	No Data
Coastline Type	Rocky	Artificial
Shoreline Protection	Marginal	Engineered
Backshore	Undeveloped Infrastructure Vegetation	Undeveloped Infrastructure Vegetation
Notes	---	Revetment in good condition
Shoreline Status	Non-Critical	Non-Critical

13.2 Talo'fo'fo' Bay Reaches C-E

Reach	Reach C	Reach D: First Beach	Reach E
Beach Width	No Beach	50+ feet	40-60 feet
Reach Length	200 feet	200 feet	2,700 feet
Forshore Slope	No Data	No Data	1 on 8
Coastline Type	Artificial	Sandy	Sandy
Shoreline Protection	Engineered	Natural	Natural
Backshore	Undeveloped Infrastructure No Vegetation	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	Revetment in good condition, 2-3 ft diameter stone	---	
Shoreline Status	Non-Critical	Non-Critical	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

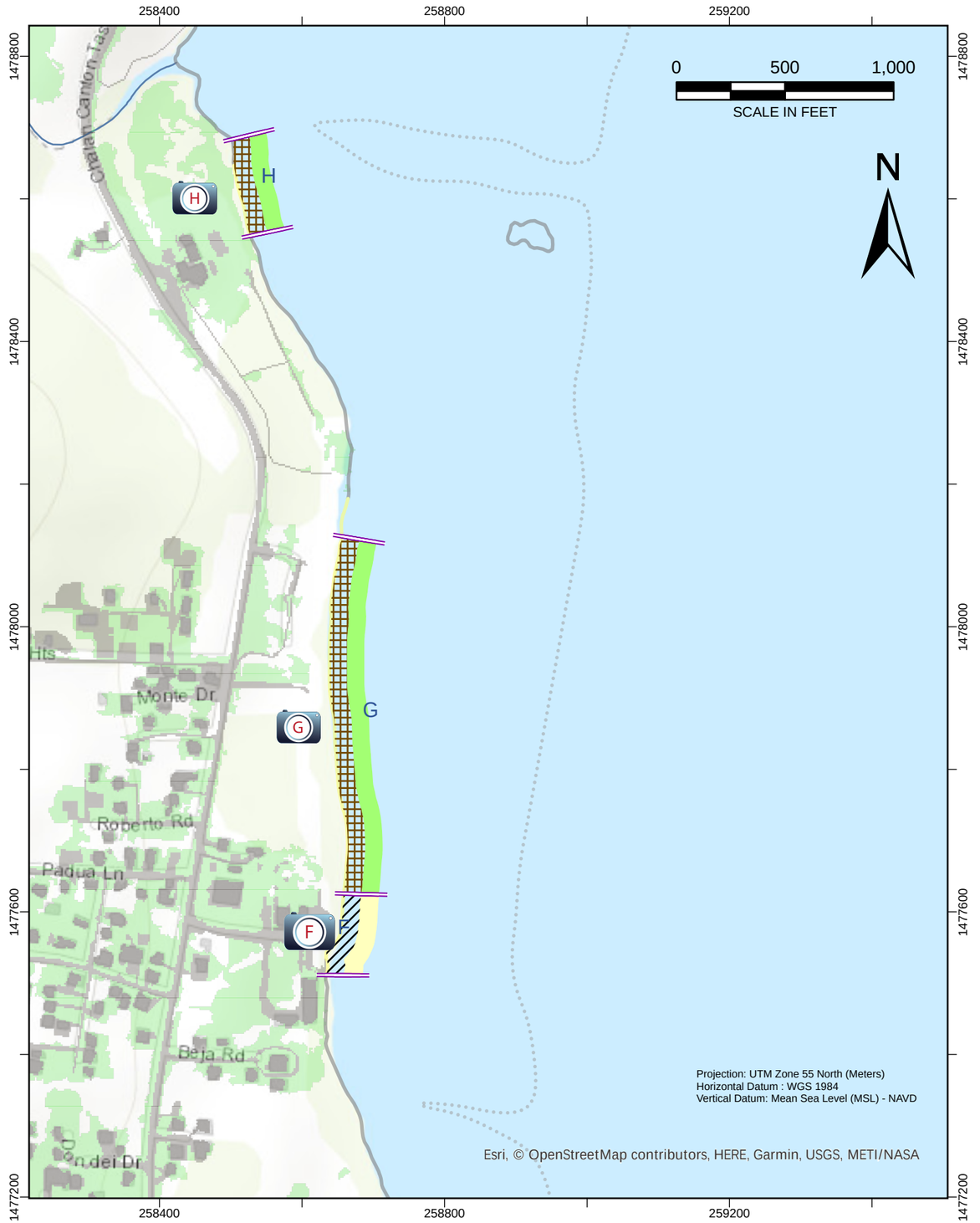
Reef Line

Stream

Reach Extents

13.2 Talo'fo'fo' Bay Reaches F-H

Reach	Reach F: Jones Beach	Reach G: Ypan Beach Park	Reach H: Togcha Bay
Beach Width	20-50 feet	30-40 feet	30-40 feet
Reach Length	450 feet	1,550 feet	400 feet
Forshore Slope	1 on 10	No Data	No Data
Coastline Type	Sandy	Sandy	Sandy
Shoreline Protection	Marginal	Natural	Natural
Backshore	Partially Developed No Infrastructure Partially Vegetated	Undeveloped No Infrastructure Vegetation	Undeveloped No Infrastructure Vegetation
Notes	Abandoned structure with ~10 ft high retaining wall in poor to fair condition	---	WWII bunker Restaurant set well back from shoreline
Shoreline Status	Potentially Critical	Non-Critical	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

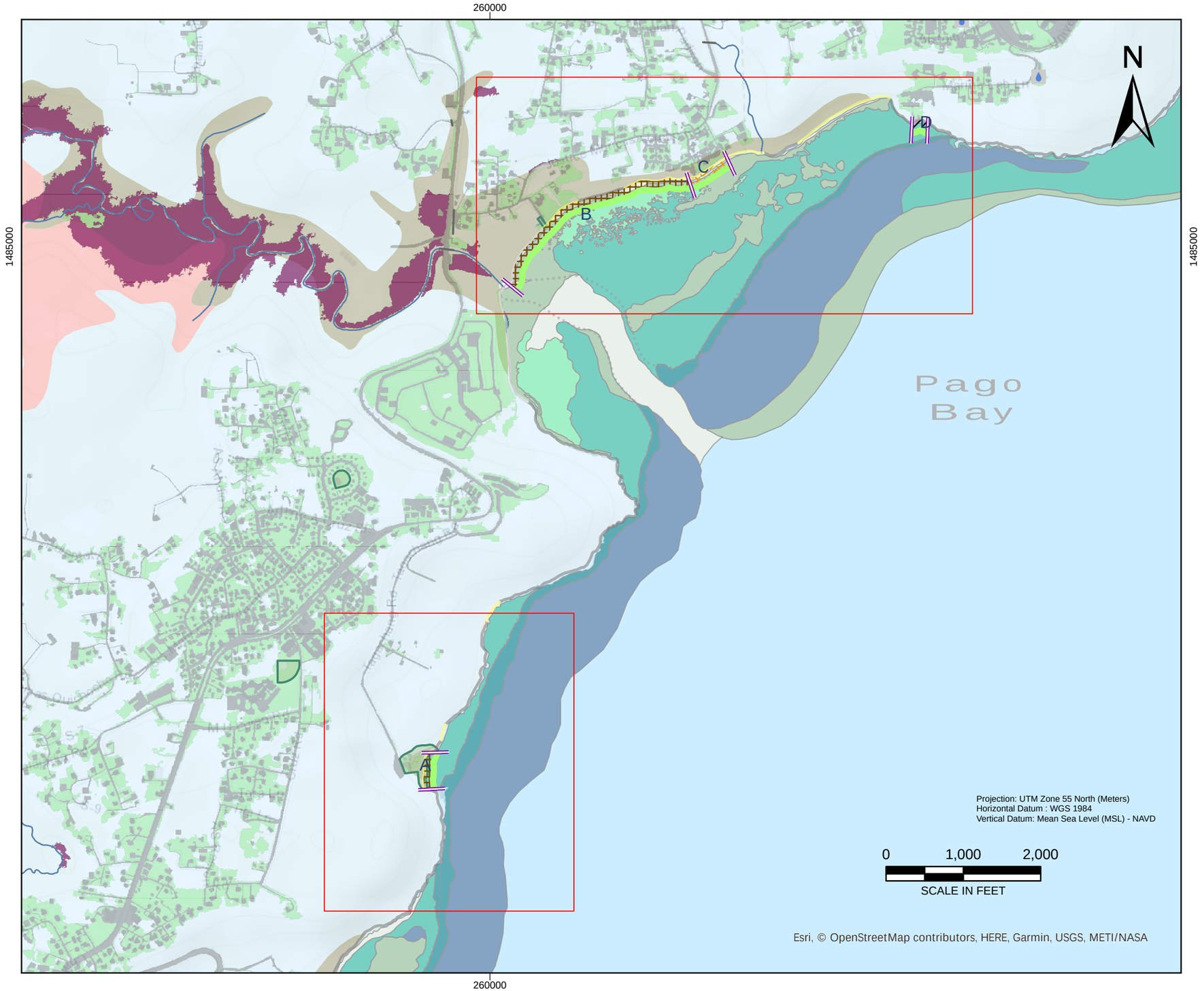
14

SHORELINE DESCRIPTION YONA & PAGO BAY

14.1 Yona and Pago Bay Overview

This area extends along the east coast of Guam. Beach deposits have accumulated at the heads of all the bays along this sector and form a wide coastal terrace from Ylig to Asanite Points.

Prominent rocky headlands are found near Ylig Bay and north of Pago Bay. The fringing reef flat borders most of the shoreline and is composed primarily of reef rock pavement. Two rivers are found in this region; the Ylig and Pago Rivers. River channels cut completely through the reef flat at Ylig Bay and Pago Bay.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

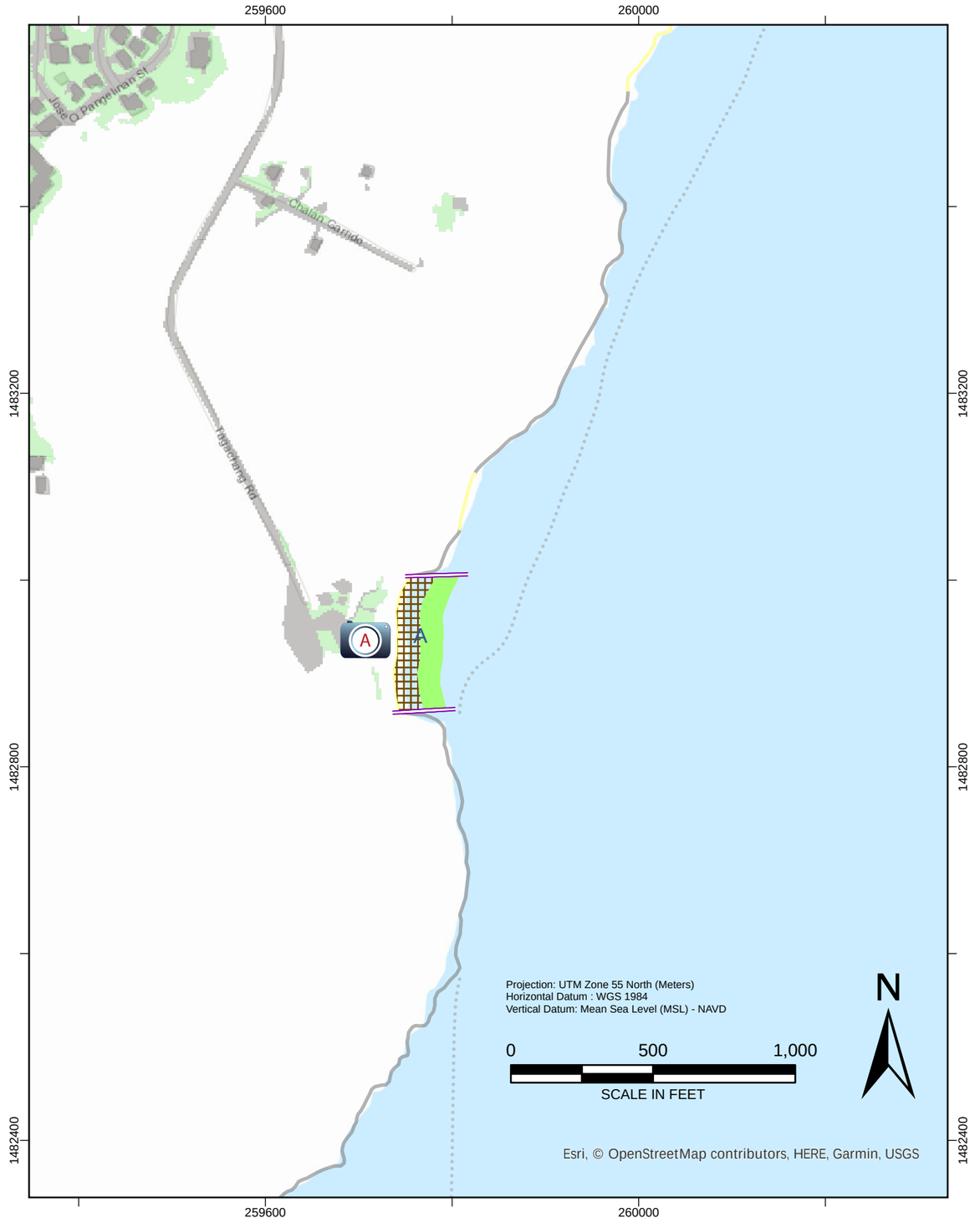
Stream

Reef Line

Reach Extents

14.2 Yona and Pago Bay Reaches A

Reach	Reach A: Tagachan Beach Park
Beach Width	90+ feet
Reach Length	500 feet
Forshore Slope	No Data
Coastline Type	Sandy
Shoreline Protection	Natural
Backshore	Undeveloped No Infrastructure Vegetation
Notes	---
Shoreline Status	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

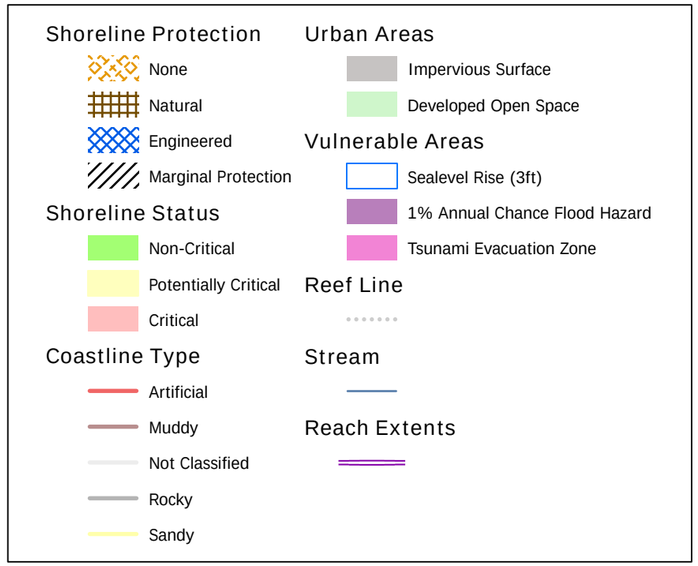
Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

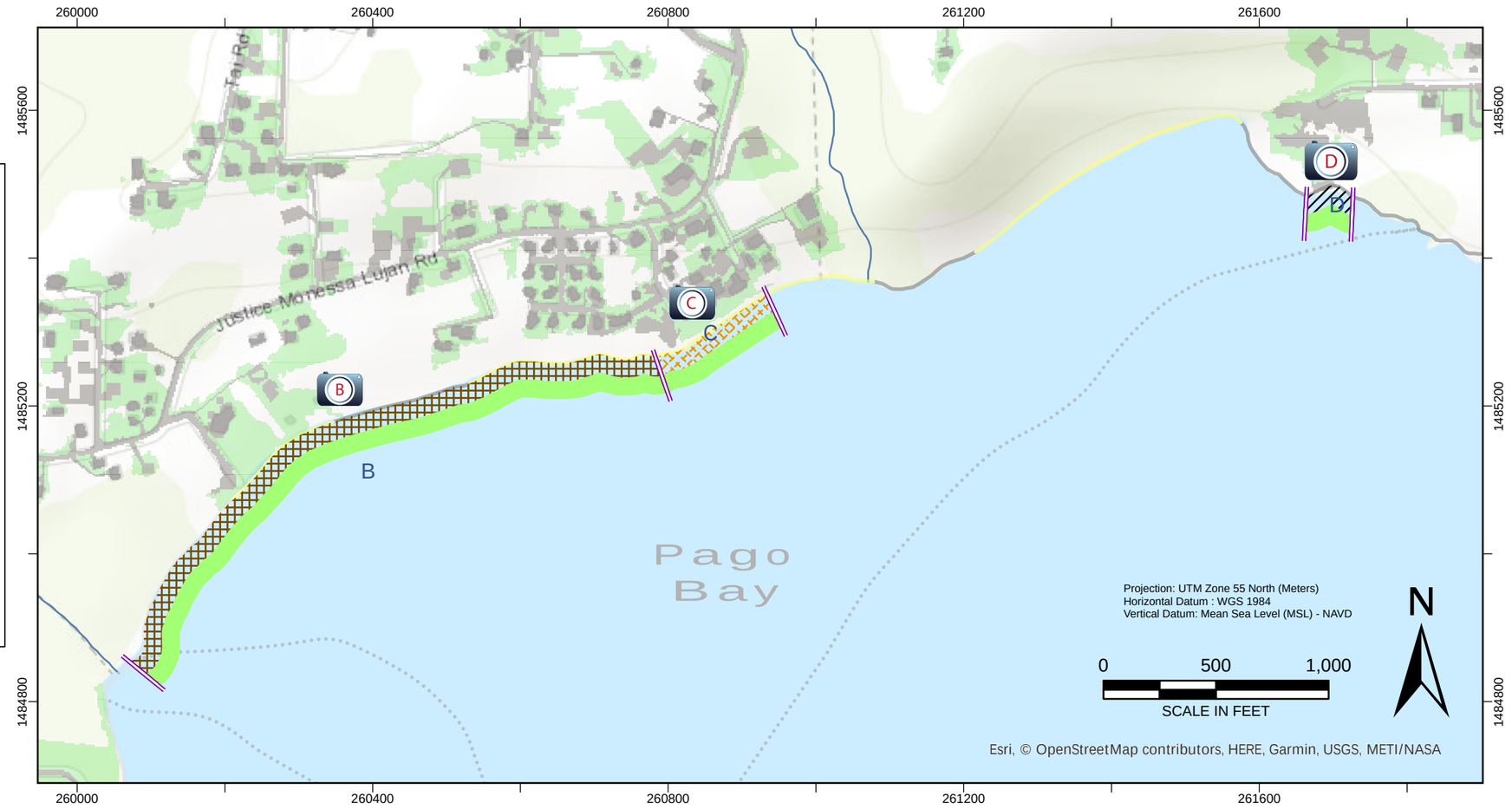
Reef Line

Stream

Reach Extents

14.2 Yona and Pago Bay Reach B-D





Reach	Reach B: Pago Bay	Reach C: Pago Bay	Reach D: UoG Marine Lab
Beach Width	< 20 feet	< 20 feet	30 feet
Reach Length	2,800 feet	500 feet	120 feet
Forshore Slope	1 on 9	No Data	No Data
Coastline Type	Sandy	Sandy	Rocky
Shoreline Protection	Natural	None	Marginal
Backshore	Partially developed No Infrastructure Vegetation	Developed No Infrastructure Vegetation	Developed No Infrastructure Vegetation
Notes	River contributes sediment Homes at center of reach are set well back from shoreline	---	University of Guam Marine Lab set well back
Shoreline Status	Non-Critical	Non-Critical	Non-Critical

Go To Photo Appendix– Pago Bay

Roll Over for Pop-up, Click for Full-size Photo

Click to Open Layers Panel

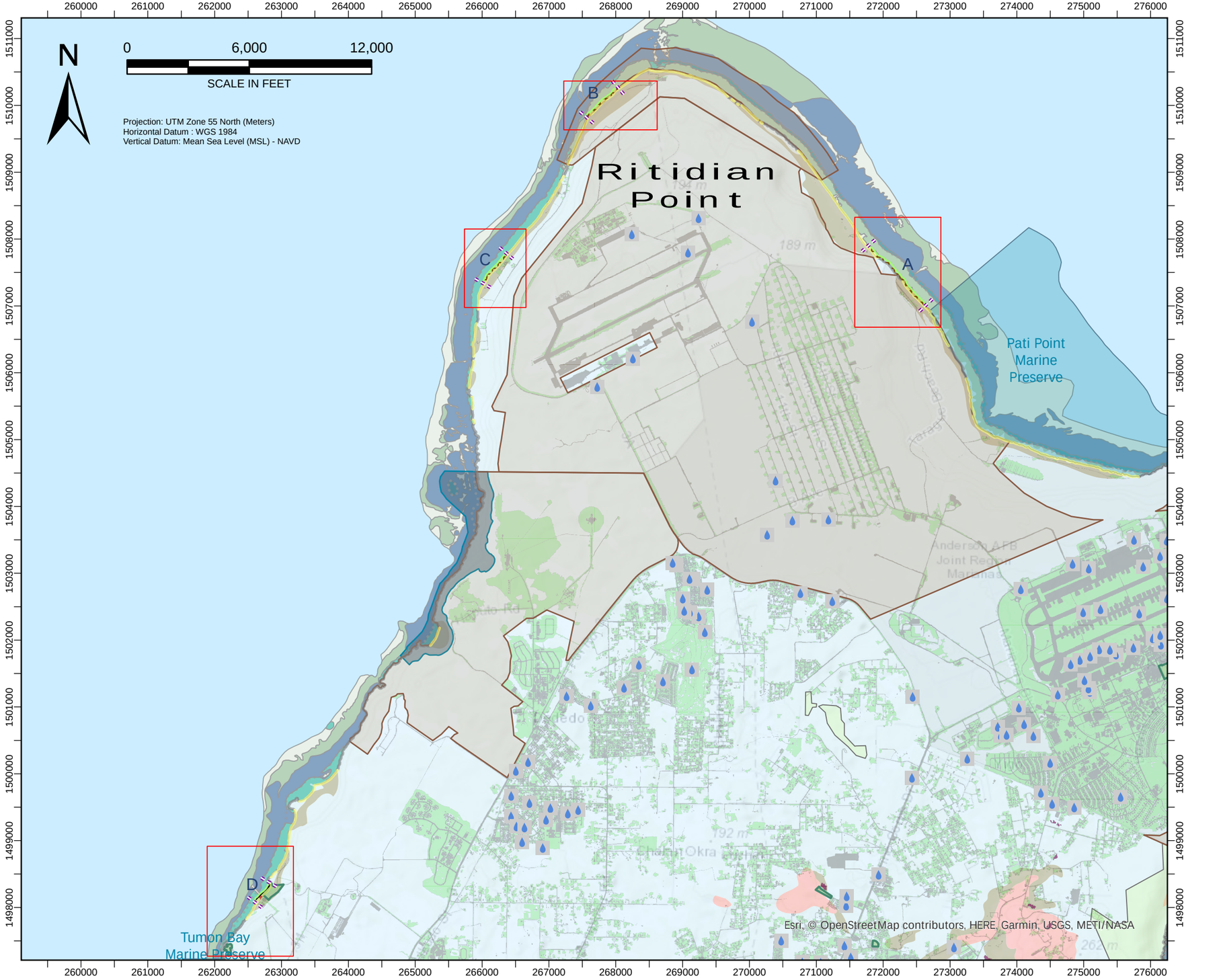
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SHORELINE DESCRIPTION ANDERSEN, RITIDIAN, HARMON

15.1 Andersen, Ritidian, Harmon Overview

Anderson and Ritidian point are located in the northern most section of Guam. The beaches have little development and are heavily vegetated. There is a fringing reef around the area. Pati Point Marine Preserve, on the eastern side, is one of five marine preserves on Guam. The beach material is primarily calcareous sand, with some limestone boulders. No rivers are present in this region. The Andersen Air Force Base and the Guam National Wildlife Refuge are located within this section.

Harmon is located on the western shore of Guam. The beach is fairly narrow with a heavily vegetated backshore. There is little development in the area other than a power plant. The fringing reef continues around this area. A channel cuts through the reef just in front of the power plant. There is a nearby beach trail road which parallels the shoreline.



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Wetlands
- Coastal Wetland (mostly Mangrove)
- Other Wetland

Geology
- Limestone Terrain
- Other
- Volcanic Terrain

Benthic Structure
- Unconsolidated Sediment
- Coral Reef and Hardbottom

Benthic Habitat
- Coral
- Coralline Algae
- Macroalgae
- Seagrass
- Turf
- Uncolonized

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Protected Areas
- Marine Protected Areas
- Public Parks
- Seashore Reserve (Draft)
- National Wildlife Refuge
- Ecological Reserve Area
- Conservation Area

Stormwater Infrastructure
- Ponding Basin
- Bridge or Culvert

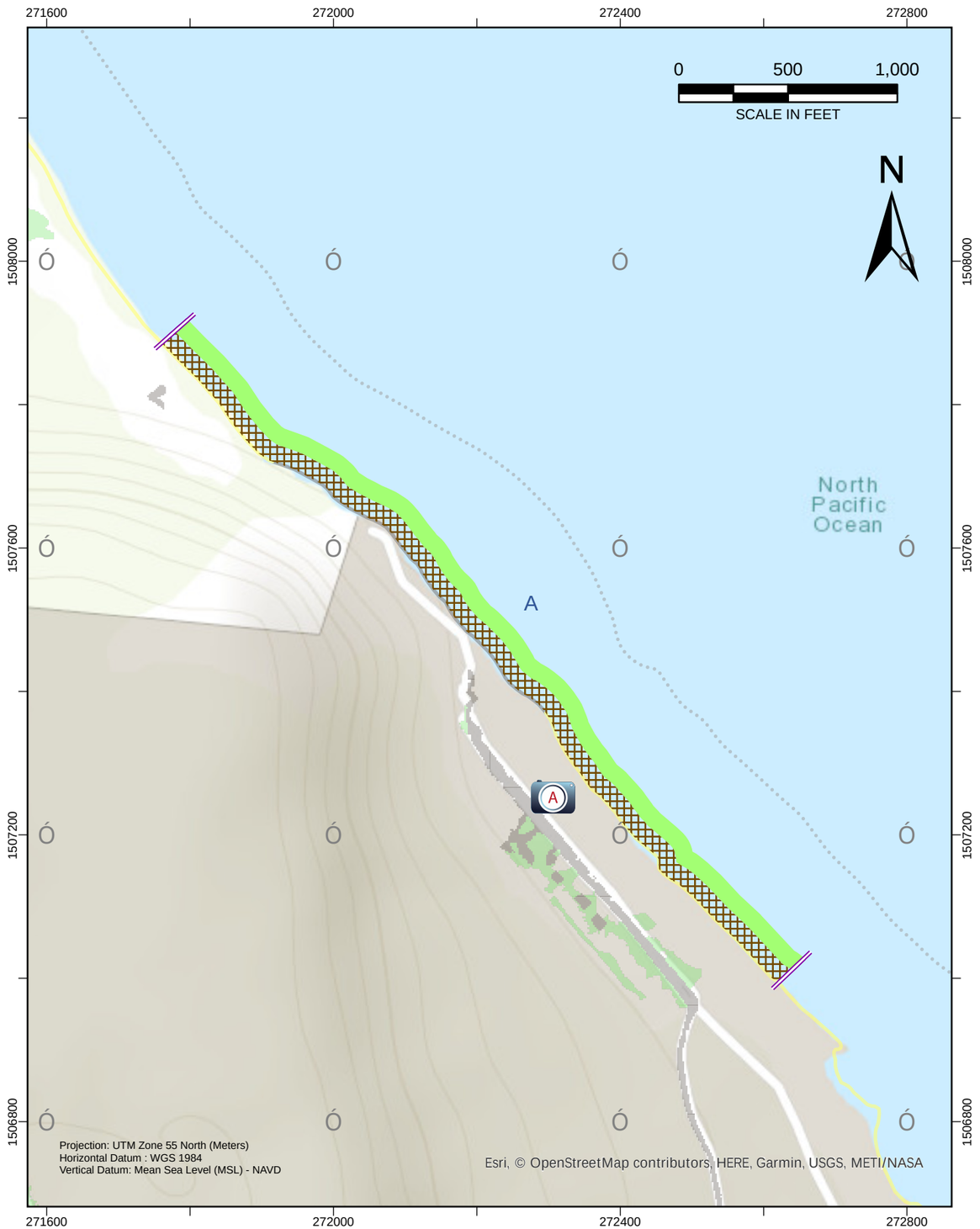
Stream

Reef Line

Reach Extents

15.2 East Andersen Reach A

Reach	Reach A: East Andersen
Beach Width	50+ feet
Reach Length	4,200 feet
Forshore Slope	No Data
Coastline Type	Sandy, Rocky
Shoreline Protection	Natural
Backshore	Undeveloped No Infrastructure Vegetation
Notes	Tarague Beach Park Mix of sand and beach rock
Shoreline Status	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

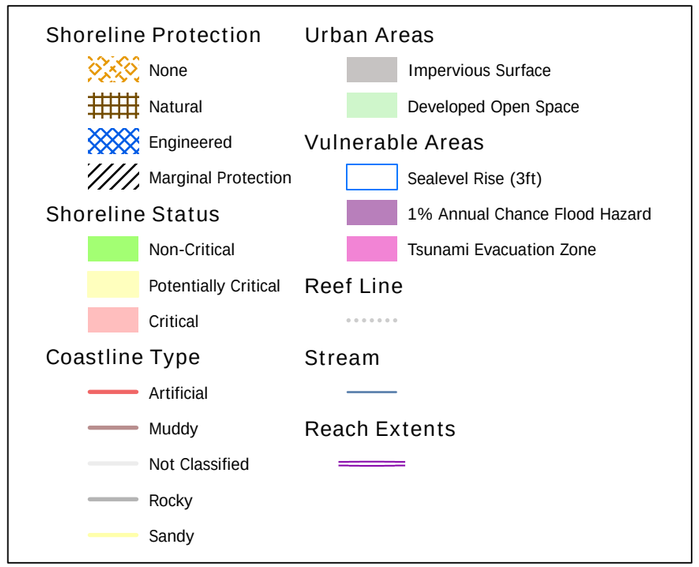
Go To Photo Appendix– Andersen, Ritidian

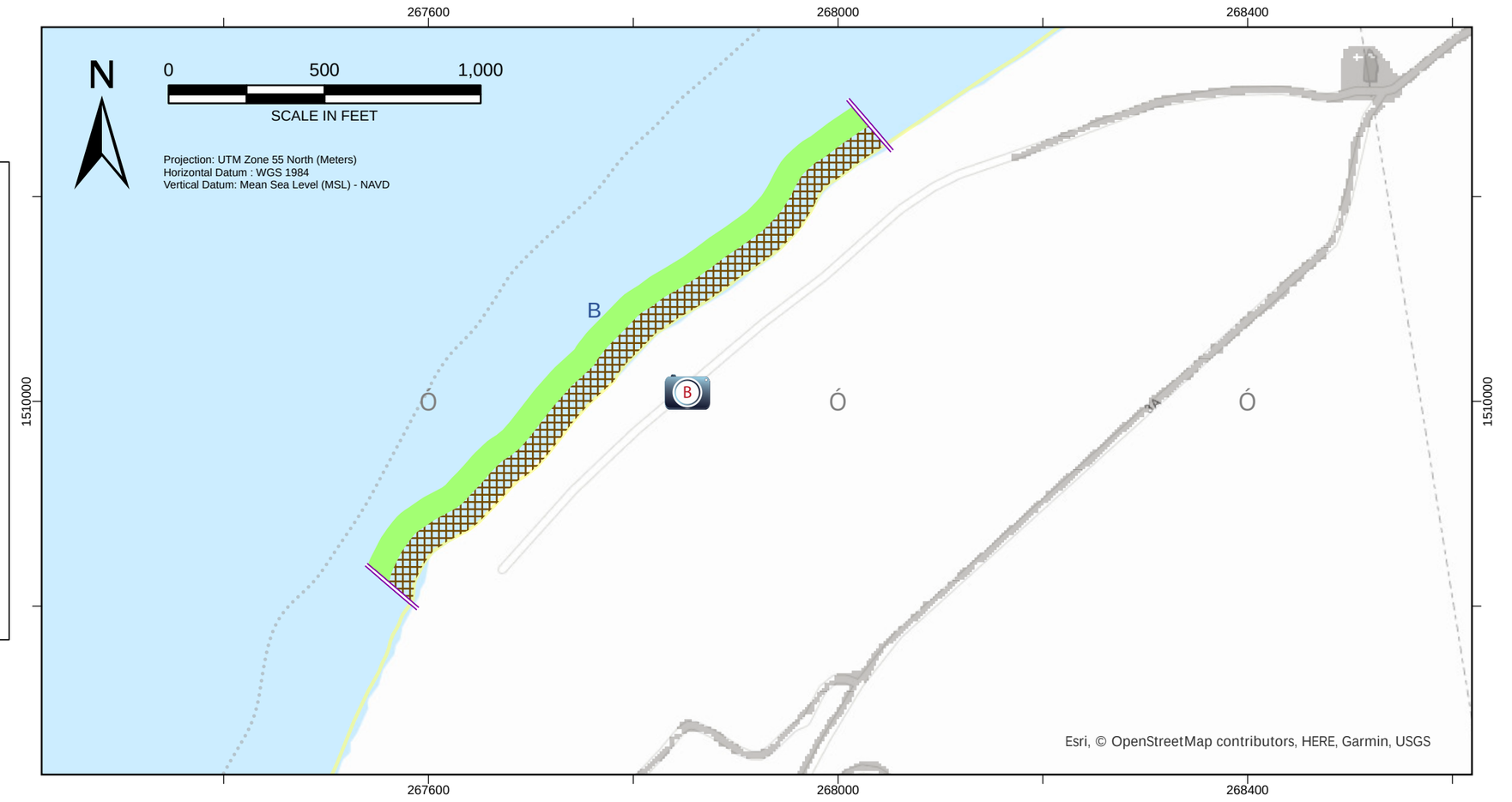
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Click to Open Layers Panel

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15.3 Ritidian Point Reach B

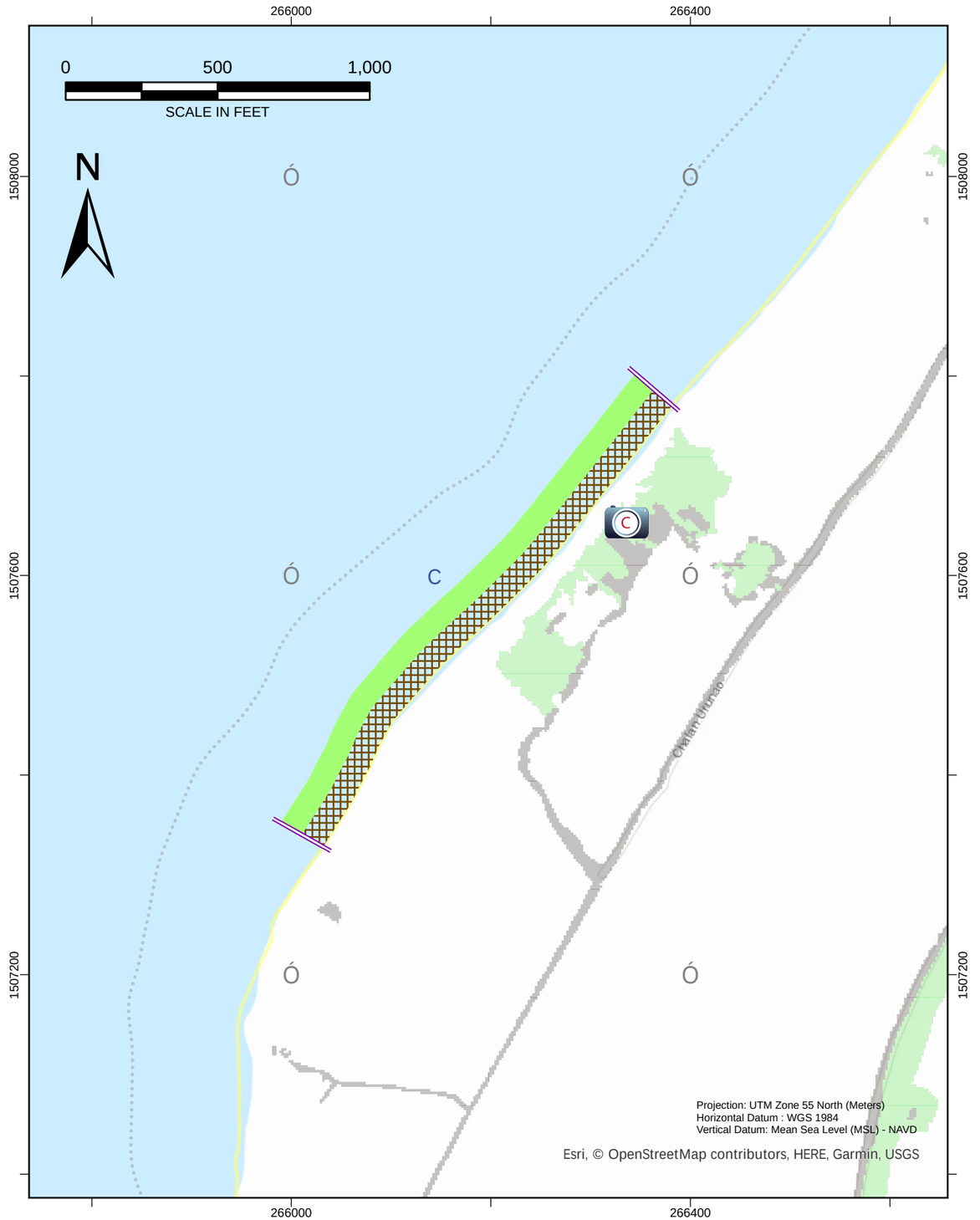




Reach	Reach B: Ritidian Point
Beach Width	50+ feet
Reach Length	No Data
Forshore Slope	No Data
Coastline Type	Sandy
Shoreline Protection	Natural
Backshore	Undeveloped No Infrastructure Vegetation
Notes	Area closed at time of survey due to harzardous surf; photos included taken March 2018
Shoreline Status	Non-Critical

15.4 West Andersen Reach C

Reach	Reach C: West Andersen
Beach Width	50+ feet
Reach Length	No Data
Forshore Slope	No Data
Coastline Type	Sandy
Shoreline Protection	Natural
Backshore	Developed No Infrastructure Vegetation
Notes	Restaurant and recreation area
Shoreline Status	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

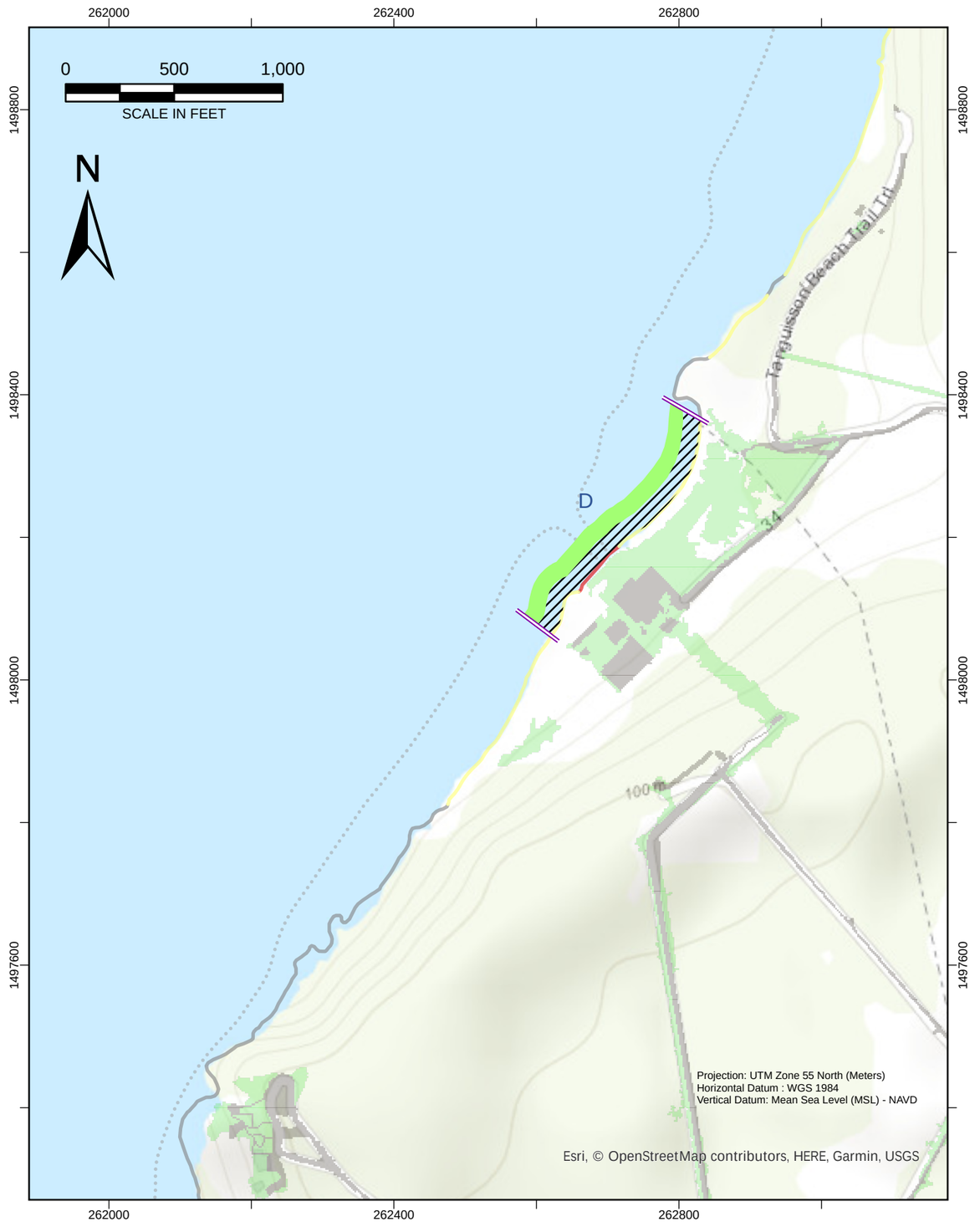
Reef Line

Stream

Reach Extents

15.5 Tanguisson Reach D

Reach	Reach D: Tanguisson
Beach Width	30 feet
Reach Length	1,200 feet
Forshore Slope	No Data
Coastline Type	Sandy, Artificial
Shoreline Protection	Marginal
Backshore	Partially Developed Infrastructure Vegetation
Notes	Tanguisson Power Plant
Shoreline Status	Non-Critical



Shoreline Protection
- None
- Natural
- Engineered
- Marginal Protection

Shoreline Status
- Non-Critical
- Potentially Critical
- Critical

Coastline Type
- Artificial
- Muddy
- Not Classified
- Rocky
- Sandy

Urban Areas
- Impervious Surface
- Developed Open Space

Vulnerable Areas
- Sealevel Rise (3ft)
- 1% Annual Chance Flood Hazard
- Tsunami Evacuation Zone

Reef Line

Stream

Reach Extents

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Appendix 1: Reach Photos

Appendix 1: Tumon Bay Photos

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Appendix 1: Tumon Bay Photos

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Appendix 1: Tumon Bay Photos

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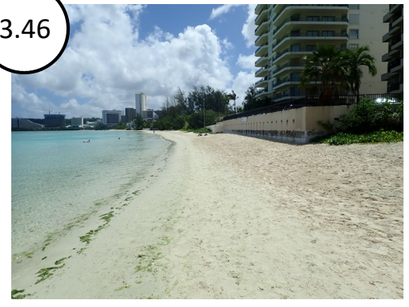
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Appendix 1: Tumon Bay Photos

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Appendix 1: Hagåtña Bay Photos

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Appendix 1: Hagåtña Bay Photos

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Appendix 1: Hagåtña Bay Photos

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Appendix 1: Hagåtña Bay Photos

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Appendix 1: Asan Bay Photos

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Appendix 1: Asan Bay Photos

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Appendix 1: Piti Bay Photos

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Appendix 1: Piti Bay Photos

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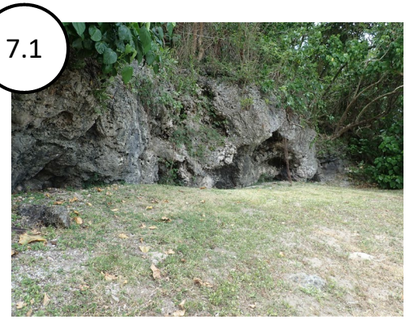


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Appendix 1: Orote Peninsula Photos

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Appendix 1: Hågat Bay, Apaca, Bangi Photos

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Appendix 1: Hågat Bay, Apaca, Bangi Photos

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Appendix 1: Nimitz Beach Photos

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Appendix 1: Nimitz Beach Photos

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Appendix 1: Humåtak Bay Photos

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Appendix 1: Humåtak Bay Photos

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Appendix 1: Malesso Photos

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Appendix 1: Manell and Inalåhan Photos

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Appendix 1: Manell and Inalåhan Photos

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Appendix 1: Manell and Inalåhan Photos

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Appendix 1: Manell and Inalåhan Photos

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Appendix 1: Talo'fo'fo' Bay and Ipan Photos

13.1



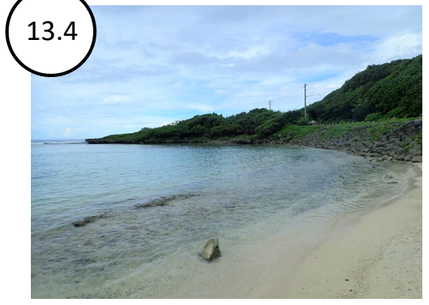
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Appendix 1: Talo'fo'fo' Bay and Ipan Photos

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Appendix 1: Yona and Pago Bay Photos

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Appendix 1: Yona and Pago Bay Photos

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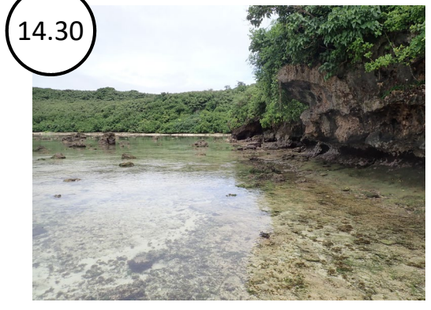
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Appendix 1: Andersen and Ritidian Photos

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Appendix 1: Andersen and Ritidian Photos

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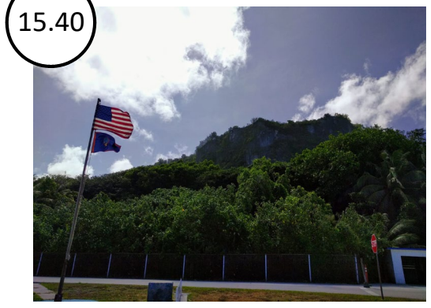
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Appendix 1: Andersen and Ritidian Photos

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Appendix 1: Andersen and Ritidian Photos

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