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HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30067

May 1, 2024

TO: JAMES KUNANE TOKIOKA, DIRECTOR
DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT
AND TOURISM

THROUGH: MARY ALICE EVANS, DIRECTOR
ENVIRONMENTAL REVIEW PROGRAM
OFFICE OF PLANNING AND SUSTAINABLE DEVELOPMENT

FROM: EDWIN H. SNIFFEN
DIRECTOR OF TRANSPORTATION

SUBJECT: DRAFT ENVIRONMENTAL ASSESSMENT AND ANTICIPATED FINDING OF NO SIGNIFICANT IMPACT FOR KAMEHAMEHA HIGHWAY SHORELINE EROSION MITIGATION IN KUALOA, KAAAWA, PUNALUU, AND HAUULA
FEDERAL-AID PROJECT NO. NH-081-1(084)
KUALOA 1 AND 2, KAAAWA, MAKAUA 1 AND 2, KAHANA, WAIONO, PUHEEMIKI, KAPANO, HALEAHA, KALUANUI, KAPUKA, AND MAKAO AHUPUAA, KOOLAUPOKO MOKU, OAHU ISLAND

The Hawaii Department of Transportation has reviewed the enclosed Draft Environmental Assessment and anticipates a Finding of No Significant Impact determination for the proposed Kamehameha Highway Shoreline Erosion Mitigation in Kualoa, Kaaawa, Punaluu, and Hauula project on the island of Oahu for publication in the next available edition of the Environmental Notice.

Should you have any questions, please contact Ms. Mung Fa Chung, Engineering Program Manager at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

Enclosure

From: webmaster@hawaii.gov
To: DBEDT OPSD Environmental Review Program
Subject: New online submission for The Environmental Notice
Date: Wednesday, May 1, 2024 4:23:28 PM

Action Name

Kamehameha Highway Shoreline Erosion Mitigation in Kualoa, Ka‘a‘awa, Punalu‘u, and Hau‘ula

Type of Document/Determination

Draft environmental assessment and anticipated finding of no significant impact (DEA-AFNSI)

HRS §343-5(a) Trigger(s)

- (1) Propose the use of state or county lands or the use of state or county funds
- (2) Propose any use within any land classified as a conservation district
- (3) Propose any use within a shoreline area

Judicial district

Ko‘olauloa, O‘ahu

Tax Map Key(s) (TMK(s))

(1) 4-9-004:001; (1) 4-9-009:011; (1) 4-9-009:012; (1) 4-9-009:013; (1) 4-9-009:014; (1) 4-9-009:015; (1) 5-1-013:010; (1) 5-1-013:011; (1) 5-1-006:017; (1) 5-1-001:008; (1) 5-1-001:009; (1) 5-1-009:028; (1) 5-1-002:025; (1) 5-1-010:029; (1) 5-1-010:030; (1) 5-1-010:031; (1) 5-1-012:001; (1) 5-1-003:003; (1) 5-1-003:006; (1) 5-1-003:007; (1) 5-1-003:010; (1) 5-1-003:011; (1) 5-1-003:018; (1) 5-1-003:019; (1) 5-1-003:022; (1) 5-1-003:023; (1) 5-1-005:021; (1) 5-3-006:037; (1) 5-3-014:016; (1) 5-3-014:018; (1) 5-3-014:015; (1) 5-3-014:014; (1) 5-3-014:013; (1) 5-3-014:010; (1) 5-3-014:009; (1) 5-3-016:001

Action type

Agency

Other required permits and approvals

National Environmental Policy Act; Department of the Army Permit; National Historic Preservation Act Section 106 Consultation; Endangered Species Act Section 7 Consultation; Magnuson-Stevens Fisheries Conservation and Management Act Essential Fish Habitat Consultation; Coastal Zone Management Act Consistency Review; U.S. Department of Transportation Act Section 4(f) Determination; Hawai'i Revised Statutes Chapter 6E-8 Historic Preservation Review; Conservation District Use Permit; Clean Water Act Section 401 Water Quality Certification; Clean Water Act Section 402 National Pollutant Discharge Elimination System Permit; Hawai'i Revised Statutes 195D Consultation

Proposing/determining agency

State of Hawai'i Department of Transportation

Agency contact name

Mel Chung

Agency contact email (for info about the action)

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Agency address

869 Punchbowl Street
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United States
Map It

Is there a consultant for this action?

Yes

Consultant

AECOM

Consultant contact name

Courtney Hymes

Consultant contact email

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Consultant contact phone

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Consultant address

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Honolulu, Hawai'i 96813
United States
Map It

Action summary

The Kamehameha Highway Shoreline Erosion Mitigation in Kualoa, Kaʻaʻawa, Punaluʻu, and Hauʻula Project would mitigate coastal erosion along nine discrete sections of the highway that the Hawaiʻi Department of Transportation has identified as needing action to maintain the usability of the highway in the near to mid-term, until a long-term plan to deal with the effects of sea level rise can be developed and implemented. The proposed action includes construction of rock revetments or hybrid seawalls with armor stone aprons at nine locations along the makai side of Kamehameha Highway.

Reasons supporting determination

See Chapter 6 of the Draft Environmental Assessment

Attached documents (signed agency letter & EA/EIS)

- RUSH-HWY-L-24-2.30067-KKPH-Draft-EA-part-1-signed.pdf
- KKPH-Shoreline-Mitigation-Draft-EA-May-2024.pdf

Action location map

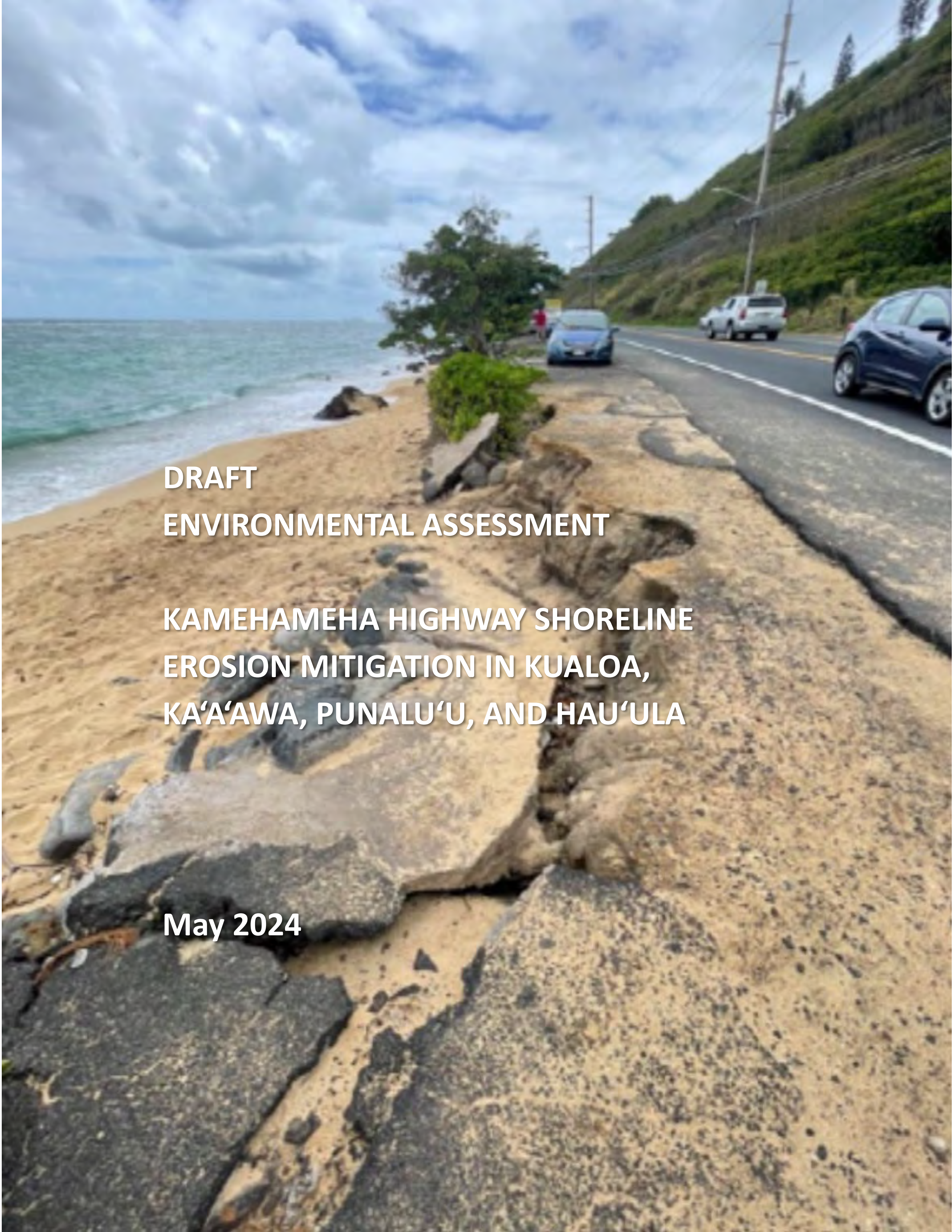
- ProjectAreas.zip

Authorized individual

Courtney Hymes

Authorization

- The above named authorized individual hereby certifies that he/she has the authority to make this submission.



DRAFT

ENVIRONMENTAL ASSESSMENT

KAMEHAMEHA HIGHWAY SHORELINE EROSION MITIGATION IN KUALOA, KAʻAʻAWA, PUNALUʻU, AND HAUʻULA

May 2024

DRAFT
ENVIRONMENTAL ASSESSMENT

KAMEHAMEHA HIGHWAY SHORELINE EROSION MITIGATION IN KUALOA, KAʻAʻAWA, PUNALUʻU, AND HAUʻULA

Prepared for:

State of Hawaiʻi
Department of Transportation
Highways Division
869 Punchbowl Street, Room 405
Honolulu, HI 96813

Prepared by:

AECOM Technical Services, Inc.
1001 Bishop Street, 16th Floor
Honolulu, HI 96813

Project Summary

This Environmental Assessment (EA) has been prepared in accordance with the requirements of Hawai‘i Revised Statutes (HRS) Chapter 343 and Hawai‘i Administrative Rules (HAR) Chapter 11-200.1, which set forth the requirements for the preparation of EAs.

Project Name	Kamehameha Highway Shoreline Erosion Mitigation in Kualoa, Ka‘a‘awa, Punalu‘u, and Hau‘ula (KKPH) Project
Project Location	Nine (9) locations along Kamehameha Highway, in the towns of Hau‘ula, Punalu‘u, Ka‘a‘awa, and near Kualoa Ranch and Kualoa Beach Park
Tax Map Keys	Numerous, refer to Section 3.15, Land Use and Land Ownership
Community Plan	Ko‘olau Loa and Ko‘olau Poko Sustainable Communities Plan
State Land Use District	Agricultural, Conservation, Urban
County Zoning	Country, General Agriculture, General Preservation, Residential, and Restricted Preservation Districts
Special Management Area	Within Special Management Area
Flood Zone	A, AE, VE
Proposed Action	Improvements to stabilize the embankment and mitigate shoreline erosion at nine (9) locations along Kamehameha Highway.
Trigger for an Environmental Document under HRS 343	Use of State lands, Use of State funds, Use of land in the conservation district, Use within a shoreline area
Proposing Agency	State of Hawai‘i Department of Transportation
Agency Determination	Anticipated Finding of No Significant Impact

Table of Contents

Appendices

Figures

Tables

List of Acronyms

µg	Micrograms
%	Percent
BMP	Best Management Practice
BWS	Honolulu Board of Water Supply
CCH	City and County of Honolulu
CDUP	Conservation District Use Permit
CWA	Clean Water Act
CWB	Clean Water Branch, Department of Health, State of Hawaiʻi
CZM	Coastal Zone Management
DA	Department of the Army
DAR	Division of Aquatic Resources, Department of Land and Natural Resources, State of Hawaiʻi
dBA	Decibels A
DLNR	Department of Land and Natural Resources, State of Hawaiʻi
DOFAW	Division of Forestry and Wildlife, Department of Land and Natural Resources, State of Hawaiʻi
DOH	Department of Health, State of Hawaiʻi
DPP	Department of Planning and Permitting, City and County of Honolulu
DPR	Department of Parks and Recreation, City and County of Honolulu
EA	Environmental Assessment
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency, United States Department of Homeland Security
FONSI	Finding of No Significant Impact
HAR	Hawaiʻi Administrative Rules

HDOT	Department of Transportation, State of Hawaiʻi
HEPA	Hawaiʻi Environmental Policy Act
HPD	Honolulu Police Department, City and County of Honolulu
HRS	Hawaiʻi Revised Statues
IPaC	Information for Planning and Consultation
KKPH	Kualoa, Kaʻaʻawa, Punaluʻu, and Hauʻula
LUC	Land Use Commision, State of Hawaiʻi
MSA	Magnuson-Stevens Fisheries Conservation and Management Act
MSL	Mean Sea Level
MUS	Management Unit Species
NHO	Native Hawaiian Organization
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service, National Oceanic and Atmospheric Administration, United States Department of Commerce
NOAA	National Oceanic and Atmospheric Administration, United States Department of Commerce
NPDES	National Pollutant Discharge Elimination System
OCCL	Office of Conservation and Coastal Lands, Department of Land and Natural Resources, State of Hawaiʻi
Pac-SLOPES	Standard Local Operation Procedures for Endangered Species in the Central and Western Pacific Region
ppb	Parts Per Billion by Volume
ppm	Parts Per Million by Volume
ROH	Revised Ordinances of Honolulu
SHPD	State Historic Preservation Division, Department of Land and Natural Resources, State of Hawaiʻi
SHPO	State Historic Preservation Officer
SIHP	State Inventory of Historic Places
TMK	Tax Map Key

U.S.	United States
USFWS	United States Fish and Wildlife Service, United States Department of the Interior
USACE	United States Army Corps of Engineers
USC	United States Code
WQC	Water Quality Certification

1. Introduction

1.1 Introduction

Coastal erosion is progressively eroding and undermining the shoreline embankment that supports Kamehameha Highway (Hawaiʻi State Route 83) at numerous locations on the windward coastline of Oʻahu, which could lead to closure of the road. Closure of Kamehameha Highway would adversely affect local residents that depend on the Highway for access to their homes, work, school, emergency services, and other goods and services, as well as tourists visiting the windward coastline.

The proposed Kamehameha Highway Shoreline Erosion Mitigation in Kualoa, Kaʻaʻawa, Punaluʻu, and Hauʻula (KKPH) Project would mitigate coastal erosion along nine (9) discrete sections of the highway that the Hawaiʻi Department of Transportation (HDOT) has identified as needing action to maintain the usability of the highway in the near to mid-term, until a long-term plan to deal with the effects of sea level rise can be developed and implemented.

1.2 Project Location

The project area consists of nine (9) separate project sites along Kamehameha Highway on the windward coastline of Oʻahu (Figure 1-1). This includes two (2) sites in Kualoa, four (4) sites in Kaʻaʻawa, two (2) sites in Punaluʻu, and one (1) site in Hauʻula.

1. **Kualoa Park:** The Kualoa Park Project Site is approximately 220 feet in length, located at the northern corner of Kualoa Beach Park (Figure 1-2).
2. **Kualoa Ranch:** The Kualoa Ranch Project Site is approximately 950 feet in length, beginning near the entrance to Kualoa Ranch, in the south, and extending north to the vicinity of the Old Kualoa Sugar Mill (Figure 1-2).
3. **Kaʻaʻawa Valley:** The Kaʻaʻawa Project Site in the vicinity of Kaʻaʻawa Valley is the longest of the project sites, stretching over 4,590 feet from Kaʻōʻio Point in the south to the Kaʻaʻawa Stream Bridge in the north (Figure 1-3).
4. **Kaʻaʻawa Beach Park:** The Kaʻaʻawa Project Site in the vicinity of Kaʻaʻawa Beach Park extends 820 feet from the northern end of Kalaeʻōʻio Beach near Pohuehue Road to Kaʻaʻawa Beach Park, just north of Kaʻaʻawa Elementary School (Figure 1-3).
5. **Puakenikeni Road:** The Kaʻaʻawa Project Site in the vicinity of Puakenikeni Road extends 1,740 feet from between ʻŌhelokai Road and Puakenikeni Road in the south to just north of Polinalina Road (Figure 1-3).
6. **Crouching Lion:** The Kaʻaʻawa Project Site in the vicinity of Crouching Lion starts just north of Swanzy Beach Park and runs approximately 3,250 feet northwest to the flashing light and hairpin turn, about 400 feet past the Crouching Lion Inn (Figure 1-3).
7. **Punaluʻu South:** The Punaluʻu South Project Site is approximately 700 feet in length near the intersection with Hale Aha Road (Figure 1-4).

8. **Punaluʻu North:** The Punaluʻu North Project Site is a short 330-foot section of highway located just north of Kaluanui Stream, near the park area formerly known as Sacred Falls (Figure 1-4).
9. **Hauʻula:** The Hauʻula Project Site is the second longest project site, encompassing a 2,490-foot-long stretch of Kamehameha Highway from Hulahula Place in the south, to Maheiwi Stream Bridge in the north, just south of Hauʻula Homestead Road (Figure 1-5).

Table 1-1. Summary of the project sites and approximate lengths.

Area	Project Site	Approximate Length (feet)
Kualoa (Figure 1-2)	Kualoa Park	220
	Kualoa Ranch	950
Kaʻaʻawa (Figure 1-3)	Kaʻaʻawa Valley	4,590
	Kaʻaʻawa Beach Park	820
	Puakenikeni Road	1,740
	Crouching Lion	3,250
Punaluʻu (Figure 1-4)	Punaluʻu South	700
	Punaluʻu North	330
Hauʻula (Figure 1-5)	Hauʻula	2,490
	TOTAL	**15,720**

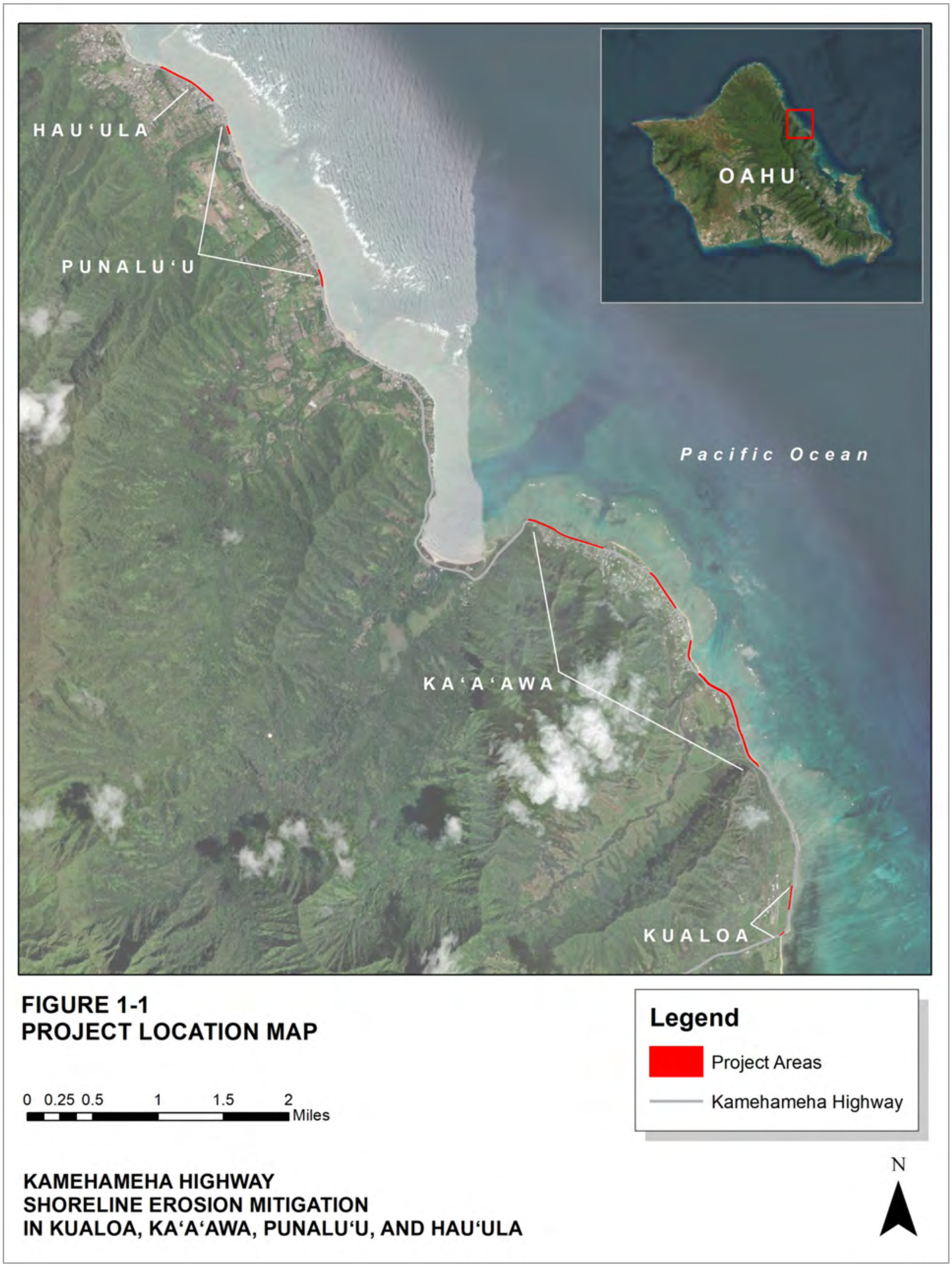


Figure 1-1. KKPH project location map.

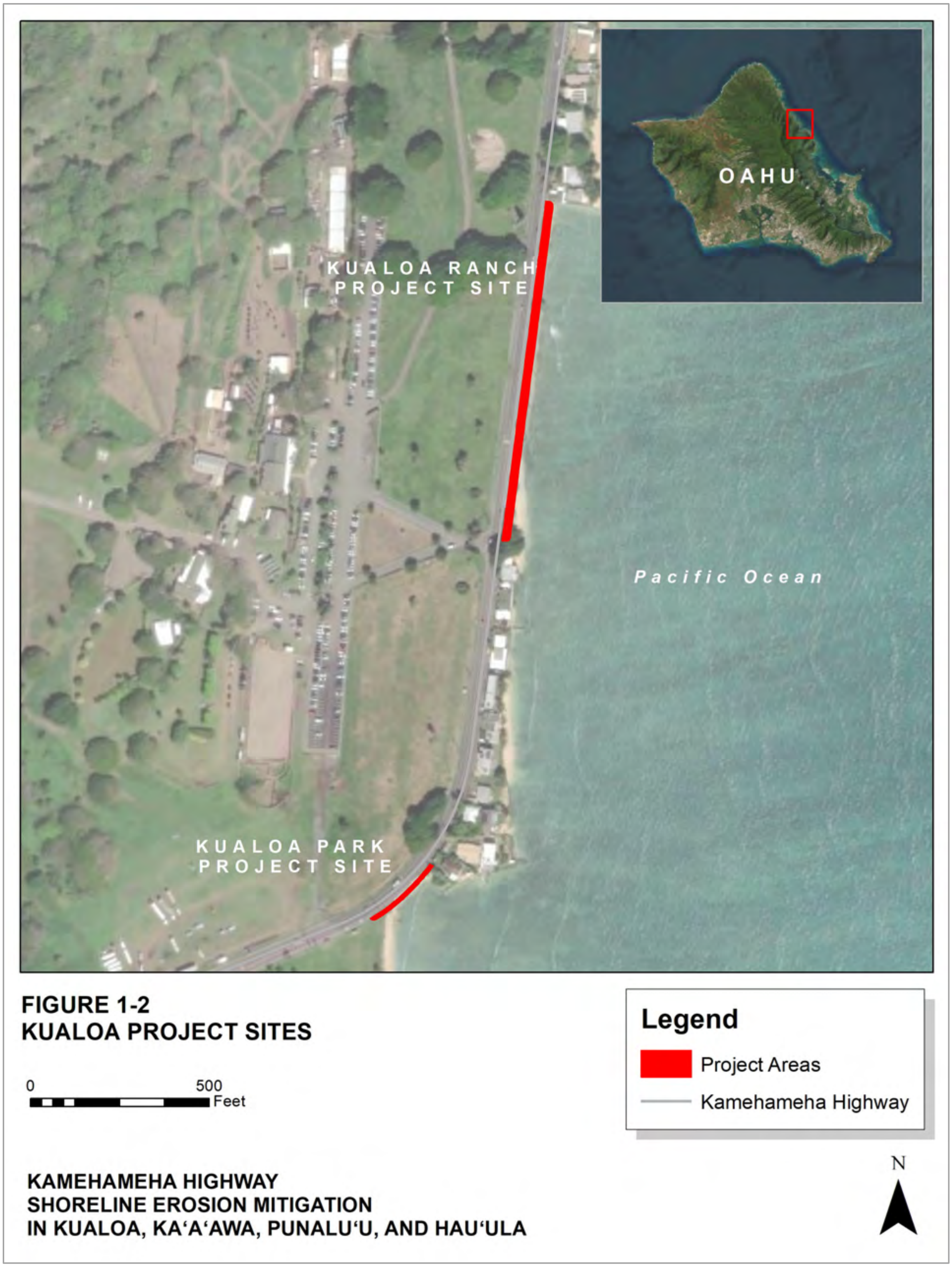


Figure 1-2. Kualoa Project Sites.

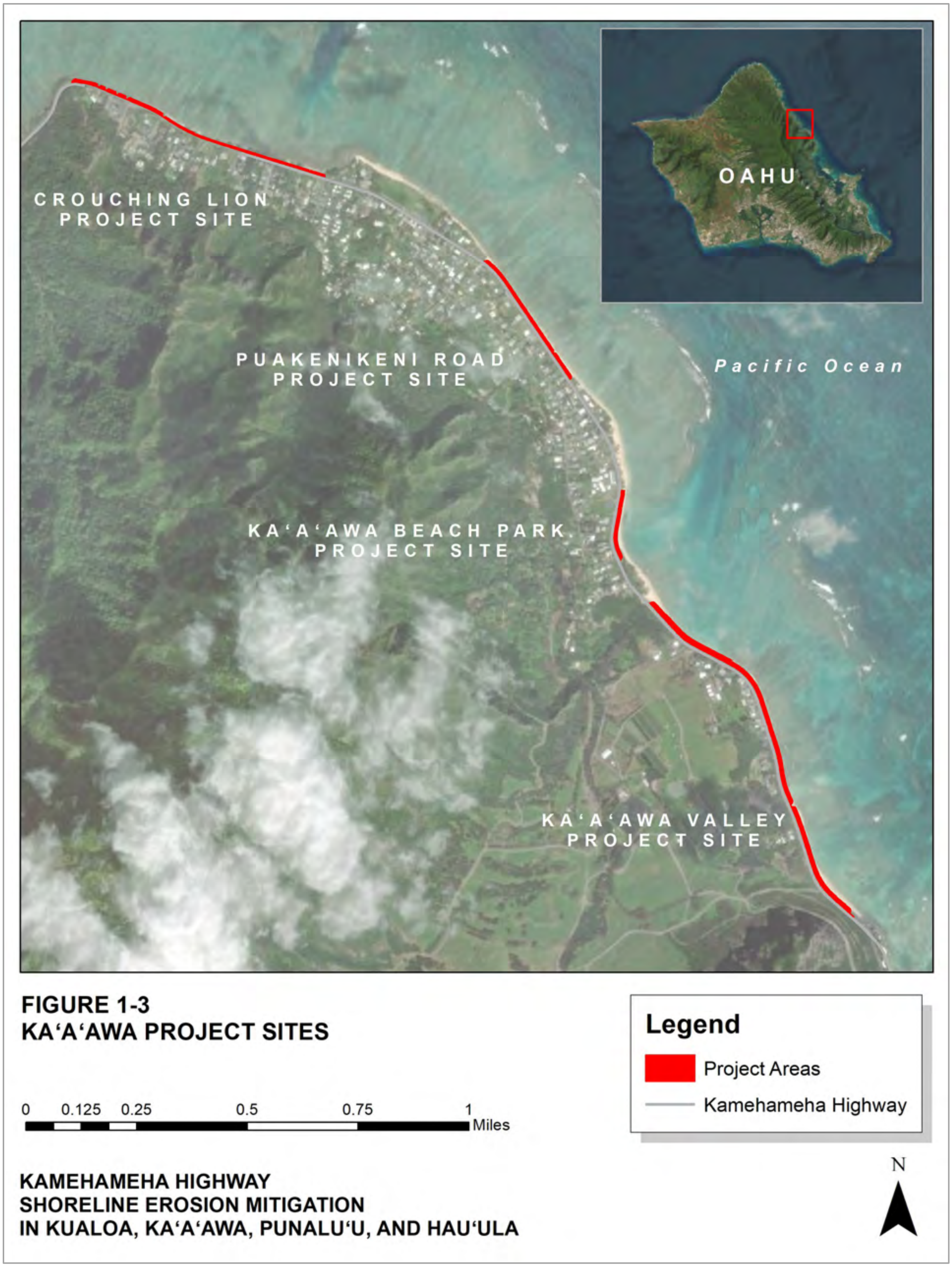


Figure 1-3. Kaʻaʻawa Project Sites.

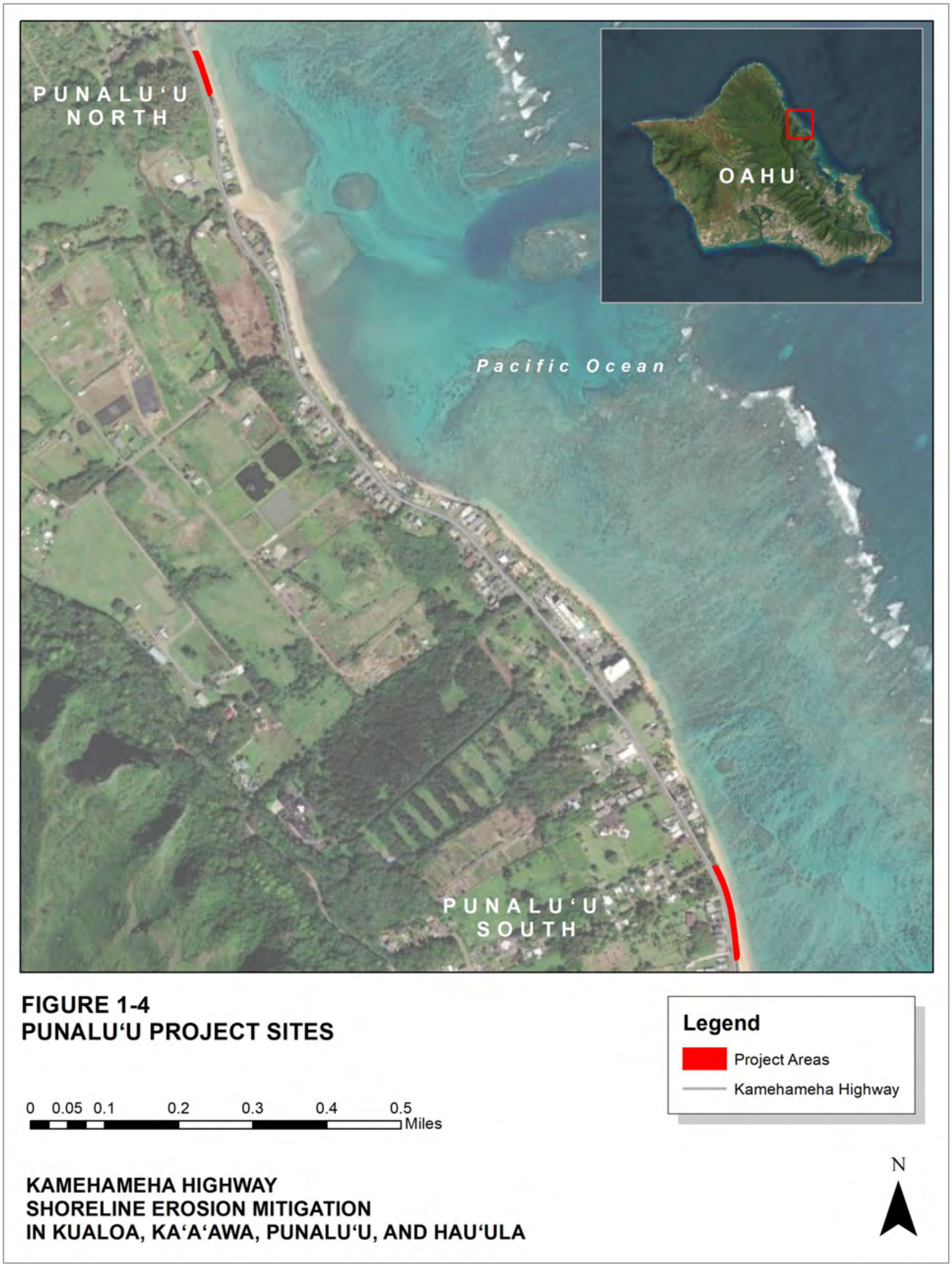


Figure 1-4. Punalu'u Project Sites.

Figure 1-5. Hauʻula Project Site.

1.3 Project Site Conditions

The project area lies on the windward side of Oʻahu, directly exposed to both the persistent easterly trade winds, and the rough wind swells generated by these winds. Most of the project shoreline is effectively sheltered from the direct approach of large open ocean swells by an extensive complex of broad and shallow fringing reefs. These outer reefs typically absorb a large fraction of the incoming wave energy; however, there are intermittent channels and deeper basins that cut across the nearshore reef plateaus, some of which allow increased wave exposure to those shoreline areas that front these features. The size, configuration, and extent of the reefs, channels, and other nearshore features have a significant effect on the character of the shoreline's beaches, and whether the shoreline has a beach at all. Shoreline configurations range from relatively wide, seemingly healthy beaches which exist throughout the year, to sections which are altered dramatically by the seasonal change of wave conditions, and some locations which remain rocky with little sand throughout the year. The individual project sites vary in these respects and are discussed in greater detail in the following subsections, organized by location.

1.3.1 Kualoa Park Project Site

The Kualoa Park Project Site is approximately 220 feet in length, located at the northern corner of Kualoa Beach Park (Figure 1-2). This project site is an erosional hotspot. The significant erosion in this area is likely the result of its location at the downstream side of a small groin field that protects a number of shoreline residences directly to the north.

The net sediment transport in this area is from north-to-south. This is visually indicated by the buildup of sand on the north facing side of groins and other obstructions, and the chronic erosion on the south facing sides. Persistent longshore currents transport sand and beach material southward, along the shoreline into Kāneʻohe Bay, where they eventually accrete into new beach areas fronting Moliʻi Fishpond and "Secret Island."

As beach sediments are lost from the project site, new material is prevented from arriving from the north due to the groin walls protecting the homes. The result is a receding shoreline, retreating from north to south, as seen from the perspective shown in Figure 1-6, revealing the unprotected earthen embankment that supports the Highway as it progresses.

Currently, this section of exposed roadway is protected by approximately 90 feet of non-engineered riprap that was placed as an emergency measure. The erosion scarp follows along the edge of pavement for most of this site and can be seen exposed on the left side of Figure 1- 6.

Figure 1-6. Kualoa Park Project Site. Erosion under the highway and non-engineered emergency riprap protection.

1.3.2 Kualoa Ranch Project Site

The Kualoa Ranch Project Site is approximately 950 feet in length, beginning near the main entrance to Kualoa Ranch, in the south, and extending north to the vicinity of the Old Kualoa Sugar Mill (Figure 1-2). This low-lying stretch of highway is frequently washed over by small waves bringing sand, coral rubble, and other debris onto the travel lanes during the highest tides or periods of elevated surf. Road deck elevations along this stretch of the highway range from 5 ½ to 6 feet above mean sea level (MSL).

There is a narrow and intermittent strip of sediment and coral rubble along the shoreline in this area. Similar in configuration to the Kualoa Park Project Site, this strip of cobbles and coral rubble is narrower to the north and wider at the southern end of the project site, due to the predominant north-to-south sediment transport that is active in this shoreline area.

A large groin protecting a private residence immediately to the north of this site traps and limits sediment transport from the north, with the effect of depleting the beach directly south of the groin structure.

The eroded shoreline along this stretch of Kamehameha Highway has been protected with dumped riprap (a non-engineered structure) on numerous occasions using various materials, including concrete square piles and quarry stone, shown in Figure 1-7. The displacement of the piles from their original stacked wall configuration, and movement of armor stones to a position lower in the shoreline profile shown in this photo of the Kualoa Ranch Project Site, are evidence of active erosion along the road shoulder in this area.

Figure 1-7. Kualoa Ranch Project Site, looking south from vicinity of Old Kualoa Sugar Mill.

1.3.3 Kaʻaʻawa Valley Project Site

The Kaʻaʻawa Valley Project Site is the longest of the project sites, stretching over 4,590 feet from Kaʻōʻio Point in the south to the Kaʻaʻawa Stream Bridge in the north (Figure 1-3). This stretch of highway winds along a more exposed and slightly higher elevation section of coastline. The broad and shallow reef platform that shelters much of the Kualoa shoreline becomes deeper and more fractured in this part of coastal Kaʻaʻawa, with significantly more wave energy propagating into the shoreline as a result.

The typical roadway deck elevation in this area ranges from 10 ½ to 13 feet above MSL. The paved shoulder width varies from 4 to 6 feet. Beyond the edge of pavement, unpaved shoulder widths vary from non-existent to 8 to 10 feet. The irregular shoulder widths along this stretch are a result of localized erosion hotspots which chisel away the shoreline at numerous locations (Figure 1-8). The narrow beach most prominent at the southern end of the site is sometimes only revealed at lower tides. Towards the middle and northern end of the project site, there are long sections with little to no dry beach even at low tides (Figure 1-9).

Due to its proximity to the shoreline and high exposure to waves, this section of road is routinely over-washed during higher tides, storms, or periods of elevated surf. A series of emergency repairs using materials including concrete piles and stone riprap, have been placed to form a non-engineered revetment along this aggressively eroding stretch over the last several years. The resulting rubble mound slope is showing signs of differential settling and displacement in many places, and the underlying earthen erosion scarp is visible in certain locations.

Figure 1-8. Kaʻaʻawa Valley Project Site in the vicinity of Kaʻōʻio Point.

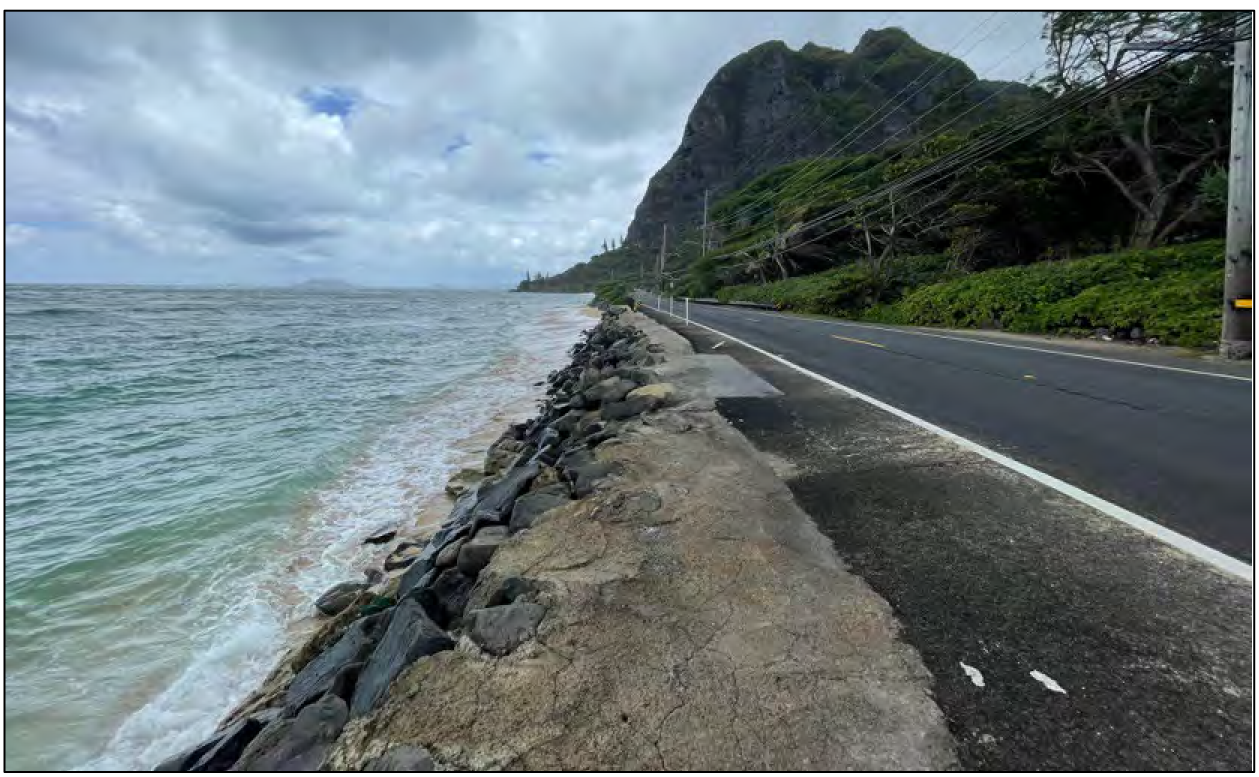


Figure 1-9. Central stretch of the Kaʻaʻawa Valley Project Site.

1.3.4 Kaʻaʻawa Beach Park Project Site

The Kaʻaʻawa Beach Park Project Site extends 820 feet from the northern end of Kalaeʻōʻio Beach near Pōhuehue Road to Kaʻaʻawa Beach Park, just north of Kaʻaʻawa Elementary School (Figure 1-3). This project site is generally lower in elevation than the Kaʻaʻawa Valley Project Site, and notably less exposed to direct wave attack. Towards the northern side of the project site is a large and complex outer reef formation with a broad and shallow platform reef and nearshore water depth of 1 to 2 feet. Towards the southern side of the project site a well-defined cross-shore channel cuts through the reef flat and transitions into a relatively deep and protected lagoon, with water depths varying from 4 to 10 feet. The southern half of this project site is typically more energetic than the northern section, with increased wave energy able to reach the shoreline through the deeper waters of the channel in the south. The northern half is more sheltered in comparison, largely protected from wave energy by the broad and shallow reef. The nearshore circulation pattern and sediment transport pathway is persistently north-to-south along this section of shoreline and the resulting erosion is more significant in the northern half of the project site.

Road deck elevations along this stretch vary from approximately 6 to 8 feet above MSL. Coastal vegetation is present alongside portions of the shoreline for in this area, particularly at the southern end (Figure 1-10). There is a narrow and gently sloping beach of mixed sands, cobbles, and coral rubble along this stretch of shoreline.

Figure 1-10. Shoreline in the southern half of the Kaʻaʻawa Beach Park Project Site near Pōhuehue Road.

The shoreline in the southern half of the project site is in a relatively natural configuration with no existing shoreline protection structures or improvements (Figure 1-10), while the northern half is lined almost entirely protected with non-engineered riprap and stacked concrete piles (Figure 1-11).

This section of Kamehameha Highway is routinely susceptible to wave overtopping and over-washing of the roadway during periods of elevated surf and higher tides, particularly along the low-lying southern half of the project site near Pōhuehue Road. Large amounts of water-borne debris including logs, rocks, and sand have been known to wash over the road here during extreme surf and severe weather events.

Towards the northern end of this project site, the road deck elevations increase; however, chronic erosion has impacted the exposed earthen embankment that supports the road shoulder which has resulted in the previous emergency repairs.

Figure 1-11. Shoreline in the northern half of the Kaʻaʻawa Beach Park Project Site near Kaʻaʻawa Beach Park.

1.3.5 Puakenikeni Road Project Site

This project site extends 1,740 feet from a point between ʻŌhelokai Road and Puakenikeni Road in the south, to just north of Pōlinalina Road (Figure 1-3). There is a broad and shallow reef flat offshore from this project site. The physical extent of the reef flat, along with its shallow waters, act to limit the typical wave height at the shoreline here, resulting in generally calm conditions. However, although normally tranquil, the road's low profile and proximity to the water still makes this area vulnerable to erosion and wave overtopping of the highway during high tides and periods of elevated surf. Ponded seawater, sand, coral rubble, and other ocean debris are occasionally found along this section of the highway.

Most of the shoreline in this area is typified by a very narrow and often submerged strip of sand and cobble beach. Towards the northern end of the project site the shoreline becomes rockier with increasingly less sand.

The entire length of the Puakenikeni Road Project Site's shoreline is armored with a series of emergency repairs. This includes concrete blocks stacked to form a 140-foot-long non-engineered seawall and non-engineered riprap revetments to the north and south of the seawall. These existing shoreline protection structures show signs of settling and stone displacement due to foundation erosion and scour.

The paved road shoulder width varies from 2 to 6 feet and directly abuts the riprap (Figure 1- 12). Erosion of the underlying road embankment is visible in many places.

Figure 1-12. Riprap directly abutting paved roadway shoulder in the northern portion of the Puakenikeni Road Project Site.

1.3.6 Crouching Lion Project Site

The Crouching Lion Project Site begins just north of Swanzy Beach Park and runs approximately 3,250 feet northwest to the flashing light and hairpin turn, about 400 feet past the Crouching Lion Inn (Figure 1-3).

This project site has two (2) distinct sections. The approximately 2,000-foot-long southern section is characterized by a relatively high vertical erosion scarp cut into the native earthen embankment adjacent to a sloped cobblestone and boulder beach that runs out onto the very shallow reef (Figure 1-13). The highway shoulder runs alongside this scarp, with the edge of pavement only 2 to 3 feet from the edge of the eroded slope. The approximately 1,000-foot-long northern section has little to no beach material and is hardened by a discontinuous combination of non-engineered riprap and seawall structures (Figure 1-14).

The broad and shallow reef at this site is effective at absorbing incoming wave energy, resulting in typically calm conditions at the shoreline, particularly towards the southern end of the project site. Kamehameha Highway along the Crouching Lion Project Site traverses a very narrow corridor of flat coastal lands between the ocean and the base of the Koʻolau Mountains.

Figure 1-13. Sloped cobblestone and boulder beach and vertical erosion scarp cut into the native earthen embankment along the southern section of the Crouching Lion Project Site.

Figure 1-14. Absence of beach material, seawall, and non-engineered riprap along the northern section of the Crouching Lion Project Site followed by discontinuous non-engineered riprap.

1.3.7 Punaluʻu South Project Site

The Punaluʻu South Project Site is approximately 700 feet in length, along Kamehameha Highway near the intersection with Haleʻaha Road (Figure 1-4). This site is located at an inflection point in the surrounding coastline making it susceptible to increased erosion. The beach is approximately 10 to 20 feet wide in this area and the shoreline has been previously armored with stone and concrete riprap (Figure 1-15).

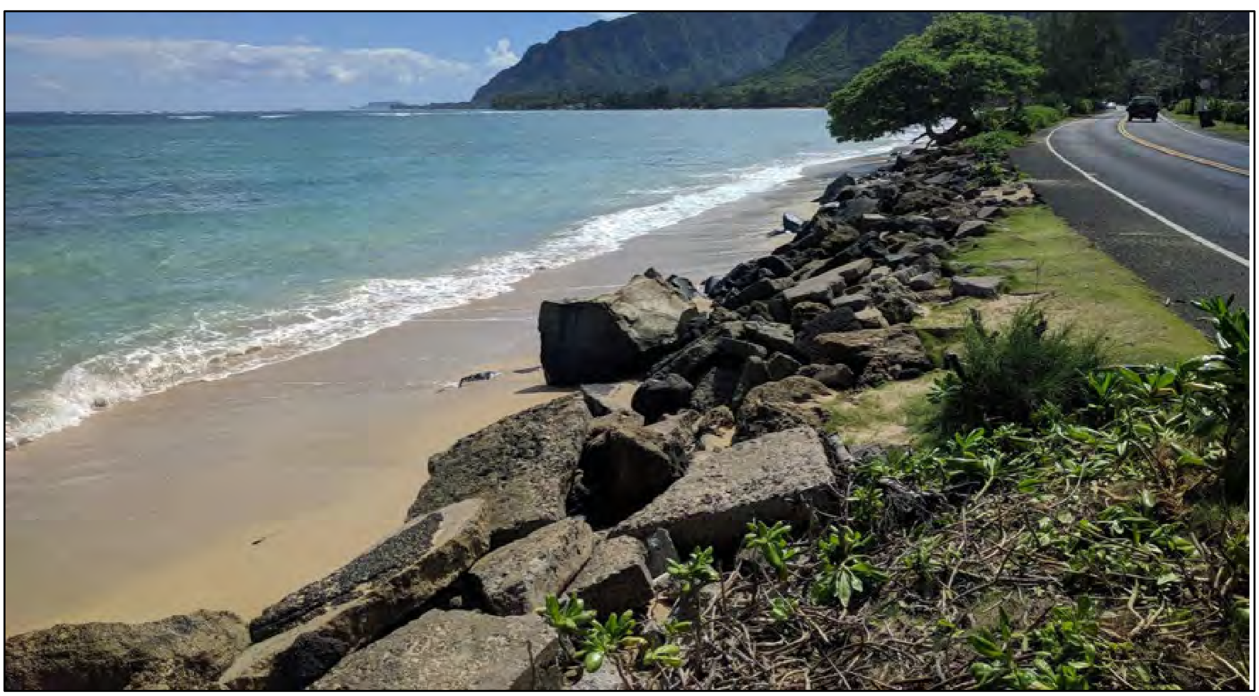


Figure 1-15. Stone and concrete riprap along the Punaluʻu South Project Site.

1.3.8 Punaluʻu North Project Site

The Punaluʻu North Project Site is a short 330-foot section of highway located just north of Kaluanui Stream, near the park area formerly known as Sacred Falls (Figure 1-4). Sediment transport along this section of shoreline in the north to south direction. Seawall structures protecting the ocean-front homes at Kalaipaloa Point to the north effectively block longshore transport of sand to the adjacent downstream shoreline, contributing to the erosional conditions at this site.

This section of shoreline has been previously hardened with a combination of non-engineered measures, including stacked square concrete piles to form a seawall with riprap placed on the ocean-side (Figure 1-16).

Figure 1-16. Stacked square concrete piles forming a seawall with riprap at Punaluʻu North Project Site.

1.3.9 Hauʻula Project Site

The Hauʻula Project Site is the second longest project site, encompassing a 2,490-foot-long stretch of Kamehameha Highway from Hulahula Place in the south, to Maheiwi Stream Bridge in the north, just south of Hauʻula Homestead Road (Figure 1-5). This section of coastline is bracketed between two (2) deep and very well-defined cross-shore channels. The nearshore circulation pattern is dictated by the shallow reef and deep channel bathymetry system and driven by the persistent flow of trade wind waves, forcing water landward over the shallow reef and draining back to offshore waters via the channels. The point of land formed by Kalaipaloa, located between the Hauʻula Project Site and the Punaluʻu North Project Site, appears to be a zone of divergence, with currents and sediment transport going south of this point, while flowing northward above it.

Overall sediment transport at the Hauʻula site is from south to north (opposite that of all the other project sites).

The Hauʻula Project Site shoreline has been previously lined with stacked Kyowa rock bags (Figure 1-17) and non-engineered riprap revetment (Figure 1-18). Road deck elevations along the Hauʻula Project Site are in the range of 7 to 8 feet above MSL.

Figure 1-17. Kyowa rock bags at the Hauʻula Project Site.

Figure 1-18. Non-engineered rock revetment at the Hau ʻula Project Site.

1.4 Project Purpose & Need

1.4.1 Need

As a result of global warming and sea level rise, chronic coastal erosion is increasingly chipping away at Windward Oʻahu coastlines and is currently threatening to undermine the flank of shoreline earthen embankment that support Kamehameha Highway. Found to be occurring at numerous locations along the windward coast, progressive erosion has advanced close enough to threaten adverse impacts to the continued safe operation of the highway. Kamehameha Highway is critical infrastructure, as it is the only roadway connecting the windward communities of Kāneʻohe, Kahaluʻu, Kaʻaʻawa, Punaluʻu, Hauʻula, Lāʻie, Kahuku, and the North Shore. Damage to and closure of the highway disrupts transportation routes, emergency services, commuter lines, and access for residents and tourists. The HDOT has identified nine (9) sections of the highway where action is needed to maintain the usability of the highway in the near to mid-term. A near to mid-term solution is intended to maintain the useability of the highway for the next 25 years, until a long-term solution can be developed and implemented.

1.4.2 Purpose

The purpose of the KKPH project is to maintain usability of Kamehameha Highway for the near to mid-term, allowing the highway to remain open and serviceable for commuters, commerce, emergency services, and all motorists for the next 25 years—a period of time during which a long-term permanent solution, to address sea level rise impacts on the highway, would be developed and implemented. This mid-term project is not intended to address the long-term effects of sea level rise. Execution of this project is intended to allow time for development and implementation of a future, long-term, solution to mitigate sea level rise impacts, while maintaining a transportation corridor for affected communities.

2. Proposed Action and Alternatives

2.1 Alternatives Considered

Several alternatives to address impacts to Kamehameha Highway from coastal erosion were considered during the initial planning phases of the project, including:

- No Action
- Managed Retreat
- Beach Nourishment
- Rock Revetment
- Traditional Seawall
- Hybrid Seawall with Armor Stone Apron

These alternatives were evaluated based on their ability to meet the purpose and need (maintain usability of Kamehameha Highway for the near to mid-term). The following additional objectives were secondary considerations during the evaluation of alternatives:

- Effectiveness - capable of achieving the project purpose
- Feasibility - constructability, regulatory requirements, community support
- Design Considerations - suitability, durability, design life
- Potential Impacts - to coastal processes, water quality, marine habitat, biological resources, shoreline access, recreation, historic and cultural resources, the community, and other resources
- Costs - relative to other alternatives

The following sections provide descriptions of the alternatives considered, along with their advantages and disadvantages. Following the discussion of the alternatives, Table 2-1 provides an evaluation of the alternatives based on the purpose and need and objectives listed above. Table 2-2 summarizes the results of the evaluation.

2.1.1 No Action

The no action alternative would involve leaving the highway in its existing condition with no repairs or modifications. If no action is taken, wave action and coastal erosion would continue to undermine large sections of the shoreline embankments that support Kamehameha Highway and compromising the integrity of the roadway.

Conclusion

The no action alternative does not meet the purpose and need for the project or any of the additional objectives and was therefore rejected.

2.1.2 Managed Retreat

Managed retreat generally involves relocating the highway and allowing the shoreline to naturally migrate inland. There are two types of managed retreat. A horizontal retreat would involve moving the highway further inland. A vertical retreat would involve elevating the roadway above the coastal hazards.

The KKPH Project Sites lie on a relatively flat coastal plain between the ocean and the steep Koʻolau Mountain range. For most of the project sites, the adjacent and inland coastal plain is fully occupied by developed residential communities. Managed retreat of the highway inland would require realignment of the highway through existing homes and private properties, or alternately, through steep mountainous terrain at the base of the coastal slopes currently designated as conservation district. A vertical retreat would involve construction of an elevated structure on piers or a retaining wall. Design and construction of an elevated structure within existing roadway right-of-way or offshore would present a number of environmental, design, and construction challenges.

Advantages

- Reduces vulnerability of transportation infrastructure to shoreline erosion, coastal hazards, and sea level rise. Potentially providing a long-term solution to these hazards.
- Allows the shoreline to migrate naturally inland.
- Horizontal retreat could avoid or minimize construction activities along the shoreline and associated potential effects to beaches and the nearshore marine environment.

Disadvantages

- Horizontal retreat would require government acquisition of large areas of private property and or forcible displacement of local residents within the realigned highway corridor.
- Horizontal retreat of the highway alignment further inland, closer to the base of the Koʻolau mountains, would require significant disruption and alteration of currently protected conservation lands.
- Under a vertical retreat approach, to allow the existing highway to remain open during the construction, the new highway alignment would likely result in potentially significant impacts to visual resources, biological resources, and the nearshore marine environment.
- Both horizontal and vertical retreats would be extremely costly and take many years to complete due to the complex engineering and construction. The vertical offshore roadway would have the highest engineering and construction costs, while the horizonal retreat would have high costs and extensive time considerations associated with land acquisition.

Conclusion

Managed retreat does not meet the purpose and need of maintaining the useability of the highway in the near to mid-term. The cost and time needed to design and construct a new highway inland or offshore could not be completed and put into service in the near term. Managed retreat may be a suitable long-term solution to coastal erosion and sea level rise. The implementation of the proposed mid-term solution would not prevent, and would allow time for, implementation of a long-term solution, such as managed retreat.

2.1.3 Beach Nourishment

Beach nourishment involves the placement of additional beach material sourced offshore or off-site and transported to the site, thereby expanding the width of the existing beach to offset the effects of beach erosion. This alternative is generally supported by regulatory agencies and the public, and it is consistent with local State and County policies that seek to preserve and enhance beach resources.

Beach nourishment is most effective at locations where an existing beach is present and additional sand is required to maintain a stable beach profile. Some limited stretches of some of the KKPH sites have existing stable beaches, however, significant portions of many of these sites do not have existing stable beaches. Portions of the Kaʻaʻawa Valley Project Site, Puakenikeni Road Project Site, Crouching Lion Project Site, and Hauʻula Project Site do not have existing stable beaches and are therefore not well suited for beach nourishment.

A major constraint that can diminish the effectiveness of beach nourishment projects is the attrition (gradual removal) of newly placed beach material due to natural processes such as suspension and transport via longshore and cross-shore currents, particularly during higher tides and periods of elevated surf. In regions that have natural features such as headlands, points, embayments, or other hard physical boundaries disrupt sediment transport and effectively work to stabilize the beach material. However, in most other cases where these features and conditions do not exist, such as the KKPH Project Sites, it is typically necessary to construct engineered beach containment structures such as groins or jetties, which serve to trap and maintain the nourished beach material within their limits. If the beach is nourished without a protective structure, the newly placed material would likely be lost rapidly or gradual depending on the wave conditions at the site.

Advantages

- Provides a temporary increase in beach volume and width without stabilizing structures, such as groins or jetties, or a more long-term increase in beach volume and width with stabilizing structures, such as groins or jetties.
- Increases natural wave absorption and dissipation of wave energy, providing additional protection against wave overtopping.

Disadvantages

- Terrestrial sand sources are difficult to find and often not suitable for beach nourishment due to the size of the sand grains typically high fractions of fines and silt.
- Offshore sand borrow sites are typically expensive to explore and difficult to access. Wave and weather conditions along the windward side would limit the number of days the large work barges and support vessels could safely access nearshore sites.
- Sand is unlikely to remain stable, even in the near-term, without marine construction of stabilizing structures, such as groins or jetties.
- It would be a costly requiring a substantial amount of compatible material and regulatory requirements, particularly with the addition of necessary groins or jetties.
- The addition of groins or jetties would significantly increase the impacts to nearshore marine habitats, with footprints extending offshore well past the typical toe of the beach, and out into clearer and more pristine reef flat environments.

Conclusion

Beach nourishment has the potential to increase beach width along the project sites. However, without engineered stabilization structures like groins, the beach profile would be unstable and likely transient, and the sand would eventually be redistributed along the shoreline or transported offshore into one of the many channels that cut across the reef.

Beach nourishment with stabilizing structures, would create a wider, stable beach, and provide longer-term protection for the roadway. However, even with stabilization structures, the longevity of the nourished beach cannot be guaranteed. The project would require a large array of groin and/or jetty structures along the highway's shoreline. The construction of groin and/or jetty structures would result in a very large project footprint in the marine environment, and larger area of direct impacts from marine construction activities.

Beach nourishment without the necessary stabilizing structures would most likely not provide effective shoreline protection, particularly for a period of 25 years, and therefore does not meet the purpose and need of this project. Beach nourishment with stabilizing structures would not meet the purpose and need, to maintain usability of Kamehameha Highway for the near to mid-term, due to challenges associated with locating, collecting, and transporting suitable sand material, trapping the material at the site of placement. Beach nourishment with stabilizing structures could be a consideration for long-term implementation.

2.1.4 Rock Revetment

A rock revetment is a sloping rock or stone structure used to protect the adjacent shoreline from erosion (Figure 2-1). The most common method of revetment construction is to place a layer of armor stone sized according to site-specific design wave height, installed over an inner layer of smaller stone (underlayer) that rests on a core or prepared slope covered with filter fabric. This underlayer is designed to distribute the weight of the outer armor layer and to prevent erosion and loss of fine material from the supporting embankment or core through voids in the revetment stone.

Rock revetments are effective in reducing wave reflection, runup, and overtopping, by gradually absorbing the water’s momentum and as a result, increasing the potential for sand accumulation seaward of the structure. The rough and porous surface and sloping face of rock revetments effectively absorb and dissipate wave energy, in contrast to seawalls whose smooth, impermeable, vertical surfaces are highly reflective, creating conditions in the nearshore water column that often limit the accumulation of sand near the structure.

Figure 2-1. Example of an engineered, uncemented revetment near Crouching Lion.

Advantages

- Properly engineered and constructed rock revetments are durable, flexible, and highly resistant to wave damage, remaining functional even after damage from large waves.
- Increases resilience to coastal hazards and sea level rise.
- Less reflective than a seawall and may facilitate sand accretion seaward of the revetment, where sufficient sand volumes are present.
- The rocky appearance of the revetment structures resembles natural rocky shorelines elsewhere in Hawaiʻi and offers similar suitable habitat for marine life.
- Requires a much smaller offshore footprint compared to the beach nourishment with groin alternative.
- Readily removable or modifiable. Can be integrated with future (long-term) erosion mitigation solutions without significant cost or environmental impacts.

Disadvantages

- Occupies a larger footprint on the shoreline than a seawall.

Conclusion

An uncemented rock revetment could be designed and constructed in the near term and would be effective in protecting and stabilizing the shoreline for a period of 25-years, and therefore, meets the purpose and need. A revetment is an appropriate solution for the KKPH Project Sites and would satisfy project objectives to protect the existing highway against coastal erosion forces, reduce or minimize wave overtopping and wave over-wash onto the road, and increase the resilience of the highway to sea level rise for the next quarter century while longer-term solutions are developed.

2.1.5 Traditional Seawall

Traditional seawalls are engineered hardened shore protection structures utilized to prevent further erosion of a shoreline by holding soil in place, while providing protection from wave and tidal action (Figure 2-2). Seawalls also have a secondary function as coastal flood defenses. Constructed parallel to the shore, seawalls vary widely in type and configuration, and may include steel sheet pile walls, monolithic concrete barriers, cemented or dry-stack brick or block walls, or gabions (wire baskets filled with rocks). Typically, seawalls are heavily engineered, rigid structures and are generally expensive to construct and require proper design and construction supervision (United Nations Framework Convention on Climate Change, 1999), and require multi-disciplinary engineering including civil, coastal, structural, and geotechnical engineers. Seawalls are generally not appropriate for high energy wave environments and are used more often in sheltered waters or as a backstop to existing beach areas. Seawalls exposed to direct wave approach are highly reflective.

Figure 2-2. Example of a traditional seawall.

Advantages

- A well maintained and appropriately designed seawall provides a high degree of protection against coastal flooding and erosion.
- Seawalls occupy much less area than a sloped revetment or beach nourishment with groins.
- It is possible to progressively upgrade these structures by increasing the structure height in response to sea level rise.
- They are potentially long-lived structures when adequately maintained.

Disadvantages

- Smooth, vertical seawalls are highly reflective and the least effective at dissipating wave energy; instead, the structures reflect wave energy seawards, making them and adjacent areas more prone to erosion.
- Seawalls prevent natural sediment movement and alter beach dynamics which can lead to beach loss. Where the seawall ends, the adjacent shoreline remains free to respond to natural conditions. These non-hardened areas could move inland, resulting in accelerated loss of the remaining beach. Significant loss of the beach material, adjacent to the seawalls, could undermine the stability of the seawalls.

Conclusion

Although a traditional seawall serves to minimize erosion and provide protection from wave action, it would not be the preferred mid-term solution as such a structure would necessitate continued investment in maintenance and upgrades, it would be inconsistent with attempting to limit impacts to surrounding beaches, and limit future coastal management options.

2.1.6 Hybrid Seawall with Armor Stone Apron

A hybrid seawall with an armor stone apron is a shoreline protection structure that combines the desirable small footprint of a traditional vertical seawall with the absorptive properties of a revetment by incorporating a low height sloping rock apron at the wall's base—used for protection of the wall's foundation from scour and undermining (Figure 2-3). A hybrid seawall would be constructed from two (2) primary elements, including a seawall (which could include sheet pile, reinforced concrete, or cemented rock masonry), and an uncemented armor stone rubble-mound apron installed seaward of the seawall.

Figure 2-3. Example hybrid seawall with rock apron in Kapaʻa, Kauai.

Advantages

- Combines the effectiveness and minimal disturbance footprint of a vertical wall, with the dissipative and absorptive characteristics of a rock revetment.
- Localized damage to the armored apron can be easily repaired by placement of additional armor stone.
- Less reflective than a seawall and may facilitate sand accretion seaward of the structure.
- Appropriate for project sites with low wave energy environments and low elevations.
- Structure could be adapted to withstand future sea level rise.

Disadvantages

- Although smaller than for a rock revetment, a hybrid seawall still has a larger footprint than a traditional seawall.

Conclusion

A hybrid seawall with armor stone apron is an appropriate engineering solution for the lowest elevation project sites with the smallest design wave heights. This would include the Kualoa Park Project Site and the Kualoa Ranch Project Sites, as well as south end of the Crouching Lion Project Site. This alternative would satisfy the project objectives to protect the highway from existing coastal erosion forces, reduce wave overtopping, and increase the resilience of the highway to sea level rise.

Table 2-1. Alternative evaluation.

Alternative	Meet Purpose and Need *Maintain usability of Kamehameha Highway for the near to mid-term*	Additional Objectives – Secondary Considerations				
		Effectiveness - *capable of achieving the project purpose*	**Feasibility** - *constructability, regulatory requirements, community support*	**Design Considerations** - *suitability, durability, design life*	**Potential Resource Impacts**	**Cost Ranking** *Highest 1 to Lowest 3*
No Action	**No**	N/A	N/A	N/A	N/A	N/A
Managed Retreat	**No** The cost and time needed to permit, acquire right-of-way, design, and construct a new highway inland or offshore could not be completed and put into service in the near to mid-term.	N/A Would be effective in maintaining the useability of Kamehameha Highway in the long term, but not in the near to mid-term.	• Realignment of the highway that requires displacement of many local residents may not be feasible and would not have community support. • An elevated roadway structure may have significant visual impacts and may not be supported by regulatory agencies or the community. • Construction of an elevated roadway structure or new highway closer to the base of the Ko‘olau mountains would be challenging.	• Would be durable and resilient to coastal hazards and sea level rise. • May have the longest design life	• An elevated structure may have significant visual impacts. • Construction of an elevated highway offshore may have significant impacts to the marine environment. • Construction of a new highway closer to the base of the Ko‘olau mountains, would require significant disruption and alteration of currently protected conservation lands.	1 (highest cost)
Beach Nourishment	**No** Could not be completed in the near to mid-term, due to challenges associated with locating, collecting, and transporting suitable sand material, and trapping the material at the site.	N/A Could be effective in maintaining the useability of Kamehameha Highway in the long term in combination with other shoreline stabilization measures.	• Constructability challenges associated with locating, collecting, and transporting suitable sand material, and trapping the material at the site. • Favored by some regulatory agencies, but with lots of regulatory requirements associated with potential impacts to water quality and marine biological resources. • Has community support.	• May not be suitable for sites that do not have existing stable beaches. • May require maintenance and placement of additional material to address gradual loss of sand.	• Require the largest footprint of direct permanent fill and impacts to the marine environment. • Greatest potential for water quality impacts from sand placement	2 (second highest cost)
Uncemented Rock Revetment	**Yes** (Preferred Alternative)	Would be effective in protecting the highway from coastal erosion and maintaining the usability of the highway for the near to mid-term.	• No significant constructability challenges. Can be constructed from the roadway shoulder. • Complies with HAR 13-5-22, P-15 Shoreline Erosion Control, and other regulatory requirements. • No substantial community opposition.	• Durable and resilient to wave damage and coastal hazards • Design life exceeds 25-years	No significant impacts. Minor loss of sandy beach area.	3 (comparable to traditional seawall and hybrid seawall with armor stone apron)
Traditional Seawall	**Yes** (Not a Preferred Alternative, due to potential coastal erosion effects)	May be effective in protecting the highway from coastal erosion and maintaining the usability of the highway for the near to mid-term. Significant loss of the beach material, adjacent to the seawalls, could undermine the stability of the seawalls.	• No significant constructability challenges. Can be constructed from the roadway shoulder. • Complies with HAR 13-5-22, P-15 Shoreline Erosion Control, and other regulatory requirements. • No substantial community opposition.	• Durable and resilient to wave damage and coastal hazards • Design life exceeds 25-years	Reflect wave energy seawards, making adjacent areas more prone to erosion	3 (comparable to rock revetment and hybrid seawall with armor stone apron)
Hybrid Seawall with Armor Stone Apron	**Yes** (Preferred Alternative)	Would be effective in protecting the highway from coastal erosion and maintaining the usability of the highway for the near to mid-term.	• No significant constructability challenges. Can be constructed from the roadway shoulder. • Complies with HAR 13-5-22, P-15 Shoreline Erosion Control, and other regulatory requirements. • No substantial community opposition.	• Durable and resilient to wave damage and coastal hazards • Design life exceeds 25-years	No significant impacts. Minor loss of sandy beach area.	3 (comparable to rock revetment and traditional seawall)

*Grey cells indicated an evaluation of additional objectives for alternative that do not meet the purpose and need for the project.

Table 2-2. Summary of alternative evaluation.

Alternative	**Meets Purpose and Need**	**Preferred Alternative**
No Action	No	No. Does not meet the purpose and need or any additional objectives.
Managed Retreat	No	No. Does not meet the purpose and need of maintaining the useability of the highway in the near to mid-term.
Beach Nourishment	No	No. Beach nourishment without the necessary stabilizing structures would most likely not provide effective shoreline protection and beach nourishment with stabilizing structures would potentially meet the purpose and need, however is not guaranteed, and is not the preferred alternative due to various challenges.
Uncemented Rock Revetment	**Yes**	**Yes, meets the purpose and need.**
Traditional Seawall	Yes	No, not preferred because it would necessitate continued investment in maintenance and upgrades, it would be inconsistent with attempting to limit impacts to surrounding beaches, and limit future coastal management options
Hybrid Seawall with Armor Stone Apron	**Yes**	**Yes, meets the purpose and need.**

2.2 Description of the Proposed Action

The proposed action includes construction of rock revetments or hybrid seawalls with armor stone aprons at nine (9) locations along the makai side of Kamehameha Highway. The preferred alternative for each site is listed in Table 2-3. In general, uncemented rock revetments were the preferred alternative selected for the majority of the project sites. These structures are effective in dissipating wave energy, highly resilient, and capable of protecting shorelines with high wave energy. At a few of the sites with the lowest wave heights a low-crested hybrid seawall with armor stone apron was selected as the preferred alternative. An advantage to a hybrid seawall with armor stone apron is it occupies a smaller footprint than a rock revetment resulting in less fill in the marine environment along the shoreline.

Table 2-3. Summary of proposed action.

Project Site	Proposed Action	Length of Proposed Erosion Control Structure (feet)
Kualoa Park	Hybrid Seawall with Stone Apron	220
Kualoa Ranch	Hybrid Seawall with Stone Apron	950
Kaʻaʻawa Valley	Uncemented Rock Revetment	4,590
Kaʻaʻawa Beach Park	Uncemented Rock Revetment	820
Puakenikeni Road	Uncemented Rock Revetment	1,740
Crouching Lion	Uncemented Rock Revetment (North End) Hybrid Seawall with Stone Apron (South End)	3,250
Punaluʻu South	Uncemented Rock Revetment	700
Punaluʻu North	Uncemented Rock Revetment	330
Hauʻula	Uncemented Rock Revetment	2,490

Rock Revetments

The proposed rock revetments would be constructed 10 feet from the edge of travel way. There would be a 1-foot vertical step up to an 8-foot-wide rock revetment crest. The face of the rock revetment would be at a 1:1.5 or 1:2 slope, depending on the site. The revetment structure would consist of up to three layers of uncemented stone. The prepared excavated base for the revetment may have a graded bed of gravel, upon which a layer of geotextile filter fabric would be installed. The following filter stone layer would be comprised of smaller stones designed to distribute the weight of the outer armor stone layer. The gravel bed, filter fabric, and filter stone layers would act to prevent erosion and loss of fine material from the embankment through voids in the armor stone. The top armor layer, also known as the cover layer, would be constructed of quarried armor stones that are sized to meet site-specific conditions calculated from the design wave heights. Figure 2-1 presents a concept drawing of a proposed rock revetment structure in cross section. Figure 2-2 presents a concept drawing of a proposed rock revetment structure in plan view, on an aerial image, showing the area of the shoreline that would be within the footprint of the rock revetment.

In recent years, large armor stone has been more difficult to source, on-island, because of numerous shore protection projects. Man-made concrete armor units can be utilized as an alternative to natural armor stone, providing the same protective features and energy absorbing properties as large stone. The use of man-made concrete armor units would only be considered if larger armor stone becomes scare or uneconomical to source locally. Addition information regarding concrete armor units can be found in the Basis of Design (Appendix A).

Construction of the rock revetment may require some grading and excavation along the shoreline to prepare the site for placement of the foundation, including filter fabric, underlayer stones, and armor stones. Removal of sand or other beach materials from the site is not anticipated. The width of the rock revetments would range from approximately 15 to 40 feet wide, including an 8-foot-wide crest at the top of the revetment. The width and design for the toe of the revetment would depend on whether the structure's base would rest on a hard coral or rock bottom, or a soft sand or gravel bottom. The distribution of sand at many of the project sites changes dramatically with the seasonal changes in wave conditions. It is likely that the lower portions of some of the rock revetments would be covered by sand over time or seasonally with the changes in wave conditions. Additional concept drawings are provided in the Basis of Design (Appendix A).

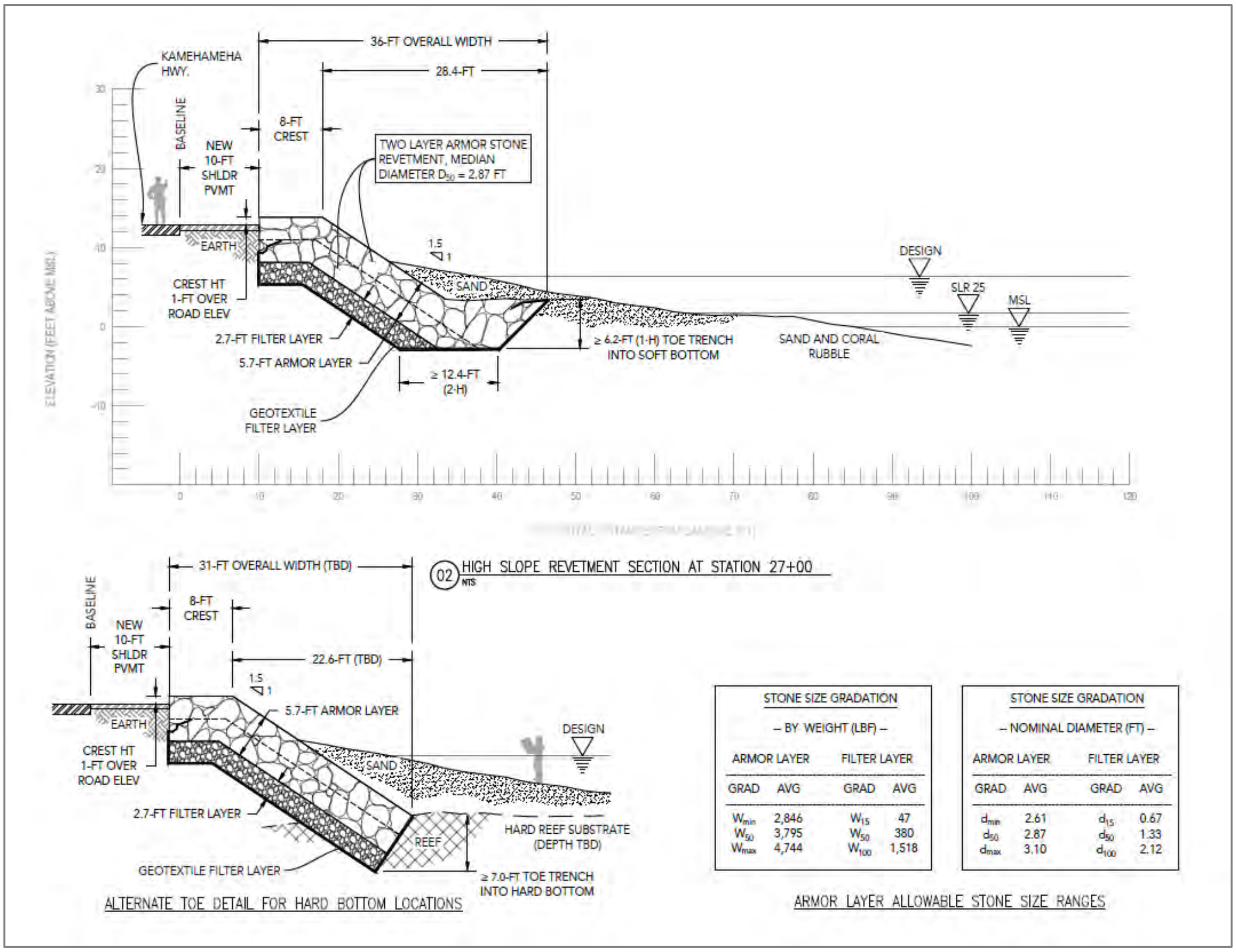


Figure 2-1. Cross section concept drawing of a proposed rock revetment structure.

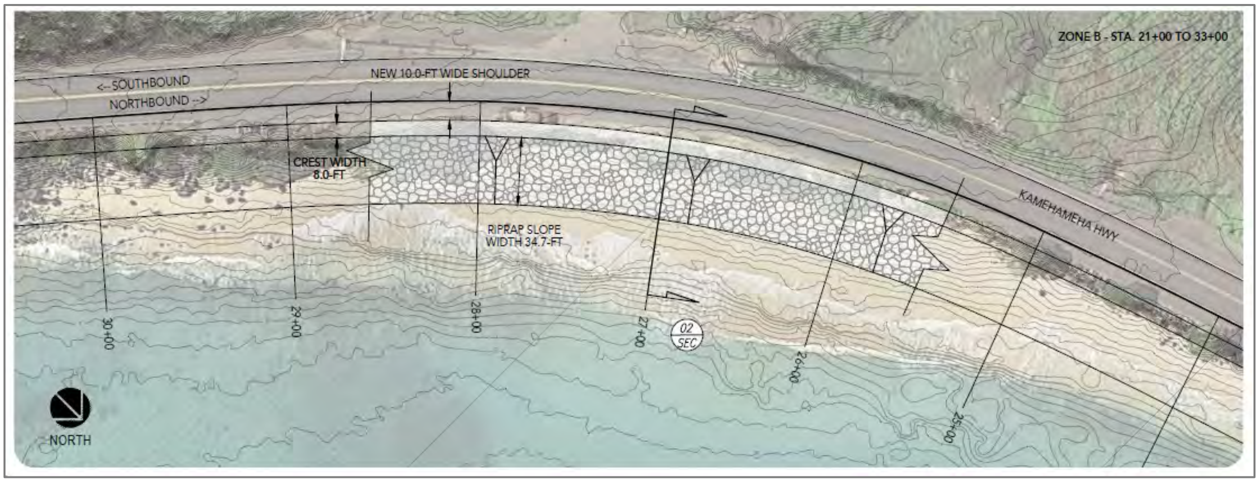


Figure 2-2. Plan view concept drawing of a proposed rock revetment structure.

Hybrid Seawall with Armor Stone Apron

The proposed hybrid seawalls could be constructed of driven sheet piles, precast concrete walls, or cast-in-place concrete walls. The riprap toe would be constructed of armor stone with an underlying layer of filter stone and geotextile fabric. A hybrid seawall with armor stone apron system would be approximately 10 to 20 feet wide. Figure 2-3 presents a concept drawing of a proposed hybrid seawall with armor stone apron structure in cross section. Figure 2-4 presents a concept drawing of a proposed hybrid seawall with armor stone apron structure in plan view, on an aerial image, showing the area of the shoreline that would be within the footprint of the hybrid seawall and armor stone apron.

Construction Methods

All the stone and related materials used to construct the rock revetments and hybrid seawalls with armor stone aprons would be placed in a controlled manner to avoid impacts beyond the designed footprint of the structure. All construction equipment and vehicles used in construction of these shoreline erosion mitigation structures would be operated from the paved travel way or roadway shoulder. No construction equipment or vehicles would be driven on or operated from the water or beaches. Silt curtains would be installed around the active construction operations to contain turbid water and avoid impacts to water quality outside and down current of the active construction area.

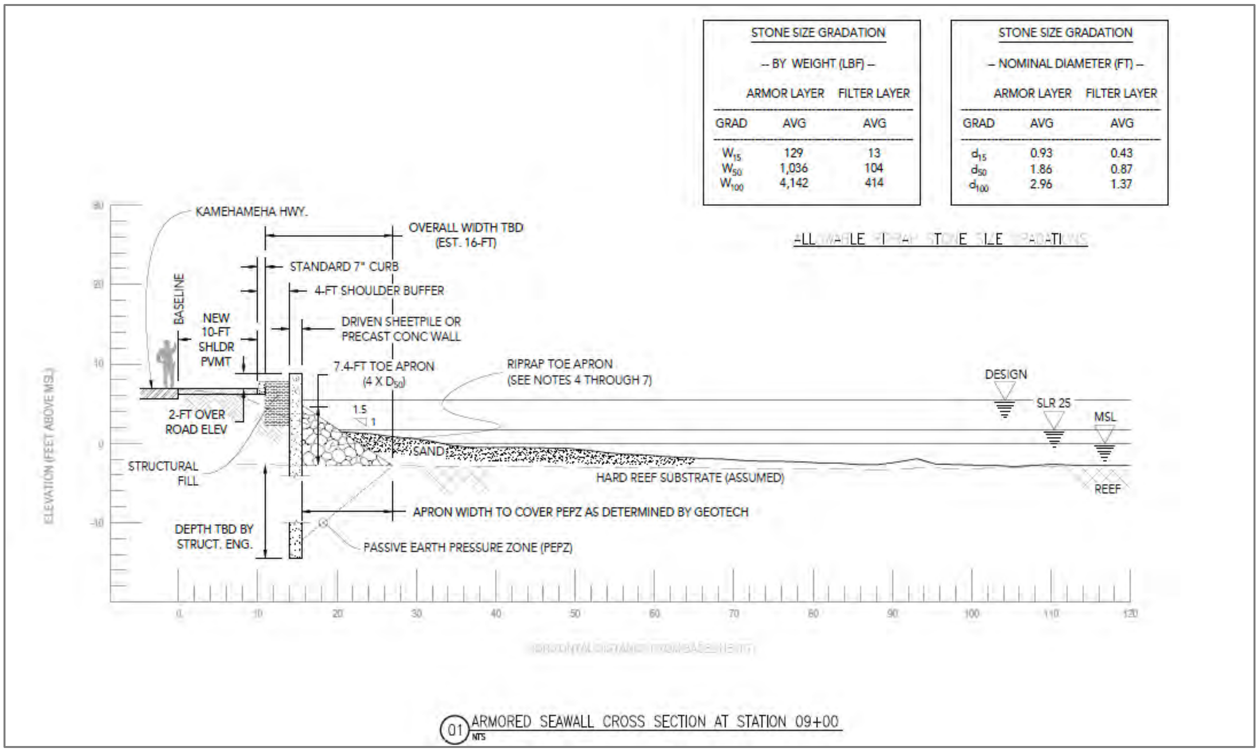


Figure 2-3. Cross section concept drawing of a proposed hybrid seawall with armor stone apron.

Figure 2-4. Plan view concept drawing of a proposed hybrid seawall with armor stone apron.

2.3 Required Federal and State Approvals

2.3.1 Required Federal Approvals

- **National Environmental Policy Act (NEPA)**
- **Department of the Army (DA) Permit** issued by the United States (U.S.) Army Corps of Engineers (USACE) pursuant to:
  - *Section 10 of the Rivers and Harbors Act of 1899 (Title 33 United States Code (USC) 403 or 33 USC 403):* All work or structures in or affecting the course, condition, location, or capacity of navigable waters of the U.S., including tidal wetlands, require DA authorization pursuant to Section 10.
  - *Section 404 of the Clean Water Act (CWA) (33 USC 1344):* Activities involving the discharge of dredged or fill material into waters of the U.S. require a DA permit pursuant to Section 404.
- **National Historic Preservation Act (NHPA) Section 106 Consultation** with the State Historic Preservation Officer (SHPO), native Hawaiian organizations (NHO), and other interested parties.
- **Endangered Species Act (ESA) Section 7 Consultation** with the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS).
- **Magnuson-Stevens Fisheries Conservation and Management Act (MSA) Section 305(b)(2) Essential Fish Habitat (EFH) Consultation** with the NMFS.
- **Coastal Zone Management (CZM) Act Consistency Review** with the Hawaiʻi State Office of Planning and Sustainable Development CZM Program Office.
- **U.S. Department of Transportation Act Section 4(f) Determination**

2.3.2 Required State of Hawaiʻi Approvals

- **Environmental Assessment (EA)** pursuant to, Hawaiʻi Revised Statutes (HRS), Chapter 343.
- **HRS Chapter 6E-8 Historic Preservation Review** by the State Historic Preservation Division (SHPD).
- **Conservation District Use Permit (CDUP)** for the Board of Land and Natural Resources pursuant to Title 13 Chapter 5, Hawaiʻi Administrative Rules (HAR).
- **CWA Section 401 Water Quality Certification (WQC)** from the State of Hawaiʻi Department of Health (DOH) Clean Water Branch (CWB) certifying that the proposed discharge resulting from an activity would not violate applicable water quality standards.
- **CWA Section 402 National Pollutant Discharge Elimination System (NPDES) General Permit Coverage** from the DOH CWB for stormwater discharges associated with construction activity and construction site dewatering.

- **HRS 195D Consultation** with the Department of Land and Natural Resources (DLNR) Division of Forestry and Wildlife (DOFAW) and Division of Aquatic Resources (DAR)

3. Existing Conditions, Potential Impacts, and Mitigation Measures

3.1 Soils and Geological Conditions

3.1.1 Existing Conditions

The project sites in Kualoa, Kaʻaʻawa, Punaluʻu and Hauʻula lie on a relatively flat coastal plain between the ocean and the steep Koʻolau Mountain range. Elevation throughout the project sites vary between 0 to 10 feet above MSL.

Soil types within the project area were identified by using data from the U.S. Department of Agriculture, Natural Resources Conservation Service. As shown on Figures 3-1 to 3- 4, seven (7) soil types are found within the project limits. These include Beach sand (BS), Jaucas sand (JaC) on 15 percent (%) slopes, Marsh (MZ), Mokuleia loam (Ms) on 0 to 2 % slopes, Kaena very stony clay (KanE) on 10 to 35 % slopes, Waialua stony silty clay (WIE), and Waialua very stony silty clay (WmD) on 12 to 30 % slopes. The most common soil types found in the project area are Jaucas sand (JaC) and Mokuleia loam (Ms). Jaucas sand (JaC) areas are mainly comprised of light-colored calcareous sands derived from coral and broken shell material from marine invertebrates. Jaucas sand (JaC) is generally considered archaeologically sensitive since they often contain traditional Hawaiian burials and cultural layers dating from the pre-Contact or early historic period. Mokuleia loam (Ms) consists of well drained soils that formed in recent alluvium deposited over coral sand. Although not sand, the Mokuleia loam (Ms) soil series has a unique relationship to coral sand and often associated with cultural deposits including artifacts and burial.

The two (2) Kualoa Project Sites are located entirely in Mokuleia loam (Ms). The Kaʻaʻawa Valley Project Site is located within Waialua stony silty clay (WIE), Jaucas sand (JaC), and Mokuleia loam (Ms). The Kaʻaʻawa Beach Park Project Site and Puakenikeni Road Project Site are located within Jaucas sand (JaC) and Mokuleia loam (Ms). The Crouching Lion Project Site is located within Mokuleia loam (Ms), Waialua stony silty clay (WIE), Waialua very stony silty clay (WmD), and Kaena very stony clay (KanE). The Punaluʻu South Project Site is located entirely within Jaucas sand (JaC), and the Punaluʻu North Project Site is located entirely within Beach sand (BS). The Hauʻula Project Site is also located entirely within Jaucas sand (JaC).

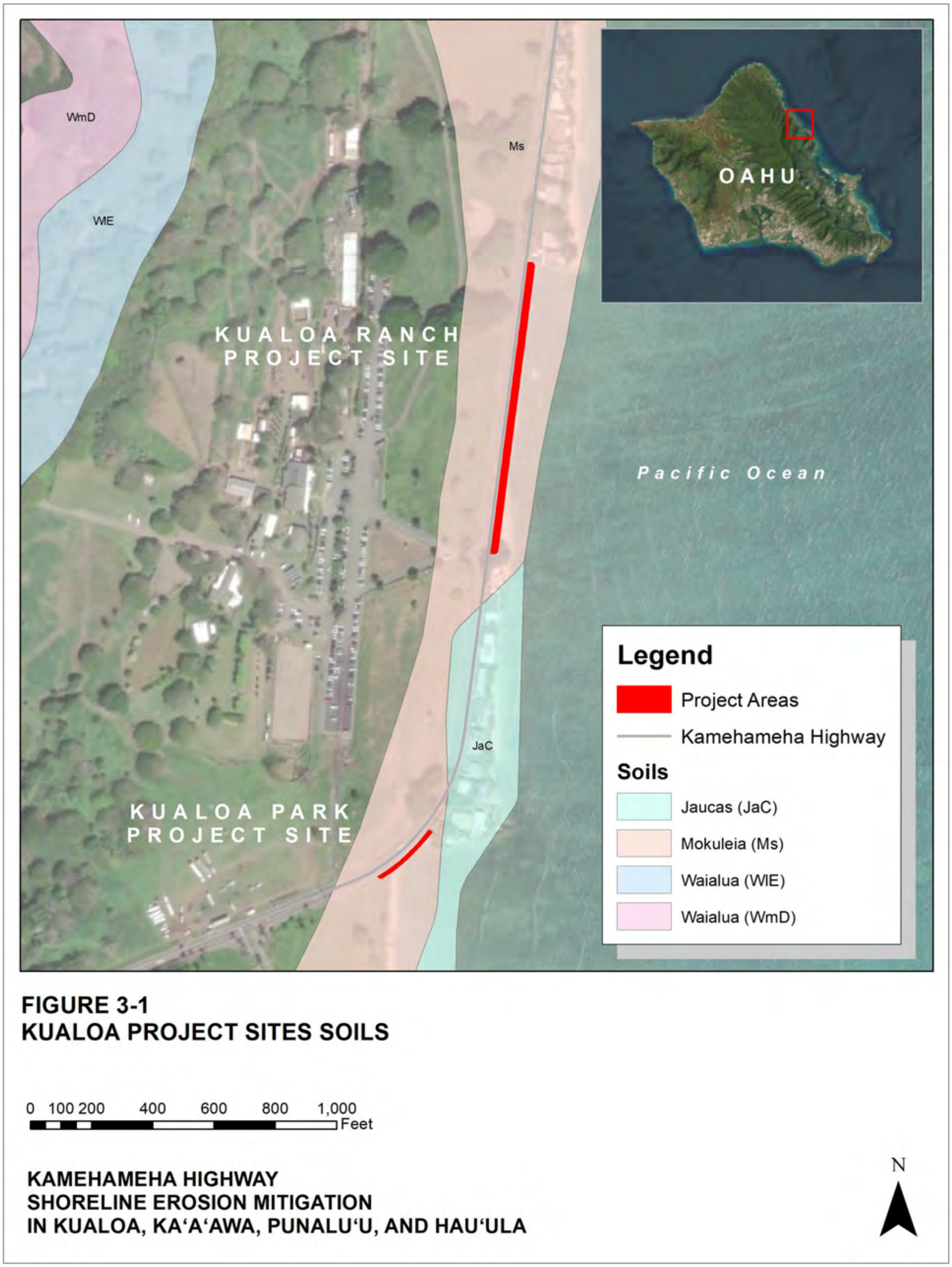


Figure 3-1. Kualoa Project Sites soils.

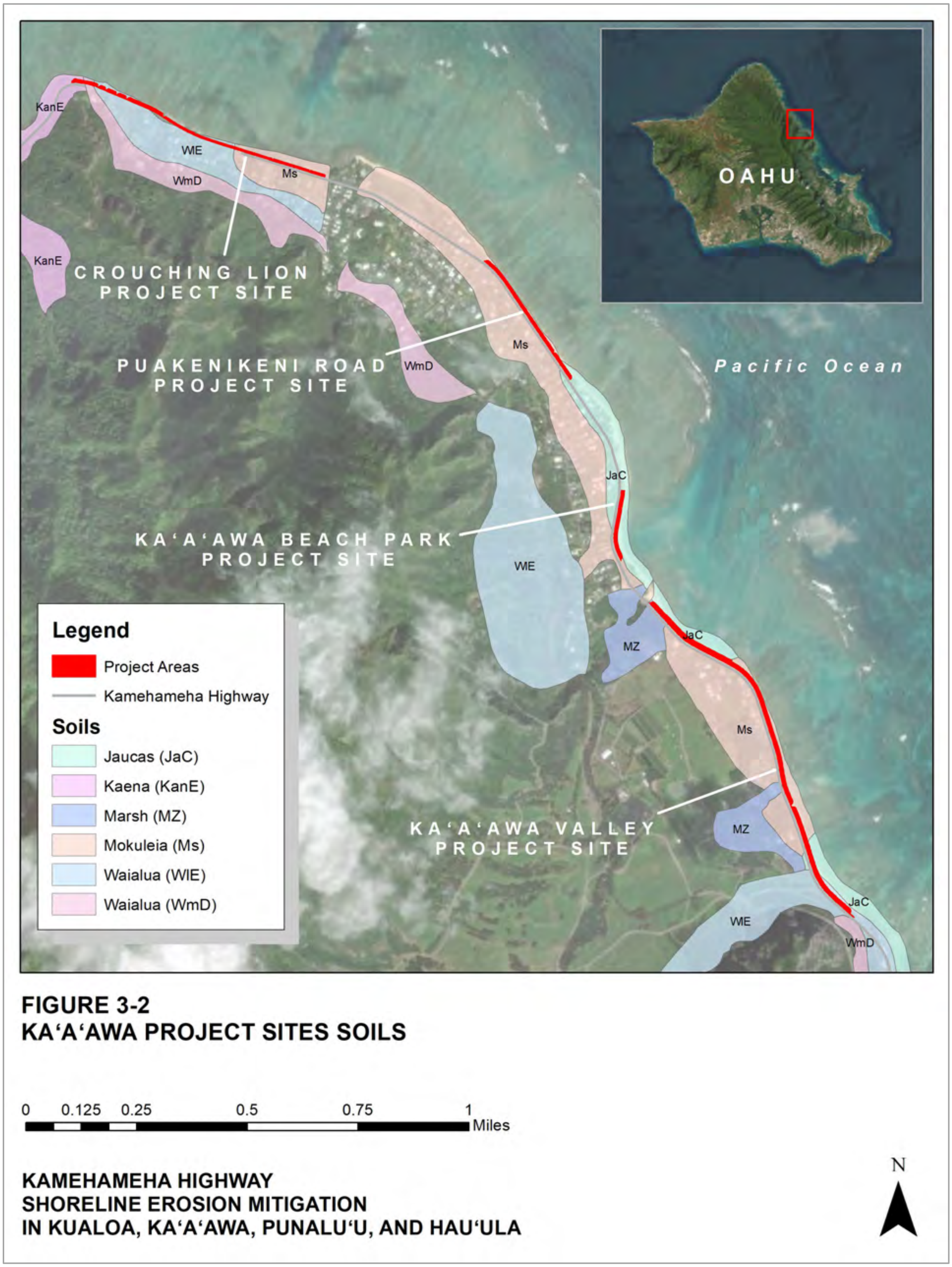


Figure 3-2. Ka‘a‘awa Project Sites soils.

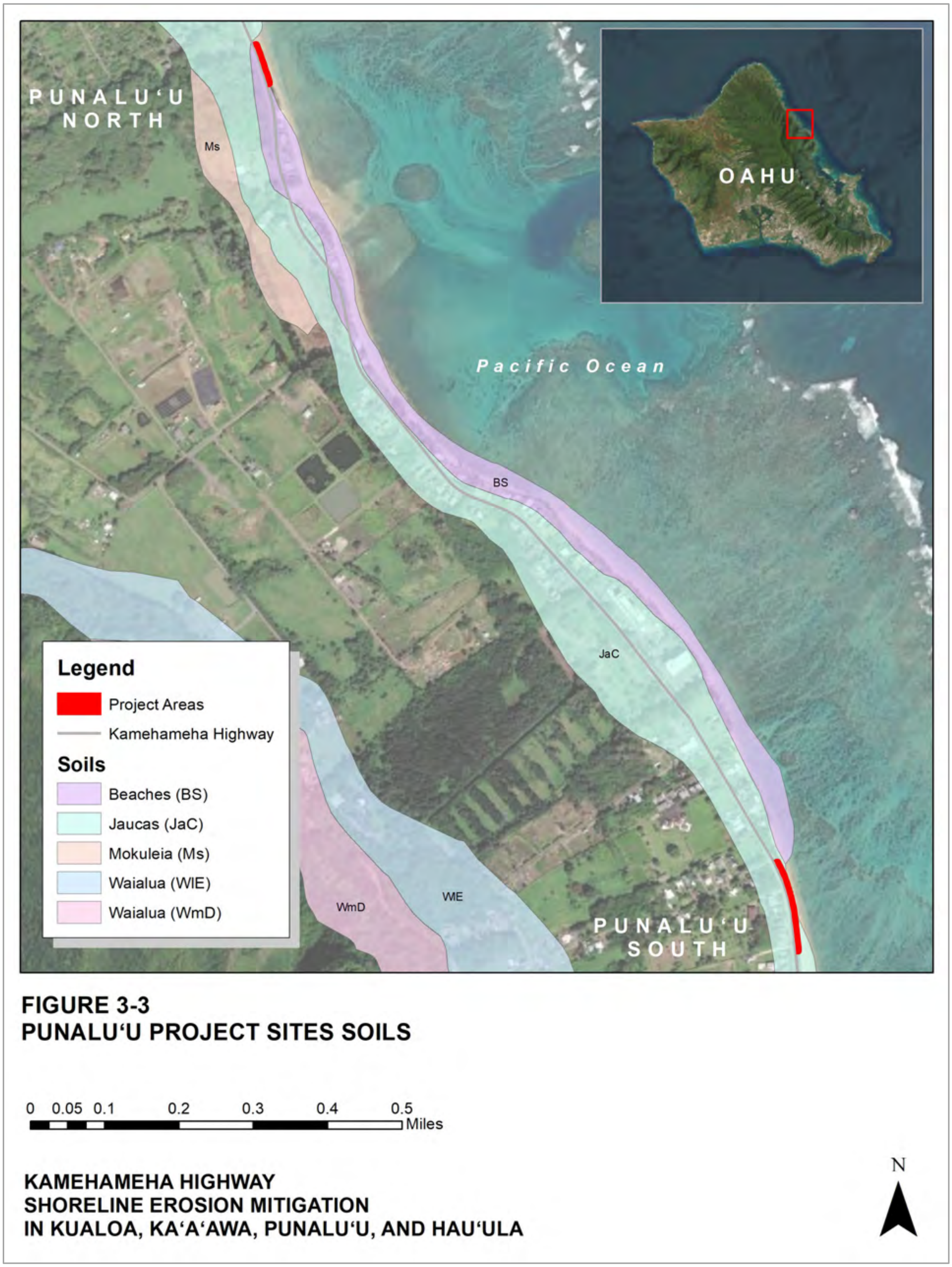


Figure 3-3. Punaluʻu Project Sites soils.

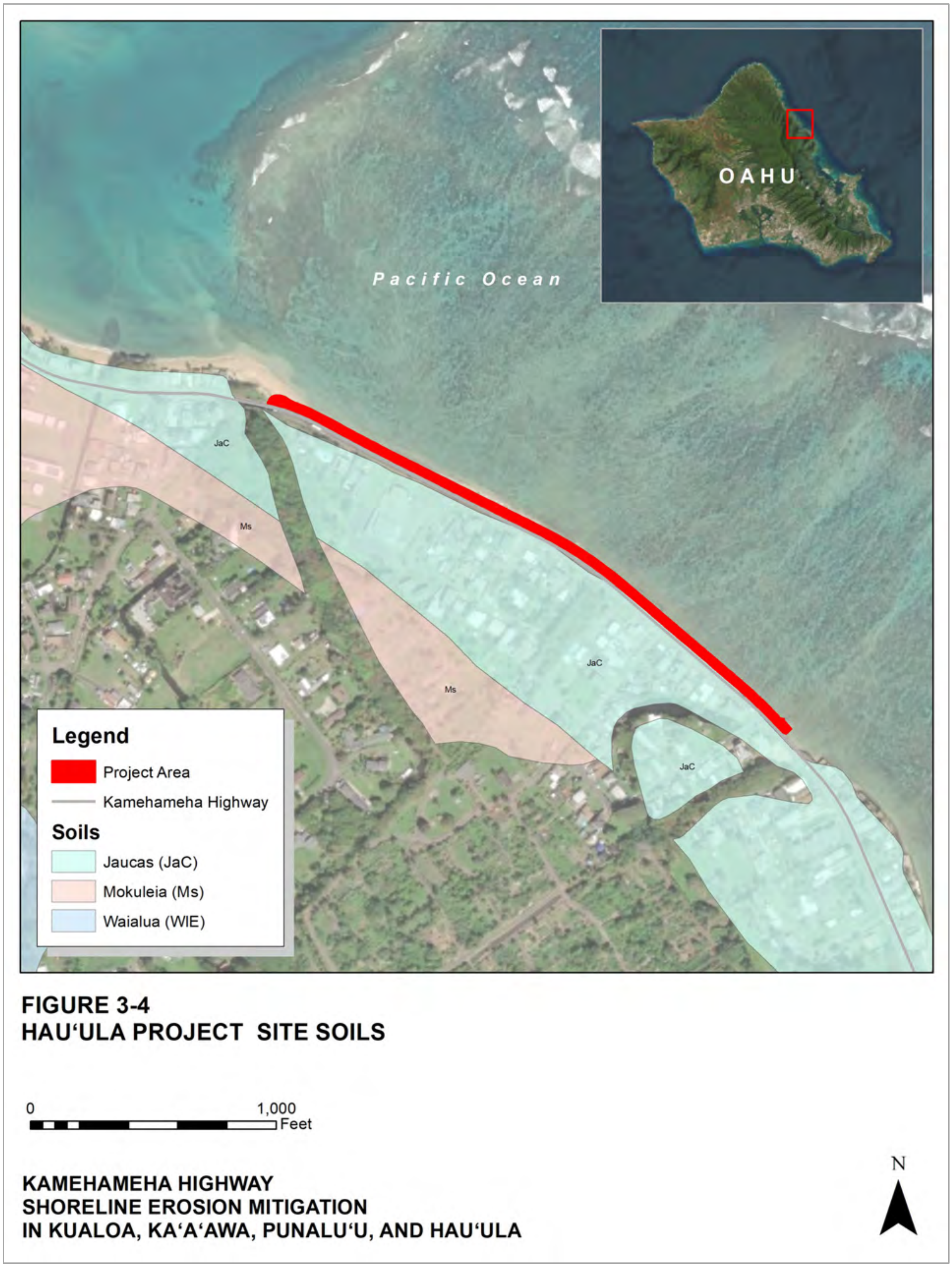


Figure 3-4. Hauʻula Project Site soils.

3.1.2 Potential Impacts and Mitigation Measures

No impacts to existing soils or geological conditions are anticipated.

3.2 Surface Waters and Water Quality

3.2.1 Existing Conditions

The project sites are located on the wet windward side of Oʻahu and span nine (9) watersheds: Kualoa, Kaʻaʻawa, Makaua, Kahana, Punaluʻu, Halehaʻa, Papaʻakoko, Kaluanui, and Waipuhi. There are no streams within the project sites, however, there are several streams located in the vicinity. The Kaʻaʻawa Stream is located just north of the limits of the Kaʻaʻawa Valley Project Site. There are also two (2) culverts associated with minor tributaries of Kaʻaʻawa Stream that run under the roadway just south of the southern end of the Kaʻaʻawa Valley Project Site. The southern end of the Crouching Lion Project Site terminates just before the Makaua Stream, and the northern end of the Crouching Lion Project Site terminates just before Kahana Bay. The southern end of the Hauʻula Project Site terminates just before the Kapaka Stream.

The State of Hawaiʻi Water Quality Standards in HAR Chapter 11-54 classify State waters as either inland or marine. Inland waters are further classified into use categories. The three (3) perennial streams located near the project sites— Kaʻaʻawa , Makaua, and Kapaka—are classified as Inland Class 2 waters. Class 2 waters are protected for their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. Additionally, the regulations state that these waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with Class 2 waters.

The majority of the project sites' coastal waters are classified as Class "A" marine waters. As per HAR 11-54, Water Quality Standards, Class A Marine Waters are "to be protected for recreational purposes and aesthetic enjoyment. Uses are permitted as long as the use is compatible with the protection and propagation of fish, shellfish, and wildlife, as well as with recreation." The northern end of the Crouching Lion Project Site in Kaʻaʻawa terminates at Kahana Bay, which is classified as Class "AA" waters. AA waters are regulated as the most unspoiled in Hawaiʻi. HAR 11-54 mandates that Class AA waters "remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source of actions" (DOH, 2014).

The DOH CWB is responsible for monitoring and protecting quality of State waters in accordance with the Federal CWA and HAR Chapters 11-53 to 11-56. Submerged lands beneath coastal waters are part of the State Conservation District under the regulatory jurisdiction of the DLNR Office of Conservation and Coastal Lands (OCCL).

As part of the 2023 Marine Assessment (Appendix B) for this project, marine water quality was assessed along thirteen (13) transects at each of the project sites to a distance of ten (10) to twenty (20) meters offshore. Water quality results indicate that within five (5) meters of the shoreline, both stream water and groundwater inputs are rapidly mixed with marine waters through wind, wave, and current action. The stormwater runoff is so low that it does not result in levels exceeding DOHʻs water quality standards beyond five (5) meters of the shoreline.

3.2.2 Potential Impacts and Mitigation Measures

The project would require coverage under the existing National Pollutant Discharge Elimination System (NPDES) General Permit for stormwater discharges associated with construction activities. As part of the permit process, a Stormwater Pollution Prevention Plan (SWPPP) and construction site Best Management Practices (BMP) plan would be prepared and include an erosion and sediment control plan, a site-specific plan to minimize erosion of soil and discharge of other pollutants into State waters, and descriptions of post-construction pollutant minimization measures. BMPs would be installed prior to ground-disturbing activities and would be inspected and maintained throughout the construction period.

The project would also require coverage under the NPDES General Permit for discharges associated with construction activity dewatering. As part of the permit process, a site-specific dewatering plan would be prepared.

The project would additionally require a DA permit pursuant to the CWA Section 404 for the discharge of dredged and fill material and a CWA Section 401 WQC from the DOH CWB. A Section 401 WQC is a statement which asserts that a proposed discharge resulting from an activity would not violate applicable water quality standards. The WQC may require an Applicable Monitoring and Assessment Plan to verify compliance with applicable water quality standards. The HDOT would comply with all permit conditions, which would minimize potential impacts to water quality.

All project activities would follow the applicable requirements of HAR Chapter 11-54, Water Quality Standards, and HAR Chapter 11-55, Water Pollution Control, including State antidegradation policy and water quality criteria, and the conditions set forth in the NPDES permit coverage.

The shoreline excavation and placement of stone associated with the construction of the revetments and hybrid seawalls with armor stone aprons would result in the suspension of sand and sediment, temporary reduction in water clarity, and the deposition of sand and sediment. The use of silt curtains would help contain the suspended sediment to within ten (10) feet of the active work area, reducing the area affected by potential water quality impacts. Additionally, construction would proceed along the shoreline in approximately 25-foot increments, limiting the amount of substrate exposed to potential erosion and damaging wave action during construction. The proposed action would not result in an increase of fresh water discharges or concentration of fresh water flows to the marine environment. The accidental release or spill of other pollutants is possible, but not anticipated given the nature of the proposed construction activities and the use of appropriate BMPs.

The project would adhere to following water quality BMPs, that are based on recommendations received from NMFS as part of the pre-assessment consultation. This list of BMPs may be modified or expanded based on further consultation with NMFS, DAR, DOH-CWB and other resources agencies:

- Silt curtains would be used to contain suspended sediment within ten (10) feet of the active work area and would be monitored to detect failure.
- All rocks, boulders, sediment, and materials removed from the marine environment would be dewatered and disposed of in an appropriate upland location.
- All construction activities would cease under unusual conditions, such as large tidal events, storms, and high surf conditions.
- Intertidal work would be conducted at low and or slack tides to the extent feasible.
- To the extent practical in-water construction activities would be avoided during the mass-coral spawning times and peak coral spawning season. The HDOT would coordinate with the local NMFS Habitat Conservation Division to determine the exact period when coral spawning would occur for the given year.
- Work would be conducted during the dry season to the extent practical. Work would stop during storms or heavy rains.
- All equipment would be inspected prior to beginning each work day to ensure that the equipment is in good working condition, and that there is no contaminant leaks. Work would be stopped until all leaks are repaired, and equipment is cleaned. Equipment would be stored in appropriate staging areas when not in use or during fueling.
- Fueling of equipment and project-related vehicles would take place at least fifty (50) feet away from the water and within an impervious containment area.
- The use of treated wood that would be in contact with the water would be avoided. Only materials that are non-toxic to aquatic organisms, such as untreated wood, concrete, or steel would be used.
- Bentonite and other drilling fluids would be prevented from contacting benthic organisms.
- Discharged of chemicals and other fluids dissimilar to seawater would be prevented.

The proposed action would have no impacts to groundwater, wetlands, streams, or other inland surface waters. The revetments and hybrid seawalls are expected to provide beneficial effects for the long-term quality of nearshore water quality since they would minimize ongoing shoreline erosion and mitigate the release of fine soils into the water column from exposed and eroding earthen embankments. The revetments and hybrid seawalls would also offer shoreline protection from wave action, which would therefore decrease the amount of turbidity in nearshore waters.

3.3 Climate, Climate Change, and Sea Level Rise

3.3.1 Existing Conditions

The Hawaiian Island chain is situated south of the large Eastern Pacific semi-permanent high-pressure cell, the dominant meteorological feature affecting air circulation in the Central Pacific basin. Near the Hawaiian Islands, this high-pressure cell persistently produces northeasterly to east-northeasterly winds called trade winds. During the winter months, low pressure systems and their associated cold fronts sweep across the north-central Pacific Ocean, bringing rain and stormy weather to the Hawaiian Islands, intermittently modifying the trade wind regime.

The climate along the Kamehameha Highway shoreline on the windward side of Oʻahu is relatively mild throughout the year, due in part to its location within the trade wind zone and its proximity to the ocean and the Koʻolau mountain range. Winds are predominantly trade winds from the east-northeast, except for occasional periods when "Kona" storms generate strong winds from the south, or when the trade winds are weak and land breeze to sea breeze circulations develop. Trade wind speeds average between 5 and 15 miles per hour providing relatively good ventilation throughout the island.

Temperature and Rainfall

Due to the tempering influence of the Pacific Ocean and the low-latitude tropical location of the Hawaiian Islands, the islands experience extremely small diurnal and seasonal variations in ambient temperature. Temperatures along the shoreline that encompass the project area are moderate with an average monthly minimum and maximum temperatures ranging from 72 degrees to 83 degrees Fahrenheit. Rainfall along the shoreline ranges from 53 inches in Kualoa to 70 inches in Punaluʻu (University of Hawaiʻi at Mānoa Rainfall Atlas, 2023). The persistent northeast trade winds, in combination with the islands' high relief topography, evolved to become the two (2) primary factors that influence the amount of precipitation that falls on a given location on Oʻahu or the rest of the Hawaiian Islands.

Sea Level Rise

Sea level rise continues to threaten coastal communities by damaging homes and roadway infrastructure. Current projections indicate that differences between sea level scenarios are closely associated with differences in potential anthropogenic greenhouse gas emissions pathways and associated global warming. Climate change is the biggest driver of rising sea levels. As global land-based ice sheets and mountain glaciers melt, and marine waters warm causing thermal expansion, global sea level continues to rise at an unprecedented rate. Tropical and specifically coastal regions are most vulnerable to the impacts of sea level rise due to their proximity to marine waters. Even small changes in sea level can cause increased flooding due to storm surges, high tides, and sinking land along coastlines that amplify flooding in some regions.

Figures 3-5 to 3-8 display the extent of 1.1 feet of sea level rise by 2050 and 3.2 feet of sea level rise by 2100. These exposure areas are from the 2017 Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report, which is based on an upper-end projection in the 2013 Intergovernmental

Panel on Climate Change Fifth Assessment Report of 3.2 feet of global MSL rise by 2100. Based on this, the Hawaiʻi Climate Change Adaptation and Mitigation Commission recommends planning for 3.2 feet of sea level rise by 2100.

However, the science on sea level rise observations and forecasts has continued to advance. More recent scientific literature points to 3 to 4 feet of sea level rise by 2100 as a mid-range, rather than high-end, scenario for Hawaiʻi. In 2017, NOAA revised their sea level change projections through 2100 considering up-to-date scientific research and measurements (Sweet et al., 2017). According to the NOAA global sea level rise projections, the intermediate scenario represents approximately 3.3 feet of sea level rise by 2100 and the extreme scenario represents more than 8 feet of sea level rise by 2100 (Figures 3-5 to 3-8). The extreme scenario in the NOAA report corresponds to a continued trajectory of increasing greenhouse gas emissions (i.e., no reductions in the increasing rate of emissions) and worst case for glacier and polar ice loss in this century.

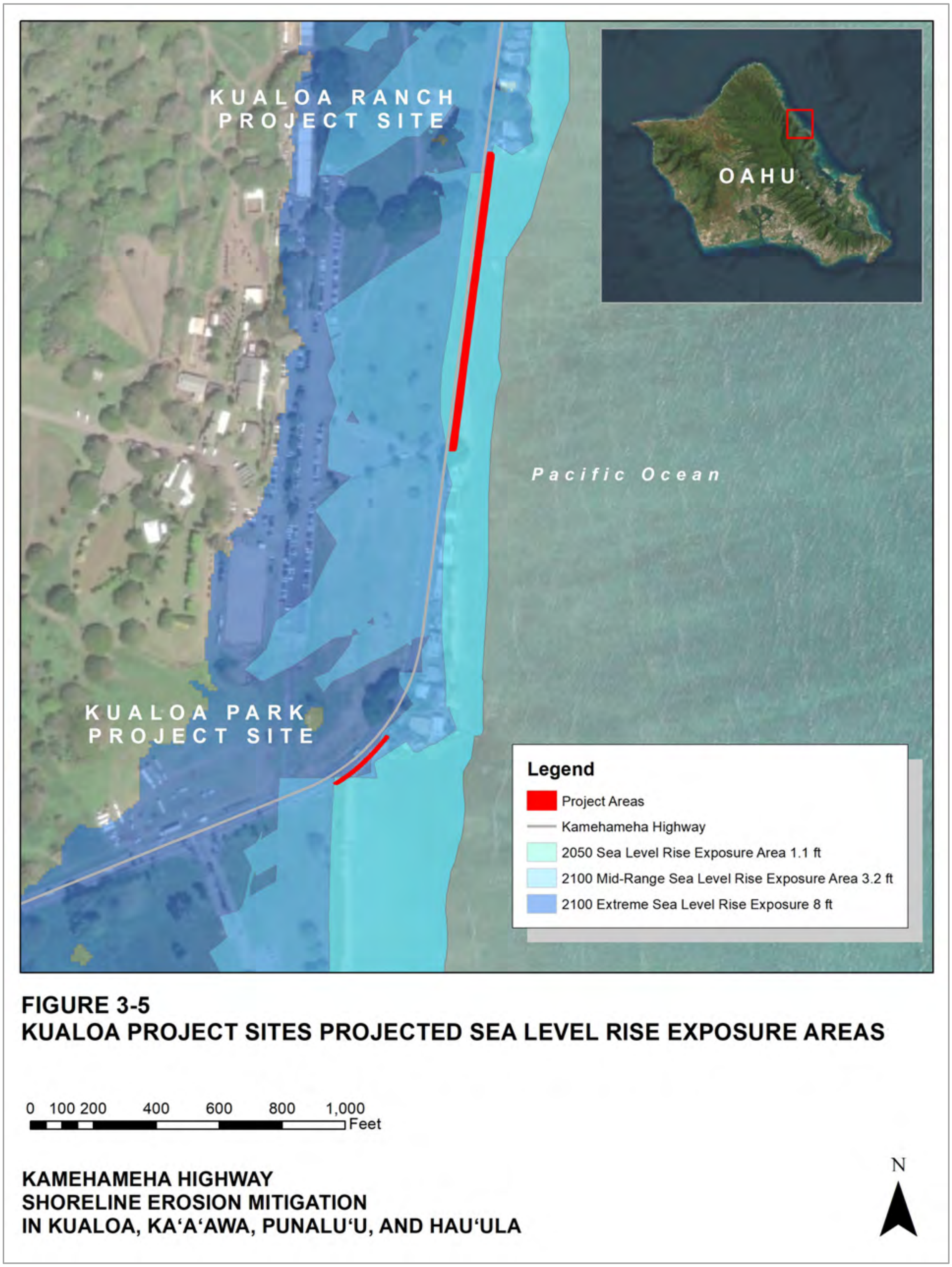


Figure 3-5. Kualoa Project Sites projected sea level rise exposure areas.

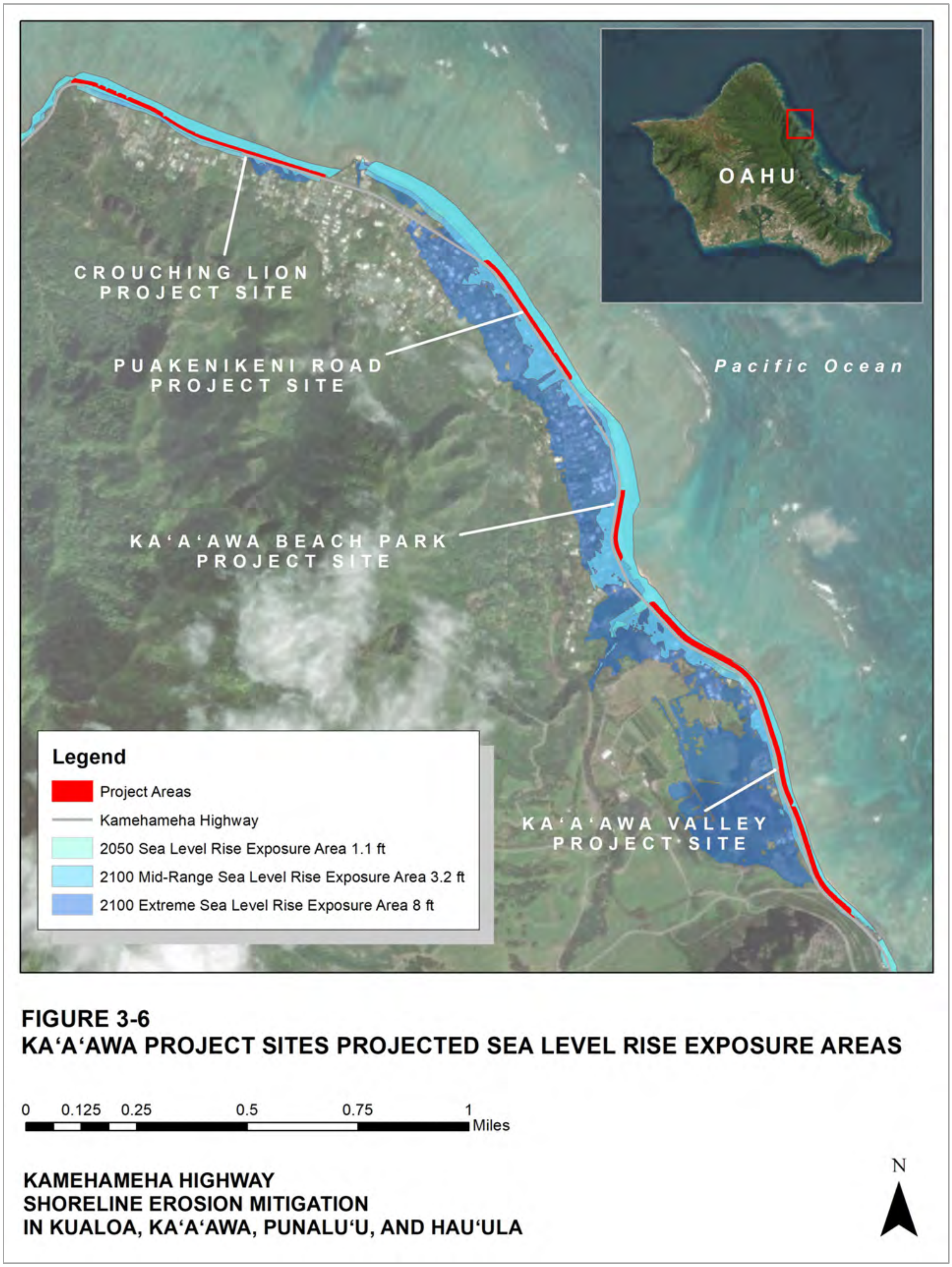


Figure 3-6. Ka'a'awa Project Sites projected sea level rise exposure areas.

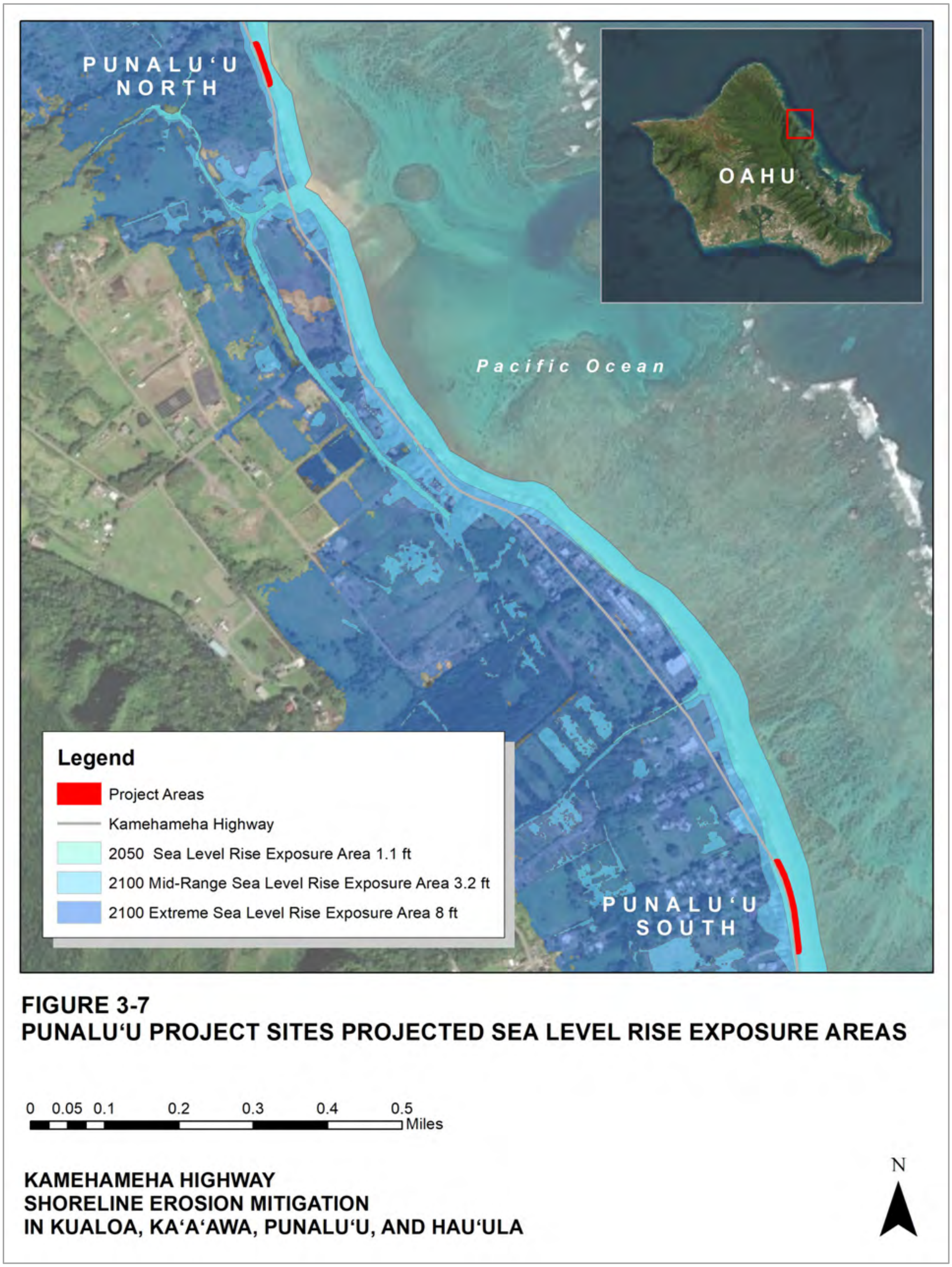


Figure 3-7. Punalu'u Project Sites projected sea level rise exposure areas.

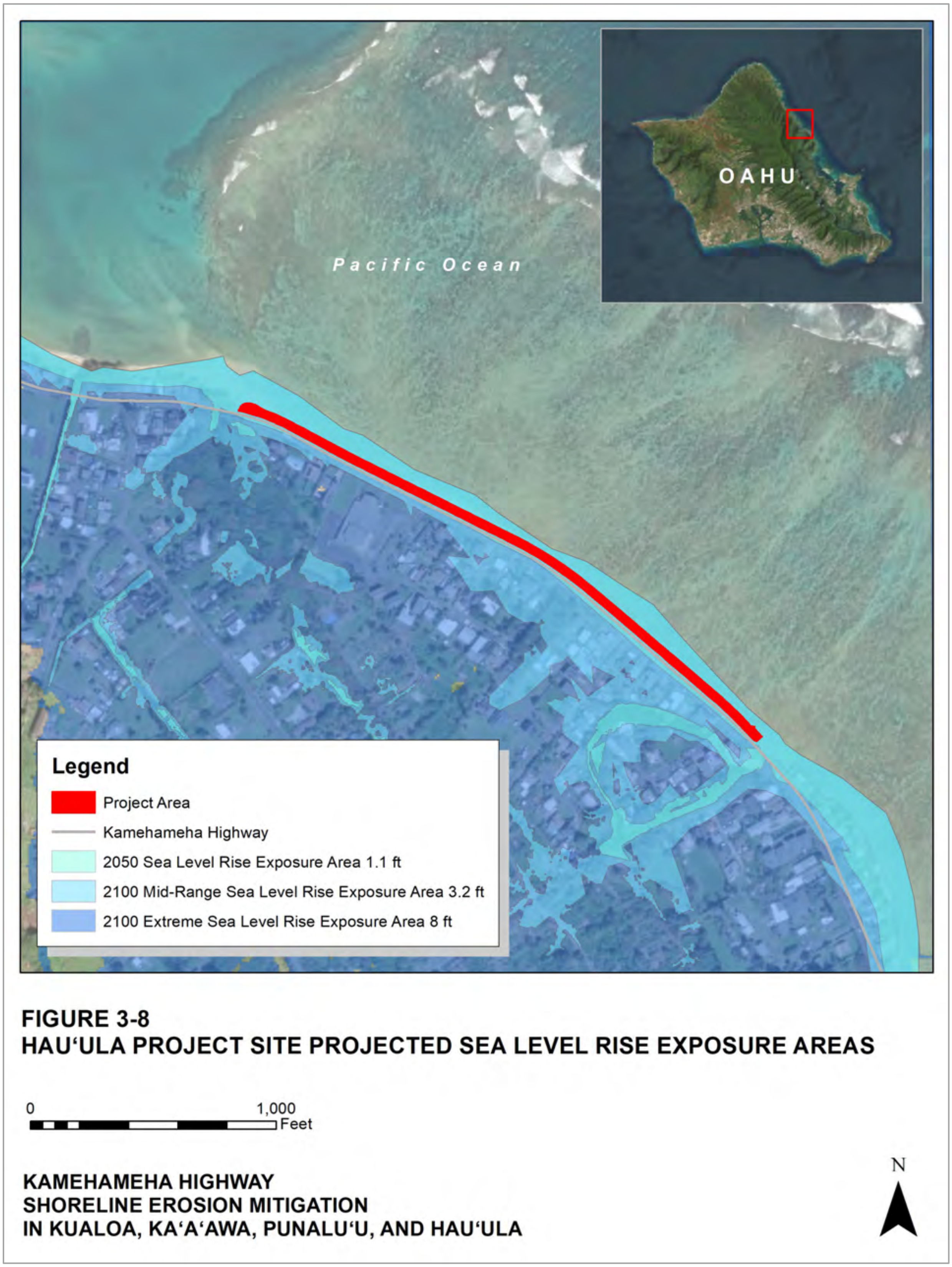


Figure 3-8. Hau‘ula Project Site projected sea level rise exposure areas.

3.3.2 Potential Impacts and Mitigation Measures

The proposed project is not anticipated to have any impacts on temperatures or rainfall. Additionally, the proposed shoreline protection structures would have little to no effect on the progression of climate change; however, they would increase the mid-term resilience of the highway from rising sea levels by protecting the roadway foundation and supporting embankment from coastal erosion and undermining, while also generally reducing wave runup, overtopping, and over-wash onto the road deck.

Based on the sea level rise projections presented in Figures 3-5 through 3-8, the project sites and the adjacent coastal communities would be impacted by sea level rise. The intent of the project is to mitigate coastal erosion and highway failures for the next 25 years until a long-term solution to sea level rise can be identified and implemented. The proposed rock revetments and hybrid seawalls may help to minimize the impacts of sea level rise on highway infrastructures for the near- to mid-term (next 25 years) but would not mitigate the long-term impacts of sea level rise to the highway. The proposed shoreline stabilization measures would not worsen sea level rise impacts at the project site or in the adjacent communities. The proposed rock revetments and hybrid sea walls are potentially removable structures that could be modified or removed as needed to allow for construction or implementation of alternative shoreline protection and sea level rise adaptation measures. The rock revetments and hybrid seawalls would not preclude and could remain and continue to be used in combination with other future shoreline protection and sea level rise adaptation measures that could include beach nourishment, traditional fishpond restoration, or managed retreat.

3.4 Oceanographic Setting

3.4.1 Existing Conditions

General Wind Climate

The prevailing winds throughout the year are the northeasterly trade winds. Average trade wind frequency varies from more than 90% during the summer season to only 50% in January, with an overall annual frequency of 70%. Westerly or Kona winds occur primarily during the winter months and are generated by low pressure systems that typically move north of the islands from west to east.

Trade winds are generated by the outflow of air from the Pacific Anticyclone high-pressure system, also known as the Pacific High. The center of this system is typically located well north and east of the Hawaiian Islands and moves to the north and south seasonally. In the summer months (May through September), the center moves to the north, causing the trade winds to be at their strongest. In the winter months (October through April), the center moves to the south, resulting in decreasing trade wind frequency. During these months, the trade winds continue to blow, however, their average monthly frequency decreases to 50%.

During the winter months, wind patterns of a more transient nature increase in prevalence. Winds from extra-tropical storms can be very strong from almost any direction, depending on the strength and position of the storm. The low-pressure systems associated with these storms typically track west to east across the North Pacific, north of the Hawaiian Islands. At the Daniel K. Inouye International Airport in Honolulu, wind speeds resulting from these storms have exceeded 60 miles per hour on several occasions. Kona winds are generally from a southerly to a southwesterly direction and are usually associated with slow-moving low-pressure systems, or cold-core cyclonic storms known as Kona lows situated to the west of the Hawaiian Islands. These storms are often accompanied by heavy rains.

General Wave Climate

Ocean waves that affect people and the built environment on a normal basis (excluding tsunami) can generally be categorized into three groups, including: long period swell (characteristically with periods between 12 to 20+ seconds) generated by distant north or south Pacific storm systems; short period wind waves (typically with 6 to 12 second periods) generated by regional winds; and, the unpredictable and episodic wave events associated with intense local storms or cyclones (with periods often between 11 and 17 seconds). More specifically, the Hawaiian Islands receive waves from six well-documented sources, which are: (1) northeast trade winds waves; (2) southeast trade winds waves from the near southern hemisphere; (3) south swells from the far southern hemisphere; (4) north swells from the Aleutians or other parts of the North Pacific; (5) Kona storm wind waves; and (6) hurricane waves.

Trade wind waves occur throughout the year and are typically most persistent from April through September when they tend to dominate the wave climate in Hawaiian waters. These waves are produced from the strong and persistent trade winds, generally blowing from the northeast quadrant, over long fetches of open ocean in the east and central pacific. The deep-water wave conditions for this source are typically between 3 to 8 feet high, with periods of 6 to 12 seconds depending on maximum wind speeds and how far east of the Hawaiian Islands the fetch extends. The direction of approach, like the trade winds themselves, varies between north-northeast and east-southeast and is centered in the east-northeast direction. The project sites along the northeast shoreline of O‘ahu (Ko‘olauloa) are fully exposed to the direct approach of trade winds and trade wind waves and are a significant component for the project site’s design conditions.

During the winter months in the northern hemisphere, strong storms frequently track through the North Pacific’s mid-latitudes (40 to 50 degrees north latitude), often near the Aleutian Islands. These storms generate the well-known large North Pacific swells made famous by their large surf breaks at the North Shore, that range in direction from west-northwest to northeast and arrive at north-facing Hawaiian shores with little loss of energy. Deep water wave heights often reach 15 feet and in extreme cases can reach up to 40 feet. Periods vary between 12 and 20+ seconds, depending on the track and intensity of the originating storm. Because of the northerly component, these waves can also have a significant impact on northeast-facing shores of O‘ahu, including the project sites.

South swells are generated by intense storms thousands of miles away in the southern hemisphere's mid latitudes and are most prevalent during the late spring and summer months of April through September. Traveling distances of up to 5,000 miles, these waves arrive with relatively small deep-water wave heights of 1 to 5 feet but characterized with having long periods of 15 to 20+ seconds. South swells' direction of approach to the Islands is typically between southwest to southeast, depending on the originating storm's track across the Southern Ocean. The project sites' shorelines, which face northeast, are fully sheltered from swells from this approach by the island of Oʻahu itself.

Wind swell from Kona storms is episodic and relatively infrequent, occurring usually about 10% of the time during a typical year. A Kona storm is a seasonal cyclone, generally classified as extratropical (cold core), which typically approaches the islands with strong westerly to southwesterly winds that can also bring additional hazards such as heavy rain, flash flooding, hail, and even blizzards at high elevations such as on the upper slopes of Mauna Kea or Haleakalā. Kona wind waves are typically experienced as short period wind swell, which range in period from 6 to 10 seconds, along with wave heights of 5 to 20 feet from the west to southwest. The project sites are sheltered from Kona storm wind swell, however, the associated high winds that are funneled by the steep mountain slopes and valleys can be very damaging as they blow offshore, sometimes accompanied by torrential downpours that can affect the drainage along portions of the project area (Sea Engineering Inc., 2022).

3.4.2 Potential Impacts and Mitigation Measures

The proposed shoreline erosion mitigation improvements are not anticipated to have an effect on the oceanographic setting. The proposed revetments and hybrid seawalls would help protect the shoreline and highway from general wind and wave climates.

The proposed installations of rock revetments and hybrid seawalls are designed to dissipate wave energy and minimize overtopping through absorption of the water's momentum by forcing percolation of wave runup into the porous slopes of the structures. Likewise, the porous structures are also expected to reduce reflected wave energy. The decrease in wave energy and water movement in the direct vicinity of the structures is expected to have a potentially beneficial impact on sand accretion along the project sites, depending on the availability of sediments and beach material in the area. The absorptive structures would also benefit nearby surf spots by reducing harmful wave backwash and chop generated by wave reflections at the shoreline. There are no anticipated short-term or long-term impacts on the larger-scale regional coastal wave environment.

3.5 Coastal Hazards

3.5.1 Existing Conditions

Flood Inundation

The Federal Emergency Management Agency (FEMA) considers rivers, heavy rain, poor drainage, and coastal flooding to be factors that can influence flood damage. The National Flood Insurance Program, administered by FEMA, creates maps that indicate areas of high vulnerabilities known as Flood Insurance Rate Maps. Figures 3-9 to 3-12 display the project sites in relation to their respective FEMA designated flood zones.

The Kualoa Park and Kualoa Ranch Project Sites are located in Flood Zone X (Figure 3-9). Flood Zone X includes areas of minimal flood hazard, that are higher in elevation than the 0.2-percent-annual-chance of flooding or 500-year flood event.

The Kaʻaʻawa Valley Project Site is located in Flood Zones AE, VE, and X (Figure 3-10). The northern portion of the Kaʻaʻawa Beach Park Project Site is located in Flood Zone VE and the southern portions is located in Flood Zone AE (Figure 3-10). The Puakenikeni Road Project Site is located in Flood Zone VE (Figure 3-10). The Crouching Lion Project Site is located in Flood Zones X and VE (Figure 3-10).

The Punaluʻu South, Punaluʻu North, and Hauʻula Project Sites are located in Flood Zone VE (Figures 3-11 and 3-12).

Zone AE is described as having a 1% chance of annual flooding, based on the 100-year flood. Zone VE is characterized as a high-risk coastal area due to storm-induced high velocity wave action, where storm waves and flooding can cause extensive damage. Flood Zones AE and VE are classified as Special Flood Hazard Areas by FEMA and regulated by City and County of Honolulu (CCH) in accordance with Revised Ordinances of Honolulu (ROH) Chapter 21A.

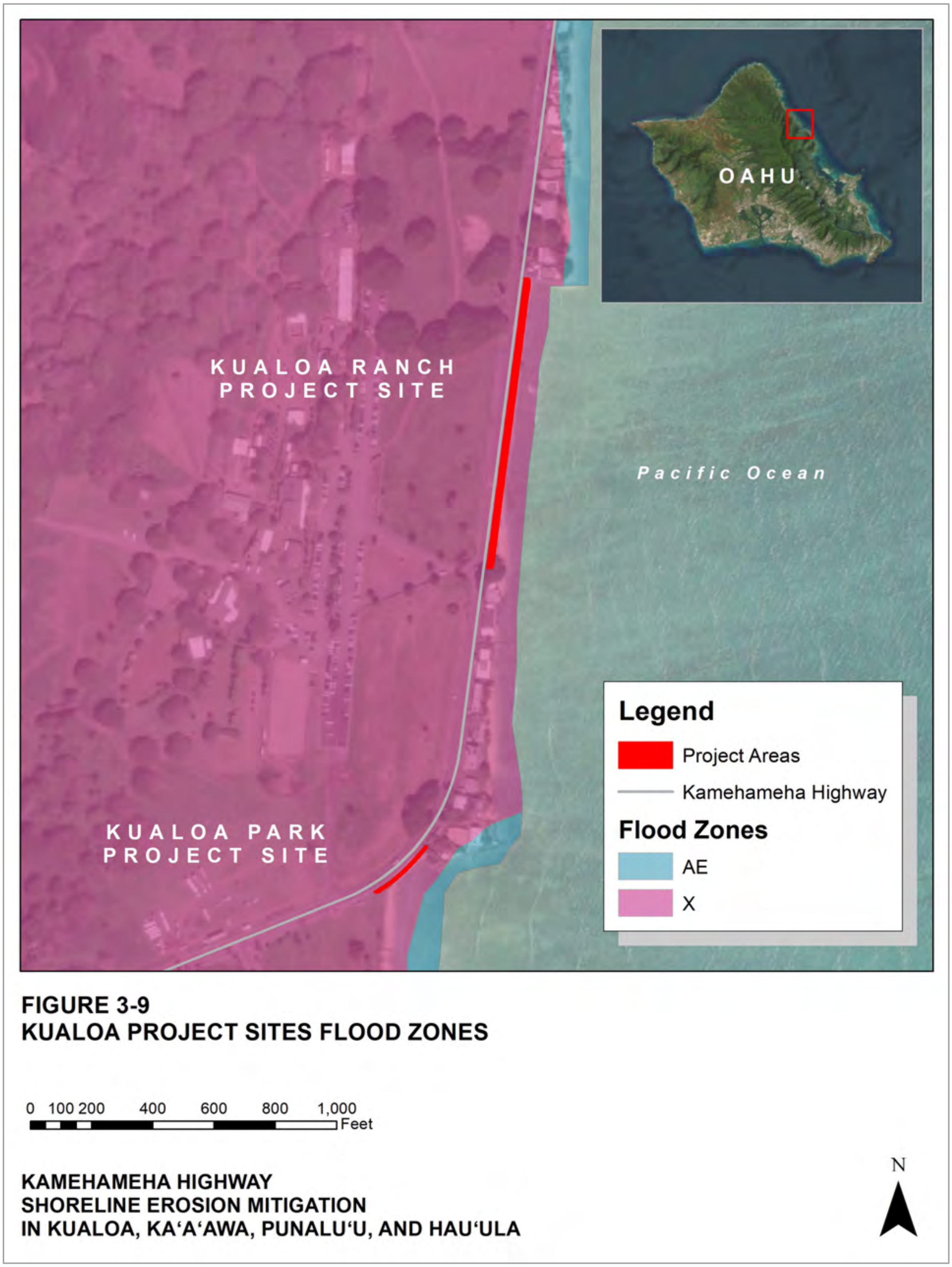


Figure 3-9. Kualoa Project Sites flood zones.

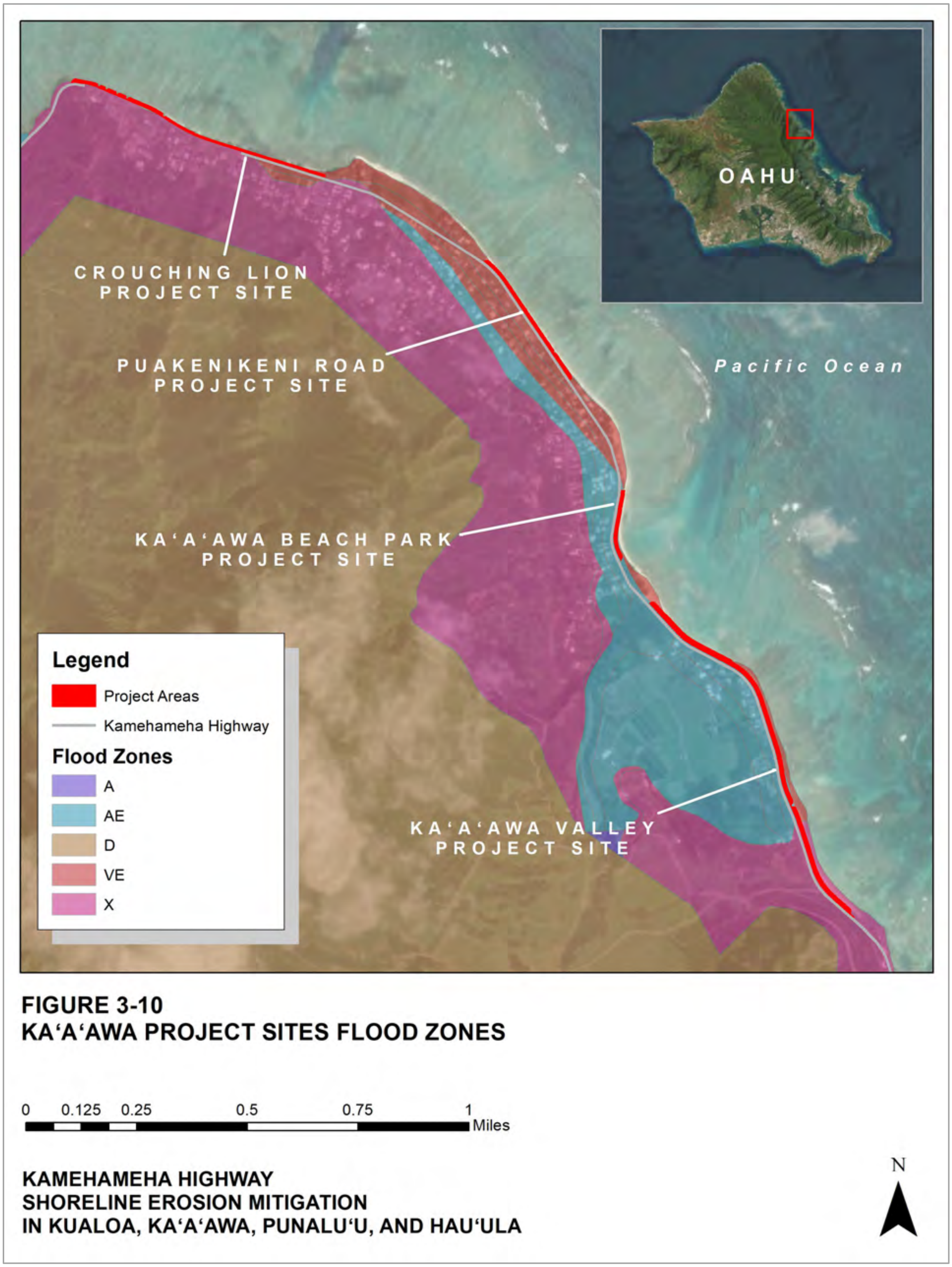


Figure 3-10. Kaʻaʻawa Project Sites flood zones.

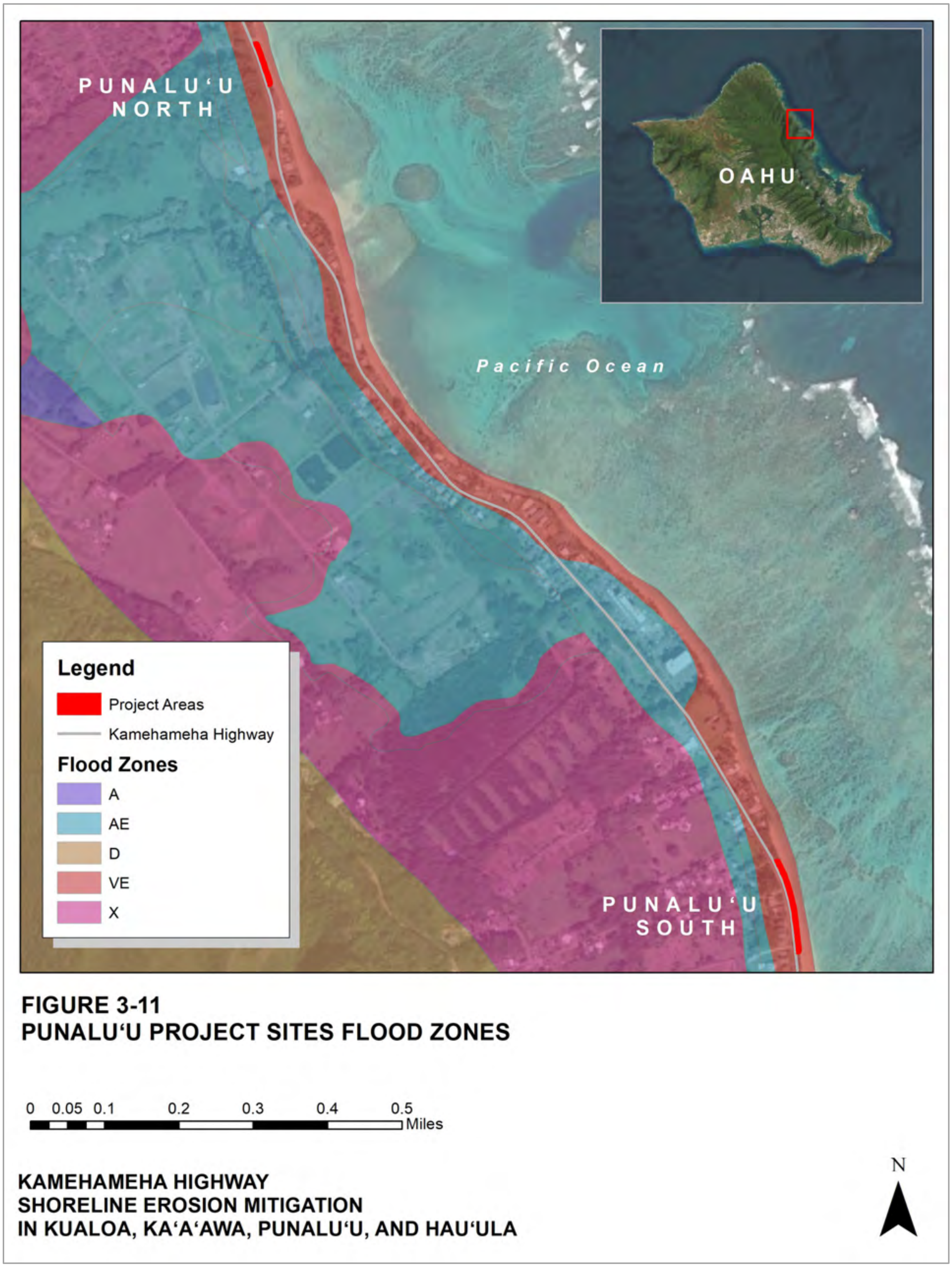


Figure 3-11. Punaluʻu Project Sites flood zones.

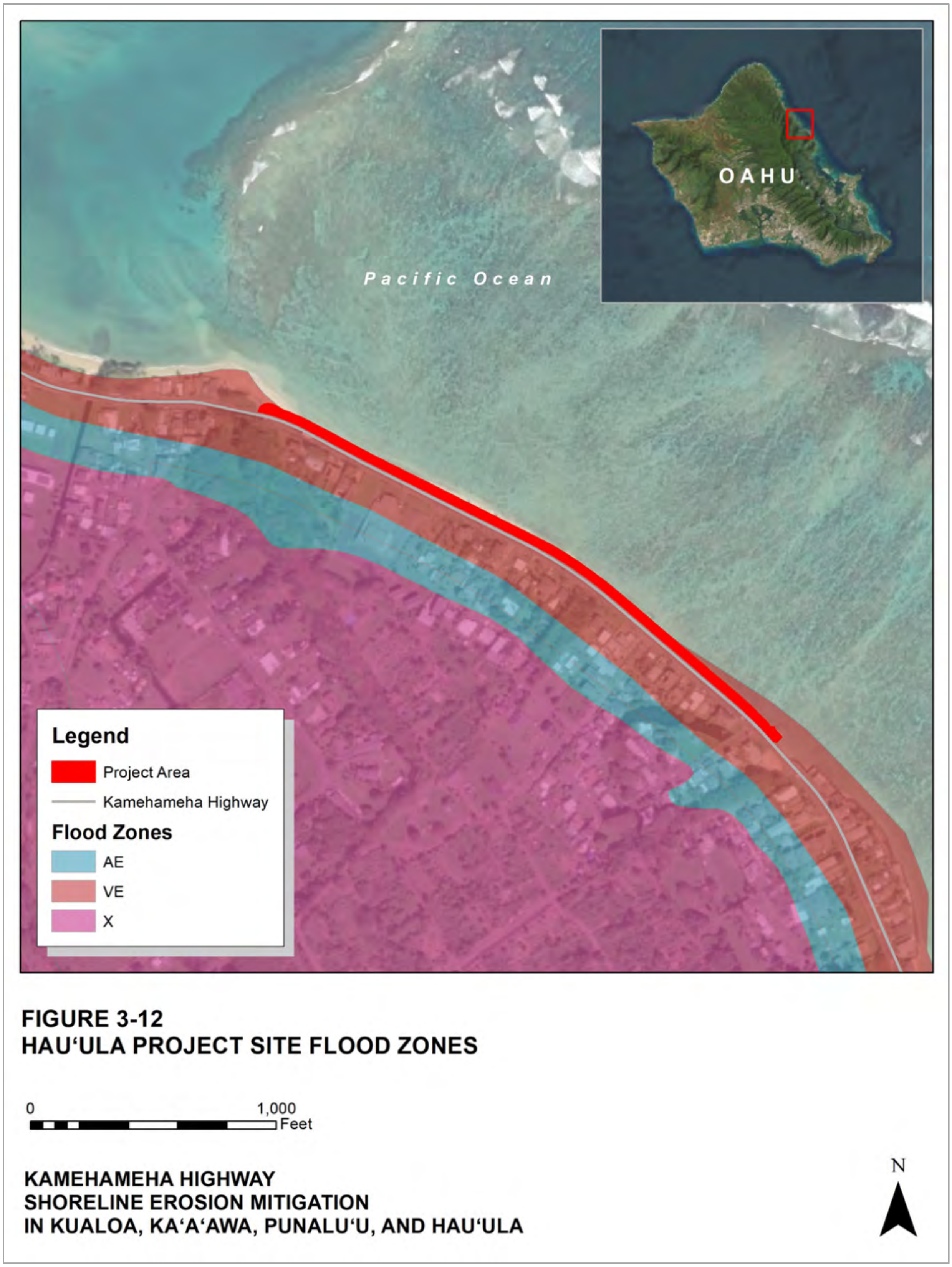


Figure 3-12. Hauʻula Project Site flood zones.

Tsunami Inundation

Tsunamis are natural phenomena that occur in the Earth's oceans and are usually triggered by underwater disturbances, such as earthquakes, volcanic eruptions, or underwater landslides. They are characterized by a series of ocean waves that travel across vast distances, causing significant damage and loss of life when they reach coastal areas. All the project sites in Kualoa, Kaʻaʻawa, Punaluʻu, and Hauʻula are on the northeastern coast of Oʻahu in the tsunami evacuation zone (Figure 3-13 – Figure 3-16).

Tsunamis are primarily generated by underwater disturbances. When tectonic plates beneath the ocean floor shift suddenly, they release a tremendous amount of energy. The energy displaces large amounts of water above quickly, generating powerful tsunami waves that radiate outward from the earthquake's epicenter. There are two (2) measures that express features of tsunamis, magnitude, and intensity. The magnitude corresponds to the total energy, and intensity is the local strength of the tsunami at a given location. Tsunamis can have wavelengths on the order of hundreds of miles and travel at speeds near 500 miles per hour. In all cases waves transmit energy, not water, across the ocean and if not obstructed they have the potential to traverse across an entire ocean basin.

Most tsunamis that have impacted the state of Hawaiʻi originated in the Pacific Ocean's "Ring of Fire," a geologically active area where tectonic shifts make volcanoes and earthquakes common. Seismic waves originating at the Ring of Fire would reach Hawaiʻi in only a few hours. The United States National Weather Service Pacific Tsunami Warning Center currently has thirty-nine (39) observational buoys throughout the Pacific Ocean. The complex network of sensors can provide Hawaiʻi several hours of advanced warning for a tsunami.

Tsunamis and floods pose serious risks to coastal communities and can cause significant damage to roadway infrastructure. When a tsunami reaches the shoreline, it can cause a sudden and powerful surge of water, leading to widespread flooding in coastal areas. The force and volume of water carried by a tsunami can result in the destruction of buildings, infrastructure, and coastal defense. The inundation of land areas by water makes coastal regions particularly vulnerable which can result in the submersion of infrastructure, damage to buildings and roadways, and disruption of essential services.

FIGURE 3-13
KUALOA PROJECT SITES TSUNAMI INUNDATION ZONES

0 100 200 400 600 800 1,000 Feet

KAMEHAMEHA HIGHWAY
SHORELINE EROSION MITIGATION
IN KUALOA, KA'A'AWA, PUNALU'U, AND HAU'ULA

N

Figure 3-13. Kualoa Project Sites tsunami inundation zones.

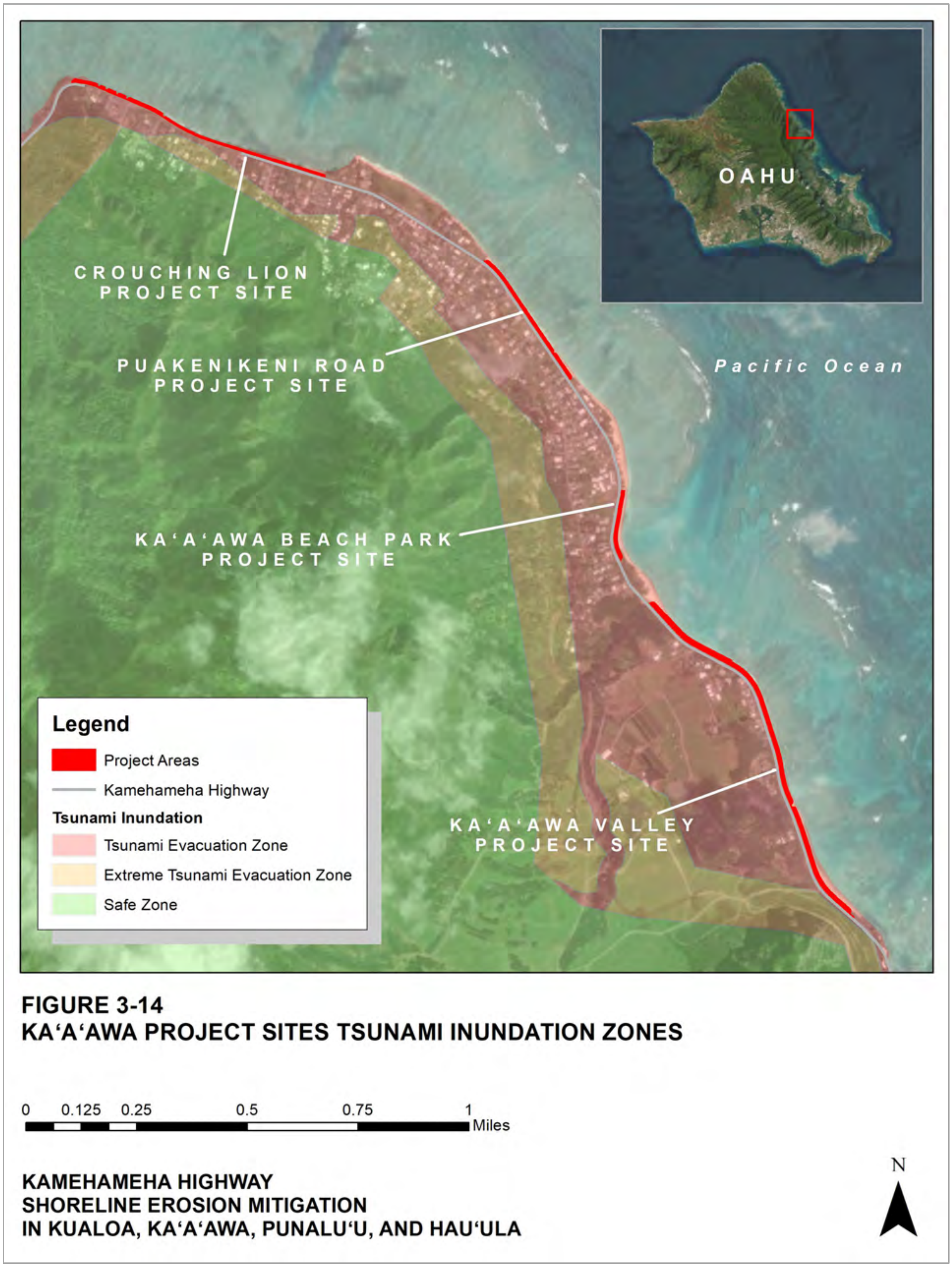


Figure 3-14. Ka'a'awa Project Sites tsunami inundation zones.

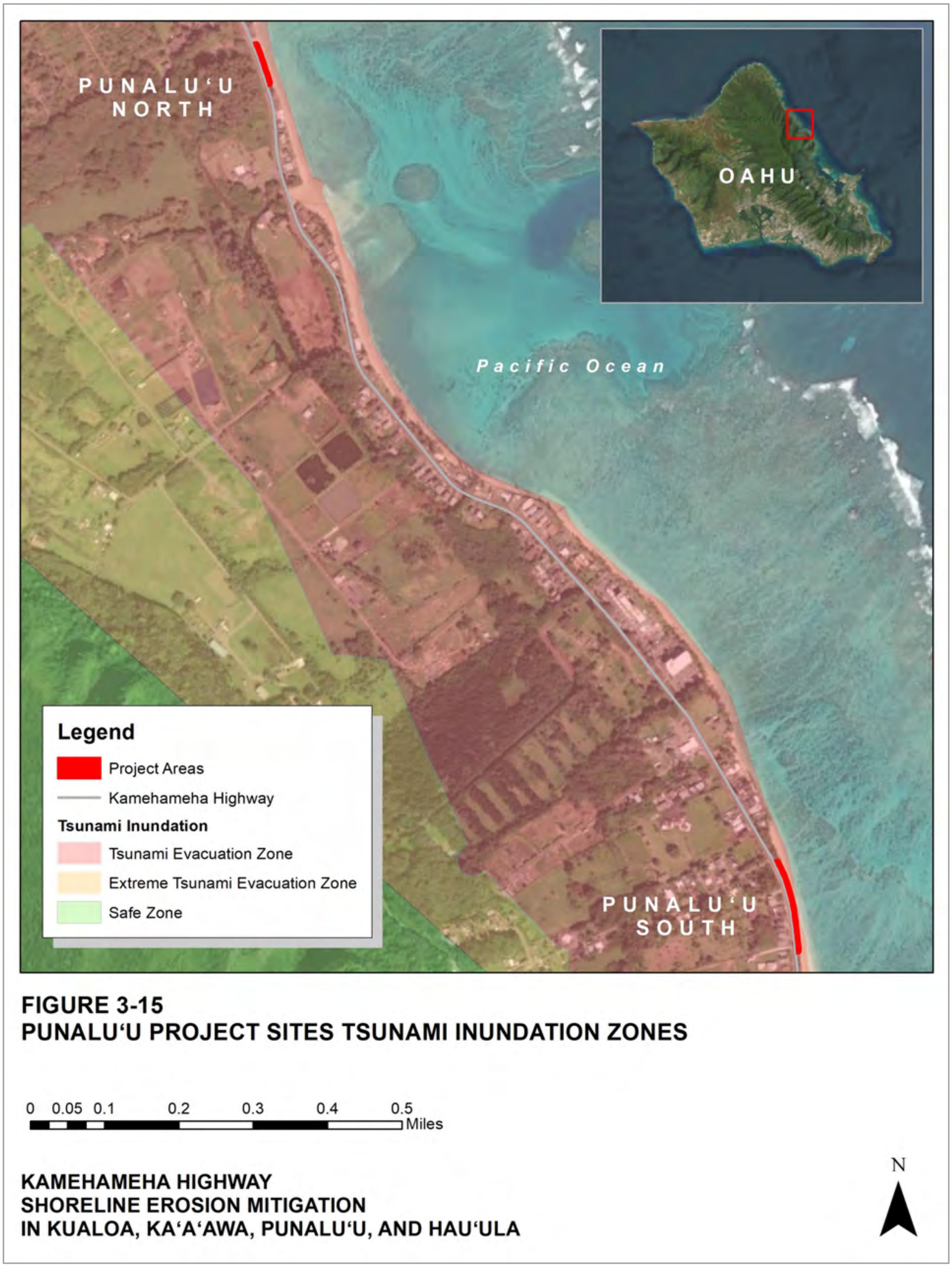


Figure 3-15. Punaluʻu Project Sites tsunami inundation zones.

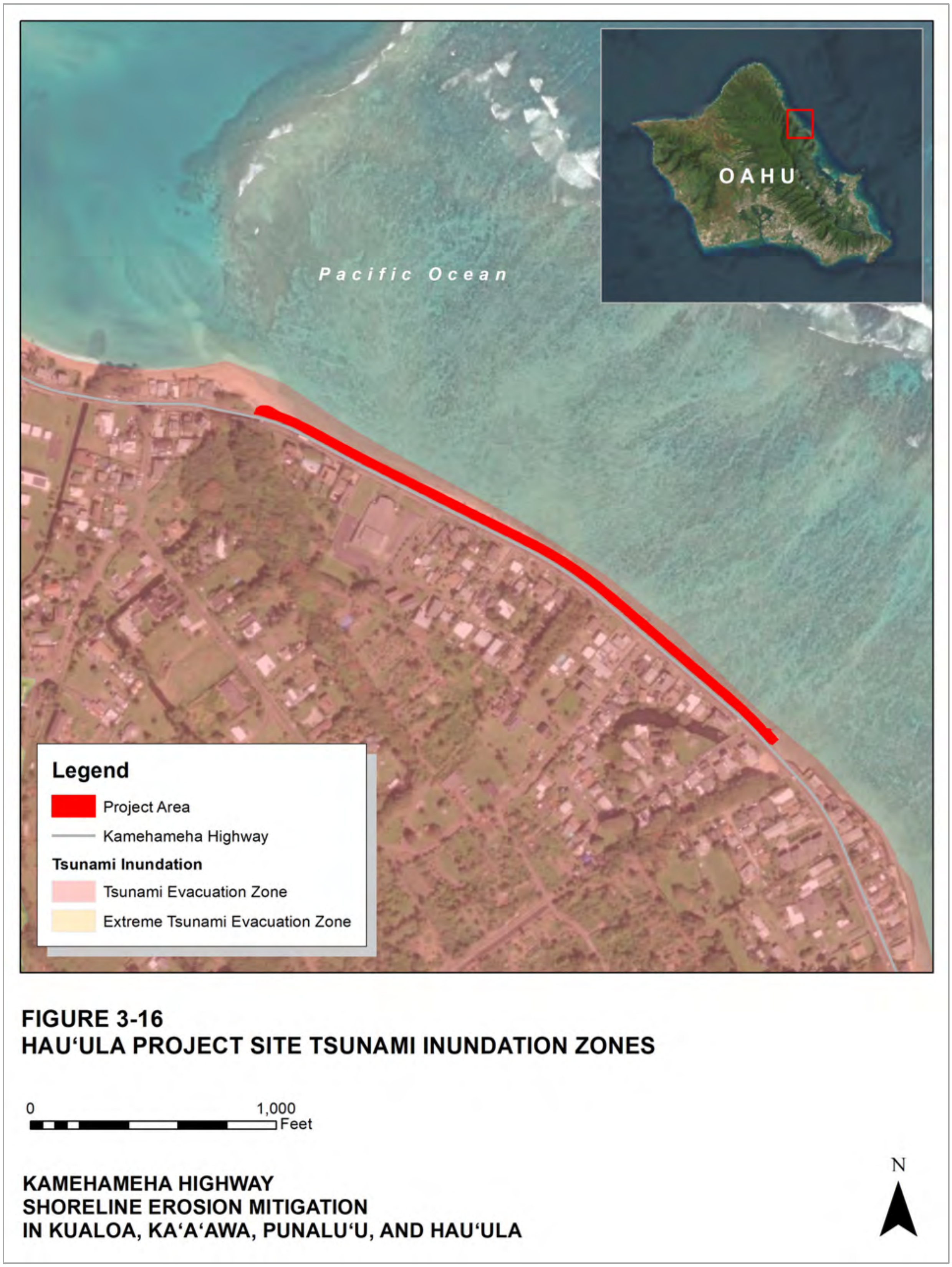


Figure 3-16. Hauʻula Project Site tsunami inundation zones.

3.5.2 Potential Impacts and Mitigation Measures

The proposed shoreline erosion mitigation improvements would not increase the likelihood or worsen the effects of coastal hazards. The proposed revetments and hybrid seawalls would help protect the shoreline and highway from coastal flooding and tsunami damage. The highway would play a critical role in providing emergency response and services to these coastal communities following a tsunami, hurricane, or significant coastal flooding event.

The height of the proposed hybrid seawalls and crest of the proposed rock revetments would only be 1 to 2 feet above the existing road deck elevation (ranging from approximately 6 to 10 feet above MSL) and would have minimal impact on the progression of major coastal hazard such as a tsunami or hurricane, which would be expected to inundate large sections of the highway.

The existing shoreline drainage features would be incorporated into the design for the proposed shoreline stabilization structures to maintain conveyance of terrestrial runoff back to the ocean.

3.6 Air Quality

3.6.1 Existing Conditions

The U.S. Environmental Protection Agency has set primary and secondary National Ambient Air Quality Standards for ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, concentrations of particulate matter less than 10-microns and less than 2.5-microns, and airborne lead. These ambient air quality standards establish the maximum concentrations of pollution considered acceptable, with an adequate margin of safety, to protect public health and welfare. Primary standards set limits to protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly, while secondary standards set limits to protect public welfare which includes protection against decreased visibility, and damage to animals, crops, vegetation, and buildings. The State of Hawaiʻi has additionally adopted ambient air quality standards for some pollutants. In some cases, the State requirements are more stringent than the Federal standards. In addition, the State of Hawaiʻi has set standards for hydrogen sulfide. The ambient air quality standards are presented in the Table 3-1.

Table 3-1. Ambient Air Quality Standards.

Air Pollutant	Hawaiʻi Standard	Federal Primary Standard	Federal Secondary Standard
Carbon Monoxide			
1-hour average	9 ppm	35 ppm	None
8-hour average	4.4 ppm	9 ppm	None
Lead			
3-month average	1.5 $\mu g/m^3$ (calendar quarter)	0.15 $\mu g/m^3$ (running 3-month)	0.15 $\mu g/m^3$ (running 3-month)

Air Pollutant	Hawaiʻi Standard	Federal Primary Standard	Federal Secondary Standard
Nitrogen Dioxide			
1-hour average	---	100 ppb	---
Annual average	0.04 ppm	53 ppb	53 ppb
Particulate Matter less than 10-microns			
24-hour block average	150 µg/m^3	150 µg/m^3	150 µg/m^3
Annual average	50 µg/m^3	---	---
Particulate Matter ess than 2.5-microns			
24-hour block average	---	35 µg/m^3	35 µg/m^3
Annual average	---	12 µg/m^3	15 µg/m^3
Ozone (O_3)			
8-hour rolling average	0.08 ppm	0.070 ppm	0.070 ppm
Sulfur Dioxide (SO_2)			
1-hour average	---	75 ppb	---
3-hour block average	0.5 ppm	---	0.5 ppm
24-hour block average	0.14 ppm	---	---
Annual average	0.03 ppm	---	---
Hydrogen Sulfide (H_2S)			
1-hour average	25 ppb	---	---

ppb = parts per billion by volume
ppm = parts per million by volume
µg/m^3 = micrograms per cubic meter of air
Source: Hawaiʻi DOH (2022).

Air quality in the Hawaiʻi is generally considered to be quite good due in part to the state's location in the middle of the Pacific Ocean, far away from any major sources of pollution. Air quality in the vicinity of the project site is typically very good due to the steady and persistent onshore trade winds, which bring ashore clean air from the open ocean as well as quickly evacuating airborne pollutants. The DOH monitors ambient air quality in Hawaiʻi. In 2022 the State of Hawaiʻi was in attainment of all National Ambient Air Quality Standards (DOH 2022).

3.6.2 Potential Impacts and Mitigation Measures

During construction there may be minor temporary impacts to air quality. These minor temporary impacts to air quality would be associated with vehicle and construction equipment exhaust emissions and fugitive dust. This negative impact on air quality would be limited to active construction hours and would dissipate once construction activities cease. The emissions from heavy equipment and other construction vehicles' internal combustion engines are expected to be too small to have a significant or lasting effect on overall air quality. The project does not include any grading and only minor ground disturbance primarily below the high tide line; therefore, the project site is not anticipated to generate much, if any fugitive dust. As part of the construction process, the contractor should implement appropriate BMPs to minimize construction-related emissions. Implementation of the following BMPs would help mitigate air quality impacts resulting from construction activities:

- Properly tune and maintain construction equipment and vehicles daily.
- Store equipment and materials storage sites as far away from residential and commercial uses as practical. Keep construction areas clean and orderly.

The application of water or dust palliative to control fugitive dust is not anticipated to be necessary, as the proposed construction activities are not anticipated to generate noticeable levels of fugitive dust. Once construction is completed, the project would have no long-term air emissions or further impact on air quality.

3.7 Terrestrial Biological Resources

3.7.1 Existing Conditions

Terrestrial Flora

There are varying amounts of coastal vegetation at each of the project sites. Coastal erosion and prior shoreline stabilization measures have impacted vegetation at most of the project sites. There is no existing vegetation within the Hauʻula Project Site or the majority of the Puakenikeni Road Project Site. There is some lawn area and a few bushes (milo and noni) within the Kualoa Park project area. Most of the former lawn area within the Kualoa Park project limits has eroded away and the palm trees that were once present have been inundated and killed by sea water. There are scattered plants, or a narrow strip of coastal vegetation along much of the shoreline through most of the Kualoa Ranch, Kaʻaʻawa Valley, Kaʻaʻawa Beach Park, Crouching Lion, and the Punaluʻu North and South Project Sites. Some of this vegetation is growing through gaps in the existing non-engineered shoreline stabilization measures. Coastal plant species found within the project area include:

- Naupaka kahakai (*Scaevola sencea*)
- Beach heliotrope (*Tournefortia argentea*)
- Coconut trees (*Cocos nucifera*)
- False kamani (*Terminalia catappa*)
- Guinea grass (*Megathyrsus maximus*)
- Hala (*Pandanus tectorius*)
- Hau (*Hibiscus tilaceus*)
- Milo (*Thespesia populnea*)
- Ironwood (*Casuarina equisetifolia*)

- Noni (*Morinda citrifolia*)
- Koa haole (*Leucaena leucocephala*)
- Lauaʻe (*Phymatosorus grossus*)
- Spider lily (*Crinum asiaticum*)

In 1975, the Hawaiʻi State Legislature passed HRS Chapter 58 to protect the State's exceptional trees. A tree, stand, or grove of trees can be designated as exceptional by a County Arborist if the has historic or cultural value, or based on its age, rarity, location, size, aesthetic quality, or endemic status. There are currently no officially designated exemptional trees in the project area.

The USFWS Information for Planning and Consultation (IPaC) tool provided an Official Species List including eight (8) Federally endangered plant species that could potentially occur in the vicinity of the project area.

Table 3-2. List of Federally and State endangered plant species potentially occurring within the project sites.

Common Name	Latin Name	Status
Flowering Plants		
ʻAkoko	*Euphorbia celastroides var. kaenana*	Federal and State Endangered
ʻEnaʻena	*Pseudognaphalium sandwicensium var. molokaiense*	Federal and State Endangered
Awiwi	*Schenkia sebaeoides*	Federal and State Endangered
Carter's Panicgrass	*Panicum fauriei var. carteri*	Federal and State Endangered
Hilo Ischaemum	*Ischaemum byrone*	Federal and State Endangered
Ihi	*Portulaca villosa*	Federal and State Endangered
Kamanomano	*Cenchrus agrimonioides*	Federal and State Endangered
Ferns and Allies		
No common name	*Microlepia strigosa var. mauiensis*	Federal and State Endangered

There are no designated critical habitats for listed plant species in the project area.

Terrestrial Fauna

The USFWS IPaC tool provided an Official List including eleven (11) Federally threatened and endangered animal species that could potentially occur in the vicinity of the project area.

Table 3-3. Federally and State listed threatened and endangered species potentially occurring within the project sites.

Common Name	Latin Name	Status
Mammals		
Hawaiian Hoary Bat	*Lasiurus cinereus semotus*	Federal and State Endangered
Birds		
Band-rumped Storm-petrel	*Oceanodroma castro*	Federal and State Endangered
Hawaiian (koloa) Duck	*Anas wyvilliana*	Federal and State Endangered
Hawaiian Common Gallinule	*Gallinula galeata sandvicensis*	Federal and State Endangered
Hawaiian Coot	*Fulica americana alai*	Federal and State Endangered
Hawaiian Petrel	*Pterodroma sandwichensis*	Federal and State Endangered
Hawaiian Stilt	*Himantopus mexicanus knudseni*	Federal and State Endangered
Newell's Townsend's Shearwater	*Puffinus auricularis newelli*	Federal and State Threatened
Short-tailed Albatross	*Phoebastria* (=*Diomedea*) *albatrus*	Federal and State Endangered
Reptiles		
Green Sea Turtle*	*Chelonia mydas*	Federal and State Threatened
Hawksbill Sea Turtle*	*Eretmochelys imbricata*	Federal and State Endangered

*Sea turtles and Hawaiian monk seals are discussed in Section 3.8 *Marine Biological Resources.*

Hawaiian Hoary Bat

The endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*) is the only native terrestrial mammal to Hawaiʻi. The habitat requirements of the Hawaiian hoary bat are not well-understood and has been identified as one of the primary data needs for species recovery (USFWS, 1998 and Gorresen et al., 2013). The species has been observed foraging in both open and forested habitats (USFWS, 1998). The mobility of the species by flight results in all areas from the coast to the highest mountains being accessible to foraging by the Hawaiian hoary bat (Gorresen et al., 2013). Hawaiian hoary bats forage for insects as low as 3 feet above the ground in a variety of habitats; making entanglement in barbed wire fencing a threat for this species (USFWS, 1998). The bats are solitary roosting in both native and non-native trees greater than 15 feet in height (Bonaccorso et al., 2015). During the Hawaiian hoary bat birthing and pup rearing season, from June 1 through September 15, bat pups that cannot yet fly may be present in roost trees.

Hawaiian Seabirds

Threatened and endangered Hawaiian seabirds include the endangered Hawaiian petrel (*Pterodroma sandwichensis*), the endangered band-rumped storm-petrel (*Oceanodroma castro*), and the threatened Newell's Townsend's shearwater (*Puffinus auricularis newelli*). These birds feed in the ocean and nest at high elevation on the steep slopes of extinct volcanos. They may fly over the project area at night during their breeding, nesting, and fledging seasons from March 1 to December 15. Outdoor lighting can result in seabird disorientation, fallout, and injury or mortality. Seabirds are attracted to lights and after circling the lights they may become exhausted and collide with nearby wires, buildings, or other structures or may land on the ground. Downed seabirds are subject to increased mortality due to collision with automobiles, starvation, and predation by dogs, cats, and other predators. Young birds (fledglings) on their first flight from their mountain nests to the sea, are particularly vulnerable to light attraction. The fledging season for these seabirds is from September 15 to December 15 (USFWS, 2023).

Hawaiian Waterbirds

Endangered Hawaiian waterbirds, including the Hawaiian common gallinule (*Gallinula galeata sandvicensis*), Hawaiian stilt (*Himantopus knudseni*), Hawaiian coot (*Fulica alai*), and Hawaiian duck (*Anas wyvilliana*) can be found in a variety of wetland habitats including freshwater marshes, ponds, coastal estuaries, artificial reservoirs, taro loʻi, and irrigation ditches. Hawaiian waterbirds, particularly Hawaiian stilts are highly mobile and may occupy newly, sometimes unintentionally, created habitat for foraging and even nesting, wherever standing water is present.

Short-tailed Albatross

The endangered short-tailed albatross (*Phoebastria albatrus*) spends most of its time at sea, foraging diurnally and possibly nocturnally, either alone or in groups and predominantly hunt for prey by surface-seizing, feeding primarily on squid, crustaceans, and various fishes (USFWS, 2023). Short-tailed albatross in Hawaiʻi nest predominately on isolated, windswept, offshore islands, with restricted human access such as Midway Atoll and Kure Atoll in the Northwestern Hawaiian Islands. There are no short-tailed albatross nesting sites on the island of Oʻahu. There is a Layson albatross nesting colony at Kaʻena Point, the relatively isolated northwestern tip of Oʻahu. No albatross nesting or roosting has been documented on the windward coast of Oʻahu near the project sites.

3.7.2 Potential Impacts and Mitigation Measures

The mitigation measures described in this section are based on pre-assessment consultation comments from USFWS and DOFAW, and USFWS's general project design guidelines for species included on the Official Species List provided by the USFWS IPaC tool. These mitigation measures may be modified based on further consultation with USFWS, DOFAW, and other resources agencies.

Terrestrial Flora

The construction of new shoreline stabilization structures would require the removal of vegetation within each project site. There are no suitable locations for replacement planting within project area or adjacent HDOT right-of-way. The HDOT would work with CCHʻs Department of Parks and Recreation (DPR) Division of Urban Forestry to discuss and evaluate potential opportunities for replacement planting on park properties.

As stated above there are no trees officially designated as exceptional trees under HRS Chapter 58 in the project area. However, because the project will require some tree removal Outdoor Circle, a local organization committed to keeping Hawaiʻi clean, green, and beautiful by preserving, protecting, and enhancing the environment, would be consulted.

Based on the Official Species List provided by the USFWS IPaC tool there are eight (8) endangered plant species with the potential to be present in the project area. The USFWS and DOFAW will be consulted regarding the potential for these species and other special-status plant species to be present in the project area. Botanical surveys and other measures to avoid and minimize potential impacts to endangered plants would be implemented as needed based on USFWS and DOFAW's recommendations.

Any plants used for restoration or landscaping would be tested in place before transport to the project site or alternative planting location for little fire ants and coconut rhinoceros beetle to prevent the spread of these highly invasive pests. Plant material removed from the project site would be properly recycled, composted or disposed of as trash for incineration and not left in piles that could become nesting sites for the coconut rhinoceros beetle.

Terrestrial Fauna

Hawaiian Hoary Bat

To avoid inadvertent harm or mortality to young bats that cannot yet fly, trees and other woody plants greater than 15 feet in height would not be removed or trimmed during the Hawaiian hoary bat birthing and pup rearing season from June 1st to September 15th. If this cannot be avoided, DOFAW and USFWS would be consulted. As discussed above bats can become entangled in barbed wire fencing. The project does not include the installation of any barbed wire fencing or other types of fencing. If temporary construction fencing is required, the use of barbed wire would be avoided. With the implementation of these mitigation measures, potential impacts to Hawaiian hoary bats would be avoided.

Hawaiian Seabirds

The project does not include the installation of any new permanent lighting. However, lighting from night construction can disorient seabirds, resulting in collision with manmade structures or grounding of seabirds. No night construction is not anticipated. In the highly unlikely event that nighttime construction work is required, all construction lighting would be downward facing and fully shielded to avoid and minimize impacts. In addition, nighttime construction work that requires outdoor lighting would be avoided, during the seabird fledging season from September 15th through December 15th. If downed seabirds are detected both DOFAW and USFWS would be contacted. The use of temporary construction fencing is not anticipated. In the unlikely event that temporary construction fencing is required three strands of polytape (or similar measure) would be integrated into the fence to increase visibility. With the implementation of these mitigation measures, potential impacts to Hawaiian seabirds from construction activities would be avoided.

Hawaiian Waterbirds

There are no streams, wetlands, or other standing water habitat in the project sites. Hawaiian waterbirds would not generally be found in the saltwater marine environment, roadway shoulder, or narrow strip of beach in between that comprises the KKPH project area. However, there are several streams located in the vicinity of the project sites, as well as minor drainage features where Hawaiian waterbirds could be found. Adjacent brackish stream mouths, including those where sand plugs have formed at the mouth of the stream could provide standing water habitat for Hawaiian waterbirds.

Prior to undertaking construction activities or vegetation clearing within 100 feet of locations with habitat suitable for Hawaiian waterbirds (e.g., streams mouths and drainage features), a biological monitor that is familiar with the species' biology would survey the area for Hawaiian waterbird nests. These surveys would be repeated within three (3) days of project initiation and after any subsequent delay of work of three (3) or more days (during which birds may attempt to nest). If a nest is discovered, DOFAW and USFWS would be contacted within 48-hours of the discovery for further guidance, and a 100-foot buffer would be established and maintained around all active nests and/or chicks until the chicks have fledged. No potentially disruptive activities or habitat alterations would occur within the buffer. If a Hawaiian waterbird is observed in the project area, all work within 100 feet would cease and not resume until the birds leave the area of their own accord. In addition, project personnel and contractors would be informed about the presence of endangered species on-site. Appropriate sediment and erosion control and spill prevention BMPs would be implemented to minimize water quality impacts that could affect Hawaiian waterbirds. With the implementation of these mitigation measures, potential impacts to Hawaiian waterbirds from construction activities would be avoided.

Short-tailed Albatross

Short-tailed albatross are not known to use habitat within the project sites; therefore, the proposed construction activities would have no effect on this species.

3.8 Marine Biological Resources

3.8.1 Existing Conditions

The shoreline along Kamehameha Highway includes rocky coastline and narrow sand beaches. Some portions of the shoreline along the highway are comprised of steep eroded soil and rock escarpments that terminate in sand beaches. Other sections adjacent to the highway consist of constructed shorelines made of boulders that extend to the waterline. In areas where the shoreline consists of sandy beaches, the sand extends through the intertidal zone and abruptly transitions into a mixed sand and rubble zone. The sand and rubble zone extends seaward for the entire offshore range of the study area and beyond. In general, the amount of sand decreases while the amount of solid rock bottom increases with distance shore. The entire sand/rubble/rock zone within the study area is shallow in depth, never deeper than approximately 2 meters. The shoreline, intertidal zone, and nearshore marine environment support a diversity of marine fauna including sea turtles, coral, algae, sea urchins or wana (long-spined urchin), sea cucumbers, crustaceans, and other marine invertebrates and reef fish.

Sea Turtles and Hawaiian Monk Seals

The threatened green sea turtle (*Chelonia mydas*) may nest on any sandy beach in the Pacific Islands. The endangered hawksbill sea turtle (*Eretmochelys imbricata*) can nest on a range of substrates, from sandy beaches to crushed coral, with nests typically placed under vegetation. Green sea turtles nest in Hawaiʻi from May through September, peaking in June and July, with hatchlings emerging in November and December. Hawksbill sea turtles have a strong nesting site fidelity, generally returning to the same beaches where they hatched decades earlier, between April and November of each year (USFWS 2023).

Endangered Hawaiian monk seals (*Monachus schauinslandi*) come to shore mainly to birth, rest, and molt. Sandy protected beaches surrounded by shallow waters are preferred for pupping. Female seals haul-out on shore for up to seven weeks to give birth and nurse their pups. Though Hawaiian monk seals give birth year-round, pups are usually born during late March to early April. A newborn Hawaiian monk seal typically nurses with its mother for about one month (The Marine Mammal Center, 2023).

Nearshore Ecosystems

In July 2023 Marine Research Consultants Inc. completed a marine biological survey of the project area (Appendix B). The survey included a total of 13 transects; with one (1) transect representing the Kualoa Project Sites; two (2) transects representing the Kaʻaʻawa Valley Project Site; two (2) transect representing the Kaʻaʻawa Beach Park Project Site; one (1) transect representing the Puakenikeni Road Project Site; two (2) transects representing the Crouching Lion Project Site; two (2) transects representing the Punaluʻu South Project Site; one (1) transect representing the Punaluʻu North Project Site; and two (2) transects representing the Hauʻula Project Site. Each transect area extended from the shoreline to 75 meters offshore. In general, the amount of sand decreases while the amount of solid rock bottom increases with distance from the shore.

The reef community in the survey area was dominated by marine algae. The majority of the sand and rubble/rock surfaces were covered with a variety of turf and macroalgae. The most common macroalgae species/species groups were *Halimeda discoidea*, *Halimeda opuntia*, *Padina sanctae-crucis*, crustose coralline algae, and cyanobacteria, which were observed in all survey area. The invasive alien red alga *Acanthophora specifera* was also present in all the survey areas with the exception of the Punaluʻu South Project Site and was a dominate species at most of the sites. The dominant species at the Punaluʻu South Project Site was the cyanobacterium, *Lyngbya majuscula*, the "stinging seaweed."

Reef building corals were present throughout the rubble and rock zones. However, corals accounted for only approximately 1% of the bottom cover. Most of the coral observed were small (<20 cm), isolated colonies of common Hawaiian reef species included, *Porites evermanni*, *Porites lobata*, *Porites compressa*, *Pocillopora meandrina*, *Pocillopora damicornis*, and *Montipora capitata*. However, a few large colonies of *Montipora* spp. and *Porites* spp. were also observed. In general, corals throughout all project sites were healthy and signs of paling, bleaching, or disease were extremely rare.

In general, there were very few non-coral macro-invertebrates observed on the reef flat. The most common non-coral invertebrates detected was the rock boring sea urchin (*Echinometra matheai*). Other non-coral invertebrates observed included three other species of sea urchin, several species of sea cucumber, and zoathids.

Reef fish were fairly uncommon on the reef flat, and the fish that were observed were generally small (less than 20 cm). A total of 44 fish species were observed across all project sites The most common fish observed were various species of surgeonfish, wrasses, and damselfishes. Appendix B includes lists of all algae, coral, macro-invertebrates and fish species observed as well as representative photographs.

Essential Fish Habitat

Section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires federal agencies to consult with NMFS on any action or proposed action that may adversely affect Essential Fish Habitat (EFH). Under the Magnuson-Stevens Act, EFH is defined as "those waters and substrate necessary to fish for spawning, breading or growth to maturity."

Fishery management councils are responsible for describing EFH for all species managed under a fishery management plan. The NMFS EFH Mapper was used to identify management unit species (MUS) with designated EFH in the project area. MUS with designated EFH in the project area include all life stages of the Main Hawaiian Islands Coral Reef Ecosystem Management Unit and several species and life stages that are part of the Bottomfish and Seamount Groundfish Management Unit, as listed in Table 3-4. The project area is not within or adjacent to any areas that have been designated as Habitat Areas of Particular Concern under the EFH regulations.

Table 3-4. MUS with designated EFH in the project vicinity.

Species	Life Stage	Management Unit
Main Hawaiian Islands Coral Reef Ecosystem	All	Coral Reef Ecosystem Management Unit
Silver Jaw Jobfish	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Thicklip Trevally	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Amberjack	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Black Jack	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Sea Bass	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Blue Stripe Snapper	Eggs, Post-Hatch, Post-Settlement, Sub-Adult, Adult	Bottomfish and Seamount Groundfish
Gray Jobfish	Eggs, Post-Hatch, Post-Settlement, Sub-Adult, Adult	Bottomfish and Seamount Groundfish
Giant Trevally	Eggs, Post-Hatch, Post-Settlement, Sub-Adult, Adult	Bottomfish and Seamount Groundfish
Pink Snapper	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Red Snapper	Eggs, Post-Hatch	Bottomfish and Seamount Groundfish
Longtail Snapper	Eggs	Bottomfish and Seamount Groundfish
Yellowtail Snapper	Eggs	Bottomfish and Seamount Groundfish
Snapper	Eggs	Bottomfish and Seamount Groundfish

3.8.2 Potential Impacts and Mitigation Measures

The mitigation measures described in this section are based on pre-assessment consultation comments from USFWS, recommendations from NMFS and USFWS for other recent shoreline projects in Hawai‘i, USFWS's general project design guidelines for protection of sea turtles, and Standard Local Operating Procedures for Endangered Species in the Central and Western Pacific Regions (Pac-SLOPES) developed by the USACE in consultation with NMFS and USFWS. This list of mitigation measures may be modified or expanded based on further consultation with NMFS, USFWS, DOFAW, DAR, and other resources agencies.

Sea Turtles and Hawaiian Monk Seals

The proposed project would include construction activities on beaches and along rocky shorelines where sea turtles or Hawaiian monk seals could be present. To avoid and minimize potential impacts to sea turtles and monk seals the following measures have been incorporated into the project:

- All construction equipment and vehicles would be parked on and operated from the roadway or paved roadway shoulder. To avoid impacts to sections of beach and sand compaction outside the footprint of the proposed stabilization structures, vehicles and equipment would not be driven or parked on beaches.
- Prior to the start of work each day, and prior to resumption of work following any break of more than one half hour, a designated competent trained observer would survey the work area and adjacent areas for sea turtles and monk seals. In addition, constant vigilance for these species would be maintained throughout construction. If a sea turtle or monk seal is observed, all construction activities within 50 meters of the ESA-listed marine species would be halted and would not continue until the animal has departed the area on its own accord.
- Night construction is not anticipated for this project. In the unlikely event that night construction is required, it would be avoided during the green sea turtle hatching season, May to September. In addition, any night construction lighting would be directed towards the ground and shielded so the bulb can only be seen from below, to avoid attracting sea turtles.
- No materials would be stockpiled in the intertidal zone or reef flat.
- The project would implement applicable USFWS BMPs for work in the aquatic environment.
- Any monk seal sighting would be reported to the NOAA Statewide Hawaii Marine Wildlife Hotline at 888-256-9840 at the time of observation. Documentation of the sighting (e.g., photos, video, reports, etc.) would be emailed to: pifsc.monksealsighting@noaa.gov.
- With the implementation of these mitigation measures, potential impacts to sea turtles and Hawaiian monk seals from construction activities would be avoided.

Nearshore Ecosystem and Essential Fish Habitat

The proposed construction activities would involve in-water work. The rock revetements and hybrid seawalls with armor stone aprons would directly impact and occupy a 15- to 40-foot-wide area along the shoreline. The shoreline excavation and placement of stone associated with the construction of the revetments and hybrid seawalls with armor stone aprons would result in the suspension of sand and sediment, temporary reduction in water clarity, and the deposition of sand and sediment. The use of turbidity curtains would help contain the suspended sediment to within ten (10) feet of the active work area, reducing the area affected by potential water quality impacts.

Appropriate sediment and erosion control, stormwater management, and spill prevention and control measures would be used during construction to minimize potential impacts to the nearshore marine environment. The contractor would develop and implement a contingency plan for management of equipment, materials, and the job site in the event of an approaching severe storm event, including a tropical storm, hurricane, or predicted rain event anticipated to exceed a 2-year, 24-hour event. This would include removing or securing construction equipment and material at the site, stabilization of stockpiles and un-stabilized areas, and identification of and mitigation of other potential sources of pollution. The contingency plan would also include photographic documentation of pre- and post-storm conditions at the site and inspection, maintenance, and repair of BMPs following the storm, as needed. The USFWS' standard recommended BMPs for work in the aquatic environment would be followed. This includes:

- Scheduling in-water work, to avoid coral spawning and recruitment periods, and sea turtle nesting and hatching periods, in coordination with state and federal fish and wildlife resource agencies;
- The use of turbidity curtains or other silt containment devices, and the removal and disposal of such devices when in-water work is completed;
- Curtailing work during flooding or adverse tidal and weather conditions; and
- Ensuring all project construction-related materials and equipment to be placed in the water are inspected and free of pollutants including marine fouling organisms, grease, oil, and sediment.

The marine assessment suggests that the proposed action to stabilize shoreline erosion adjacent to Kamehameha Highway is unlikely to have any negative effect to existing marine life communities. The nearshore sand and rubble zones extend seaward to a distance greater than 75 meters offshore, likely beyond the limit of any potential effects associated with the proposed construction activities. The marine life in this nearshore area would be adapted to resuspension of sediment as sand is a major component of the nearshore habitat. The ongoing erosion of the shoreline is likely causing some input of sediment to the nearshore ocean. The proposed shoreline stabilization measures are intended to mitigate coastal erosion and the associated input of sediment to the nearshore environment. Thus, the proposed project has the potential to reduce any such impacts and may provide long-term improvement to both water quality and marine biological resources (Marine Research Consultants, 2023). Based on the proposed in-water work being conducted in very shallow water with turbidity containment barriers surrounding the work area, any exposure of marine life to turbidity and sedimentation is expected to be temporary and less than significant.

3.9 Noise

3.9.1 Existing Conditions

Existing ambient noise levels vary considerably within the project sites, but in general, existing background levels at the project sites can be relatively high due to its proximity to Kamehameha Highway. During peak commute times in the early morning and late afternoon, and midday during weekends and holidays, traffic levels at the sites can be quite high, and the amount of vehicular noise generated during those periods can therefore also be elevated.

HAR Chapter 11-46, Community Noise Control, establishes maximum permissible sound levels (see allowable levels summarized in Table 3-5 below) and provides for the prevention, control, and abatement of noise pollution in the State from stationary noise sources and from equipment related to agricultural, construction, and industrial activities. The standards are also intended to protect public health and welfare and to prevent the significant degradation of the environment and quality of life. The limits are applicable at the property line rather than at a selectively pre-determined distance from the sound source. HAR Section 11-46-7 grants the DOH's Director the authority to issue permits to operate a noise source that emits sound more than the maximum permissible levels if it is in the public interest; however, it may be subject to reasonable conditions. Those conditions include requirements to employ the best available noise control technology.

Table 3-5. Maximum permissible sound levels in dBA (decibel A).

Zoning Districts	Daytime (7AM-10PM)	Nighttime (10PM-7AM)
Class A	55	45
Class B	60	50
Class C	70	70

Table Notes:
(1) Class A zoning districts include all areas equivalent to lands zoned residential, conservation, preservation, public space, open space, or similar type.
(2) Class B zoning districts include all areas equivalent to lands zoned for multi-family dwellings, apartments, business, commercial, hotel, resort, or similar type.
(3) Class C zoning districts include all areas equivalent to lands zoned agriculture, country, industrial, or similar type.
(4) The maximum permissible sound levels apply to any excessive noise source emanating within the specified zoning district, and at any point at or beyond (past) the property line of the premises. Noise levels may exceed the limit up to 10% of the time within any 20-minute period. Higher noise levels are allowed only by permit or variance issued under HAR sections 11-46-7 and 11-46-8.
(5) For mixed zoning districts, the primary land use designation is used to determine the applicable zoning district class and the maximum permissible sound level. (6) The maximum permissible sound level for impulsive noise is 10 dBA (as measured by the "Fast" meter response) above the maximum permissible sound levels shown.
Source: HAR Chapter 11-46, Community Noise Control

3.9.2 Potential Impacts and Mitigation Measures

Construction activity may cause a temporary increase in noise during active construction. The contractor would be required to comply with applicable noise regulations, and if necessary, would obtain a noise permit from the DOH. It is not feasible to mitigate construction noise to the extent that it does not at times exceed existing background noise levels or is inaudible to nearby residents. The noise impact is also exacerbated by highway traffic noise. However, the following measures would be implemented to lessen potential noise impacts:

- Equipment operation on the shoreline would be limited to the hours between 7:30 am and 5 pm.
- Broadband noise backup alarms in lieu of higher frequency beepers would be required for construction vehicles and equipment. Broadband noise alarms tend to be less audible and intrusive with distance as they blend in with other background noise sources.
- The project would specify the use of the quietest locally available equipment, e.g., high insertion loss mufflers, fully enclosed engines, and rubber-tired equipment when possible.
- The use of horns for signaling would be prohibited.
- Worker training on ways to minimize impact noise and banging would be required.

With implementation of the mitigation measures listed above and compliance with applicable noise regulations, the short-term noise impacts associated with the proposed construction activities would be less than significant.

3.10 Historic, Archaeological, and Cultural Resources

3.10.1 Existing Conditions

Historic Context

The project sites along Kamehameha Highway are in the general location of the traditional, pre-contact Hawaiian coastal trail (ala hele or ala nui) where people could safely pass through their neighbors' ahupuaʻa without intruding upon house sites and main gardening areas that were generally located just mauka of the main coastal trail, also known as the Alanui Aupuni or ("Government Road"). The modern road was constructed on top of the 19th century coastal Government Road, which in turn follows the same path as a pre-contact trail documented in the earliest historical records.

The stabilized sand-dunes around the coastal trail were used by makaʻāinana or commoners for unmarked burial sites. These coastal settings were also used by fishermen as staging areas, for example, as places to finish and repair their tools and gear and by the community in concert with fishpond work along certain stretches of the coastline. Many of these coastal sections were also used as canoe landing and launch spots.

The project area traverses two districts (moku): Koʻolauloa and Koʻolaupoko. Within those two moku, 14 ahupuaʻa are crossed. The ahupuaʻa include the following: Kualoa 1/2 (Koʻolaupoko Moku), Kaʻaʻawa, Makaua 1/2, Kahana, Waiʻono, Puheʻemiki, Kapano, Haleʻaha, Kaluanui, Kapaka, Mākao, and Hauʻula (Koʻolauloa Moku).

Koʻolauloa is a fishing community. The nearshore reef environment provides a rich biodiversity that has helped to sustain this community for generations. The Hauʻula area is known for fishing and diving, especially for heʻe (octopus). This area is also known historically for limu picking, although limu has become scarcer in recent times. Kahana and Kaʻaʻawa also have very active fishing communities, with a fishpond names Huilua located in Kahana. There are also fishponds in Kualoa. This ocean-based lifestyle remains vibrant in Koʻolauloa, and is essential to some Ko ʻolauloa families who fish and gather not as recreation but for subsistence and cultural perpetuation. It is not uncommon to see fisherman or spearfisherman walking along the road with their fresh catch.

Kahana Valley is a place of spiritual significance for Hawaiians. The valley's lush environment, streams, and waterfalls were believed to be inhabited by ancestral spirits and deities. Native Hawaiians settled in Kahana Valley and practiced subsistence farming, fishing, and gathering of resources from both the land and sea. The fertile land allowed them to cultivate kalo, ʻuʻala, maia, and other crops essential for their sustainable use of, and survival on, the land. The sea provided an abundance of fish and other seafood that provided them with protein. This was supported by the building and active use of Huilia fishpond.

In the 19th century, with the start of commercial sugar ventures on the island, most of the current project area was part of either the original Alanui Aupuni ("Government Road") or a railroad bed that transported sugar cane from inland fields to the sugar cane mill in Kahuku. According to many historical maps dating from the late 1800s, the old government road is present in many places along the windward coast. In the early 1900s, the Koʻolau Railway Company and the Koʻolau Agricultural Company were formed to facilitate economic development. Maps from this time show a railway running from Kahuku to Kahana Bay, which sometimes ran alongside, a bit mauka of, or crossing over the old government road. The earliest version of Kamehameha Highway was first constructed along the windward coast in the late 1920s, and the current highway right-of-way was built atop the old government road and/or the old railway in various places (Rieth et al., 2017).

Archaeological Resources

An Archaeological Literature Review and Field Inspection report has been prepared for the project and is included as Appendix C. There have been numerous archaeological investigations and finds along the windward shoreline between Kualoa and Hauʻula; including several previously identified archaeological sites within HDOT right of way and within the project area. The two most common of types of archaeological sites identified within or near the project area are: (1) human burials, both intact and disturbed with incomplete fragmentary sets of remains, and (2) subsurface cultural layers consisting of Jaucas sand (JaC) culturally enriched with traditional Hawaiian and historic artifacts, midden, and other evidence of occupation. The only above ground historic property identified in the project area is a 100-meter-long mortared rock wall dating from 1920s, located along the makai shoulder of the highway in the Crouching Lion project area. Table 3-6 includes a summary of the all the previously identified archaeological sites and historic properties within the project area. Other historic properties and archaeological sites identified within 500 feet of the project area are summarized in Table 3-7.

The State Inventory of Historic Places (SIHP) numbers have been provided for the associated sites/properties. The locations of previously identified historic properties within 500 feet of the project area are shown on Figures 3-17 to 3-20.

Table 3-6. Summary of historic properties and archaeological sites within the project area.

SIHP No.	Historic Property Name	Description	Relationship to Project Areas
Kualoa Project Areas			
50-80-06-7752	Subsurface cultural layers	Traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation.	Partially within Kualoa Park project area
Kaʻaʻawa Project Areas			
50-80-06-3759	Human skeletal remains	Remains of multiple individuals eroding out of the roadway on the makai side over the course of several years.	Within Kaʻaʻawa Valley project area
50-80-06-6852	Human skeletal remains	Additional human skeletal remains eroding out of the makai side of the highway.	Within Kaʻaʻawa Valley project area
50-80-06-7921	Subsurface cultural layer (eroded by wave action)	This layer contains abundant evidence of traditional Hawaiian artifacts and habitation (under the north bound lane and makai-side shoulder of the highway).	Within Crouching Lion project area
50-80-06-7922	Rock walls	A 100-meter-long mortared rock wall dating from 1920s (along the makai shoulder of the highway).	Within Crouching Lion project area
Punaluʻu Project Areas			
50-80-06-6695	Human skeletal remains	23 human burials as well as seven other human burial sites and numerous pit features in addition to human burials.	Within Punaluʻu South project area

SIHP No.	Historic Property Name	Description	Relationship to Project Areas
50-80-06-6574 through -6580	Human skeletal remains	35 individuals; (SIHP #s 6574-6580) contain the remains of seven (SIHP # 6574), seven (SIHP # 6575), six (SIHP # 6576), three (SIHP # 6577), one (SIHP # 6578), nine (SIHP # 6579) and two (SIHP # 6580) individuals	Within Punaluʻu South project area
Hauʻula Project Area			
50-80-05-4793	Subsurface cultural layer	Several pit features and at least one traditional Hawaiian artifact.	Within Hauʻula project area
50-80-05-4792	Subsurface cultural layer	Abundant traditional Hawaiian artifacts including formal tools and debitage as well as seven human burials.	Within Hauʻula project area

Table 3-7. Summary of historic properties and archaeological sites outside, but within 500 feet of the project area.

SIHP No.	Historic Property Name	Description	Relationship to Project Areas
Vicinity of Kualoa Project Sites			
50-80-06-7397 and -7752	Subsurface cultural layers	Traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation.	Approximately 500 feet from Kualoa Park project area
50-80-06-7123	Human skeletal remains	Previously-disturbed human skeletal remains eroding into the ocean were recovered and re-located to the Kualoa Beach Park's storage unit.	Approximately 300 feet from Kualoa Park project area
50-80-06-0528, -0528 2D-1, and -0528 2D-2	Subsurface features	Subsurface features; traditional cultural deposits and human skeletal remains.	Approximately 350 feet from Kualoa Park project area
50-80-06-7913	Subsurface cultural layer	Pre-Contact to early historic-period subsurface cultural layer.	Approximately 200 feet from Kualoa Park project area

SIHP No.	Historic Property Name	Description	Relationship to Project Areas
No SIHP No. Assigned	Wilikaʻai	The ruins of an old sugar mill (known as Wilikaʻai).	Approximately 50 feet from Kualoa Ranch project area
Vicinity of Kaʻaʻawa Project Sites			
50-80-06-4728	Human skeletal remains	Remains of one individual in a house-foundation excavation just mauka of the highway in a private residential parcel.	Approximately 100 feet from Kaʻaʻawa Valley project area
50-80-06-7121	Human skeletal remains	One set of inadvertently discovered human remains at Kaʻaʻawa Elementary School.	Approximately 200 feet from Kaʻaʻawa Beach Park project area
50-80-06-7122	Traditional Hawaiian cultural layer	Fire-pit features and a pit with dog bones; charcoal, midden, fire-affected rock and basalt debitage and traditional Hawaiian tools were also found in the cultural layer.	Approximately 300 feet from Kaʻaʻawa Beach Park project area
SIHP # 50-80-06-4889	Human skeletal remains	Inadvertent burial of multiple individuals found at private residence.	Approximately 500 feet from Puakenikeni Road project area
50-80-06-3749	Human skeletal remains	One set of human skeletal remains interpreted as an undisturbed discovered during house construction excavation in mauka of the highway.	Approximately 300 feet from Puakenikeni Road project area
50-80-06-6409	Human skeletal remains	Inadvertent burial of three individuals on the mauka side of the highway found at private residence.	Approximately 400 feet from Puakenikeni Road project area
50-80-06-1540	Rock walls	A pair of rock walls attributed to the historic period.	Approximately 200 feet from Crouching Lion project area

SIHP No.	Historic Property Name	Description	Relationship to Project Areas
50-80-06-7952	Subsurface cultural layer	A subsurface trash pit at a private residence mauka of the highway.	Approximately 300 feet from Crouching Lion project area
50-80-06-6849	Rock wall	A historic-period rock wall on a private residence mauka of the highway.	Approximately 500 feet from Crouching Lion project area
50-80-06-6850	Above-ground sites	A traditional Hawaiian terrace on a private residence mauka of the highway.	Approximately 500 feet from the Crouching Lion project area
50-80-06-6934 and -6936	Retaining walls	A pair of historic-period masonry retaining walls located just south of the southern end of this section.	Approximately 100 feet from Crouching Lion project area
Vicinity of Punaluʻu Project Sites			
SIHP # 50-80-06-5308	Human skeletal remains	A human burial inadvertently discovered at a private residence mauka of the highway.	Approximately 350 feet from Punaluʻu South project area
SIHP # 50-80-06-3977	Human skeletal remains	A human burial inadvertently discovered at a private residence mauka of the highway.	Approximately 200 feet from Punaluʻu South project area
SIHP # 50-80-06-7932	Historic Bridge	Remnants of a historic bridge built in 1926 has been determined to be “no longer significant.”	Approximately 300 feet from Punaluʻu South project area

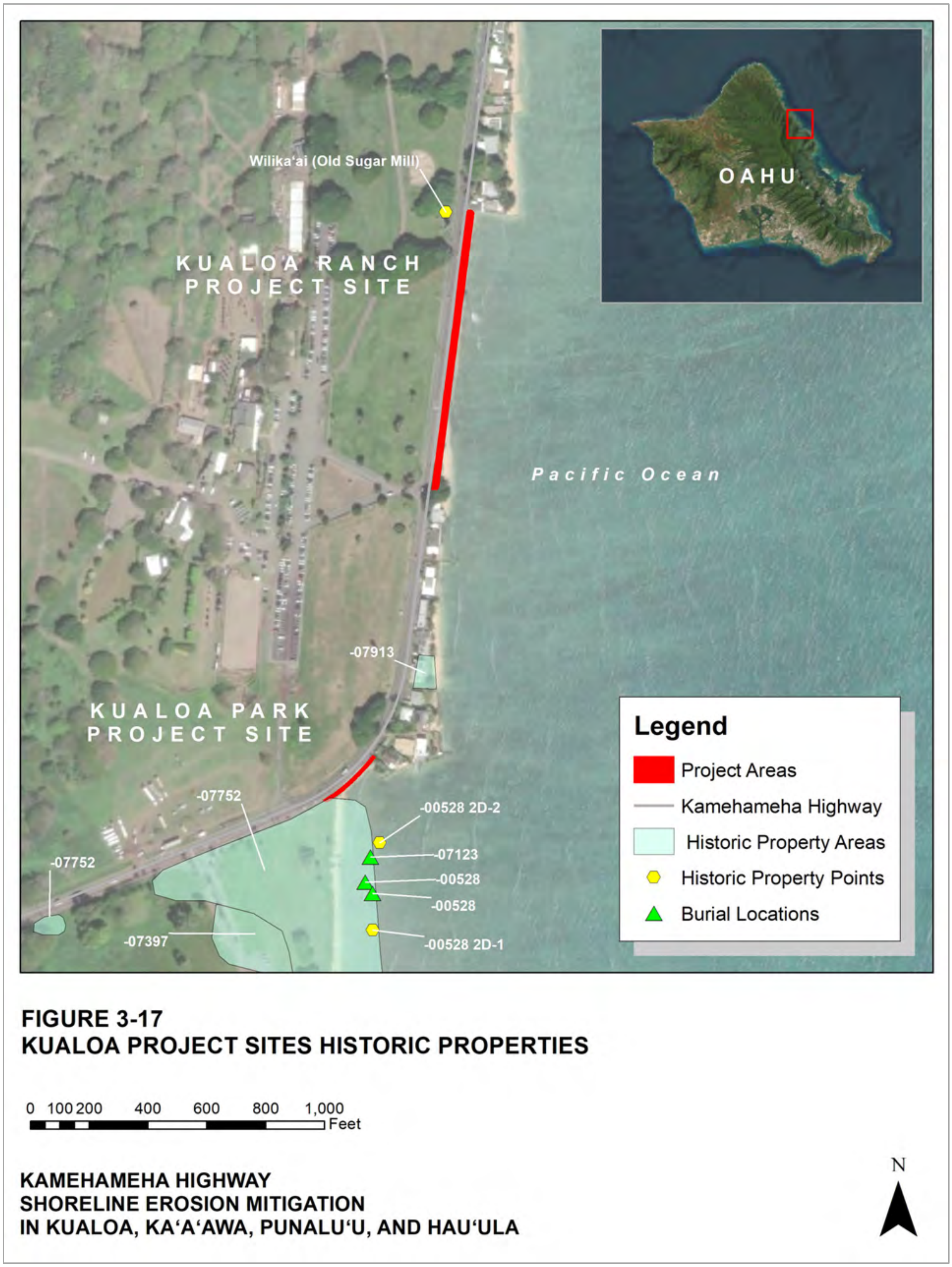


Figure 3-17. Kualoa Project Sites historic properties.

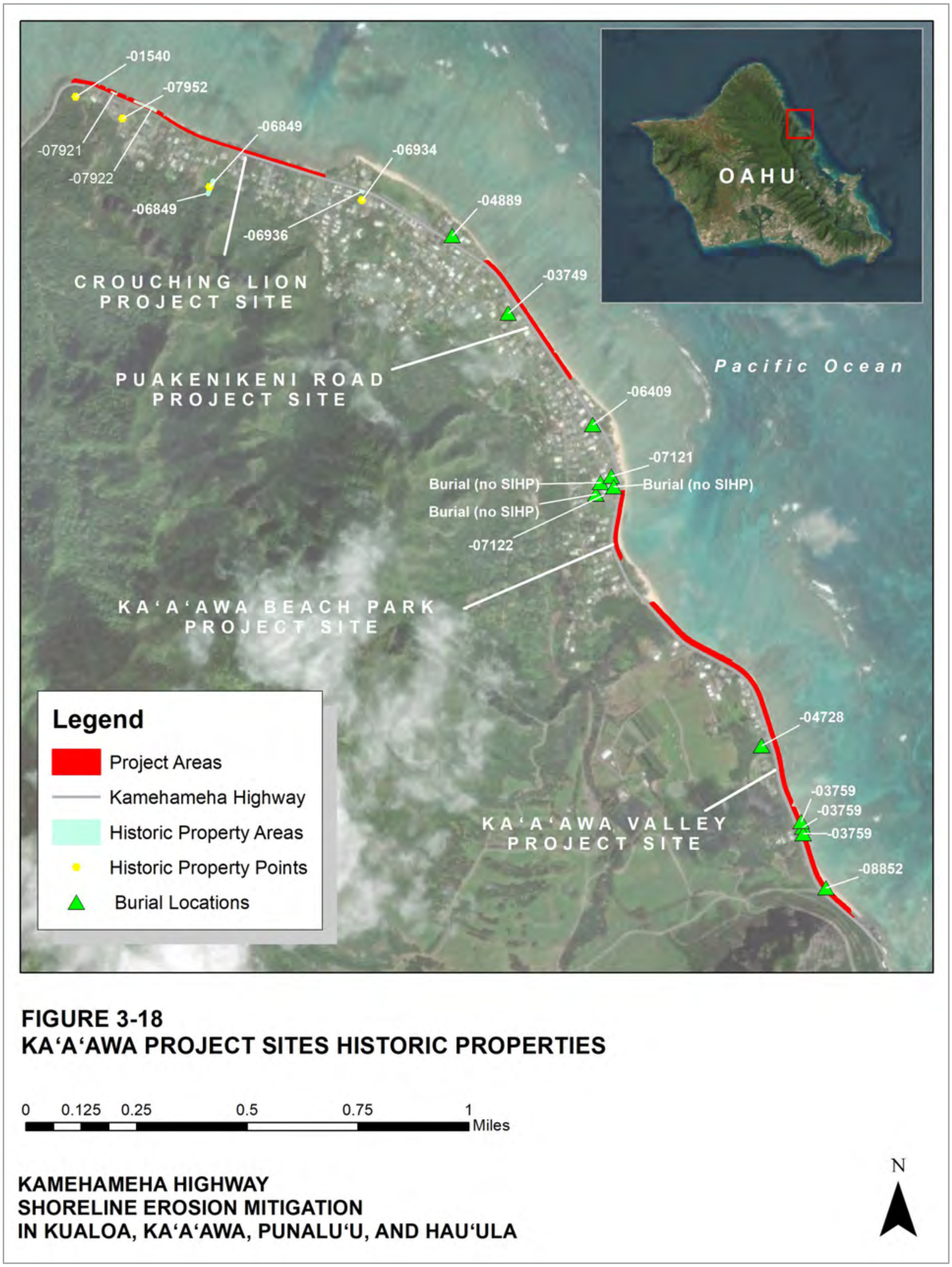


Figure 3-18. Ka‘a‘awa Project Sites historic properties.

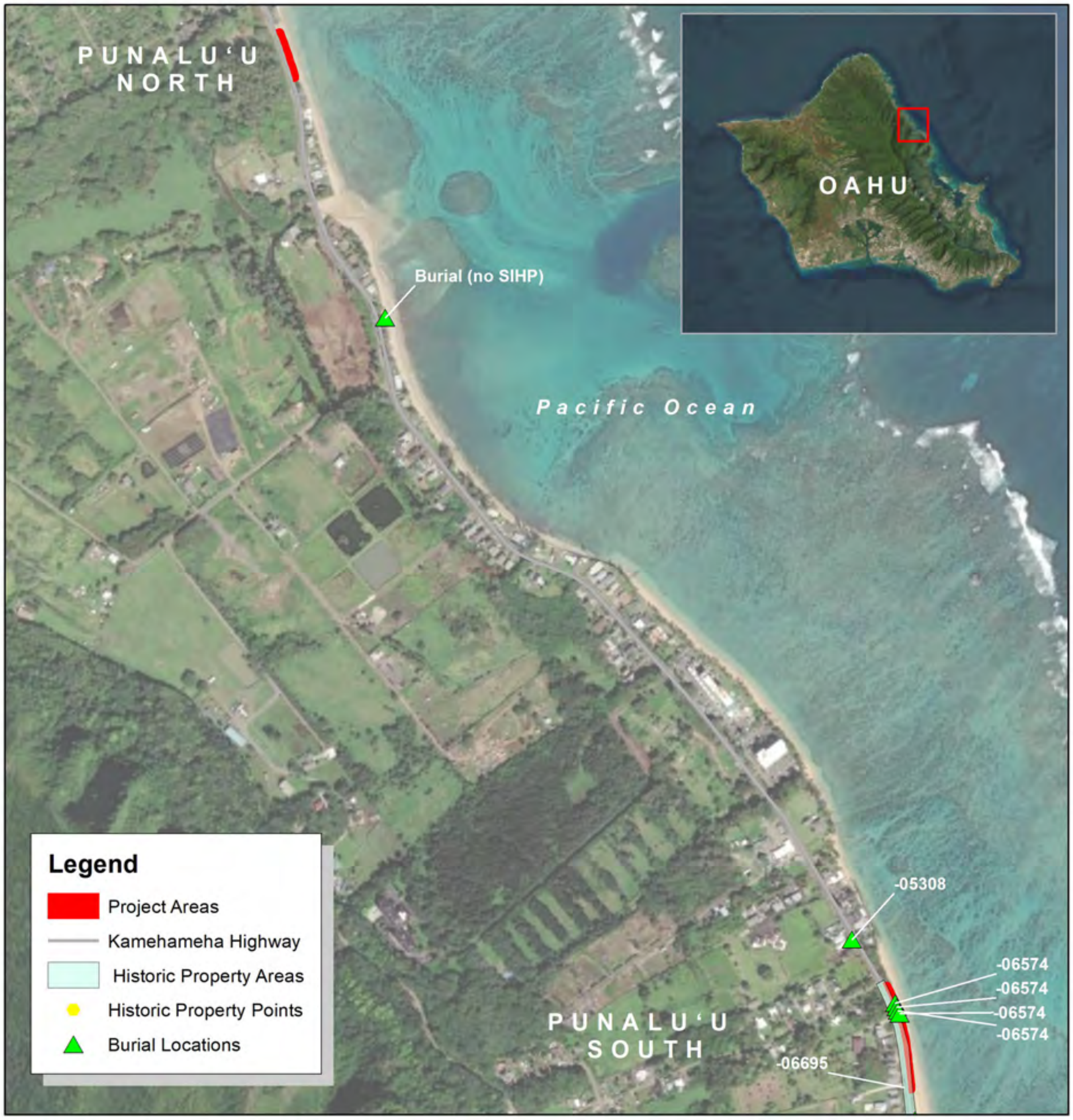


FIGURE 3-19
PUNALUʻU PROJECT SITES HISTORIC PROPERTIES

0 0.05 0.1 0.2 0.3 0.4 0.5 Miles

KAMEHAMEHA HIGHWAY
SHORELINE EROSION MITIGATION
IN KUALOA, KAʻAʻAWA, PUNALUʻU, AND HAUʻULA

N

Figure 3-19. Punaluʻu Project Sites historic properties.

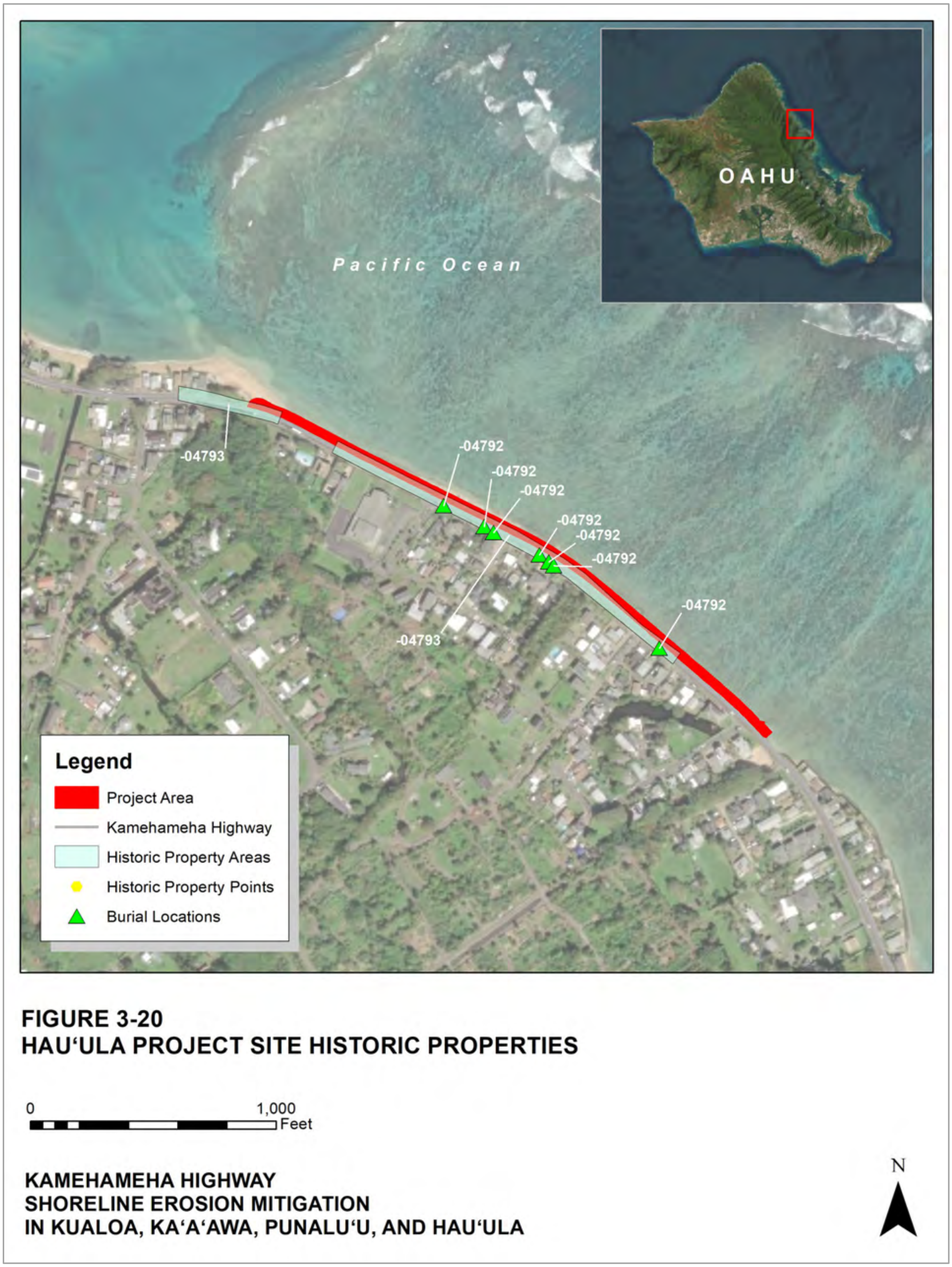


Figure 3-20. Hauʻula Project Site historic properties.

Traditional Cultural Activities and Related Resources

Traditional cultural practices are based on a profound connectivity between humans and their surrounding natural resources. Early native Hawaiian populations depended on these cultural practices for their survival. Complex systems for sustainable resource use and adaptation to seasonal and environmental changes were developed in response to specific environmental contexts. Many of these cultural practices and systems have been passed down from generation to generation, and some Hawaiian communities continue to observe these traditions and practices.

In support of this EA, a Cultural Impact Assessment was prepared by Honua Consulting, LLC and is included as Appendix D. The methodology used for the Cultural Impact Assessment included gathering cultural information from stories and other oral histories about the project area to provide a cultural foundation for the report. This was done by identifying information about the project area, including cultural, historic, and natural resources from previous studies performed in the range of the project area. The gathered information was then updated with interviews conducted with cultural or lineal descendants or other knowledgeable cultural practitioners, using their Ethnographic methodology. Interviews were conducted with seven (7) individuals who have lineal and cultural ties to the area and its vicinity. Specific information and concerns were shared regarding regional biocultural resources, potential impacts to these biocultural resources, and mitigation measures to minimize and/or avoid these impacts. Complete transcripts of the interviews are provided in Appendix D. The following is a summary of the interviews.

The individuals interviewed recall the coastline being culturally important for fishing, diving, and gathering of limu (seaweed). Important fish species (ʻōʻio, papio, ʻāweoweo, kala, and weke), limu species (kohu, wawaeʻiole, manauea, and līpoa), turtles, octopus, squid, crabs, lobster, and monk seals are cultural resources present in the project area. The coastline area is also known to contain burials and iwi.

The beach along the shoreline is where some conduct traditional Hawaiian ceremonies such as hiʻuwai[1], e ala e[2], and kapu kai[3]. For those who practice hula, the shoreline is a place where they gather culturally important plants that hālau hula use during their competitions.

[1] A *hiʻuwai* is a water purification ceremony, traditionally held on the second night of the month of Welehu (near the end of the month). purification festivities (Pukui and Elbert, 1986).
[2] *E ala ē* is a an *oli* (chant), meaning to “arise or awaken.” It is a traditional *oli* performed on the beach just before the sun peaks over the horizon and continues until the sun rises. (Kanahele et al., 2017).
[3] Kapu kai is a ceremonial sea bath for purification. This is done to purify oneself after evil or defilement, to remove the *kapu* (taboo). Historically women took this *kapu kai* after each menstrual period. Sometimes *kapu kai* is a precautionary measure. Preformed as a preparatory ceremony of a hula dancer's *ʻailolo* or "graduation" from training, and at the close of treatment by a medical *kahuna* (practitioner) (Pukui, 1972).

3.10.2 Potential Impacts and Mitigation Measures

Archaeological and Historic Resources

The proposed project includes the use of federal funds and therefore would require consultation with SHPO, NHOs, and other potentially interested parties in accordance with Section 106 of the NHPA. The project would also be reviewed by the SHPD in accordance with HRS Chapter 6E-8.

Large portions of the project area are within or immediately adjacent to Jaucas sand (JaC). These deposits are considered archaeologically sensitive because they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

As discussed above archaeological sites including Hawaiian burials have been identified within and adjacent to the project sites. There is a high likelihood that both previously identified and unidentified subsurface historic properties including burials would be encountered during construction.

The discovery of archaeological resources, other than burials, during construction would follow procedures prescribed in HAR Chapter 13-280. This would include halting construction activities in the vicinity of the historic property, protecting it from further disturbance, and notifying the SHPD. Construction would not resume in the vicinity of the archaeological resource until the findings have been evaluated by SHPD and the SHPD has verified that any required protection measures have been implemented, data recovery completed, and or mitigation executed. The discovery of burial sites and human remains during construction would follow procedures prescribed in HAR Chapter 13-300. This would include notification to the SHPD and police department, halting all activities in the vicinity, and protecting the burial site from damage. This would also include consultation with the Oʻahu Island Burial Council, lineal descendants, and appropriate NHOs.

To minimize potential impacts to archaeological resources shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term.

If no action is taken archaeological sites, including burials located in the project area may be impacted by coastal erosion in the near to mid-term (next 25-years). Stabilization of the shoreline would help protect archaeological sites located mauka of the roadway shoulder. The project presents an opportunity to protect in-place archaeological sites mauka of the roadway shoulder, and where found appropriate in consultation with the SHPO and NHOs, inventory and relocated historic properties in the project area that are threatened due to coastal erosion.

Cultural Resources

The proposed shoreline stabilization project has the potential to impact cultural resources and associated protected Native Hawaiian traditional and customary rights within the project area.

Those interviewed expressed worry that the proposed project would affect the access to traditional and cultural fishing, diving, and gathering spots along the shoreline, as those spots have been harder to access during previous roadwork events. They have concerns that the proposed project would change the face of what the area is today. If the project were to line the shoreline with large boulders, they are concerned that there could be a negative impact to the ecosystem, cultural resources (such as important species), and access for traditional and customary practices. Some are concerned that certain shoreline erosion mitigation measures along the beach may take up valuable space used by Hawaiian green sea turtles and Hawaiian monk seals. Others shared concerns regarding potential runoff caused by the proposed project. Past roadwork in the area impacted the ocean with loose rocks and they believe runoff from the proposed project could have a negative impact on the environment. One individual expressed concern regarding the use of concrete, as they believe that the lime in the concrete is harmful to the ecosystem and ocean. The general concern shared by all individuals is that there is a high possibility that the project would uncover iwi or other items of cultural significance.

Individuals interviewed provided recommendations for protecting the highway from coastal erosion including elevating the highway in anticipation of sea level rise and the addition of sand. Those interviewed also recommended avoiding any actions that would inhibit people from accessing the ocean or walking on the beach, that the proposed project should be a long-term solution, that the community be consulted regarding the project, and that there should be on-site cultural monitors, practitioners, consultants, or archaeologists during ground disturbing activities.

Access to the shoreline for traditional and customary practices within the project area will be impacted during construction. To minimize this impact construction activities at the project sites will be phased. The shoreline stabilization structures would not eliminate access to the shoreline but would make it more difficult to access for traditional and customary practices.

To minimize impacts to public access, shoreline resources, and cultural practices, shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term. As discussed above, the project would follow HAR governing procedures for the discovery of historic properties and relating to the protection of burial sites and human remains. In compliance with Section 106, consultation with NHOs will be performed and may result in solutions to alleviate limited access and continue Native Hawaiian traditional and customary practices in the project area.

3.11 Recreation

3.11.1 Existing Conditions

The relatively calm shoreline conditions and narrow sand beach in the project area and project vicinity make for an ideal location for coastal recreation. The broad offshore reef helps dissipate wave energy allowing for year-round use by shoreline fisherman, snorkelers, swimmers, paddlers, sailors, surfers, and spearfishermen.

There are several popular beach parks in the project vicinity, these include Kualoa Regional Park, Kalaeoio Beach Park, Kaʻaʻawa Beach Park, Swanzy Beach Park, Makaua Beach Park, and Punaluʻu Beach Park. These CCH and State parks, as well as public shoreline access points in the project vicinity are shown on Figures 3-21 to 3-24.

Section 4(f) of the U.S. Department of Transportation Act requires federal agencies to consider park and recreation land during the planning of transportation projects. Before approving a project that uses a park property, FHWA must determine there is no feasible and prudent alternative that would avoid the Section 4(f) properties and that the project includes all possible planning to minimize harm to the property, or FHWA makes a finding that the project has a *de minimis impact*.

Section 6(f) of the Land and Water Conservation Act requires that the conversion of lands or facilities acquired with Land and Water Conservation Act funds under a state assistance program be coordinated with the National Park Services. No prior projects using Land and Water Conservation Act funds have taken place in the project area.

3.11.2 Potential Impacts and Mitigation Measures

To minimize impacts to the shoreline and recreation resources, shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25 years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term.

The proposed project would include construction activities at both Kualoa Regional Park and Kaʻaʻawa Beach Park. An approximately 220-foot-long hybrid seawall with stone apron is proposed at the northern end of Kualoa Regional Park. An approximately 820-foot-long rock revetment would be constructed along a narrow strip of shoreline at Kaʻaʻawa Beach Park between Pohuehue Road and Kaʻaʻawa Elementary.

In general, HDOT would attempt to limit staging of construction materials and equipment to the existing roadway right-of-way. Some temporary staging on park property maybe required. The location and extent of staging areas would be selected to minimize impacts to park resources and public access. Any use of CCH land or CCH Parks for construction, access, or staging would be at the discretion of the CCH and would require a right-of-entry permit.

The hybrid seawall with stone apron at Kualoa Regional Park and the rock revetment at Kaʻaʻawa Beach Park would be considered a permanent use of Section 4(f) properties. Staging of construction equipment on park properties would be considered a temporary use. These proposed uses are not anticipated to adversely affect the activities, features, or attributes of the park properties and therefore would have a *de minimis* impact. The project would not eliminate any existing public shoreline access. However, the rock revetments would make it more difficult to access or walk along the shoreline.

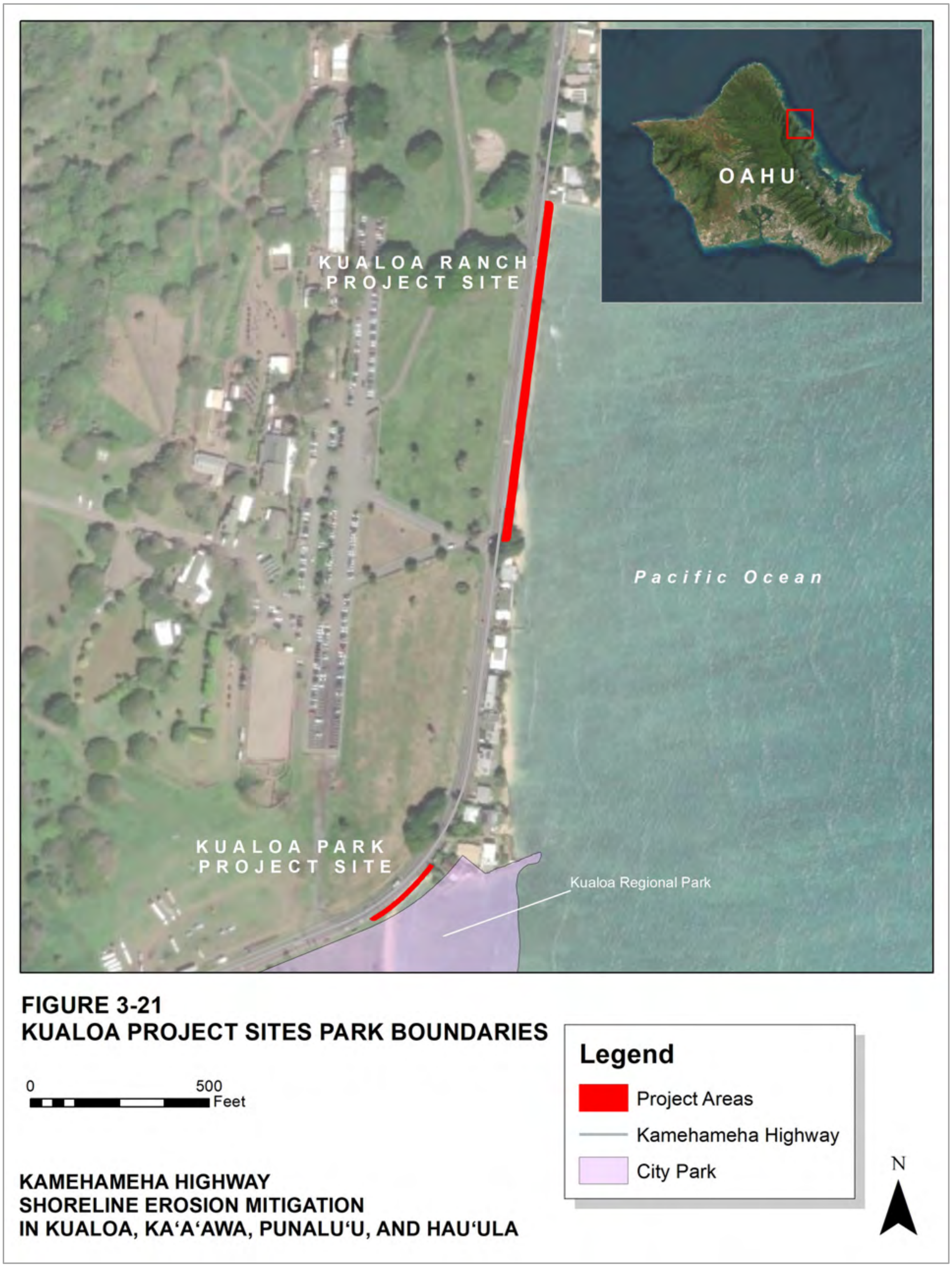


Figure 3-21. Kualoa Project Sites park boundaries.

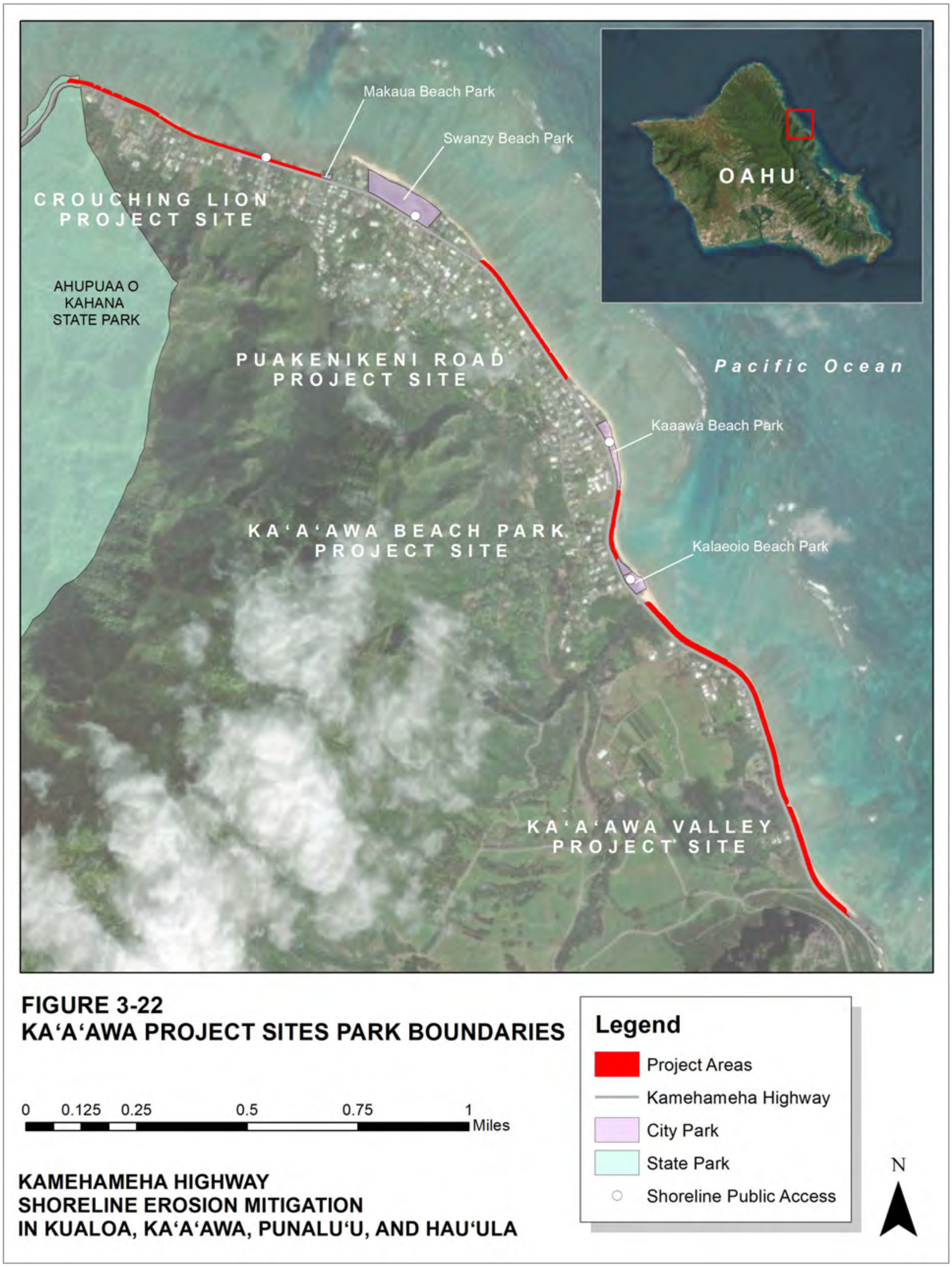


Figure 3-22. Ka'a'awa Project Sites Park boundaries.

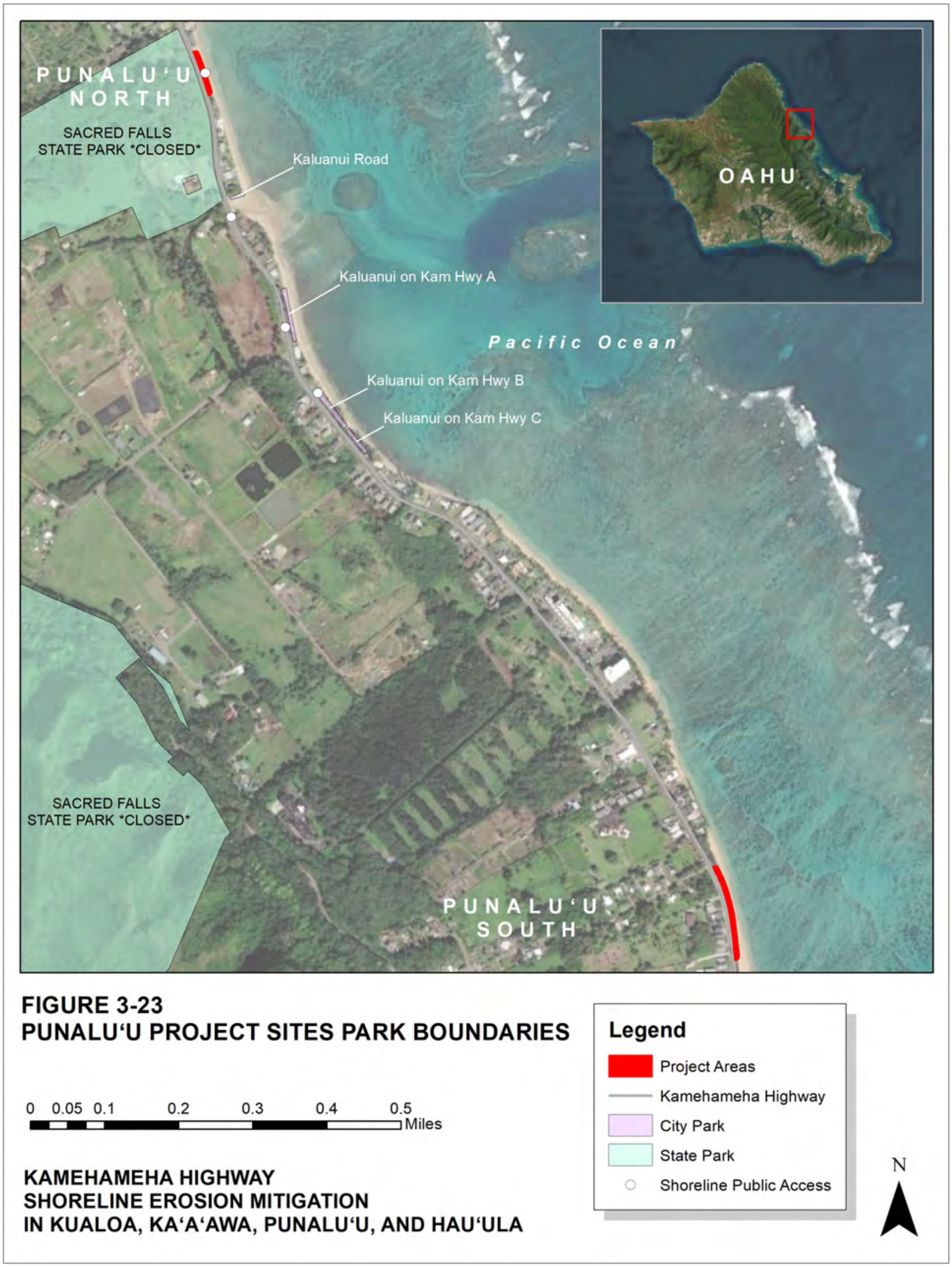


Figure 3-23. Punaluʻu Project Sites park boundaries.

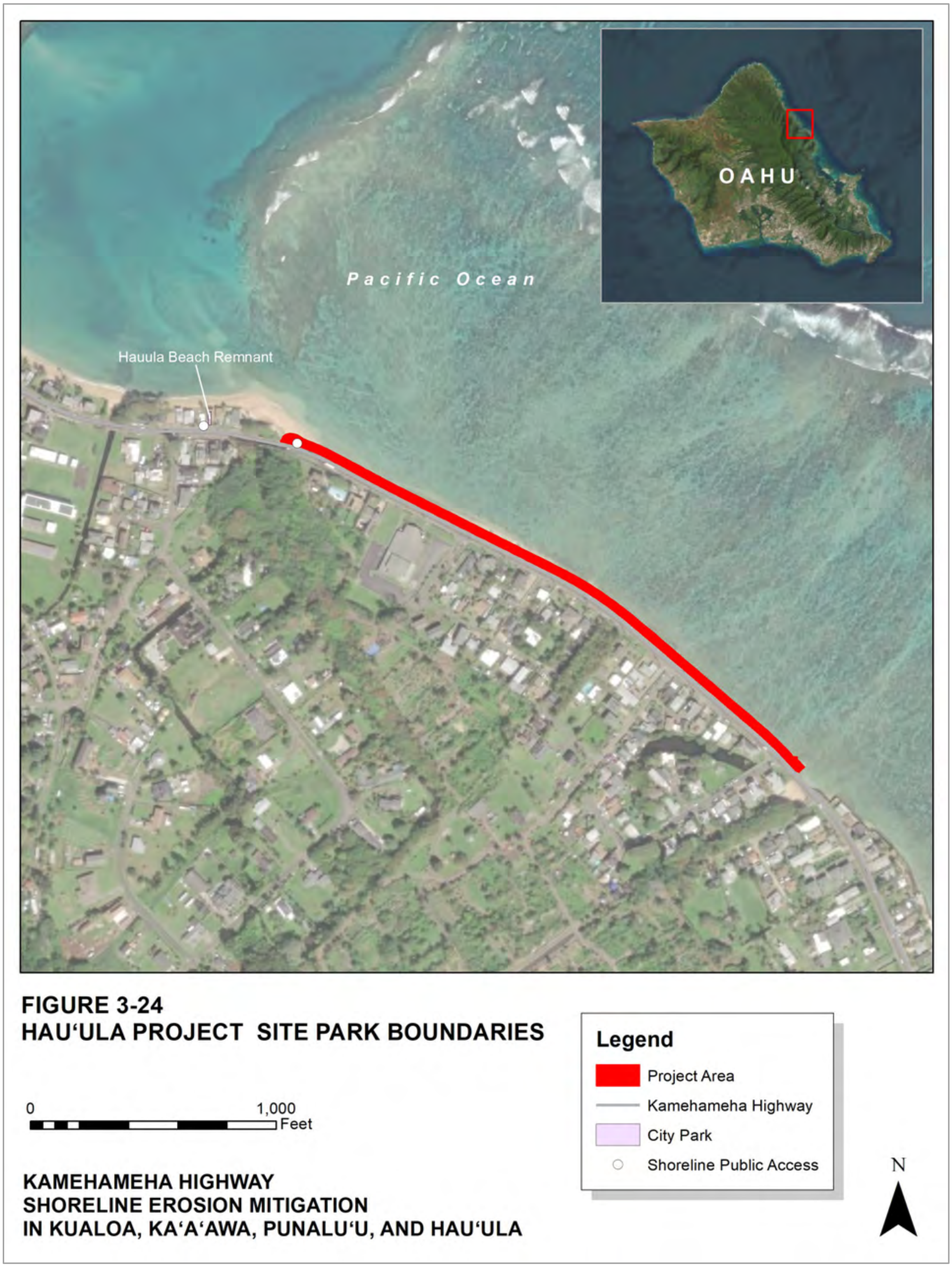


Figure 3-24. Hau‘ula Project Site park boundaries.

3.12 Socioeconomics

3.12.1 Existing Conditions

The windward coast in the vicinity of the project area is primarily residential. Near the project sites is an elementary school and a few convenience stops. The major economic driver along the windward coast is tourism, with attractions including undeveloped scenic shorelines, beach parks, and Kualoa Ranch which is a major employer. Many of the residents in this area rely on the highway to commute to jobs in other parts of Oʻahu.

3.12.2 Potential Impacts and Mitigation Measures

Kamehameha Highway is critical infrastructure as the only roadway connecting the windward communities of Kāneʻohe, Kahaluʻu, Kaʻaʻawa, Punaluʻu, Hauʻula, and Lāʻie. Maintaining the useability of the highway is critical to the economic welfare of the communities. The project may result in temporarily traffic delays during construction. These traffic delays are not anticipated to impact tourism or revenue at Kualoa Ranch. The purpose of the project is to maintain the useability of the highway in near to midterm for both residents and visitors; and prevent traffic impacts resulting from coastal erosion damage to the roadway.

3.13 Scenic and Aesthetic Resources

3.13.1 Existing Conditions

The coastal highway along the windward coast of Oʻahu is a very scenic drive, with the ocean view only occasionally obstructed by homes.

3.13.2 Potential Impacts and Mitigation Measures

There would be a temporary impact to scenic and aesthetic resources during construction. The proposed revetment crest and hybrid seawalls would be only 1 to 2 feet higher than the highway elevation and would not obstruct ocean views. The removal of coastal vegetation from these sections of shoreline would alter the appearance and feeling of the sites. Opportunities to incorporate landscaping into the rock revetment structures was considered. However, it was determined this could not be done without compromising the stability and resilience of the structures. At many locations the proposed shoreline stabilization structures would replace existing stabilization measures that are no longer effective. The proposed shoreline stabilization structures would modify the appearance of the natural shoreline but would be similar in appearance to other rock revetments seen at numerous locations on the windward coast. If the desired quarried armor stones are not available man-made concrete armor units could be utilized as an alternative. This would result in a more significant change to the appearance of the shoreline. The use of man-made concrete armor units would only be considered if larger armor stone becomes scare or uneconomical to source locally.

3.14 Public Infrastructure and Services

3.14.1 Existing Conditions

Transportation

Kamehameha Highway extends from Kāneʻohe near the east end of the island along the northeast (windward) coast to the North Shore town of Haleʻiwa. It is the only highway connecting the coastal communities of Kāneʻohe, Kahaluʻu, Kaʻaʻawa, Punaluʻu, Hauʻula, Lāʻie, and Kahuku. The HDOT records the annual average daily vehicle traffic count as 13,000 vehicles. It is the primary access for police, fire, and emergency medical vehicles.

Water

The Honolulu Board of Water Supply (BWS) is responsible for Oʻahu's municipal water system, an integrated, island-wide system with interconnections between water sources and service areas. The BWS has water transmission and distribution mains traversing through the entire length of the project area along Kamehameha Highway.

Telecommunication and Electric Power

Telecommunication and powerlines are primary located mauka of the highway with sporadic lines makai of the highway Electrical power is provided to the properties in the area by Hawaiian Electric Company overhead service lines.

Schools

Kaʻaʻawa Elementary School is located on the mauka side of the highway at the Kaʻaʻawa Beach Park Project Site. The Hauʻula Elementary School is located 1/3 mile north of the Hauʻula Beach Project Site.

Police, Fire, and Emergency Medical Services

Kualoa, Kaʻaʻawa, Punaluʻu and Hauʻula are served by the CCH Honolulu Police Department (HPD) District 4, which covers the area from Waimānalo to Kahuku. The Kahuku Police Substation is located approximately 5 miles north of the Hauʻula Project Site, and the Kāneʻohe Police Substation is located approximately 10 miles south of the Kualoa Park Project Site.

The closest hospital to most of the project sites that provides emergency room services is Kahuku Medical Center, located approximately 5 miles north of the Hauʻula Beach Project Site. The closet hospital with emergency medical services to the Kualoa Project sites is Castle Hospital in Kailua, which is located approximately 15 miles south of the Kualoa Park Project Site.

The closest medical clinic to most of the project sites is the Koʻolauloa Health Center at the Hauʻula Kai Shopping Center, located approximately 1 mile north of the of the Hauʻula Project Site. The Straub Medical Center-Kāneʻohe Clinic and Windward Urgent Care is located approximately 10 miles south of the Kualoa Park Project Site and would be the closest medical clinics or urgent care to that project site.

The Kaʻaʻawa Fire Station is located between the Crouching Lion Project Site and the Puakenikeni Road Project Site, and also provides emergency medical services. The Hauʻula Fire Station is located less than 1 mile north of the Hauʻula Project Site.

3.14.2 Potential Impacts and Mitigation Measures

Transportation

Chronic coastal erosion is increasingly chipping away at the windward Oʻahu coastline and has the potential to undermine Kamehameha Highway at each of the project sites in the near to mid-term. If the ongoing erosion forces the closure of Kamehameha Highway, travel between Kualoa Ranch and Hauʻula would be severely affected. All vehicles, including trucks, buses, emergency vehicles, and residential commuters would be detoured around the damaged area to State Routes H2 and H3, significantly impacting the livelihood and safety of all windward coast residents.

The proposed project would temporarily mitigate potentially significant shoreline erosion impacts to transportation along the windward coast. This project does not mitigate for anticipated sea level rise or its impacts on windward communities, but does allow this important infrastructure to remain functional, for at least another 25 years, while the problem of sea level rise is addressed.

Construction of this project would require closure of the northbound (makai) lane during periods of active construction. A traffic control plan would be developed to manage traffic flow during the lane closure. Flaggers and HPD enforcement would be utilized to allow for one-lane, two-way roadway closures. Lane closure times would be limited so as not to affect heavy commute periods. No work would be permitted on weekends or State holidays.

Since the project consists of nine (9) sites along the windward coast, construction at these sites would be phased and staggered to avoid cumulative construction impacts on traffic.

Water

The proposed construction activities makai of the roadway shoulder are not anticipated to affect the BWS distribution system as the BWS system is generally located under Kamehameha Highway. However, the HDOT would coordinate with the BWS to obtain copies of as-builts for all transmission and distribution mains within the project vicinity to ensure impacts to the municipal water distribution system are avoided. The proposed shoreline stabilization measures are intended to protect both the highway and underlying utilities for a period of 25-years until a long-term solution to coastal erosion and sea level rise is identified and implemented.

Telecommunication and Electric Power

Relocation of telecommunication and electric power lines is expected to be minimal as most of the overhead utilty poles are along the mauka side of the highway. Temporary relocation may be necessary to facilitate construction activities. Coordination would be conducted with the telecommunication and power companies prior to any modifications.

Schools

Construction activity could result in some noise and traffic impacts to Kaʻaʻawa Elementary School and traffic impacts to Hauʻula Elementary School. Construction noise mitigation measures discussed in Section 3.9.2 would be utilized.

Police, Fire, and Emergency Medical Services

Potential highway damage and closures, due to coastal erosion, would adversely affect access and response time for emergency vehicles. Depending on the location of the roadway closure, the nearest police, fire, and emergency medical service provider may not be the closest station.

The proposed project would mitigate this adverse effect, by protecting the highway from coastal erosion and maintaining the usability of the highway while a long-term solution to sea level rise can be developed.

During construction, traffic resulting from temporary lane closures, could have a minor impact on response times for emergency vehicles. The use of one-lane, two-way traffic lane closures would allow vehicular movement along Kamehameha Highway during construction. Flaggers would be posted at either end of the traffic control closure to direct traffic. The HPD enforcement officers would be positioned at the construction area to assist with prioritizing emergency vehicles through the construction zone. Additionally, the multiple sites comprising this project would be staggered so that the resulting traffic delays would be reduced.

3.15 Land Use and Land Ownership

3.15.1 Existing Conditions

Under HRS Chapter 205 lands in the State of Hawaiʻi are classified into four major land use districts (State Land Use Districts) which are Urban, Rural, Agricultural, and Conservation Districts. The project sites are located in the Agricultural, Conservation, and Urban Land Use Districts. Figures 3-25 through 3-28 below show the project area's State Land Use designations.

All areas makai of the shoreline are considered State Waters and a part of the Conservation District under the authority of the DLNR. Per HRS 205A, "shoreline" means the upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves, or as otherwise defined in section 205A-1. The use of land and waters makai of the shoreline would require a land use approval from the DLNR Land Division and a Conservation District Use Approval from the DLNR OCCL.

The project areas include HDOT roadway right-of-way as well as adjacent parcels owned by the State of Hawaiʻi, CCH, Kualoa Ranch Incorporated, and other private landowners listed in Table 3.8. Most of the project area that is outside HDOT roadway right-of-way is on submerged tidal land. While there is a registered fee owner associated with these submerged lands, they are the property of the State of Hawaiʻi under the management of the DLNR. Lands owned by the CCH in the project area are part of Kualoa Regional Park and Kaʻaʻawa Beach Park.

Table 3-8. Tax Map Keys (TMKs), land owners, and land uses.

TMK	Owner	Use
Kualoa Park Project Site		
4-9-004:001	CCH	Kualoa Regional Park
Kualoa Ranch Project Site		
4-9-009:011	Yap, Theodore T, Yap, Harriet T, Kualoa Ranch Incorporated	Submerged tidal land
4-9-009:012	Kualoa Ranch Incorporated	Submerged tidal land
4-9-009:013	Kualoa Ranch Incorporated	Submerged tidal land
4-9-009:014	Kualoa Ranch Incorporated	Submerged tidal land
4-9-009:015	Kualoa Ranch Incorporated	Submerged tidal land
Kaʻaʻawa Valley Project Site		
5-1-013:010	Kualoa Ranch Incorporated	Submerged tidal land
5-1-013:011	Kualoa Ranch Incorporated	Submerged tidal land
5-1-006:017	Kualoa Ranch Incorporated	Submerged tidal land
5-1-001:008	Kualoa Ranch Incorporated	Submerged tidal land
5-1-001:009	Kualoa Ranch Incorporated	Submerged tidal land
Kaʻaʻawa Beach Park Project Site		
5-1-009:028	CCH	Kaʻaʻawa Beach Park
5-1-002:025	CCH	Kaʻaʻawa Beach Park
Puakenikeni Road Project Site		
5-1-010:029	Tani, Agnes L Trust; Tani, Tokuo Trust	Submerged tidal land
5-1-010:030	Kualoa Ranch Incorporated	Submerged tidal land
5-1-010:031	Kualoa Ranch Incorporated	Submerged tidal land
5-1-012:001	Kualoa Ranch Incorporated	Submerged tidal land
Crouching Lion Project Site		
5-1-003:003	CCH	Submerged tidal land

TMK	Owner	Use
5-1-003:006	Cement 6 LLC	Submerged tidal land
5-1-003:007	Cement 6 LLC	Submerged tidal land
5-1-003:010	Prow, Denise M; Prow, Marcella A	Submerged tidal land
5-1-003:011	Smythe, Alfred K; Smythe, Timothy K; Smythe, Donald K	Submerged tidal land
5-1-003:018	Takeru, Inc.	Submerged tidal land
5-1-003:019	Takeru LLC	Submerged tidal land
5-1-003:022	Nozawa, Robert	Submerged tidal land
5-1-003:023	Tokiwa, Masao; Hayashi, Jade Y	Submerged tidal land
5-1-005:021	State of Hawaiʻi	Submerged tidal land
Punaluʻu South Project Site		
5-3-006:037	Choy, Hung Fat; Choy, Agnes K	Submerged tidal land
Punaluʻu North Project Site		
N/A	N/A	Submerged tidal land
Hauʻula Project Site		
5-3-014:016	Hayashi, Alan; Hayashi, Amy	Submerged tidal land
5-3-014:018	State of Hawaiʻi	Submerged tidal land
5-3-014:015	State of Hawaiʻi	Submerged tidal land
5-3-014:014	State of Hawaiʻi	Submerged tidal land
5-3-014:013	State of Hawaiʻi	Submerged tidal land
5-3-014:010	State of Hawaiʻi	Submerged tidal land
5-3-014:009	State of Hawaiʻi DLNR	Submerged tidal land
5-3-016:001	State of Hawaiʻi	Submerged tidal land

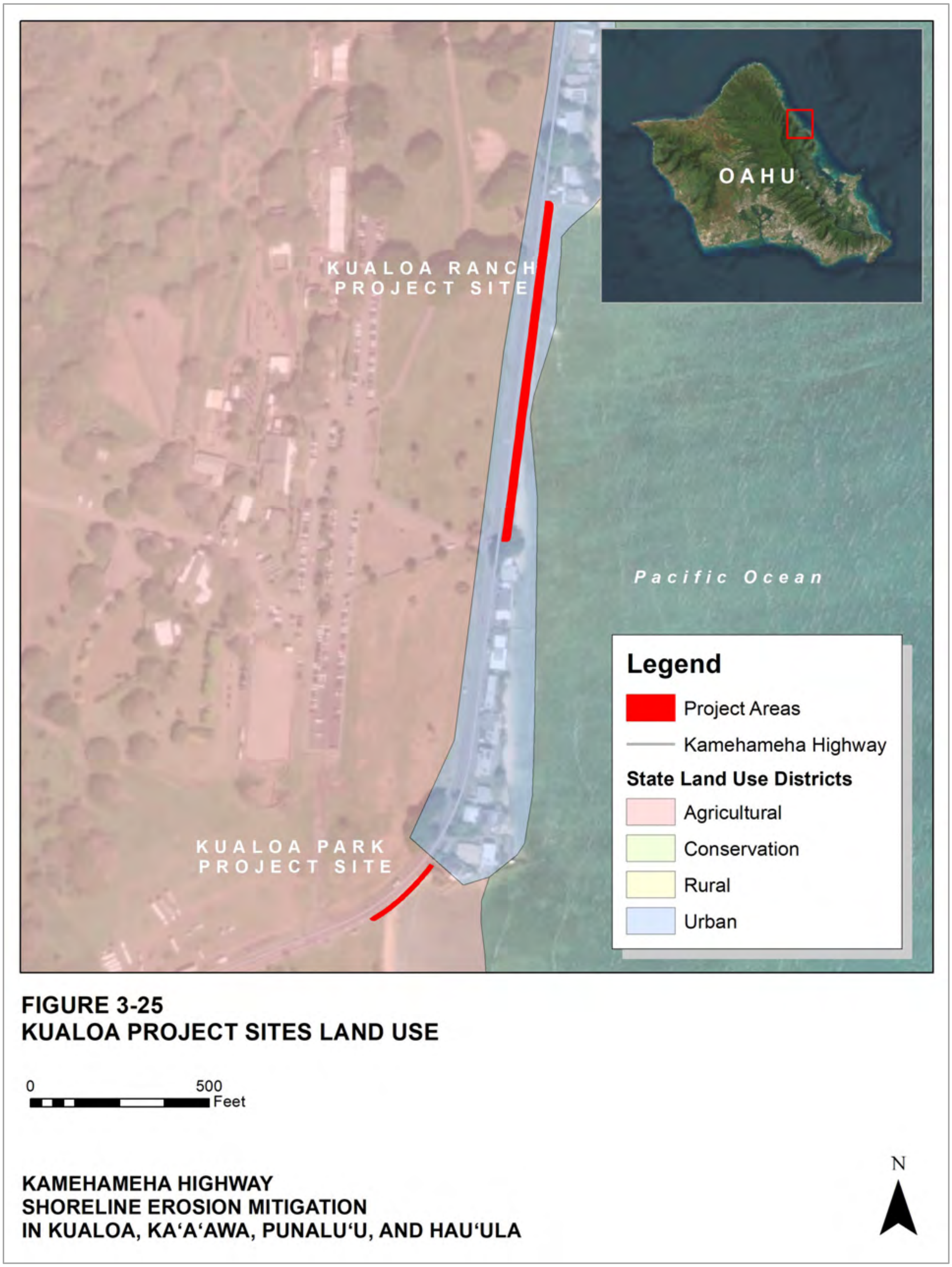


Figure 3-25. Kualoa Project Sites land use.

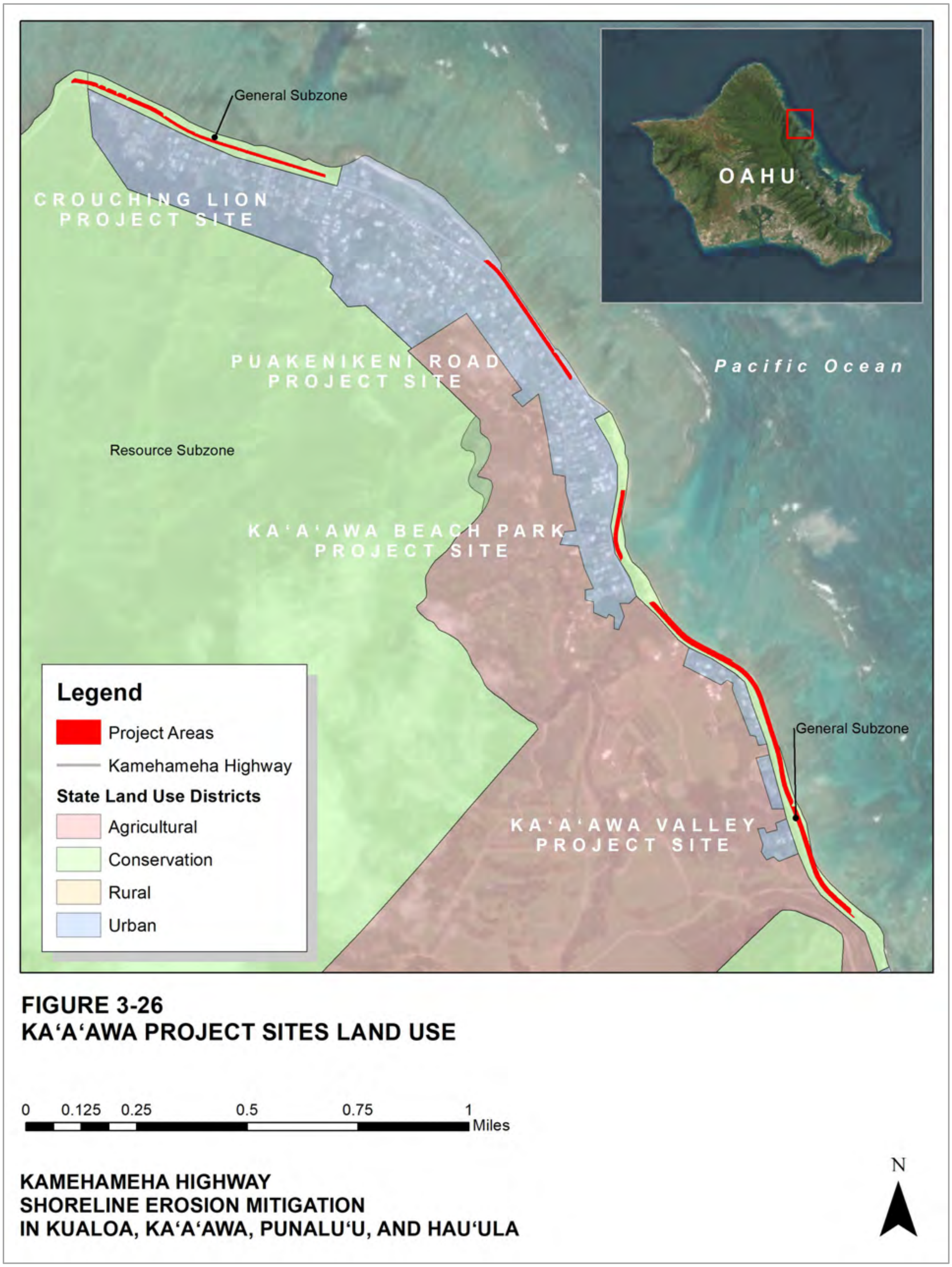


Figure 3-26. Kaʻaʻawa Project Sites land use.

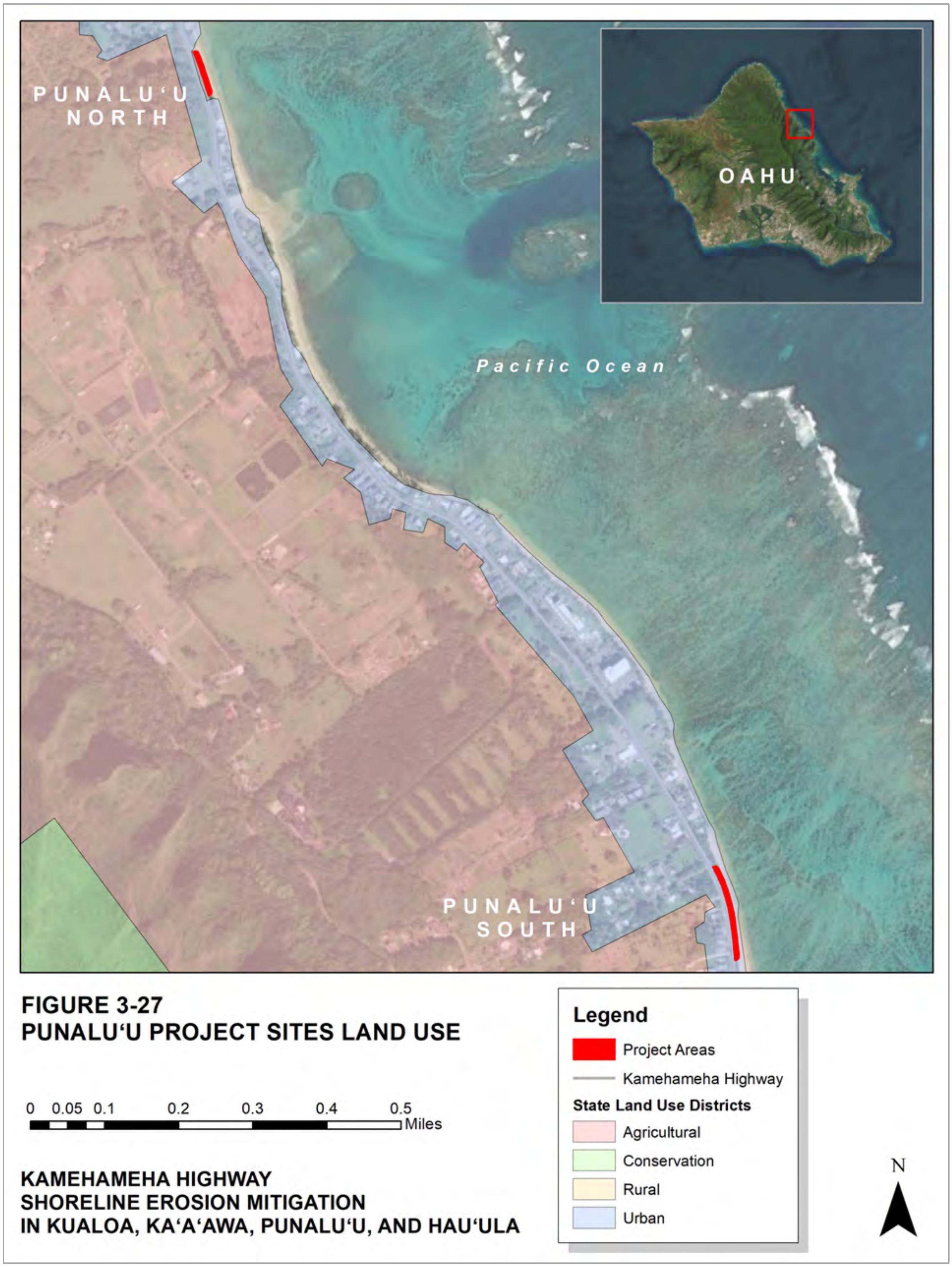


Figure 3-27. Punaluʻu Project Sites land use.

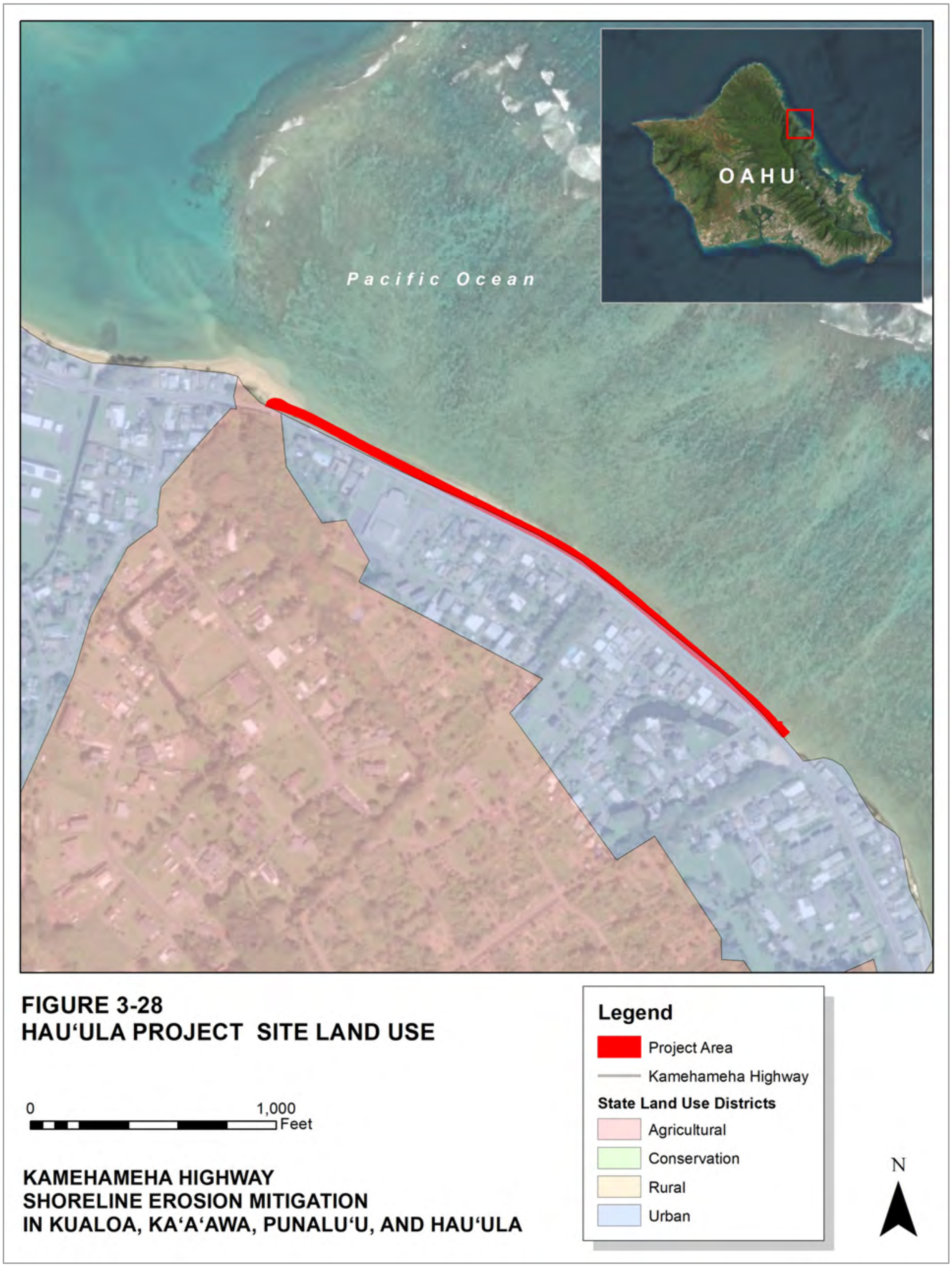


Figure 3-28. Hau'ula Project Site land use.

3.15.2 Potential Impacts and Mitigation Measures

The HDOT would work with the CCH DPR and the DLNR Land Division to secure required easements, use and occupancy agreements, and or other required land use approvals. No purchase or transfer of land ownership is anticipated. Conditions and mitigation measures associated with use of the land and potential construction impacts would be negotiated with the respective landowners. The proposed project would secure and comply with conditions of a Conservation District Use Approval.

4. Cumulative and Secondary Impacts

Per HAR Chapter 200.1 a cumulative impact is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

The proposed action, when considered in conjunction with past, present, and reasonably foreseeable future actions to the environment, may result in cumulative impacts. Below is a summary of known current and proposed shoreline stabilization projects on the windward coast and other known current and proposed construction projects in the project vicinity. A review of potential cumulative and secondary impacts of the proposed action and other known actions is also provided.

4.1 Past, Present, and Reasonably Foreseeable Future Projects

This section summarizes several projects that have the potential to contribute to cumulative impacts.

BWS Water System Improvement Project

The BWS has an ongoing water system improvement project to replace a water main within the limits of the project area in the vicinity of Puhuli Street and the Punaluʻu area. This project is tentatively scheduled for construction in 2027. The construction schedule would be coordinated with BWS to minimize impacts to the water system.

Hauʻula Short-Term Repair Project

This project is currently ongoing and involves removal of damaged Kyowa bags, installation of a temporary rock revetment, and repairs to the roadway shoulders. Repairs to a 100-foot section have been completed. The proposed KKPH project would replace all Kyowa bags and temporary rock revetment with an engineered rock revetment.

Kalaeʻōʻio Beach Short-Term Repair Project

This project included removal of 100-feet of guardrail, repairs to the roadway shoulder, and replacement and extension of 130 linear feet of rock revetment. It was completed in 2023. The KKPH project would replace this short-term repair with and engineered rock revetment.

Kamehameha Highway Culvert Remediation, Mile Post 23-30

The Kamehameha Highway Culvert Remediation is a proposed construction project. The proposed project limits begin in the vicinity of the Kualoa Ranch Project Site and ends just before the Punaluʻu North Project Site. It is scheduled for bid advertisement in winter 2024.

Kamehameha Highway at Kaʻaʻawa Erosion Mitigation

The Kamehameha Highway at Kaʻaʻawa Erosion Mitigation project involves the installation of 500 linear feet of engineered rock revetment. Construction is anticipated to begin in summer 2024 and be completed in 2025.

Hawaiian Fishpond Reconstruction

The HDOT has been working with OCCL and the local community to identify historic fishpond locations on the windward coast that can be reconstructed. Fishpond walls help reduce longshore sediment transport and may help to stabilize adjacent beaches. A Hawaiian fishpond reconstruction project is being planned for at Kualoa Park and possibly two other locations in Kaʻaʻawa and Hauula.

4.2 Potential Cumulative and Secondary Impacts

4.2.1 Surface Waters and Water Quality

Some of the above-mentioned projects have the potential to result in temporary increases in pollutants and turbidity from earthmoving and construction activities. Construction of these projects, including work at the nine KKPH Project Sites, would be phased to avoid and minimize cumulative impacts, and the use of appropriate BMPs would be implemented.

4.2.2 Transportation

All of the abovementioned projects have the potential to result in temporary impacts to traffic during construction. Construction of these projects, including work at the nine KKPH Project Sites, would be phased to avoid and minimize cumulative impacts.

4.2.3 Scenic and Aesthetic Resources

The above-mentioned projects, including the proposed KKPH Project Sites, have the potential to temporarily impact scenic and aesthetic resources during construction.

The revetments and hybrid seawalls, proposed as part of the KKPH project, would be only one to two feet higher than the highway elevation and would not obstruct ocean views. The removal of coastal vegetation from the KKPH Project Sites would alter the appearance and feeling of the shoreline.

The proposed Sandsaver pilot project and Sandsaver structures may slightly detract from natural scenic beauty of the beaches where they are placed only until they are fully immersed under sand, at which point they would no longer be visible.

The other shoreline stabilization projects are in locations where shoreline stabilization measures have been previously installed. The replacement and improvements to these measures would not significantly alter the aesthetics of the respective areas.

The non-shoreline stabilization projects, BWS Water System Improvement project and Kamehameha Highway Culvert Remediation projects, involve underground work and would not impact scenic or aesthetic resources.

5. Relationship to Relevant Plans and Policies

The State of Hawaiʻi maintains a statewide planning system that includes State and County land use plans, policies, and controls to provide standards and guidelines for development. The following sections evaluate the proposed action in relation to the goals and policies of the Hawaiʻi State Planning Act, the Hawaiʻi Environmental Policy Act (HEPA), Hawaiʻi State Land Use Classification, State of Hawaiʻi CZM Program, CCH General Plan, CCH Koʻolau Poko and Koʻolau Loa Sustainable Communities Plan.

5.1 Hawaiʻi State Plan

The Hawaiʻi State Planning Act (Chapter 226 HRS) provides guidance for future long-range development of the State by increasing coordination among different agencies and levels of government and providing a basis for determining priorities and allocation of resources.

The purpose of the Hawaiʻi State Plan, as defined in HRS Chapter 226, is to:

- Serve as a guide for the future long-range development of the State;
- Identify the goals, objectives, policies, and priorities for the State;
- Provide a basis for determining priorities and allocating limited resources, such as public funds, services, human resources, land, energy, water, and other resources;
- Improve coordination of Federal, State, and County plans, policies, programs, projects, and regulatory activities; and
- Establish a system for plan formulation and program coordination to provide for an integration of all major State, and county activities (HRS Title 13, Chapter 226).

The State Plan outlines goals to achieve for present and future generations to obtain the elements of choice and mobility to ensure individuals and groups may approach their desired levels of self-reliance and self-determination. The goals include:

1. A strong, viable economy, characterized by stability, diversity, and growth, that enables the fulfillment of the needs and expectations of Hawaiʻi's present and future generations.
2. A desired physical environment, characterized by beauty, cleanliness, quiet, stable natural systems, and uniqueness, that enhances the mental and physical well-being of the people.
3. Physical, social, and economic well-being, for individuals and families in Hawaiʻi, that nourishes a sense of community responsibility, of caring, and participation in community life.

Specific objectives and policies of the State Plan that pertain to the project are as follows.

Section 226-11 Objectives and policies for the physical environment – land-based, shoreline, and marine resources.

(a) Planning for the State's physical environment with regard to land-based, shoreline, and marine resources shall be directed towards achievement of the following objectives:

(1) Prudent use of Hawaii's land-based, shoreline, and marine resources.

(2) Effective protection of Hawaii's unique and fragile environmental resources.

(b) To achieve the land-based, shoreline, and marine resources objectives, it shall be the policy of this State to:

(1) Exercise an overall conservation ethic in the use of Hawaii's natural resources.

(2) Take into account the physical attributes of areas when planning and designing activities and facilities.

(3) Manage natural resources and environs to encourage their beneficial and multiple use without generating costly or irreparable environmental damage.

(4) Encourage the protection of rare or endangered plant and animal species and habitats native to Hawaii.

(5) Pursue compatible relationships among activities, facilities, and natural resources.

The project is a prudent use of Hawaiʻiʻs shoreline resources necessary to maintain usability of Kamehameha Highway for the near to mid-term. Implementing stabilization measures so the highway is sufficiently protected from advancing coastal erosion, allowing it to remain open and serviceable for commuters, commerce, emergency services, and all motorists for the next 25 years. The preferred alternatives were selected to minimize impacts to natural resources.

The project would not result in irreparable environmental damage. The majority of potential impacts, including those to water quality, would be minor, temporary, and contained to the immediate project vicinity. The proposed rock revetments and hybrid sea walls are potentially removable structures that could be modified or removed as needed to allow for construction of alternative shoreline protection or sea level rise adaptation measures. The rock revetments and hybrid seawalls would not preclude and could continue to be used in combination with other future projects that could include beach nourishment or managed retreat.

The project would not result in significant impacts or adverse effects to rare, threatened, endangered native species or their habitats. In addition, the project has incorporated numerous measures to further avoid and minimize any potential effects to listed plants, coral, EFH, monk seals, sea turtles, Hawaiian hoary bats, Hawaiian seabirds, and Hawaiian waterbirds, as described in Sections 3.7.2 and 3.8.2.

The proposed shoreline stabilization structures would provide hard substrates and habitat for marine invertebrates in the tidal zone.

Section 226-12 Objectives and policies for the physical environment – scenic, natural beauty, and historic resources.

(a) Planning for the State's physical environment shall be directed towards achievement of the objective of enhancement of Hawaii's scenic assets, natural beauty, and multicultural/historical resources.

(b) To achieve the scenic, natural beauty, and historic resources objectives, it shall be the policy of the State to:

(1) Promote the preservation and restoration of significant natural and historic resources.

(2) Promote the preservation of views and vistas to enhance the landscapes, and other natural features.

(3) Encourage the design of developments and activities that complement the natural beauty of the islands.

The project would have no effect to above-ground historic properties. The project sites are located in an archaeologically sensitive area where numerous subsurface archaeological sites including burials have been previously identified, as discussed in Section 3.10. The project would be reviewed by SHPD and NHOs in accordance with HRS Chapter 6E and the NHPA Section 106; and would follow HAR governing procedures for the discovery of historic properties and relating to the protection of burial sites and human remains.

The proposed rock revetment crest and hybrid seawalls would be only 1 to 2 feet higher in elevation than the adjacent shoreline/highway, and therefore would not obstruct ocean views.

Section 226-13 Objectives and policies for the physical environment – land, air, and water quality.

(a) Planning for the State's physical environment with regard to land, air, and water quality shall be directed towards achievement of the following objectives:

(1) Maintenance and pursuit of improved quality in Hawaii's land, air, and water resources.

(b) To achieve the land, air, and water quality objectives, it shall be the policy of the State to:

(1) Promote the proper management of Hawaii's land and water resources.

(2) Reduce the threat to life and property from erosion, flooding, tsunamis, hurricanes, earthquakes, volcanic eruptions, and other natural or man-induced hazards and disasters.

(3) Encourage design and construction practices that enhance the physical qualities of Hawaii's communities.

The proposed project would reduce threats to life and property from coastal erosion and help protect roadway infrastructure from other coastal hazards as discussed in Section 3.5. The project would have a minor temporary impact to nearshore water quality during construction. These potential water quality impacts would be minimized and contained to the immediate project vicinity through the use of appropriate BMPs including turbidity curtains. The revetments and hybrid seawalls are expected provide beneficial effects for the long-term quality of nearshore waters since they would minimize ongoing shoreline erosion and mitigate the release of fine soils into the water column from exposed and eroding earthen embankments. The revetments and hybrid seawall would also offer protection of the shoreline from episodic wave action caused by storms, which would therefore decrease the amount of turbidity in the nearshore waters at the project sites during these events.

5.2 Hawaiʻi Environmental Policy Act

The HEPA outlines the process of environmental review for the State and counties. The HEPA is codified in HRS Chapter 343 and implemented through HAR Chapter 11-200.1. The review ensures that environmental concerns are appropriately considered in decision-making. For the Proposed Action, an environmental review is required because the action involves the following:

- Proposed use of State lands and use of State funds, other than funds to be used for feasibility or planning studies for possible future programs or projects that the agency has not approved, adopted, or funded, or funds to be used for the acquisition of unimproved real property (HRS 343-5(a)(1)).
- Proposed use within land classified as a conservation district by the state land use commission under HRS Chapter 205 (HRS 343-5(a)(2));
- Proposed use within a shoreline area as defined in HRS Section 205A-41 (HRS 343-5(a)(3)).

This EA was prepared in accordance with all applicable provisions from both HRS Chapter 343 and HAR Chapter 11-200.1.

5.3 Hawaiʻi State Land Use District

The Hawaiʻi Land Use Commission (LUC) administers the statewide zoning law under the authority granted by the State Land Use Law. The LUC regulates land use through land classification into one of four districts: Urban, Rural, Agriculture, and Conservation. The project sites are within the Urban, Agricultural, and Conservation Districts, as discussed in Section 3.14. The land classification system is intended to preserve, protect, and encourage development and preservation of lands for those uses to which they are best suited in the interest of public health and welfare of the people (HAR Title 15, Chapter 15).

Permitted uses or activities within the Urban District are provided by ordinances or regulations of the county within which the Urban District is situated. Thus, Urban District lands on the Island of Oʻahu are regulated by the ordinances and regulations of the CCH. Kamehameha Highway is the major coastal highway providing connectivity between communities on the windward shore of Oʻahu and is consistent with the intent of the Urban District.

Public and private roadways and open area types of recreational uses including day camps, picnic grounds, and parks are permitted within lands with productivity agricultural categories A, B, C, D, E, and U, therefore, consistent with the intent of the Agricultural District.

The Office of Conservation and Coastal Lands (OCCL) regulates land uses in the Conservation District through issuance of CDUPs and Site Plan Approvals. All State marine waters makai (seaward) of the certified shoreline are within the Conservation District. Shoreline erosion control is an approved land use in the Conservation District, requiring a permit from the Board of Land and Natural Resources, pursuant to HAR 13-5-22, P-15 Shoreline Erosion Control (D-1), "Seawall, revetment, groin, or other erosion control structure or device, including sand placement, to control erosion of land or inland area by coastal waters provided that the applicant shows that (1) the applicant would be deprived of all reasonable use of the land or building without the permit; (2) the use would not adversely affect beach processes or lateral public access along the shoreline, without adequately compensating the State for this loss; or (3) public facilities (e.g., public roads) critical to public health, safety, and welfare would be severely damaged or destroyed without a shoreline erosion control structure, and there are not reasonable alternatives (e.g., relocation). Requires a shoreline certification."

5.4 Hawaiʻi Coastal Zone Management

Per the National Coastal Zone Management Act of 1972, Hawaiʻi's CZM Program outlines objectives and policies to guide the effective management, beneficial use, protection, and development of the coastal zone. The entire State of Hawaiʻi is located within the jurisdiction of the CZM Program. Hawaiʻi's CZM Program was established through HRS Chapter 205A. The objectives and policies in HRS Chapter 205A-2 were reviewed, and it has been determined that the Proposed Action is consistent with the objectives and policies of HRS Chapter 205A-2.

Table 5-1 lists applicable objectives and policies of HRS Chapter 205A-2, followed by a discussion of the consistency of the Proposed Action with them. Where an Objective and Policy section of HRS Chapter 205A-2 is not listed below, it has been analyzed and determined to be not applicable to the Proposed Action.

Table 5-1. Coastal Zone Management Act HRS Chapter 205A.

Recreational Resources

Objective: (A) Provide coastal recreational opportunities accessible to the public.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(A) Improve coordination and funding of coastal recreational planning and management.			X
(B) Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:	X		

(i)	Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;	X		
(ii)	Requiring replacement of coastal resources having significant recreational value including, but not limited to, surfing sites, fishponds, and sand beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the State for recreation when replacement is not feasible or desirable;	X		
(iii)	Providing and managing adequate public access, consistent with conservation of natural resources, to and along shorelines with recreational value;	X		
(iv)	Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;	X		
(v)	Ensuring public recreational uses of county, state, and federally owned or controlled shoreline lands and waters having recreational value consistent with public safety standards and conservation of natural resources;	X		
(vi)	Adopting water quality standards and regulating point and nonpoint sources of pollution to protect, and where feasible, restore the recreational value of coastal waters;	X		
(vii)	Developing new shoreline recreational opportunities, where appropriate, such as artificial lagoons, artificial beaches, and artificial reefs for surfing and fishing; and	X		
(viii)	Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the land use commission, board of land and natural resources, and county authorities; and crediting such dedication against the requirements of Section 46-6.	X		

Discussion: The relatively calm shoreline conditions and narrow sand beach in the project area and project vicinity make for an ideal location for coastal recreation. The broad offshore reef helps dissipate wave energy allowing for year-round use by shoreline fisherman, snorkelers, swimmers, paddlers, sailors, surfers, and spearfishermen.

There are several popular beach parks in the project vicinity, these include Kualoa Regional Park, Kalaeoio Beach Park, Kaʻaʻawa Beach Park, Swanzy Beach Park, Makaua Beach Park, and Punaluʻu Beach Park. These CCH and State parks, as well as public shoreline access points in the project vicinity are shown on Figures 3-21 to 3-24.

To minimize impacts to the shoreline and recreation resources, shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term.

The proposed project would include construction activities along a small, approximately 220-foot-long section of beach at the north end of Kualoa Regional Park and along an approximately 820-foot-long narrow strip of beach that is part of Kaʻaʻawa Beach Park. In general, HDOT would attempt to restrict staging to existing roadway right-of-way. Some temporary staging on park property maybe required. The location and extent of staging areas would be selected to minimize impacts to park resources and public access. Any use of CCH land or CCH Parks for construction, access, or staging would be at the discretion of the CCH and would require a right-of-entry permit.

Historical Resources

Objective: (A) Protect, preserve, and, where desirable, restore those natural and manmade historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(A) Identify and analyze significant archaeological resources;	X		
(B) Maximize information retention through preservation of remains and artifacts or salvage operations; and	X		
(C) Support state goals for protection, restoration, interpretation, and display of historic resources.	X		

Historical Resources

Objective: (A) Protect, preserve, and, where desirable, restore those natural and manmade historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	**C**	**N/C**	**N/A**

Discussion: An Archaeological Literature Review and Field Inspection Report was completed for the subject project (Appendix C). As discussed in Section 3.10, the project sites are located in an archaeologically sensitive area where numerous subsurface archaeological sites including burials have been previously identified. The project would be reviewed by SHPD as well as NHOs in accordance with HRS Chapter 6E and the NHPA Section 106. The discovery of archaeological resources, other than burials, during construction would follow procedures prescribed in HAR Chapter 13-280. This would include halting construction activities in the vicinity of the historic property, protecting it from further disturbance, and notifying the SHPD. Construction would not resume in the vicinity of the historic property until the findings have been evaluated by SHPD and the SHPD has verified that any required protection measures have been implemented, data recovery completed, and or mitigation executed. The discovery of burial sites and human remains during construction would follow procedures prescribed in HAR Chapter 13-300. This would include notification of the SHPD and police department, halting all activities in the vicinity, and protecting the burial site from damage. This would also include consultation with the O‘ahu Island Burial Council, lineal decedents, and appropriate NHOs.

To minimize potential impacts to archaeological resources shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term. The stabilization of the shoreline would help to protect archaeological sites located mauka of the roadway shoulder.

Scenic and Open Space Resources

Objective: (A) Protect, preserve, and, where desirable, restore or improve the quality of coastal scenic and open space resources.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	**C**	**N/C**	**N/A**
(A) Identify valued scenic resources in the coastal zone management area;	X		

Scenic and Open Space Resources

Objective: (A) Protect, preserve, and, where desirable, restore or improve the quality of coastal scenic and open space resources.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	**C**	**N/C**	**N/A**
(B) Ensure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of natural landforms and existing public views to and along the shoreline;	X		
(C) Preserve, maintain, and, where desirable, improve and restore shoreline open space and scenic resources; and	X		
(D) Encourage those developments that are not coastal dependent to locate in inland areas.	X		

Discussion: The coastal highway along the windward coast of O‘ahu is a very scenic coastal drive, with mostly unobstructed ocean views. The proposed hybrid seawalls and rock revetment crests would be only one to two feet higher in elevation than the adjacent shoreline and highway, and therefore, it would not obstruct ocean views. At many locations the proposed shoreline stabilization structures would replace existing stabilization measures that are no longer effective. The proposed shoreline stabilization structures would modify the appearance of the natural shoreline but would be similar in appearance to other rock revetments seen at numerous locations on the windward coast. If the desired quarried armor stones are not available man-made concrete armor units could be utilized as an alternative. This would result in a more significant change to the appearance of the shoreline. The use of man-made concrete armor units would only be considered if larger armor stone becomes scare or uneconomical to source locally.

Coastal Ecosystems

Objective: (A) Protect valuable coastal ecosystems, including reefs, from disruption and minimize adverse impacts on all coastal ecosystems.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	**C**	**N/C**	**N/A**
(A) Exercise an overall conservation ethic, and practice stewardship in the protection, use, and development of marine and coastal resources;	X		
(B) Improve the technical basis for natural resource management;			X

Coastal Ecosystems

Objective: (A) Protect valuable coastal ecosystems, including reefs, from disruption and minimize adverse impacts on all coastal ecosystems.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	**C**	**N/C**	**N/A**
(C) Preserve valuable coastal ecosystems, including reefs, of significant biological or economic importance;	X		
(D) Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land and water uses, recognizing competing water needs; and			X
(E) Promote water quantity and quality planning and management practices that reflect the tolerance of fresh water and marine ecosystems and maintain and enhance water quality through the development and implementation of point and nonpoint source water pollution control measures.	X		

Discussion: Appropriate sediment and erosion control, stormwater management, and spill prevention and control measures would be used during construction to minimize potential impacts to the nearshore marine environment. The contractor would develop and implement a contingency plan for management of equipment, materials, and the job site in the event of an approaching sever storm event, including a tropical storm, hurricane, or predicted rain event anticipated to exceed a 2-year, 24-hour event. This would include removing or securing construction equipment and material at the site, stabilization of stockpiles and un-stabilized areas, and identification of and mitigation of other potential sources of pollution. The plan would also include photographic documentation of pre- and post-storm conditions at the site and inspection and maintenance and repair of BMPs following the storm, as needed. In addition, the USFWS's standard recommended BMPs for work in the aquatic environment would be followed. This would include:

- Scheduling in-water work, to avoid coral spawning and recruitment periods, and sea turtle nesting and hatching periods, in coordination with state and federal fish and wildlife resource agencies.
- The use of turbidity curtains or other silt containment devises, and the removal and disposal of such devises when in-water work is completed. The turbidity curtains would help contain the suspended sediment to within ten (10) feet of the active work area, reducing the area affected by potential water quality impacts.
- Curtailing work during flooding or adverse tidal and weather conditions; and

Coastal Ecosystems

Objective: (A) Protect valuable coastal ecosystems, including reefs, from disruption and minimize adverse impacts on all coastal ecosystems.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A

- Ensuring all project construction-related materials and equipment to be placed in the water are inspected and free of pollutants including marine fouling organisms, grease, oil, and sediment.

The marine assessment suggests that the proposed action to stabilize shoreline erosion adjacent to Kamehameha Highway is unlikely to have any negative effect to existing marine life communities. The nearshore sand and rubble zones extend seaward to a distance greater than 75 meters offshore, likely beyond the limit of any potential effects associated with the proposed construction activities. The marine life in this nearshore area would be adapted to resuspension of sediment as sand is a major component of the nearshore habitat. The ongoing erosion of the shoreline is likely causing some input of sediment to the nearshore ocean. The proposed shoreline stabilization measures are intended to mitigate coastal erosion and the associated input of sediment to the nearshore environment. Thus, the proposed project has the potential to reduce any such impacts and may provide long-term improvement to both water quality and marine biological resources (Marine Research Consultants, 2023). Based on the in-water work being conducted in very shallow water with turbidity containment barriers surrounding the work area, any exposure of marine life to turbidity and sedimentation is expected to be temporary and less than significant.

Economic Uses

Objective: (A) Provide public or private facilities and improvements important to the State's economy in suitable locations.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(A) Concentrate coastal dependent development in appropriate areas;	X		
(B) Ensure that coastal dependent development and coastal related development are located, designed, and constructed to minimize exposure to coastal hazards and adverse social, visual, and environmental impacts in the coastal zone management area; and	X		

Economic Uses

Objective: (A) Provide public or private facilities and improvements important to the State's economy in suitable locations.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(C) Direct the location and expansion of coastal development to areas designated and used for that development and permit reasonable long-term growth at those areas, and permit coastal development outside of designated areas when:	X		
(i) Use of designated locations is not feasible;	X		
(ii) Adverse environmental effects and risks from coastal hazards are minimized; and	X		
(iii) The development is important to the State's economy.	X		

Discussion: The Windward coast in the vicinity of the project area is primarily residential. The major economic driver along the Windward coast of Oʻahu is tourism, with attractions including undeveloped scenic shorelines, beach parks, and Kualoa Ranch. Kualoa Ranch is a major employer on the Windward coast. Many of the residents in this area rely on the highway to commute to jobs in other parts of Oʻahu. The purpose of the project is to maintain the useability of the highway in the near to mid-term for both residents and visitors; and prevent traffic impacts resulting from coastal erosion damage to the roadway. Maintaining the useability of the Highway is critical to the economic welfare of the communities.

Coastal Hazards

Objective: (A) Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, subsidence, and pollution.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(A) Develop and communicate adequate information about storm wave, tsunami, flood, erosion, subsidence, and point and nonpoint source pollution hazards;	X		
(B) Control development in areas subject to storm wave, tsunami, flood, erosion, hurricane, wind, subsidence, and point and nonpoint source pollution hazards;	X		

Coastal Hazards

Objective: (A) Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, subsidence, and pollution.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(C) Ensure that developments comply with requirements of the National Flood Insurance Program; and	X		
(D) Prevent coastal flooding from inland projects.	X		

Discussion: The proposed shoreline erosion mitigation improvements would not increase the likelihood or worsen the effects of coastal hazards. The proposed revetments and hybrid seawalls would help protect the shoreline and highway from coastal flooding and tsunami damage. The highway would play a critical role in providing emergency response and services to these coastal communities following a tsunami, hurricane, or significant coastal flooding event.

The height of the proposed hybrid seawalls and crest of the proposed rock revetments would only be 1 to 2 feet above the existing road deck elevation (ranging from approximately 6 to 10 feet above MSL) and would have minimal impact on the progression of major coastal hazard such as a tsunamis or hurricane, which would be expected to inundate large sections of the highway.

Managing Development

Objective: (A) Improve the development review process, communication, and public participation in the management of coastal resources and hazards.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(A) Use, implement, and enforce existing law effectively to the maximum extent possible in managing the present and future coastal zone development;			X
(B) Facilitate timely processing of applications for development permits and resolve overlapping or conflicting permit requirements;			X
(C) Communicate the potential short and long-term impacts of proposed significant coastal developments earlier in their life cycle and in terms understandable to the public and facilitate public participation in the planning and review process.	X		

Managing Development

Objective: (A) Improve the development review process, communication, and public participation in the management of coastal resources and hazards.

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
Discussion: During the preparation of this EA, the HDOT shared information about this project and solicited community input at Kaʻaʻawa-Hauʻula Townhall meetings on 03/06/23, 05/11/23, and 09/29/23. These meetings provided opportunities for agencies, citizens groups, and the general public to assist in determining the range of actions, alternatives to be considered and potential impacts and mitigation measures to be analyzed in the draft EA. In addition, during the preparation of this EA letters were sent to agencies having jurisdiction to solicit input in the identification of potential impacts and mitigation measures. Copies of these letters are provided in Appendix E.			

Beach and Coastal Dune Protection

Objective: (A) Protect beaches and coastal dunes for:

(i) Public use and recreation;
(ii) The benefit of coastal ecosystem

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(A) Locate new structures inland from the shoreline setback to conserve open space, minimize interference with natural shoreline processes, and minimize loss of improvements due to erosion;		X	
(B) Prohibit construction of private shoreline hardening structures, including seawalls and revetments, at sites having sand beaches and at sites where shoreline hardening structures interfere with existing recreational and waterline activities;			X
(C) Minimize the construction of public shoreline hardening structures, including seawalls and revetments, at sites having sand beaches and at sites where shoreline hardening structures interfere with existing recreational and waterline activities;		X	
(D) Minimize grading of and damage to coastal dunes;			X
(E) Prohibit private property owners from creating a public nuisance by inducing or cultivating the private property owner's vegetation in a beach transit corridor; and			X

Beach and Coastal Dune Protection

Objective: (A) Protect beaches and coastal dunes for:

(i) Public use and recreation;
(ii) The benefit of coastal ecosystem

C=Consistent; N/C=Not Consistent; N/A=Not Applicable

Policies:	C	N/C	N/A
(F) Prohibit private property owners from creating a public nuisance by allowing the private property owner's unmaintained vegetation to interfere or encroach upon a beach transit corridor.			X

Discussion: To minimize impacts to the shoreline and recreation resources, shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term. The proposed shoreline stabilization measures are not anticipated to significantly impact existing recreational activities.

Based on the above discussion and as analyzed in the various chapters of this EA, it has been determined that the Proposed Action is consistent, to the maximum extent practicable, with the objectives and policies of the State CZM Program outlined in HRS 205A-2 and ROH Section 25.

5.5 City and County of Honolulu General Plan

The General Plan for the CCH sets long-range objectives and policies to address the physical, social, cultural, economic, environmental, and design concerns of the people of Oʻahu (CCH Department of Planning and Permitting (DPP), 2021). This general plan divides the objectives and policies into eleven (11) key focus areas: population, balanced economy, the natural environment and resource stewardship, housing and communities, transportation and utilities, energy systems, physical development and urban design, public safety and community resilience, health and education; culture and recreation, and government operations and fiscal management.

Natural Environment and Resource Stewardship

Objective A: To protect and preserve the natural environment.

Policy 1: *Protect Oʻahu's natural environment, especially the shoreline, valleys, and ridges from incompatible development.*

Policy 2: *Seek the restoration of environmentally damaged areas and natural resources.*

Policy 4: Require development projects to give due consideration to natural features such as slope, flood and erosion hazards, water-recharge areas, distinctive landforms, and existing vegetation, as well as plan for coastal hazards that threaten life and property.

Policy 7: Protect the natural environment from damaging levels of air, water, and noise pollution.

Policy 8: Protect plants, birds, and other animals that are unique to the State of Hawaii and the island of Oʻahu and protect their habitats.

Policy 12: Plan, prepare for, and mitigate the impacts of climate change on the natural environment, including strategies of adaptation.

Objective B: To preserve and enhance the natural monuments and scenic views of Oʻahu for the benefit of both residents and visitors as well as future generations.

Policy 2: Protect Oʻahu's scenic views, especially those seen from highly developed and heavily traveled areas.

Policy 4: Promote public access to the natural environment for recreational, educational, and cultural purposes and the maintenance thereof in a way that does not damage natural or cultural resources.

Discussion: The project would comply with all of the objectives and policies listed above. As discussed in Section 3.2 *Surface Water and Water Quality*, Section 3.6 *Air Quality*, Section 3.7 *Terrestrial Biological Resources*, Section 3.8 *Marine Biological Resources*, and Section 3.9 *Noise* the proposed action is not anticipated to have significant impacts to any of these resources. In addition, numerous avoidance and minimization measures and BMPs have been incorporated into the project to further reduce the potential for adverse effects and impacts.

The proposed revetments and hybrid seawalls would help protect the shoreline and highway from coastal flooding and tsunami damage. The highway would play a critical role in providing emergency response and services to these coastal communities following a tsunami, hurricane, or significant coastal flooding event.

Based on the sea level rise projections presented above Kamehameha Highway and the adjacent coastal communities would be impacted by sea level rise. The intent of the project is to mitigate coastal erosion and potential damage to the highway for the next 25 years until a long-term solution to sea level rise can be identified and implemented. The proposed rock revetments and hybrid seawalls may help to minimize the impacts of sea level rise on highway infrastructures for the near- to mid-term (next 25 years) but would not mitigate the long-term effects of sea level rise. The proposed rock revetments and hybrid sea walls are potentially removable structures that could be modified or removed as needed to allow for construction of alternative shoreline protection and sea level rise adaptation measures. The rock revetments and hybrid seawalls would not preclude and could continue to be used in combination with other future projects that could include beach nourishment or managed retreat.

There would be a temporary impact to scenic and aesthetic resources during construction. The proposed revetment crest and hybrid seawalls would be only 1 to 2 feet higher than the highway elevation, so would not obstruct ocean views. The proposed shoreline stabilization structures would be constructed of native basalt rock and would resemble a natural rocky shoreline. The removal of coastal vegetation from these sections of shoreline would alter the appearance and feeling of the sites. Opportunities to incorporate landscaping into the rock revetment structures was considered. It was determined that this could not be done without compromising the stability and resilience of the structures. Numerous locations on the windward coast have rock revetment protection for the highway, and this project would have a similar aesthetics. Based on this the project would have less than significant impacts to scenic and aesthetic resources.

To minimize impacts to the shoreline and recreation resources, shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term. The project would not eliminate any existing public shoreline access. However, the rock revetments would make it more difficult to access or walk along the shoreline.

Transportation and Utilities

Objective A: To create a multi-modal transportation system that moves people and goods safely, efficiently, and at a reasonable cost and minimizes fossil fuel consumption and greenhouse gas emissions; serves all users, including limited income, elderly, and disabled populations; and is integrated with existing and planned development.

Policy 4: Work with the State to ensure adequate and safe access for communities served by Oʻahu's coastal highway system, and to plan for the relocation of highways and roads subject to sea level rise away from coastlines.

Objective D: To maintain transportation and utility systems which support Oʻahu as a desirable place to live and visit.

Policy 2: Evaluate the social, cultural, economic, and environmental impact of additions to the transportation and utility systems before they are constructed.

Policy 5: Evaluate impacts of sea level rise on existing public infrastructure, especially sewage treatment plants, roads, and other public and private utilities located along or near Oʻahu's coastal areas and avoid the placement of future public infrastructure in threatened areas.

Physical Development and Urban Design

Objective A: To coordinate changes in the physical environment of Oʻahu to ensure that all new developments are timely, well-designed, and appropriate for the areas in which they will be located.

Policy 1: Provide infrastructure improvements to serve new growth areas, redevelopment areas, and areas with badly deteriorating infrastructure.

Policy 11: Implement sitting and design solutions that seek to reduce exposure to natural hazards, including those related to climate change, flooding, and sea level rise.

Objective B: To plan and prepare for the long-term physical impacts of climate change.

Policy 1: Integrate climate change adaptation into the planning, design, and construction of all significant improvements to and development of the built environment.

Policy 3: Prepare for the anticipated impacts of climate change and sea level rise on existing communities and facilities through mitigation, adaptation, managed retreat, or other measures in exposed areas.

Public Safety and Community Resilience

Objective B: To protect residents and visitors and their property against natural disasters and other emergencies, traffic and fire hazards, and unsafe conditions.

Policy 2: Require all developments in areas subject to floods and tsunamis, and coastal erosion to be located and constructed in a manner that will not create any health or safety hazards or cause harm to natural and public resources.

Policy 9: Plan for the impacts of climate change and sea level rise on public safety, in order to minimize potential future hazards.

Discussion: Based on the sea level rise projections presented above Kamehameha Highway and the adjacent coastal communities would be impacted by sea level rise. The intent of the project is to mitigate coastal erosion and potential damage to the highway for the next 25 years until a long-term solution to sea level rise can be identified and implemented. The proposed rock revetments and hybrid seawalls may help to minimize the impacts of sea level rise on highway infrastructures for the near- to mid-term (next 25 years) but would not mitigate the long-term effects of sea level rise. The proposed rock revetments and hybrid sea walls are potentially removable structures that could be modified or removed as needed to allow for construction of alternative shoreline protection and sea level rise adaptation measures. The rock revetments and hybrid seawalls would not preclude and could continue to be used in combination with other future projects that could include beach nourishment or managed retreat.

Culture and Recreation

Objective B: To protect, preserve and enhance O‘ahu’s cultural, historic, architectural, and archaeological resources.

Policy 1: Promote the restoration and preservation of early Hawaiian structures, artifacts, and landmarks.

Policy 2: Identify and, to the extent possible, preserve and restore buildings, sites, and areas of social, cultural, historic, architectural, and archaeological significance.

Policy 3: Cooperate with the State and federal governments in developing and implementing a comprehensive preservation program for social, cultural, historic, architectural, and archaeological resources.

Policy 7: Encourage the protection of areas that are historically important to Native Hawaiian cultural practices and to the cultural practices of other ethnicities, in order to further preserve and continue these practices for future generations.

Objective D: To provide a wide range of recreational facilities and services that are readily available to residents and visitors alike, and to balance access to natural areas with the protection of those areas.

Policy 7: Ensure and maintain convenient and safe access to beaches, ocean environments and mauka recreation areas in a manner that protects natural and cultural resources.

Policy 12: Provide for safe and secure use of public parks, beaches, and recreation facilities.

Discussion: An Archaeological Literature Review and Field Inspection Report (Appendix C) and Cultural Impact Assessments (Appendix D) were completed for the subject project. As discussed in Section 3.10, the project sites are located in an archaeologically sensitive area where numerous subsurface archaeological sites including burials have been previously identified. The project would be reviewed by SHPD as well as NHOs in accordance with HRS Chapter 6E and the NHPA Section 106. The discovery of archaeological resources, other than burials, during construction would follow procedures prescribed in HAR Chapter 13-280. This would include halting construction activities in the vicinity of the historic property, protecting it from further disturbance, and notifying the SHPD. Construction would not resume in the vicinity of the historic property until the findings have been evaluated by SHPD and the SHPD has verified that any required protection measures have been implemented, data recovery completed, and or mitigation executed. The discovery of burial sites and human remains during construction would follow procedures prescribed in HAR Chapter 13-300. This would include notification of the SHPD and police department, halting all activities in the vicinity, and protecting the burial site from damage. This would also include consultation with the Oʻahu Island Burial Council, lineal decedents, and appropriate NHOs.

To minimize potential impacts to archaeological resources, as well as public access and recreational resources, shoreline stabilization measures are only proposed at locations where the highway would be impacted by shoreline erosion in the near to mid-term, within the next 25-years. No shoreline stabilization measures are proposed at other adjacent shoreline areas where the highway is not threatened by erosion in the near to mid-term.

If no action is taken archaeological sites in the project area may be impacted by coastal erosion in the near to mid-term (next 25-years). The stabilization of the shoreline would help to protect archaeological sites located mauka of the roadway shoulder. The project presents an opportunity to protect in place archaeological sites mauka of the roadway shoulder and appropriately inventory and relocate properties in the project area.

The project would not eliminate any existing public shoreline access. However, the rock revetments would make it more difficult to access or walk along the shoreline.

5.6 City and County of Honolulu Koʻolau Poko and Koʻolau Loa Sustainable Communities Plans

The *Koʻolau Poko and Koʻolau Loa Sustainable Communities Plans* were adopted by the CCH in 2017 and in 2020, respectively. This plan encompasses the Koʻolau Poko and Koʻolau Loa communities along the windward coast of the island of Oʻahu and seeks to preserve the rural region's open space, country character, and distinctive sense of "old Hawaiʻi" that exists in harmony with the natural environment. Its policies and guidelines define how community needs should be balanced with the protection and enhancement of Koʻolau Poko and Koʻolau Loa's spectacular natural, scenic, and cultural qualities in contrast to Oʻahu's urbanized and urban fringe areas. Koʻolau Poko encompasses the windward coastal and valley areas from Makapuʻu Point to Kaʻōʻio Point at the northern end of Kāneʻohe Bay and includes the communities of Waiāhole, Waikane, Kahaluʻu, Heʻeia, Waimānalo, Āhuimanu, Kāneʻohe, and Kailua. Whereas Koʻolau Loa spans the northern half of Oʻahu's windward coast, bordered on the north by the Waialeʻe community just beyond Kawela Bay, and on the south by the ridgeline just beyond the north end of Kāneʻohe Bay (CCH DPP, 2023).

The Koʻolau Poko plan addresses maintaining and enhancing the region's ability to sustain its unique character and lifestyle. The Plan's vision is formed around two principal concepts. First, it is the Plan's vision to protect the communities' natural, scenic, cultural, historic, and agricultural resources. And second, to address the need to improve and replace, as necessary, the region's aging infrastructure system.

The Koʻolau Loa Plan addresses transportation systems, describing Kamehameha Highway as "the only roadway linking the northerly windward Oʻahu coastline communities on the North Shore to the west and Koʻolau Poko to the southeast" (CCH DPP, 2020). The plan also cites the 2016 *Oʻahu Regional Transportation Plan 2040* set forth by the Oʻahu Metropolitan Planning Organization (2016) which enumerates planned highway improvements in the Koʻolau Loa region, including shoreline reinforcement along portions of Kamehameha Highway impacted by coastal erosion in the Kaʻaʻawa, Punaluʻu, and Hauʻula communities.

6. Findings Supporting the Anticipated Determination

6.1 Anticipated Determination

In accordance with HRS Chapter 343 and HAR, Sections 11-200.1-19, HDOT anticipates issuing a "Finding of No Signifiance Impact" (FONSI) for the proposed project.

6.2 Reasons Supporting the Anticipated Determination

The anticipated FONSI is based on an evaluation of project impacts in relation to the "Significance Criteria" specified in HAR 11-200.1-13. The Significance Criteria appears below in italics, followed by a discussion of the project in relation to the specific criterion.

1. *Irrevocably commit a natural, cultural, or historic resource.*

   Discussion: As discussed in Section 3.2 *Surface Water and Water Quality*, Section 3.7 *Terrestrial Biological Resources*, and Section 3.8 *Marine Biological Resources*, the proposed action would only have minor temporary impacts to water quality and biological resources and no adverse effects to ESA-listed species. In addition, numerous avoidance and minimization measures and BMPs have been incorporated into the project to further reduce the potential impacts.

   An Archaeological Literature Review and Field Inspection Report (Appendix C) and Cultural Impact Assessments (Appendix D) were completed for the subject project. As discussed in Section 3.10, the project sites are located in an archaeologically sensitive area where numerous subsurface archaeological sites including burials have been previously identified. The project would be reviewed by SHPD as well as NHOs in accordance with HRS Chapter 6E and the NHPA Section 106. The discovery of archaeological resources, other than burials, during construction would follow procedures prescribed in HAR Chapter 13-280. This would include halting construction activities in the vicinity of the historic property, protecting it from further disturbance, and notifying the SHPD. Construction would not resume in the vicinity of the historic property until the findings have been evaluated by SHPD and the SHPD has verified that any required protection measures have been implemented, data recovery completed, and or mitigation executed. The discovery of burial sites and human remains during construction would follow procedures prescribed in HAR Chapter 13-300. This would include notification of the SHPD and police department, halting all activities in the vicinity, and protecting the burial site from damage. This would also include consultation with the Oʻahu Island Burial Council, lineal decedents, and appropriate NHOs.

   If no action is taken archaeological sites, including burials located in the project area may be impacted by coastal erosion in the near to mid-term (next 25-years). Stabilization of the shoreline would help protect archaeological sites located mauka of the roadway shoulder. The project presents an opportunity to protect in-place archaeological sites mauka of the roadway shoulder and appropriately inventory and relocate properties in the project area.

2. *Curtails the range of beneficial uses of the environment.*

   Discussion: The proposed shoreline stabilization measures would not curtain the range of beneficial uses of the environment. The proposed stabilization measures would occupy an approximately 15- to 40-foot-wide area directly adjacent to the roadway shoulder. The proposed rock revetments and hybrid sea walls are potentially removable structures that could be modified or removed as needed to allow for construction of alternative shoreline protection or sea level rise adaptation measures. The rock revetments and hybrid seawalls would not preclude and could continue to be used in combination with other future projects that could include beach nourishment or managed retreat.

3. *Conflict with the State's environmental policies or long-term environmental goals established by law.*

   Discussion: The proposed action would comply with the State's environmental policies and long-term environmental goals established by law. Section 5 of this EA includes discussion of the proposed action in relation to relevant policies and plans.

4. *Substantially affects the economic or social welfare of the community or state.*

   Discussion: The proposed action would have a beneficial effect on the economic and social welfare of the community and State. Many of the residents in this area rely on the highway to commute to jobs in other parts of Oʻahu. The major economic driver along the Windward coast of Oʻahu is tourism, with attractions including undeveloped scenic shorelines, beach parks, and Kualoa Ranch. The purpose of the project is to maintain the useability of the highway in near to midterm for both residents and visitors; and prevent traffic impacts resulting from coastal erosion damage to the roadway.

5. *Substantially affects public health.*

   Discussion: The proposed action would have a beneficial effect on public health and safety. Maintaining usability of the highway by protecting it from coastal erosion is critical to maintaining access to emergency services and avoiding an increase in response times.

6. *Involves substantial secondary impacts, such as population changes or effects on public facilities.*

   Discussion: The project would not increase the capacity of the highway and would not contribute to population growth or further development in the area. The project would have a positive effect on public facilities. The proposed shoreline stabilization measures would help to protect the highway and underground utilities from damage resulting from coastal erosion. During construction there would be temporary impacts to traffic associated with lane closures. These impacts would be minimized through implementation of a traffic control plan.

7. *Involves a substantial degradation of environmental quality.*

   Discussion: The proposed action would not result in substantial degradation of environmental quality. The project may have very minor temporary impacts to noise, air, and water quality during active construction. There would be no degradation of environmental quality.

8. *Is individually limited but cumulatively has considerable effect upon the environment or involves a commitment for larger actions.*

   Discussion: As discussed above in Section 4 when considered with other past, present, and reasonably foreseeable future actions, the proposed project would not have any significant cumulative impacts on the environment. The proposed project would not involve a commitment to a larger action. However, future projects would be needed to address the long-term effects for sea level rise in these areas. The proposed rock revetments and hybrid sea walls are potentially removable structures that could be modified or removed as needed to allow for construction or implementation of alternative shoreline protection and sea level rise adaptation measures. The rock revetments and hybrid seawalls would not preclude, and could remain, and continue to be used in combination with other future projects that could include beach nourishment or managed retreat.

9. *Substantially affects a rare, threatened, or endangered species, or its habitat.*

   Discussion: The proposed project would not have substantial affects to rare, threatened, or endangered species, or their habitats. Section 3.7 includes lists of threatened and endangered species with the potential to be present in the vicinity of the project area. The project is not anticipated to adversely affect any listed species. In addition, as discussed in Sections 3.7.2 and 3.8.2 numerous measures have been incorporated into the project to further avoid and minimize potential effects.

10. *Detrimentally affects air or water quality or ambient noise levels.*

    Discussion: The proposed action would not have detrimental effects to air or water quality or ambient noise levels.

    During construction there may be minor temporary impacts to air quality. These minor temporary impacts to air quality would be associated with construction vehicle and equipment exhaust emissions and fugitive dust. This negative impact on air quality would be limited to active construction hours and would dissipate once construction activities cease. The emissions from heavy equipment and other construction vehicles' internal combustion engines are expected to be too small to have a significant or lasting effect on overall air quality. The project does not include any grading and only minor ground disturbance primarily below the high tide line; therefore, the project site is not anticipated to generate much, if any fugitive dust. As part of the construction process, the contractor would implement appropriate BMPs to minimize construction-related emissions. Once construction is completed, the project would have no long-term air emissions or further impact on air quality.

The shoreline excavation and placement of stone associated with the construction of the revetments and hybrid seawalls with armor stone aprons would result in the suspension of sand and sediment, temporary reduction in water clarity, and the deposition of sand and sediment. The use of turbidity curtains would help contain the suspended sediment to within ten (10) feet of the active work area, reducing the area affected by potential water quality impacts. Additionally, construction would proceed along the shoreline in approximately 25-foot increments, limiting the amount of substrate exposed to potential erosion and damaging wave action during active construction. The proposed action would not result in an increase of fresh water discharges or concentration of fresh water flows to the marine environment. The accidental release or spill of other pollutants is possible, but not anticipated given the nature of the proposed construction activities and the use of appropriate BMPs.

Construction activity may cause a temporary increase in noise during active construction. With implantation of the mitigation measures listed in Section 3.9.2 and compliance with applicable noise regulations, the short-term noise impacts associated with the proposed construction activities would be less than significant.

11. *Affects or is likely to suffer damage by being located in an environmentally sensitive area such as a flood plain, tsunami zone, beach, erosion-prone area, geologically hazardous land, estuary, fresh water, or coastal waters.*

    Discussion: The proposed shoreline erosion mitigation improvements would not increase the likelihood or worsen the effects of coastal hazards and would help mitigate coastal erosion. The proposed revetments and hybrid seawalls would be resilient to damage for severe storms and tsunamis and would help protect the shoreline and highway from coastal flooding and tsunami damage. The highway would play a critical role in providing emergency response and services to these coastal communities following a tsunami, hurricane, or significant coastal flooding event.

    The height of the proposed hybrid seawalls and crest of the proposed rock revetments would only be 1 to 2 feet above the existing road deck elevation and would have minimal impact on the progression of major coastal hazard such as a tsunamis or hurricane, which would be expected to inundate large sections of the highway.

12. *Substantially affects scenic vistas and viewplanes identified in county or state plans or studies.*

    Discussion: There would be a temporary impact to scenic and aesthetic resources during construction as a result of construction equipment and activities.

    The proposed revetment crest and hybrid seawalls would be only 1 to 2 feet higher than the highway elevation, so would not obstruct ocean views.

13. Requires substantial energy consumption or emit substantial greenhouse gases.

Discussion: The project would not require substantial energy consumption or emit substantial greenhouse gases. The temporary use of construction equipment and vehicles would require some use of fossil fuels and have some greenhouse gas emissions.

7. Consultation and Public Review

Pursuant to HAR Section 11-200.1-18, consultation with agencies and other stakeholders during the preparation of the EA is required to inform the affected community of the proposed action and solicit input in scoping the analyses to be conducted to evaluate potential impacts and identify required mitigation measures.

7.1 Pre-Assessment Consultation

A list of Federal, State, CCH, and other organizations and individuals that were consulted during the pre-assessment consultation of the Draft EA is provided in Table 7-1. Whether response letters and emails were received during the thirty (30) day comment period is indicated in Table 7-1. Copies of the written comments and the respective response letters are included in Appendix E. The Draft EA incorporates the public and agency review comments that were submitted as part of the pre-assessment consultation.

Table 7-1. Agencies, organizations, and individuals consulted during preparation of the draft EA as part of the pre-assessment consultation.

Agency/Organization/Individual Name	Comments Received?	
	Yes	No
Federal Agencies		
National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Pacific Islands Regional Office	X	
U.S. Army Corps of Engineers		X
U.S. Fish and Wildlife Service	X	
State of Hawaiʻi Agencies		
Department of Accounting General Services	X	
Office of Planning and Sustainable Development	X	
Office of Planning and Sustainable Development, Environmental Review Program		X
Department of Hawaiian Home Lands		X
Department of Health		X
Department of Land and Natural Resources, Engineering Division	X	
Department of Land and Natural Resources, Division of Forestry and Wildlife	X	
Department of Land and Natural Resources, Division of Aquatic Resources		X

Agency/Organization/Individual Name	Comments Received?	
	Yes	No
Department of Land and Natural Resources, Land Division, Oʻahu District Land Office	X	
Department of Land and Natural Resources, State Historic Preservation Division		X
Department of Land and Natural Resources, Office of Conservation and Coastal Lands	X	
Department of Public Safety		X
Land Use Commisssion		X
Office of Hawaiian Affairs		X
University of Hawaiʻi at Manoa Environmental Center		X
City and County of Honolulu (CCH) Agencies		
Board of Water Supply	X	
Department of Environmental Services		X
Department of Design and Construction		X
Department of Facility Maintenance		X
Department of Parks and Recreation	X	
Department of Planning and Permitting	X	
Department of Transportation Services		X
Private/Individuals		
Hawaiian Telcom		X

7.2 Draft EA Review and Comment

Table 7-2 provides a list of agencies, organizations, and individuals that will be provided copies of this draft EA.

Table 7-2. Draft EA distribution list.

Agency/Organization/Individual Name
Federal Agencies
National Oceanic and Atmospheric Administration, National Marine Fisheries Service
U.S. Army Corps of Engineers
U.S. Fish and Wildlife Service
State of Hawaiʻi Agencies

Agency/Organization/Individual Name
Department of Accounting General Services
Office of Planning and Sustainable Development
Department of Hawaiian Home Lands
Department of Health
Department of Land and Natural Resources
Department of Public Safety
Land Use Commisssion
Office of Hawaiian Affairs
State Representative Lisa Kitagawa (House District 48)
State Representative Sean Quinlan (House District 47)
State Senator Brenton Awa (Senate District 23)
University of Hawaiʻi at Manoa, Environmental Center
City and County of Honolulu (CCH) Agencies
Board of Water Supply
Council Member Matt Weyer (Council District 2)
Department of Environmental Services
Department of Design and Construction
Department of Facility Maintenance
Department of Parks and Recreation
Department of Planning and Permitting
Department of Transportation Services
Office of Climate Change, Sustainability and Resiliency
Private/Individuals
Kaʻaʻawa Community Association
Hauʻula Community Association
Koʻolauloa Neighborhood Board
Kahaluʻu Neighborhood Board

7.3 Public Meetings

The HDOT presented the proposed project at two town hall meetings. The first town hall meeting was held on May 5, 2023, at Kaʻaʻawa Elementary School. The second town hall meeting was held on September 29, 2023, at Swanzy Beach Park.

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Appendix A:
Basis of Design Report

WINDWARD SHORE PROTECTION AT KUALOA, KAAAWA, PUNALUU AND HAUULA (KKPH) – BASIS FOR DESIGN

Koolauloa, Oahu, Hawaii

Final Report – November 2022

Prepared for:

Hawaii Department of Transportation
(HDOT Highways Division)
and AECOM

Prepared by:

Sea Engineering, Inc.
Makai Research Pier
Waimanalo, HI 96795

SEI Job No. 25853

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1. INTRODUCTION

1.1 Preface

Kamehameha Highway is a heavily used primary roadway that extends from Kaneohe (Castle Junction) in central Windward Oahu, bisecting through the urban corridor of Kaneohe, before winding through the rural northeast (windward) coast, continuing around Kahuku Point, to the North Shore town of Haleiwa. It is the only vehicular artery connecting the coastal communities of Kaneohe, Kahaluu, Kaaawa, Punaluu, Hauula, Laie, and Kahuku providing both a commuter route as well as local service to the small towns and villages that it passes through. Kamehameha Hwy is also the primary—and only—vehicular access route for police, fire, and other emergency services vehicles. The State Department of Transportation-Highways Division (DOT-H) records the Annual Average Daily Traffic count on this roadway as 13,000 vehicles. A large portion of the highway follows along the narrow coastline, often within feet of the shoreline, and a mere 6 to 9 feet above mean sea level. At the same time, coastal erosion and shoreline retreat are an ever-increasing threat to the highway's existence. This project, the Kualoa-Kaaawa-Punaluu-Hauula (KKPH) project is composed of a series of nine discontinuous individual repair sites located within Oahu's Koolauloa District, strung along the shoreline highway from Kualoa in the south to Kaaawa and Punaluu, and finally to Hauula in the north. Landward or mauka of the shoreline, the terrain is typically defined by a narrow (often less than 1,000-foot wide) low elevation coastal plain which generally abuts the steeply rising slopes of the Koolau Mountain Range. For most of the project sites identified along Kamehameha Hwy, the coastal plain is occupied by fully developed residential communities. A project area map illustrating the relative locations of the project repair reaches on Oahu is provided in Figure 1-1 (as red lines). A closer look at the relative distribution of the individual repair reaches along the shoreline of northeast Oahu is presented in Figure 1-2, again with the discrete repair reaches highlighted in red, marked with an 'x' at the estimated start and stop points.

Northeast Oahu is exposed to a seasonal barrage of large and potentially destructive north swells every winter. Additionally, over the last 40 years two powerful hurricanes, *Iwa* (1982) and *Iniki* (1992), have directly impacted Oahu. In recent years there have also been a series of close approaches, including Category 3 *Hector* (2018) which pounded south and west shores of Oahu with dangerously large surf, and Category 5 *Lane* (2018) which was forecasted to potentially make landfall on Oahu but weakened unexpectedly and veered off to open ocean waters just hours before a predicted landfall. Of particular interest, category 1 *Douglas* was forecast to directly strike the project area in July 2020, but fortunately remained just offshore. The Cat 1 cyclone skirted the coastline as it passed by to the northwest, bringing exceptionally large surf to the project shoreline as it transited the area. Several stretches of Kamehameha Hwy from Kualoa to Punaluu were inundated and washed over with sand and coral rubble, rocks, logs, and other large debris, making some sections of the highway impassable, as shown on this report's cover.

For as long as official records have been kept, tropical storms and hurricanes have historically had a relatively low probability of occurrence in the vicinity of the Hawaiian Islands; yet the potential for damage to Hawaii's offshore and coastal infrastructure is substantial and likely increasing due to rising ocean temperatures driven by global warming and associated rising sea levels. With these near-term hazards existentially threatening critical transportation infrastructure along such a vulnerable shoreline, immediate action is required to safeguard this critical—and only—link that connects the distant coastal windward Oahu communities with the rest of the island. This document serves as the basis of design for the engineering of shore protection concepts intended to protect the most vulnerable sections of Kamehameha Highway until a longer-term solution is determined, likely decades into the future.

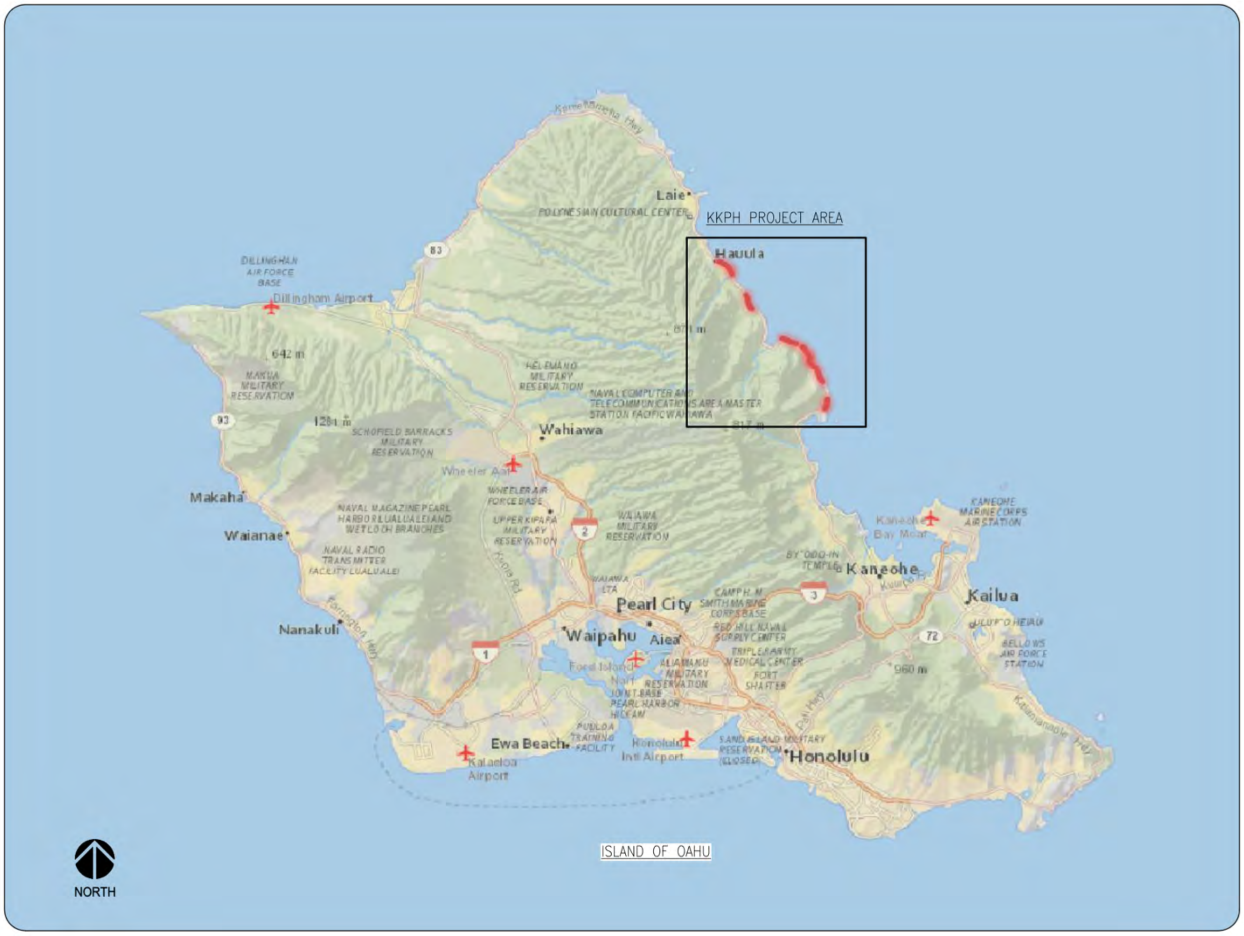

Figure 1-1. Project area map

1.2 Background

At the start of the 20th century, circa 1905, there were only a few automobiles in Hawaii, yet planners and engineers were already contemplating a new "Oahu Belt Road†." In a 25 August 1905 resolution, the Honolulu County board suggested improvements for the 'Belt Road' to form a 'main continuous highway for travel around the island.' More than a decade later, around 1920, it was decided to give this road a proper name, with the Star-Bulletin newspaper holding a vote with its readers on the issue. Top names included Lei Ilima Drive, Lei Drive, Alaloa, Alanuipuni, Moana Drive, Lanakila Highway, Aloha Drive, and in last place was Kamehameha Road. A group known as the Daughters and Sons of Hawaiian Warriors recommended the name "Kamehameha Highway," as they thought it appropriate since Kamehameha I marched up Nuuanu Valley to the Pali where he fought his last battle, overlooking the Windward Side of Oahu, where the road would soon be a reality. Kamehameha Highway was officially opened to vehicles on 01 January 1921.

† *Honolulu Star-Advertiser article, by Bog Sigall, 03 January, 2020. Accessed from www.startadvertiser.com 20 April, 2022.*

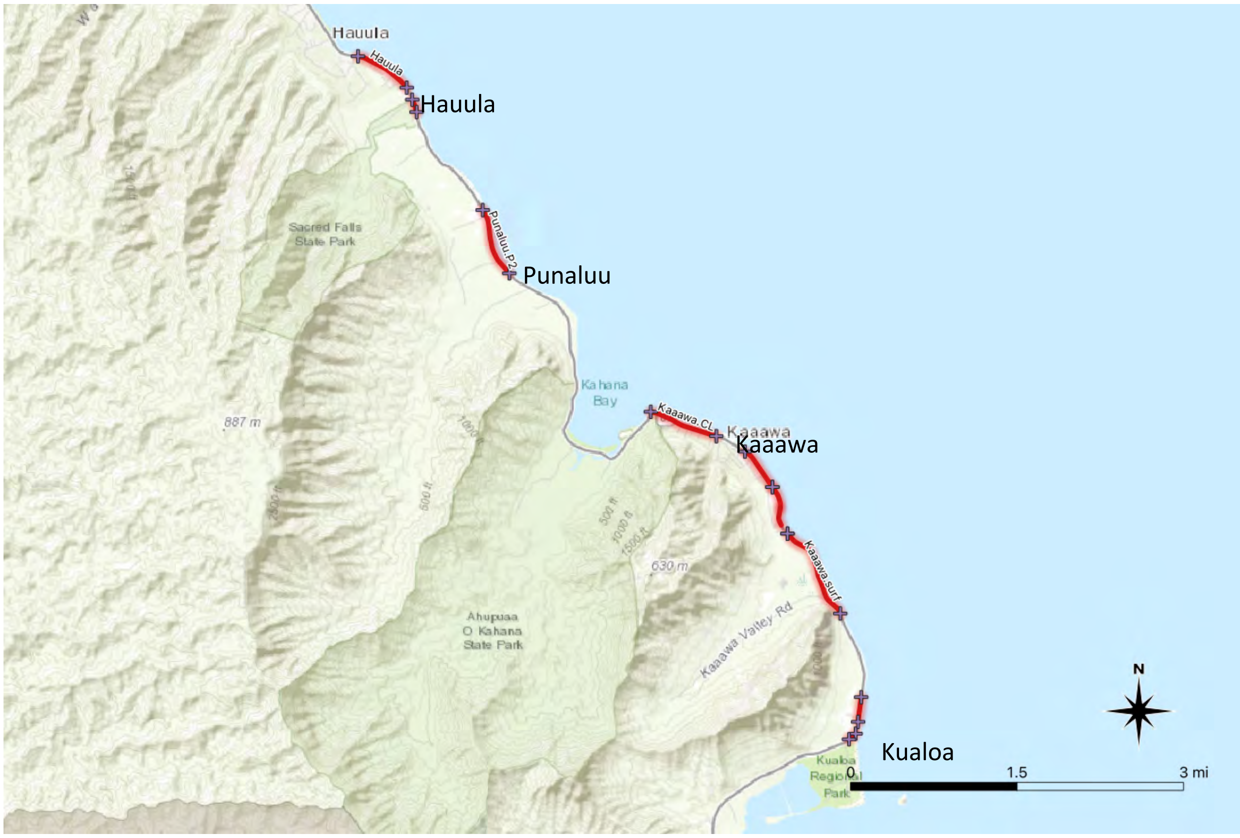

Figure 1-2. Project vicinity map

The Kamehameha Highway, State Route 83, starts at Weed Junction in Haleiwa Town where it begins its traverse of the North Shore before turning southward around Kahuku Point to the northeast Windward Oahu shoreline, ending at Castle Junction between Kaneohe and Kailua, at the base of the Pali Highway. The current alignment of the roadway follows old rail haul routes used for sugar cane transport for much of its length in Koolauloa (the Hawaiian district that encompasses the entire project vicinity). The historic sugar mill ruins at Kualoa are reminiscent of this era, as shown in Figure 1-3, with the roadway that is now known as Kamaehameha Highway visible in the foreground.

The next era of significant improvements and realignments to the roadway came during the 1940's, with World War II and the period of reconstruction following the Japanese attack. An approximately 6,500 ft long airstrip was constructed at Kualoa at the start of the war, encompassing what is now Kualoa Beach Park and portions of Kualoa Ranch, as illustrated in Figure 1-4. Kamehameha Hwy can be seen ringing the outer edge of the airfield in the photograph, quite close to the water in places. Additionally, a military base (Camp Kaaawa) was created to support the Jungle Warfare Center in Kahana Valley, illustrated in Figure 1-5, over what is now the area including Swanzy Beach Park, the Kaaawa Fire Station, and the Post Office and 7-Eleven facilities. Kamehameha Hwy can be seen crossing through the image at center. This same general area is shown in Figure 1-6, following the April 1946 tsunami which significantly impacted the highway in several places from Kualoa to Laie.

Figure 1-3. Old Kualoa Sugar Mill (precursor to present day Kamehameha Hwy in foreground)

Figure 1-4. US Army Airfield at Kualoa, circa 1942. Precursor to Kamehameha Hwy visible along shoreline.

Figure 1-5. US Army's Camp Kaaawa - Jungle Training Camp, circa 1940's. Kamehameha Hwy at center.

Figure 1-6. Camp Kaaawa following April 1946 tsunami. Kamehameha Hwy at center, Swanzy seawall lower right.

In the aftermath of the 1946 tsunami, a closer look at Kamehameha Hwy which appears to be in the vicinity of Puakenikeni Street in Kaaawa (one of the nine KKPH project sites) is revealed in Figure 1-7, which shows undermining and collapse of a portion of the concrete road deck of the northbound lane. In Punaluu, houses were destroyed, and cars overturned along Kamehameha Hwy—the grainy black and white photograph in Figure 1-8 captures a portion of the affected area. These photographs and the anecdotal accounts that came with them suggest Kamehameha Hwy has been at risk since it was first constructed.

Figure 1-7. Kamehameha Hwy in Kaaawa, following 1946 tsunami.

Figure 1-8. Kamehameha Hwy in Punaluu, following 1946 tsunami.

Several decades later, in the present year of 2022, Kamehameha Hwy is under threat from sea level rise coupled with intensifying storm activity associated with global warming. Over the last 50 years multiple ad-hoc maintenance projects have been completed to repair and fortify the road's seaward flank on an emergency basis (including the northbound lane and paved shoulder). Yet it has been within the last decade, and particularly within the last several years, that this stretch of coastal highway has seen some of the most active erosion events. Significant stretches of recent road failures have been concentrated in Kaaawa and Hauula, as illustrated in Figure 1-9, Figure 1-10, and Figure 1-11, however the entire project length of KKPH contains areas within imminent danger of future collapse. Major repair activities including the addition of new riprap along the roadside shoreline embankment as well as road shoulder improvements were completed along an approximate 0.15 mile stretch in Kualoa fronting the ranch, an approximate 0.77 mile stretch in Kaaawa from Kaoio Point to Kaaawa Stream, and a short 0.1 mile stretch fronting Kaaawa Elementary School. Also completed in 2020, an approximate 0.44 mile stretch of Kamehameha Hwy in Hauula (in the vicinity of Pokiwai Bridge) was armored with a stacked wall of rock-filled Kyowa Bags—a temporary measure classified as a 'nonengineered' emergency structure—which has since suffered from undermining and has begun to slump seaward (see Figure 1-11). All 2020 repairs were emergency efforts completed by Hawaii State Department of Transportation (HDOT).

In addition to the potential for progressive erosion to cause undermining and collapse, or other structural damage to the highway, increasingly more frequent wave overtopping and wave run-up onto and over the road deck are also of prime concern. Higher tides along with periods of elevated surf often combine to send rocks, sand, logs, and other debris tossed onto exposed portions of the road deck—a condition that can quickly become hazardous to passing vehicles. More extreme events, such as the very large surf produced from the near miss of Hurricane Douglas in 2020 can unquestionably leave the road impassible in some locations, as shown on the cover photo of this report. The newly exposed earthen embankments revealed by erosive forces are also often responsible for generating sediment plumes due to the dissolved clays, which can significantly affect nearshore areas in the vicinity of the erosion scarp (see Figure 1-9).

Figure 1-9. Pavement collapse along Kamehameha Hwy in Kaaawa, 2017. Note brown erosion plume, at right.

Figure 1-10. Undermining and collapse of a section of Kamehameha Hwy in Kaaawa, circa 2017.

Figure 1-11. Kamehameha Hwy in Hauula, January 2020. (credit: *Honolulu Star Advertiser)*

1.3 Purpose

The purpose of this report is to document the identified areas of Kamehameha Hwy in Kualoa, Kaaawa, Punaluu and Hauula that are in need of repair or protection from coastal erosion, and to develop site-specific oceanographic design criteria applicable to each of those individual locations, for use in designing shore protection alternatives for those sites. Design alternatives at a conceptual level are presented for possible roadside shore protection structures for a range of performance factors.

1.4 Repair Locations

Specific repair reach locations have been developed in coordination with HDOT and are as shown in Figure 1-12. Table 1 within the figure provides a cross reference for Reach ID, Reach Subdivisions, and conceptual drawing set titles.

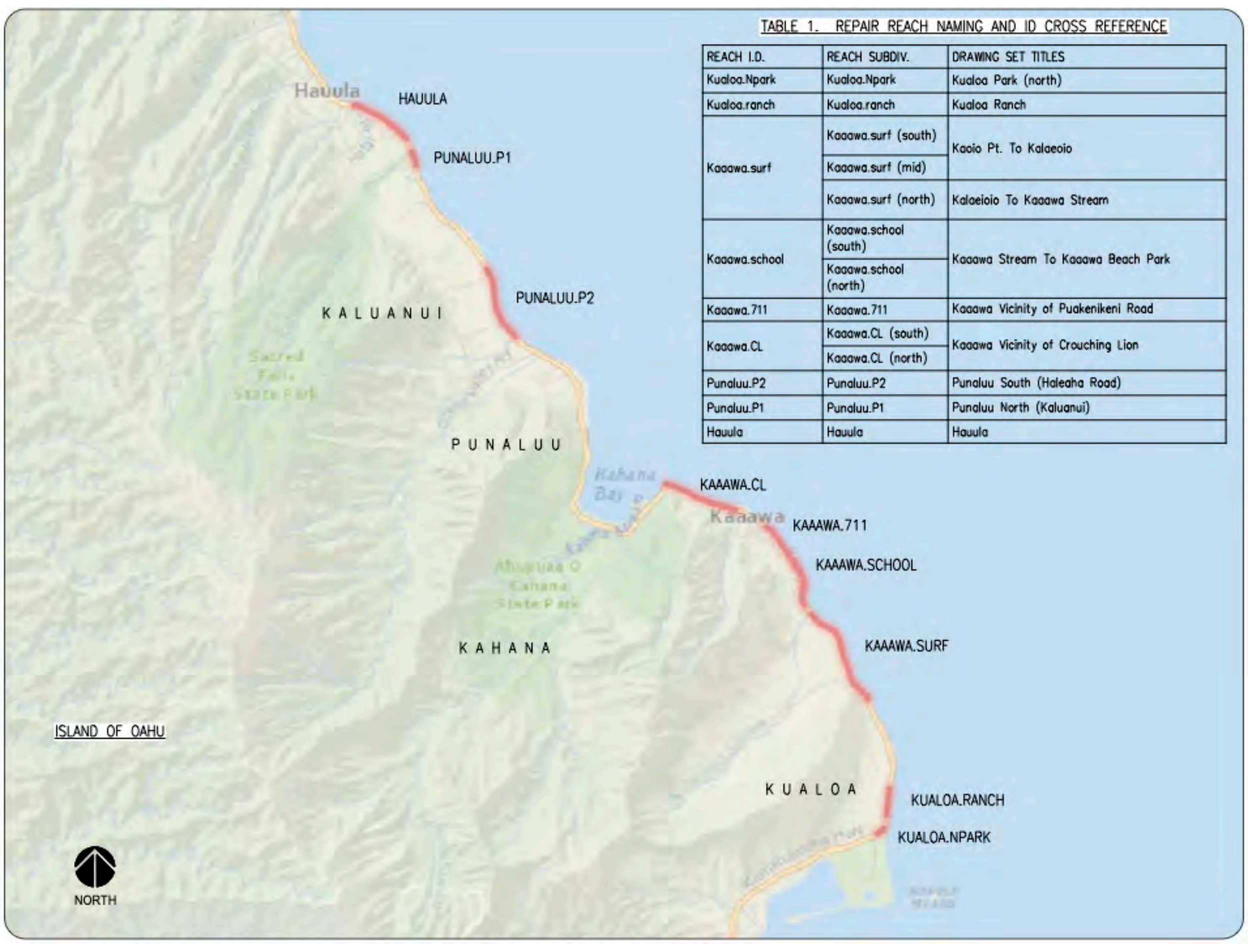

TABLE 1. REPAIR REACH NAMING AND ID CROSS REFERENCE

REACH I.D.	REACH SUBDIV.	DRAWING SET TITLES
Kualoa.Npark	Kualoa.Npark	Kualoa Park (north)
Kualoa.ranch	Kualoa.ranch	Kualoa Ranch
Kaaawa.surf	Kaaawa.surf (south)	Kaoio Pt. To Kalaeoio
	Kaaawa.surf (mid)	
	Kaaawa.surf (north)	Kalaeioio To Kaaawa Stream
Kaaawa.school	Kaaawa.school (south)	Kaaawa Stream To Kaaawa Beach Park
	Kaaawa.school (north)	
Kaaawa.711	Kaaawa.711	Kaaawa Vicinity of Puakenikeni Road
Kaaawa.CL	Kaaawa.CL (south)	Kaaawa Vicinity of Crouching Lion
	Kaaawa.CL (north)	
Punaluu.P2	Punaluu.P2	Punaluu South (Haleaha Road)
Punaluu.P1	Punaluu.P1	Punaluu North (Kaluanui)
Hauula	Hauula	Hauula

Figure 1-12. Repair reach location map

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2. PROJECT SITE DESCRIPTIONS

The full collection of individual project sites, also referred to as the repair locations for the KKPH effort, is situated on the northeast shoreline of the Island of Oahu, as shown in Figure 1-1 and Figure 1-2 from the previous section (Introduction) of this report. The project sites are further identified by name in the repair location map provided in Figure 1-12, also from the previous section. The physical environment and general setting which characterizes the entire project area is that of a long and typically narrow coastal plane, confined by the steep slopes of the Koolau Mountains on the landward boundary, opposite the Pacific Ocean on the other. This slender strip of flat usable land is almost entirely occupied along its length with rural residential communities, agricultural fields, schools, and some scattered small businesses. It's small beaches and beach parks are often fully utilized on weekends by residents and tourists alike, with bumper-to-bumper traffic not uncommon on sunny holidays.

The project area lies on the Windward side of Oahu, directly exposed to both the persistent easterly Tradewinds, and the rough wind swells generated by these winds. Most of the project shoreline is effectively sheltered from direct approach of large open ocean swells by an extensive complex of broad and shallow fringing reefs. These outer reefs typically absorb a large fraction of the incoming wave energy, however there are intermittent channels and deeper basins that cut across the nearshore reef plateaus, some of which allow increased wave exposure to those shoreline areas that front these features. The size, configuration, and extent of the reefs, channels, and other nearshore features have a significant effect on the character of the shoreline's beaches, and whether the shoreline has a beach at all. Shoreline configurations range from relatively wide seemingly healthy beaches which exist throughout the year, to sections which change dramatically with the seasonal change of wave conditions, and some locations which remain rocky and devoid of sand throughout the year. The individual project sites vary in these respects and are discussed in greater detail in the following subsections, organized by location.

2.1 Kualoa

Kualoa encompasses two of the nine identified project repair reaches: "Kualoa Park (North)," the shortest segment of all the project sites, located at the north end of Kualoa Beach Park where Kamehameha Highway rounds the corner from Kaneohe Bay and turns northward, and "Kualoa Ranch," starting in the vicinity of the main entrance to Kualoa Ranch and extending northward to the vicinity of the old sugar mill, as depicted in Figure 2-1. These two repair sites are presented in the subsections below.

2.1.1 Kualoa Park (North)

The Kualoa Park location is a very short segment, approximately 120 ft in length, that is located at the northern corner of Kualoa Beach Park, shown in Figure 2-2. This erosional hotspot is likely the result of its position at the downstream (south) side of a small groin field that protects a number of shoreline residences directly to the north. Net sediment transport is north-to-south in this area, as visually indicated by the sand buildup on north facing side of groins or obstacles, and the chronic erosion occurring on south-facing sides. In fact, this particular area has experienced some of the highest rates of erosion on all of Oahu (Hwang, 1981 and U.S. Army Corps of Engineers. 1977). Persistent longshore currents transport sand and beach material southward here, along the shoreline into Kaneohe Bay, where they eventually accrete into new beach areas fronting Molii Fishpond and "Secret Island" further into the bay. As beach sediments are lost from the project site, new material is prevented from arriving from the north due to the groin walls protection the homes. The result is a receding shoreline, retreating from right to left as shown in Figure 2-2, revealing the unprotected highway embankment as it goes. Currently, the section of exposed roadway is protected by approximately 90 ft of riprap placed as an emergency measure.

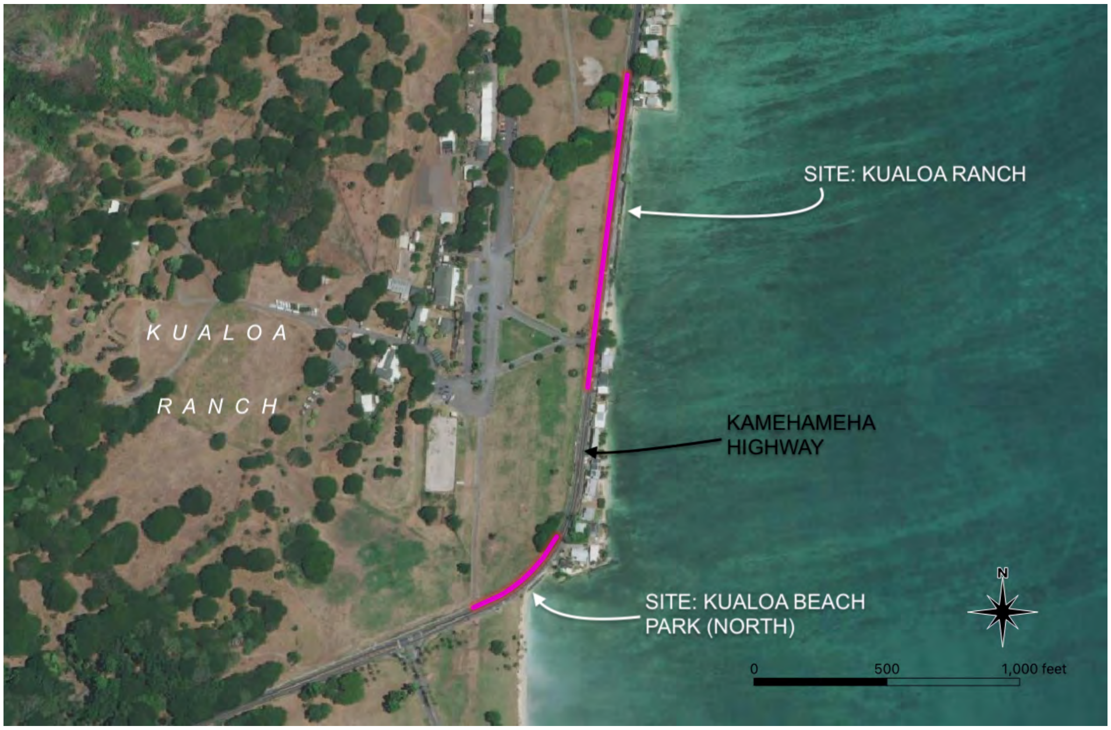

Figure 2-1. Kualoa project site locations (credit: background map from *ESRI)*

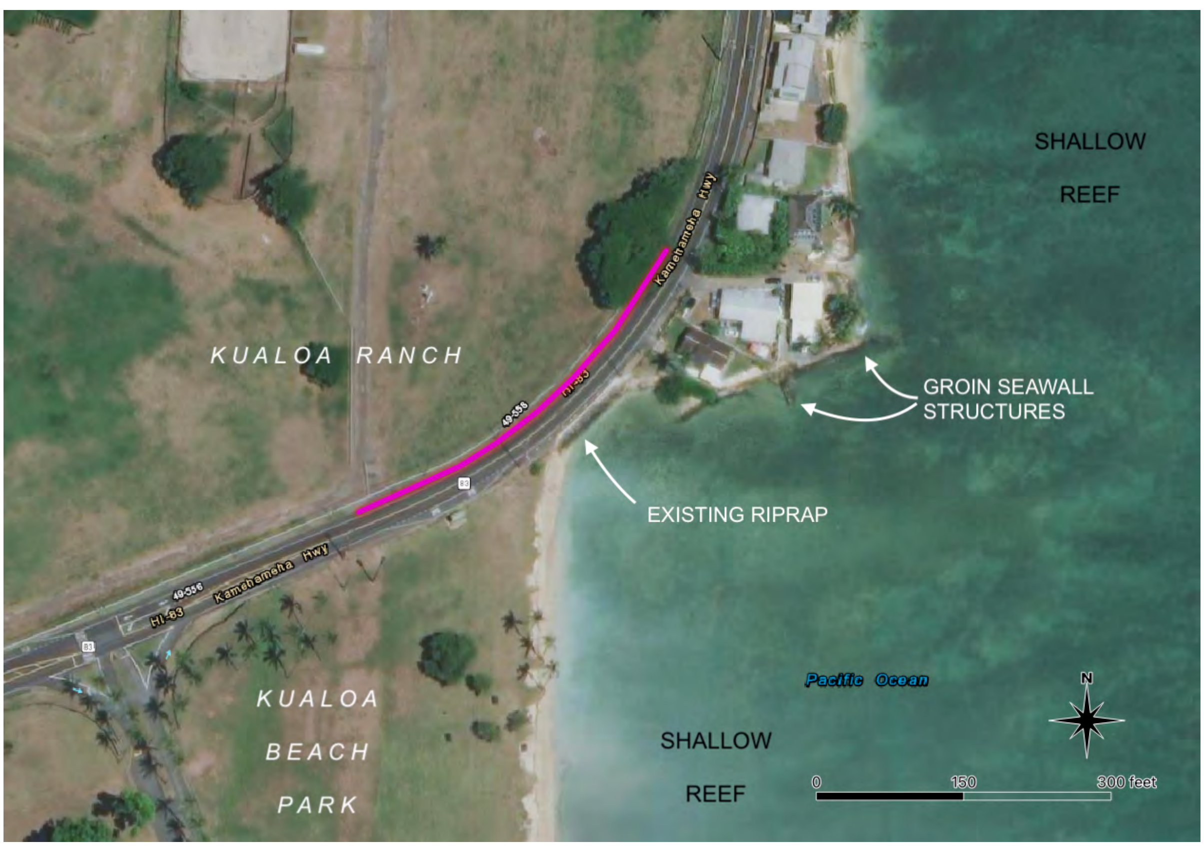

Figure 2-2. *Kualoa Park (North)*, lower shoreline receding from right to left

A ground-level photograph of the project site is shown in Figure 2-3, showing the 90 ft section of non-engineered riprap, and above that the hazard barricades placed along the eroded road shoulder along Kamehameha Highway. The erosion scarp follows along the edge of pavement for most of this site and can be seen exposed at image left. The houses to the north are seen at right in the image, and Kualoa beach is in the foreground. The beach here is actively eroding from right to left along the side of the highway. Imagery and survey data from 2013 have indicated shoreline retreat here on the order of 40 ft from that year to the current day (over approximately 10 years).

Figure 2-3. Kualoa Park (North) project site and riprap emergency protection, shoreline receding from right to left

Road deck elevations are approximately 8 to 9 feet above mean sea level (MSL), and minimal beach material currently exists for much of the repair site's length. A broad and shallow protective reef platform extends seaward for thousands of feet, with generally calm nearshore depths ranging from ½ to 2 ft. An existing condition site plan is provided on Sheet C-005 and a corresponding typical section is provided on Sheet C-009 of the Conceptual Alternatives Development drawing set in the Appendix. Theses drawings were based on high resolution LiDAR (LIght Detection and Ranging) topography/bathymetry data from 2013 (USACE), and the shoreline retreat mentioned above becomes very apparent at this location.

2.1.2 Kualoa Ranch

The Kualoa Ranch repair site, illustrated in Figure 2-4, begins near the entrance to Kualoa Ranch in the south, extending northward to the vicinity of the Old Kualoa Sugar Mill in the north, and is approximately 1,000 ft in length. This low-lying stretch of highway is similar in many ways to the previous Kualoa site to the south, with similar reefs, mild wave exposure, and shallow nearshore depths. However, due to its exceptionally low elevation, the road deck is frequently washed over by small waves bringing sand, coral rubble, and other debris onto the travel lanes during the highest tides or periods of elevated surf. Road deck elevations along this stretch are in the range of 5 ½ to 6 ft above MSL, and being so low, the roadway is also susceptible to flooding from terrestrial runoff from nearby mountain slopes during extreme rain events, as have happened in recent years. A map of the existing condition and a typical section are provided on Sheets C-013 and C-017, respectively, in the Appendix.

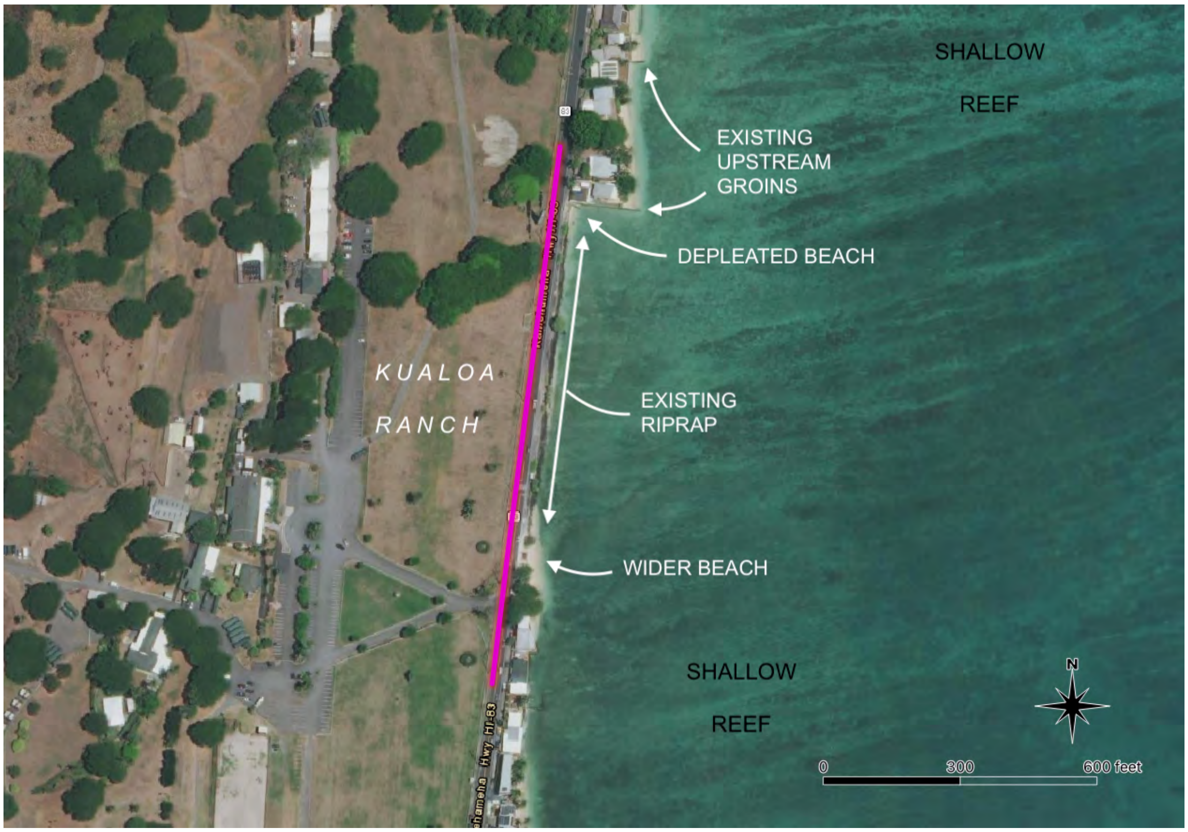

Figure 2-4. *Kualoa Ranch* repair site (entrance to Kualoa Ranch at lower center)

A very narrow and intermittent sediment and coral rubble deposit is found along the shoreline of this stretch, and similar to the Kualoa Park site, is generally narrower at the north end and wider at the south, again due to the predominant north-to-south sediment transport path, evidence of which is clearly depicted in Figure 2-4. A large groin protecting a private property immediately to the north of this site traps and limits sediment injection from the north, depleting the beach directly south of the structure as a result.

The eroded shoreline along this section of Kamehameha Hwy has been augmented with non-engineered riprap on numerous occasions, including concrete square piles and quarry stone, as shown by the image in Figure 2-5. Indications of scour, undermining and foundation erosion are evident in the image, which shows fallen and rolled piles, and displaced solitary armor stones laying several feet in front of the non-engineered structure.

Highway shoulder width varies from approximately 6 to 9 feet over this reach, with the erosion scarp collocated alongside the edge of pavement, where it then drops down 2 to 3 feet to the natural beach profile. Much of the shoreline is rocked with riprap placed during emergency repair activities, largely concealing the natural profile. An uncemented low height seawall composed of stacked concrete square piles appears to have been constructed sometime prior to the placement of riprap and is now mostly embedded in the riprap or sand.

Figure 2-5. Kualoa Ranch repair site, looking southward from vicinity of Kualoa Sugar Mill

2.2 Kaaawa

Kaaawa encompasses four of the nine identified project repair reaches: "Kaoio Point to Kaaawa Stream," the longest segment of all project sites, starting in the south as Kamehameha Hwy descends around Kaoio Pt in the vicinity of the Back Gate to Kualoa Ranch's Kaaawa Valley property, and running north to the Kaaawa Stream Bridge; "Kaaawa Stream to Kaaawa Beach Park," which begins in the vicinity of Kalaeoio Beach Park in the south and continues north to the Kaaawa Beach Park; "Kaaawa – Vicinity of Puakenikeni Road," which includes the entire stretch of road on the straightaway between beach-front homes to the north and south, in the vicinity of Puakenikeni Road; and lastly, "Kaaawa – Vicinity of Crouching Lion," which starts in the southeast near Kaaawa Park Lane near Swanzy Beach Park and runs northwest past the Crouching Lion to the vicinity of the flashing light and hairpin turn at the entrance to Kahana Bay. The four Kaaawa project sites and their relative locations are shown in Figure 2-6, where the geographic extent of the image covers Windward Oahu from Kualoa in the southeast corner to Kahana Bay in the northwest corner. Each of the four Kaaawa sites are presented in greater detail in the following subsections, in order from south to north.

2.2.1 Kaoio Point to Kaaawa Stream

This segment is by far the longest project site, stretching over 4,750 ft from Kaoio Pt in the south and continuing up to the Kaaawa Stream Bridge in the north (see Figure 2-7). Distinctly different from the previous two sites in Kualoa, this section of highway in Kaaawa winds along a rougher and slightly higher length of coastline. The broad and shallow reef platform that shelters much of Kualoa becomes deeper and more fractured in this part of Kaaawa, with significantly more wave energy propagating into the shoreline as a result, as indicated by the white water near the shoreline as seen in Figure 2-7.

Figure 2-6. Kaaawa project site locations (credit: background map from *Google Earth*)

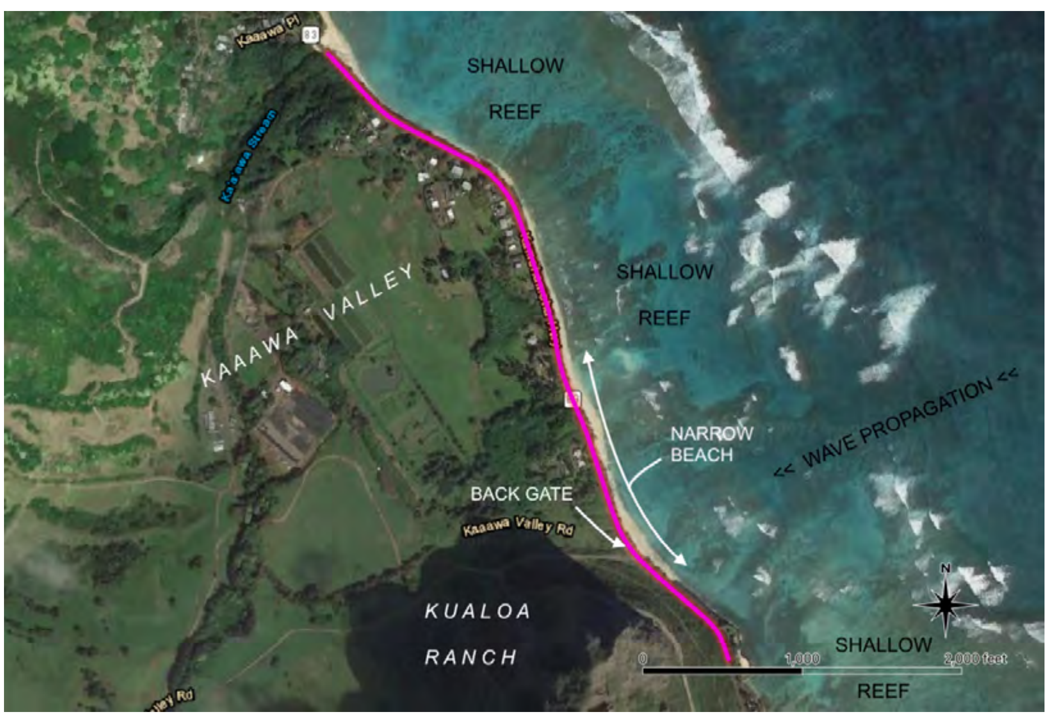

Figure 2-7. *Kaoio Point to Kaaawa Stream* repair site (credit: background map *Google Earth*)

Terrain landward of the shoreline here is characterized as relatively flat and follows the level floor of Kaaawa Valley. Typical road deck elevations range from 10 ½ to 13 ft, and paved should widths vary from 4 to 8 ft. Beyond the edge of pavement, unpaved shoulder widths vary from the non-existent to 8 to 10 ft. A map of existing conditions at this site is provided on Sheets C-021 and C-022, and typical sections on Sheets C-026 and C-030 in the Appendix. The highway shoulder throughout the project area is generally irregular and dependent on localized erosion hot spots which aggressively chisel away the shoreline along this entire reach, as illustrated in Figure 2-8. A narrow beach, mostly concentrated at the southern end of the site near the Back Gate, follows the shoreline, sometimes only revealed at lower tides. Long sections of this segment, particularly at the middle and northern end, have little to no dry beach even at low tides, typified in Figure 2-9.

Figure 2-8. Condition of highway shoulder in vicinity of Kaoio Point, looking south (*left*) and north (*right*)

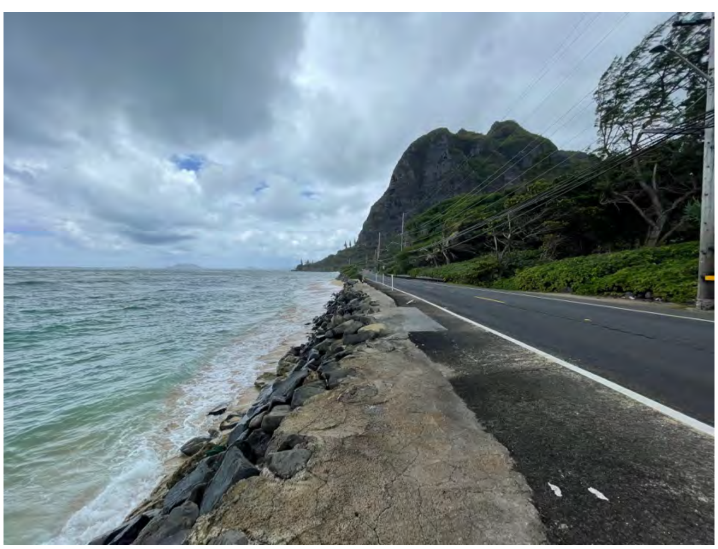

Figure 2-9. Condition of highway shoulder in vicinity of Kaaawa Valley, looking south (*left*) and north (*right*)

Due to its proximity to the shoreline and high exposure to waves, this section of road is routinely over-washed during higher tides, storms, or periods of elevated surf. Moreover, the road is so close to the water in this region, it could reasonably be said that the highway itself actually forms the shoreline, with a consistent erosion scarp dropping 2 to 3 ft vertically down from the edge of pavement—or even from beneath the pavement in one of the many areas of undermining. A series of emergency repairs, including concrete piles and stone riprap have been placed to form a non-engineered revetment along this aggressively eroding stretch over the last several years. The revetted slope is showing signs of differential settling and displacement in many places, and the underlying earthen erosion scarp is visible in places. Some limited areas of undermining have grown large enough to form small sinkholes along the shoulder, causing the pavement to collapse in those areas, as shown in Figure 2-10.

Figure 2-10. Sinkhole along the *Kaoio Point to Kaaawa Stream* repair site

2.2.2 Kaaawa Stream to Kaaawa Beach Park

The Kaaawa Stream to Kaaawa Beach Park segment covers the length of Kamehameha Highway starting from the northern end of Kalaeoio Beach in the vicinity of the intersection with Pohuehue Road in the south, running northwards to the northern end of Kaaawa Beach Park just north of Kaaawa Elementary School. This project site is generally lower in elevation than the Kaoio to Kaaawa Stream segment, and notably less exposed to direct wave attack. A large and complex outer reef formation exists here, with a broad and shallow platform reef to the north with nearshore depths of 1 to 2 ft, while a relatively deep but protected lagoon feature dominates the south end, with depths variable from approximately 4 to 10 ft. A very deep cross-shore channel cuts through the reef (lower right in Figure 2-11) and transitions into the lagoon feature at the southern end of this site. The south end of this reach is typically more energetic than the northern end, with increased wave energy able to ride in via the deeper channel's waters, while the northern half is effectively sheltered in comparison by the broad and shallow reef that begins there and runs north (upper middle in Figure 2-11). Currents along this segment are north to south along shore, and persistent, only increasing or decreasing in speed in response to the strength of the Tradewinds and wind swells. The well-defined longshore current here is primarily a function of the underwater terrain, bounding and redirecting the flux of water from persistent breakers that have rolled in over the reef, forcing that water to flow in the path of least resistance (southward)—never reversing direction—into the deep channel where it then courses back out to sea. Sand and sediment transport mirrors this circulation pattern, with a general north to south drift along the beach, ending with sand accumulation in the deep channel where the current slows and releases the sediment load from suspension. The large sand deposit visible at lower right in the channel in Figure 2-11 is consistent with this pattern.

Road deck elevations along this stretch vary from approximately 6 to 8 ft above MSL. Native trees and vegetation are relatively dense alongside the shoreline for much of this area, particularly on the south end. A narrow but gently sloping beach of mixed sands, cobbles and coral rubble is characteristic of the site, as shown in Figure 2-12. The southern half of the site is largely undeveloped with no manmade structures or improvements, while the northern half is lined almost entirely with a combination of riprap and stacked concrete piles, both of which appear non-engineered in nature (see Figure 2-13 and Figure 2-14). A map of existing conditions for this project site, including typical section, are provided on Sheets C-042 and C-046 in the Appendix. NOTE: The northern half of this site is also the location of an overlapping Kaaawa emergency roadside shore protection project, which is completely designed and is currently in the process of permit applications for estimated construction in 2023. For reference, the approximate footprint of the separately proposed rock revetment is provided on Sheet C-042.

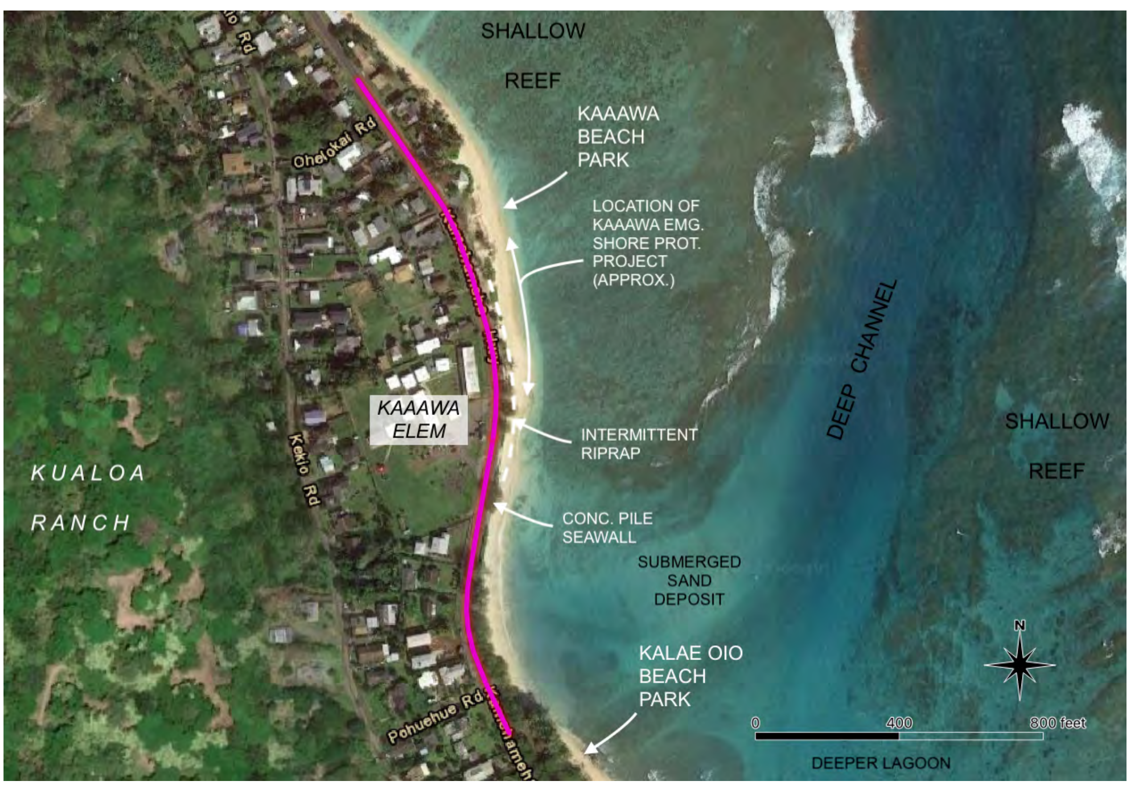

Figure 2-11. *Kaaawa Stream to Kaaawa Beach Park* project site (credit: background map *Google Earth*)

Figure 2-12. Condition of southern shoreline adjacent to highway shoulder, looking south (*left*) and north (*right*)

Figure 2-13. Condition of northern shoreline adjacent to highway shoulder, looking south (*left*) and north (*right*)

This segment of Kamehameha Highway is very susceptible to wave overtopping and over-wash during periods of elevated surf and higher tides, and particularly so along the low-lying southern half near Pohuehue Rd. Large amounts of water-borne debris including logs, rocks, and sand are prone to washing over the road here, as captured on the cover image of this report (taken during Hurricane Douglas in 2020). Toward the northern end of this site road deck elevations increase, however, erosion is aggressively attacking the embankment that supports the road shoulder, resulting in the numerous emergency repairs that have been required here in order to maintain the road in serviceable condition.

Figure 2-14. Scattered and displaced riprap and concrete piles, looking south (*left*) and pile seawall (*right*)

2.2.3 Kaaawa – Vicinity of Puakenikeni Road

The Kaaawa project site in the vicinity of Puakenikeni Road encompasses a section of Kamehameha Hwy that includes the oceanfront straightaway just south of the Kaaawa Post Office, starting from a location near the intersection of Ohelokai Road in the south and running northward to the end of the straightaway just beyond the intersection of Polinalina Road, as illustrated in Figure 2-15. Photographs of the existing condition are provided in Figure 2-16 and Figure 2-17 for the south and north ends of the site, respectively.

A broad and shallow reef flat extends seaward from the shoreline here, ranging from 900 to 1,300 ft from shore out to the surf zone. The wideness and shallowness of the reef in this area combine to limit typical wave heights at the shoreline here, which is often quite calm. However, even though normally tranquil, the road's low profile and proximity to the water nevertheless leave this stretch vulnerable to wave overtopping and over wash during high tides and periods of elevated surf. Sand, coral rubble, and other debris thrown onto the road deck along with ponding seawater are not rare here during such periods.

In terms of shoreline character, a very narrow—and often submerged—sand and cobble beach deposit exists along most of this shoreline, tapering slightly in width from south to north. Northward, the project shoreline becomes notably rockier and increasingly devoid of sand, with the exception of a small pocket beach at the northern extremity of the site. This very small beach is trapped in a gap formed between a private home's seawall to the north, the end of existing roadside riprap to the south, and the landward curvature of the road to the west (see Figure 2-18, at right). The entire length of the Puakenikeni site's shoreline is armored with a series of ad-hoc emergency repairs completed at various times over the years. The emergency repairs consist of a combination of measures, including dry stacked concrete blocks placed to form a 140-ft long non-engineered seawall (see Figure 2-18, at left) and flanked to the north and south by a non-engineered riprap revetment structure. The revetted shoreline is exhibiting signs of stone displacement and advanced settling. The paved road shoulder width varies from 2 to 6 ft and directly abuts the riprap in most places. The underlying erosion scarp is visible in places, but most prominent along the south end. This portion of shoreline is approximately 6 to 7 ft above MSL, and often only 20 to

30 ft from the water. A map of the existing condition is provided in Sheet C-050, and a typical shoreline section is found on Sheet C-054 in the Appendix.

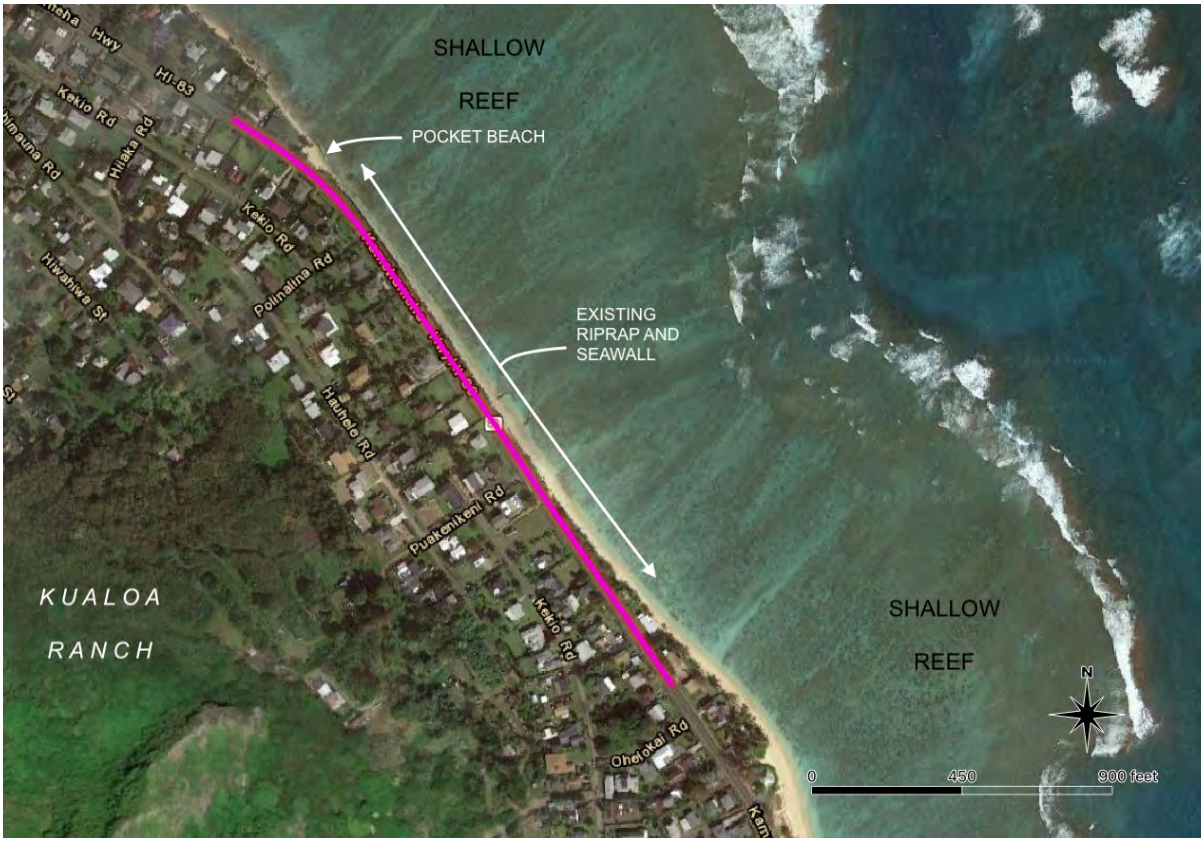

Figure 2-15. *Kaaawa – Vicinity of Puakenikeni Rd* project site (credit: background map Google Earth)

Figure 2-16. Condition of southern shoreline adjacent to highway shoulder, looking south (*left*) and north (*right*)

Figure 2-17. Condition of northern shoreline adjacent to highway shoulder, looking south (*left*) and north (*right*)

Figure 2-18. Stacked concrete block seawall, looking south (*left*) and northern pocket beach (*right*)

2.2.4 Kaaawa – Vicinity of Crouching Lion

The Kaaawa project site in the vicinity of Crouching Lion encompasses a section of Kamehameha Hwy that includes the segment starting from just north of Swanzy Beach Park and runs approximately 3,000 ft northwest to the flashing light and hairpin turn, about 400 ft beyond the Crouching Lion Inn, as depicted on the aerial image in Figure 2-19. The southern end of the project site is characterized by a relatively high vertical erosion scarp cut into the native earthen embankment that sits atop what appears to be a layer of alluvial or riverine cobble stones and boulders along the water line, as shown in Figure 2-20. The highway shoulder runs alongside this scarp, with the edge of pavement characteristically 2 to 3 ft landward from the drop-off, as illustrated in Figure 2-21.

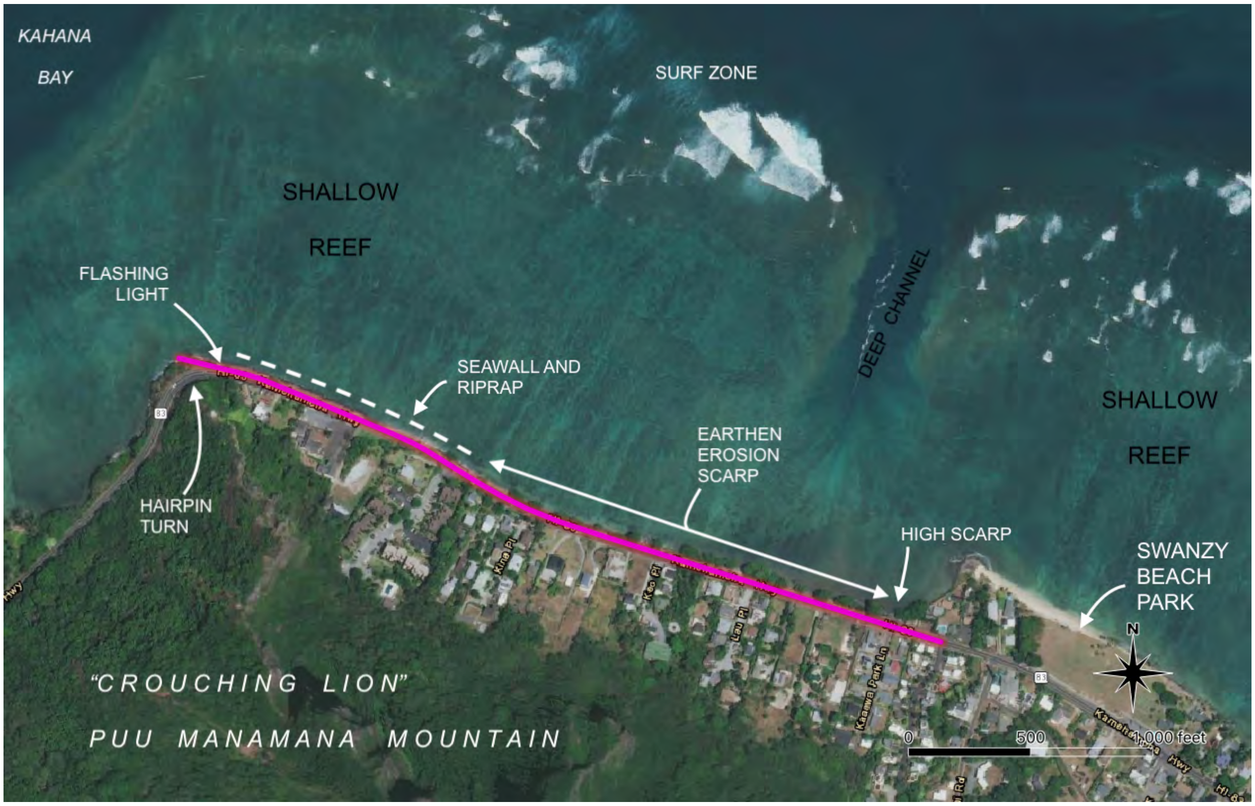

Figure 2-19. *Kaaawa – Vicinity of Crouching Lion* project site (credit: background map *Google Earth*)

Figure 2-20. Condition of southern shoreline adjacent to highway shoulder, looking south (*left*) and north (*right*)

Figure 2-21. Highway shoulder condition in vicinity of photographs shown in Figure 2-20

The 3,100 ft long section of shoreline at the Crouching Lion project site can generally be categorized into two zones: the approximately 2,000 ft long southern zone shoreline which is characterized by a vertical earthen escarpment 2 to 6 ft in height that trails along the side of the highway, with a sloped cobblestone and boulder beach at the bottom of the scarp that runs out onto the very shallow reef (see Figure 2-22); and, the shorter 1,100 ft northern zone which typically has little to no beach material along the water line, and is hardened by a combination of non-engineered riprap and seawalls, typified by the image in Figure 2-23. An oblique view of the project shoreline is given in Figure 2-24, with approximate zones of shoreline character demarcated in red for the south and magenta for the north.

What is also discernable from Figure 2-24 is the wide extent of the reef and its effectiveness in absorbing incoming wave energy. The surf zone at the outer reef's edge is approximately 1,600 ft from shore here. The reef crest at the outer edge at Crouching Lion is notoriously shallow, and as such is a great natural wave attenuator, typically resulting in very calm conditions at the shoreline, particularly for the southern end. The reef flat gradually deepens to the west, towards the northern end of the project shoreline, where wave exposure increases somewhat due to the deeper waters. The reef falls off abruptly into Kahana Bay further to the west of the project shoreline.

Kamehameha Highway along the Crouching Lion project site traverses a very narrow corridor between the ocean and the base of the Koolau Mountains as they slope steeply upwards to the ridgeline that is the project's namesake, "Crouching Lion" or Puu Manamana, hundreds of feet above the roadway. Road deck elevations typically range from 7 to 9 ft above MSL, rising quickly to over 30 ft in the vicinity of the hairpin turn at the north end of the site. Terrain generally rises steeply landward of the highway and drops down an erosion scarp seaward of the road. A topographic map of existing conditions is provided on Sheet C-058, with typical profile sections on Sheet C-063 and C-067 of the concept drawing set in the Appendix included at the end of this report.

Figure 2-22. Typical roadside shoreline condition along most of the Crouching Lion project site

Figure 2-23. North end of Crouching Lion project site, Kahana Bay in background

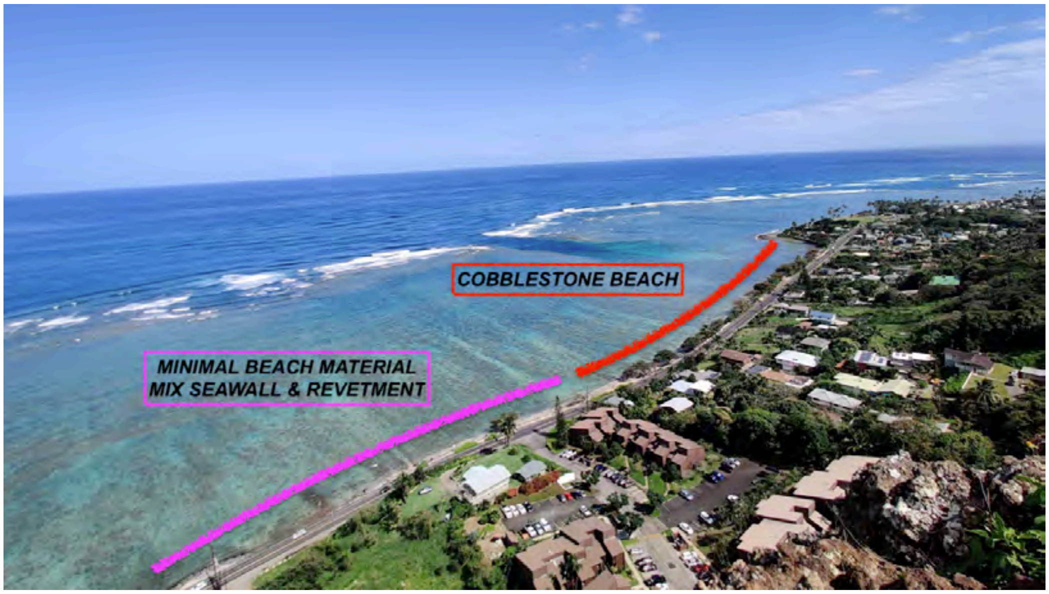

Figure 2-24. View of Crouching Lion project site and general shoreline character, looking east.

2.3 Punaluu

Punaluu holds two of the nine original project repair reaches for Kamehameha Highway: "Punaluu South," a 3,300 ft stretch originating at the crossing for Punaluu Stream in the south and running northward to a location approximately 300 ft north of the intersection with Hale Aha Road; and "Punaluu North," a short 600 ft section of highway just north of the Kaluanui Stream crossing, fronting the park area formerly known as Sacred Falls. Relative locations for these sites are illustrated on the aerial image in Figure 2-25.

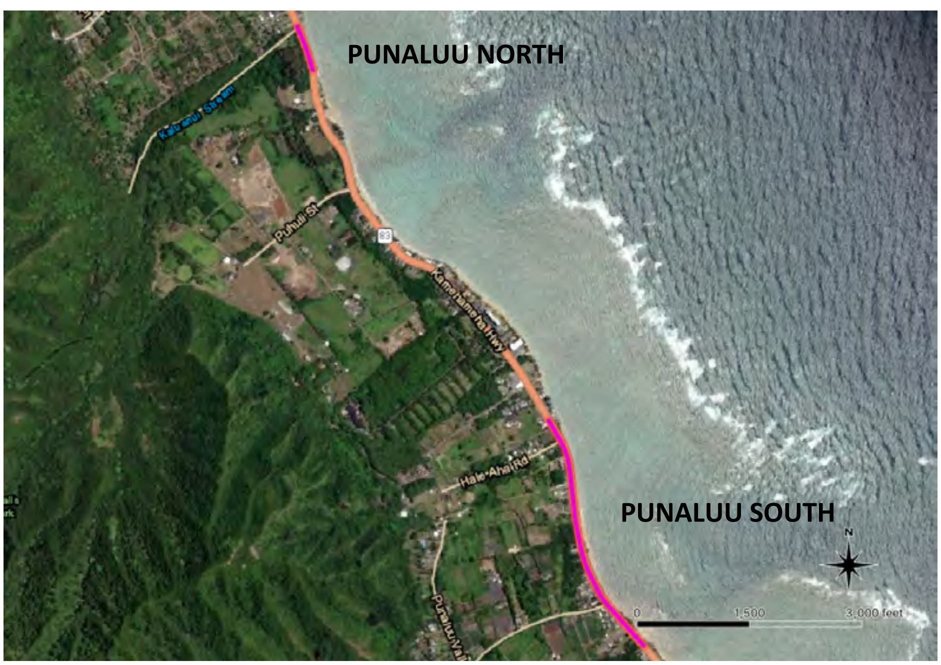

Figure 2-25. Punaluu project sites (credit: background map *ESRI*)

2.3.1 Punaluu South – Vicinity of Hale Aha Road

The original 3,300 ft project reach for "Punaluu South" is shown in Figure 2-26 below. During initial site visits, it was quickly ascertained that only a much smaller segment of this reach appears significantly threatened by erosion at this time. This was corroborated by consulting a study of future erosion rates produced by the University of Hawaii (Coastal Geology Group, 2022) that graphically illustrates predicted erosion along Oahu's shoreline. A drawing of the study's predicted shoreline erosion for the year 2050 (approximately 28 years in the future) is overlain on the project shoreline and results in the same conclusion. This comparison is provided on Sheet C-071 of the drawing set in the appendix.

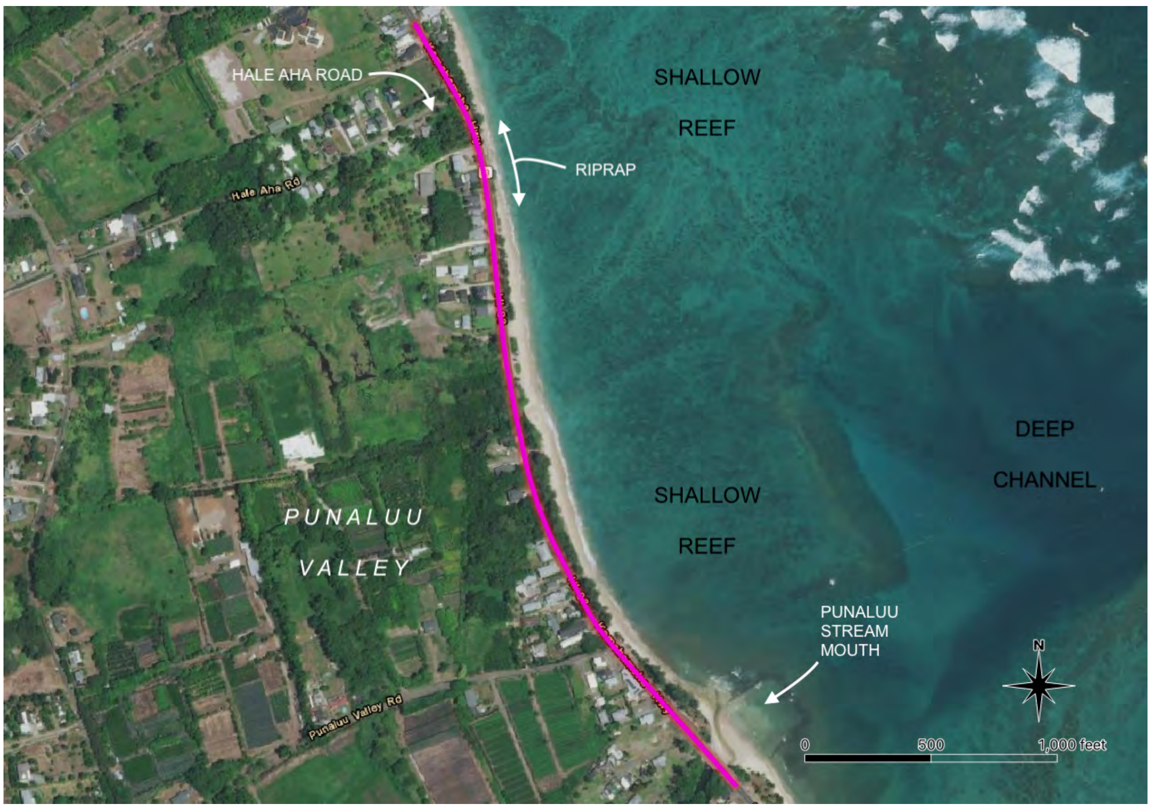

Figure 2-26. *Punaluu South* – original project extent (credit: background map *ESRI*)

Based on the findings from the field visit as well as the future erosion comparison discussed previously, it was decided to reduce the Punaluu South project from its original extent to an approximately 600 ft length of highway in the vicinity of the intersection with Hale Aha Road, as shown in Figure 2-27. This particular location appears to be at an inflection point in the surrounding coastline, which gradually bends back to landward north and south of this area, causing the Hale Aha site to become divergent and thus susceptible to increased erosion. The approximately 600-foot-long section of existing stone and concrete riprap is strong evidence of persistent erosion here (see Figure 2-28).

The general condition of the shoreline here is characterized by a broad and shallow fringing reef, extending roughly 1,700 ft offshore to the surf zone, with a narrow sandy beach at the shore. This beach gradually tapers from 30 to 40 ft north and south, down to 10 to 20 ft in the vicinity of the project site.

Landward, the terrain is generally flat and largely rural except for the row of private residences that line the highway. Road deck elevations within the site are approximately 6 to 7 ft above MSL, and the paved shoulder varies from 2 to 4 ft in width, directly abutting the riprap over some of its length. An erosion scarp of 1 to 2 ft is discernable behind the revetted slope in places. Nearshore depths along the reef flat fronting the project site range from 3 to 5 ft (below MSL). A topographic map of existing conditions is provided on Sheet C-072 along with a typical section on Sheet C-076 of the concept drawing set in the Appendix of this report.

Figure 2-27. *Punaluu South – Vicinity of Hale Aha Road* project site (credit: background map *Google Earth*)

Figure 2-28. Condition of south Punaluu project site's highway shoulder, looking south (*left*) and north (*right*)

2.3.2 Punaluu North – Vicinity of Kaluanui

The Kaluanui site in northern Punaluu is another short segment of threatened highway, approximately 600 ft in length, located in front of the undeveloped park area that was at one time referred to as Sacred Falls. The approximate location of this repair site is depicted on the aerial image of Kaluanui in Figure 2-29. This section of shoreline lies just north of the Kaluanui Stream mouth, which feeds into a deeper cross-shore channel area 10 to 13 ft in depth (bottom right of Figure 2-29). To the north of the site lies a series of ocean-front homes that rest within a protective seawall (top center of Figure 2-29) on what is known as Kalaipaloa Point. Sediment transport paths along this shoreline are wave and bathymetry driven in a north to south flow, in a pattern similar to Kualoa and Kaaawa discussed in Sections 2.1 and 2.2.2, respectively. However, the extensive seawall structure surrounding Kalaipaloa Pt to the north effectively behaves as a groin, blocking longshore transport and starving the adjacent downstream side—the north end of the Kaluanui project site—of sand injection from upstream, resulting in the eroded condition that currently exists. Consistent with the pattern of circulation, beach width widens southward, with increasing distance from the seawall structure, as seen in Figure 2-29.

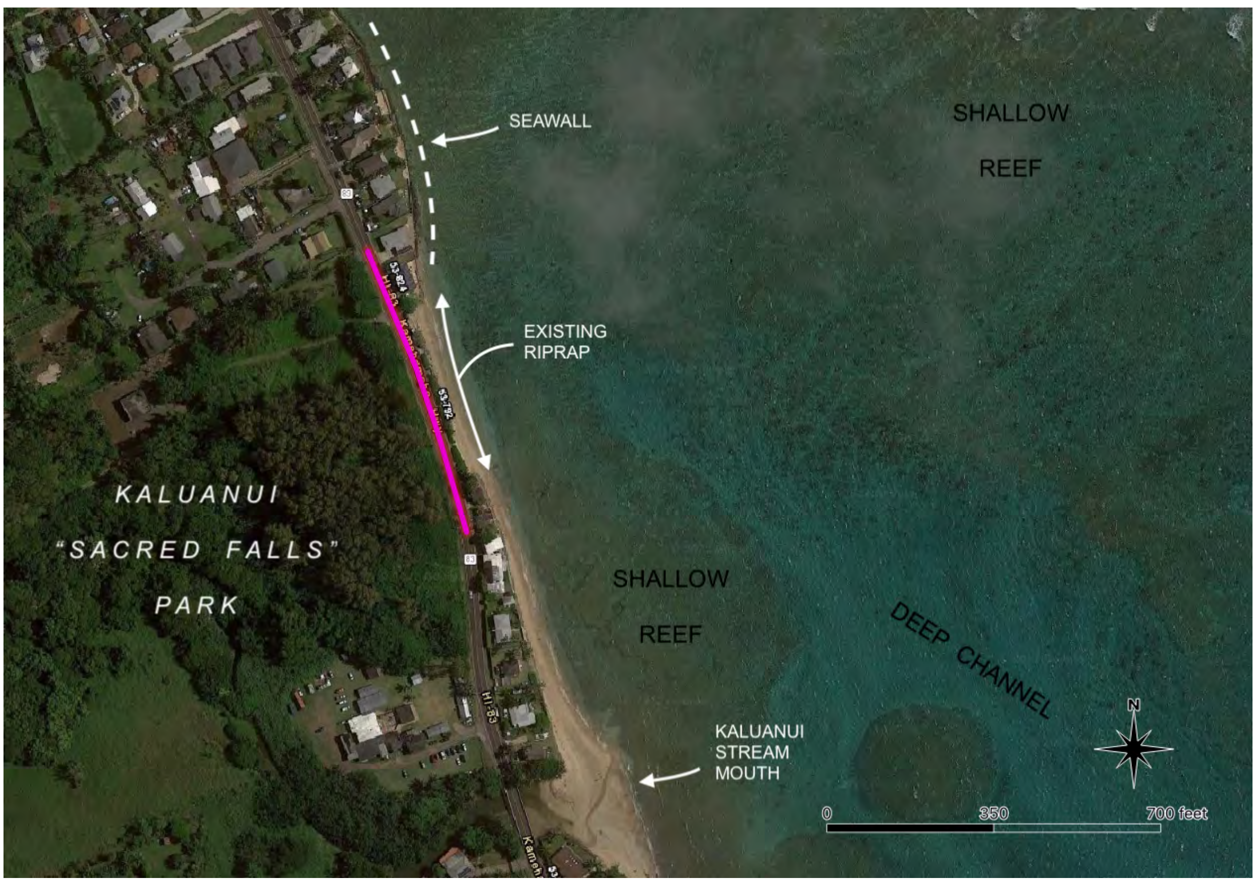

Figure 2-29. *Punaluu North – Vicinity of Kaluanui* project site (credit: background map *Google Earth*)

The Kaluanui project site's roadside shoreline appears to have been hardened sometime in the past with a combination of non-engineered measures, including dry stacked square concrete piles in the form of a low seawall, with rock riprap placed in front, captured by in the photographs in Figure 2-30. Settling and displacement have buried and/or scattered much of the riprap from the toe of the wall, rendering it largely ineffective. The concrete piles in the pile wall are extensively cracked and spalling with interior rebar exposed in many places. The south end of the pile wall appears to be rotating landward due to foundation scour possibly from terrestrial runoff and will likely eventually fail by falling over, while the remainder of the wall shows signs of moderate vertical displacement.

Figure 2-30. Kaluanui site, looking south with highway in background (*left*) and seawalls to north (*right*)

The road is relatively low-lying in this area, with deck elevations of 6 to 7 ft above MSL, increasing the vulnerability to overtopping during design conditions. Hard shoulder width varies from 3 to 4 ft, with an additional soft shoulder of 4 to 10 ft, ending at the pile wall and riprap. A topographic map of existing conditions is provided on Sheet C-080 along with a typical section on Sheet C-084 of the concept drawing set in the Appendix of this report.

2.4 Hauula

Hauula encompasses the second longest and northern-most repair reach of the KKPH project sites, and is located at the southern boundary of Hauula, just north of Kaluanui (Sacred Falls) Park. The relative location of the site is shown in Figure 2-31, where the Hauula site is highlighted by a magenta line, and the adjacent Punaluu Kaluanui site is shown for reference in red. The project site in Hauula is a 2,800 ft long stretch of Kamehameha Hwy that runs from Kalaipaloa Pt in the south, up to Makao Beach in the north, just before the intersection with Hauula Homestead Road. At this northern end of the project site, there is a freshwater outlet, similar to a stream outlet, that appears to be tied to a flood control or drainage canal that extends into the local community. Directly to the south of the project site is the seawall-surrounded beachfront community on Kalaipaloa Pt, which forms the physical separation between the *Hauula* project site and the adjacent previous project site at *Punaluu North – Vicinity of Kaluanui*. A second freshwater drainage outlet is located at the south end of the project site, approximately 80 ft north of the northern-most residence at Kalaipaloa Pt.

The overall extents of the Hauula project site are delineated by the magenta line on the aerial image provided in Figure 2-32, which is a closeup of the southern Hauula region. The larger coastline here which includes two project sites (Hauula and Punaluu - Kaluanui) is bracketed between two deep and very well defined cross-shore channels that exist to the north and south, as is seen in Figure 2-31. The aerial images provide strong visual evidence of a nearshore circulation pattern governed by this shallow reef and deep channel bathymetry system and driven by the persistent flow of Tradewind waves forcing water landward over the shallow reef and draining back into the channels along the shore. The point at Kalaipaloa (Figure 2-31, image center) appears to be a zone of divergence, with currents and sediment transport going southward below that point, and flowing northward above it, both emptying into the deep channel systems bisecting the reef at the boundaries. The beach along the Hauula project site shoreline (Makao Beach) appears represent a mirror image of the circulation pattern discussed for the Punaluu Kaluanui site, with widening of the beach to the north in Hauula as opposed to widening in the south as in Punaluu. The south end of the project shoreline, including the area surrounding the south-end drainage outlet, is completely devoid of sand, with approximately 700 ft of riprap installed along the road shoulder, sloping directly into the water and onto the shallow reef substrate. Moving northward from here along the shoreline, deposits of sand and coral rubble begin to increase and eventually become a narrow beach. Midway up the project reach, there is a slight convex inflection point in the shoreline, at which point the beach gradually widens from only a few feet into 10 – 15 ft in the vicinity of the Church of Jesus Christ of Latter-Day Saints. Northward beyond this location, the beach narrows once more to a negligible width before widening again at the northern end in the vicinity of the north drainage outlet.

Figure 2-31. Relative location of the Hauula project site, shown by magenta line (credit: background map *Google*)

The entire length of this project shoreline has been hardened over multiple efforts in previous years and is currently armored with 700 ft of non-engineered riprap revetment in the south, changing to a Kyowa rock bag stacked revetment with grouted crest for the remainder of the site to the north, illustrated by the typical photographs in Figure 2-33. Recent observations indicate that the rock bag structure (constructed in early 2020) has since been undermined by erosional forces, resulting in a general rotation of the revetment tilting seaward, separating the crest from the shoulder backfill material as it slumps, as seen in Figure 2-33 (right image).

Figure 2-32. *Hauula* project site extents (credit: background map *Google*)

Figure 2-33. Hauula site, looking south to drainage canal outlet (*left*) and north to Makao Beach (*right*)

Road deck elevations along the Hauula project site are in the range of 7 to 8 ft above MSL, with minimal paved shoulder widths for the majority of its length. A topographic map of existing conditions is provided on Sheets C-088 and C-089 along with a typical section on Sheet C-094 of the concept drawing set included in the Appendix of this report.

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3. OCEANOGRAPHIC SETTING

3.1 General Wind Climate

The prevailing winds throughout the year are the northeasterly Tradewinds. Average Tradewind frequency varies from more than 90% during the summer season to only 50% in January, with an overall annual frequency of 70%. Westerly or Kona winds occur primarily during the winter months and are generated by low pressure systems that typically move north of the islands from west to east. Figure 3-1 presents a wind rose diagram that is applicable to the project site. The diagram is based on wind data recorded daily near the airfield at Marine Corps Base Hawaii (MCBH) in Kaneohe, Oahu.

Tradewinds are generated by the outflow of air from the Pacific Anticyclone high-pressure system, also known as the Pacific High. The center of this system is typically located well north and east of the Hawaiian Islands and moves to the north and south seasonally. In the summer months (May through September), the center moves to the north, causing the tradewinds to be at their strongest. In the winter months (October through April), the center moves to the south, resulting in decreasing tradewind frequency. During these months, the tradewinds continue to blow; however, their average monthly frequency decreases to 50%.

During the winter months, wind patterns of a more transient nature increase in prevalence. Winds from extra-tropical storms can be very strong from almost any direction, depending on the strength and position of the storm. The low-pressure systems associated with these storms typically track west to east across the North Pacific north of the Hawaiian Islands. At Honolulu International Airport, wind speeds resulting from these storms have exceeded 60 mph on several occasions. Kona winds are generally from a southerly to a southwesterly direction and are usually associated with slow-moving low-pressure systems, or cold-core cyclonic storms known as Kona lows situated to the west of the Hawaiian Islands. These storms are often accompanied by heavy rains.

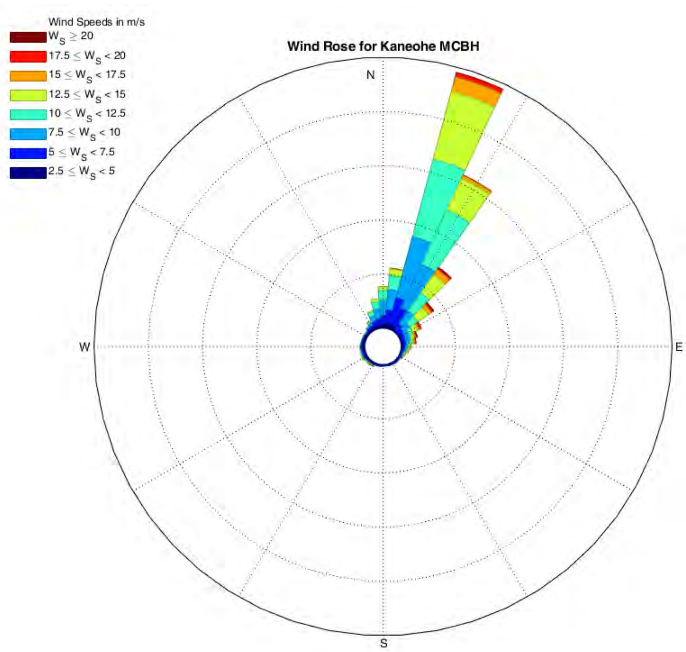

Figure 3-1. Wind Rose Kaneohe MCBH (July 2016 to July 2018)

3.2 General Wave Climate

Ocean waves that affect people and the built environment on a normal basis can generally be categorized into three groups (excluding tsunami), including: long period swell (characteristically with periods[‡] between 12 to 20+ seconds) generated by distant north or south Pacific storm systems; short period wind waves (typically with 6 to 12 second periods) generated by regional winds; and, the unpredictable and episodic wave events associated with intense local storms or cyclones (with periods often between 11 and 17 seconds). More specifically, the Hawaiian Islands receive waves from six well documented sources, which are: (1) northeast Tradewinds waves; (2) southeast Tradewinds waves from the near southern hemisphere; (3) south swells from the far southern hemisphere; (4) north swells from the Aleutians or other parts of the North Pacific; (5) Kona storm wind waves; and, (6) hurricane waves. Conceptually, the dominant swell exposure windows for Hawaii are as illustrated in Figure 3-2.

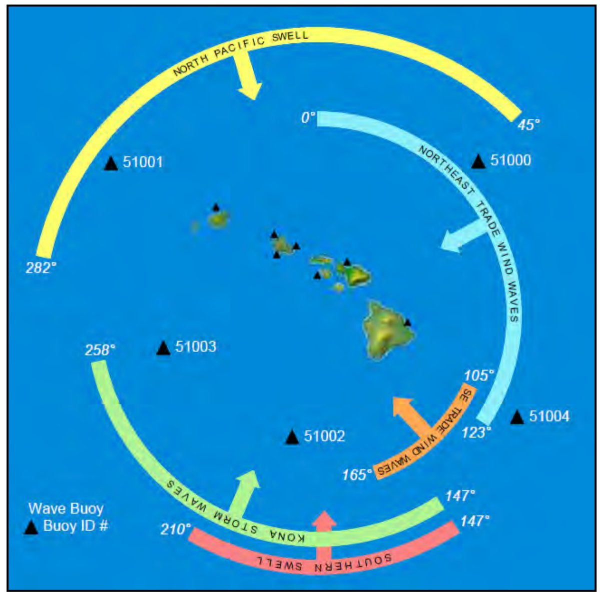

Figure 3-2. Dominant swell exposures for Hawaii

Tradewind waves occur throughout the year and are typically most persistent from April through September, when they tend to dominate the wave climate in Hawaiian waters. These waves are produced from the strong and persistent Tradewinds, generally blowing from the northeast quadrant, over long fetches of open ocean in the east and central pacific. The deep-water wave conditions for this source are typically between 3 to 8 feet high, with periods of 6 to 12 seconds depending on maximum wind speeds and how far east of the Hawaiian Islands the fetch[§] extends. The direction of approach, like the Tradewinds themselves, varies between north-northeast and east-southeast and is centered on the east-northeast direction. The project sites along the northeast shoreline of Oahu (Koolauloa) are fully exposed to the direct approach of Tradewinds and Tradewind waves and are considered to be a significant component for the project site's design conditions.

During the winter months in the northern hemisphere, strong storms frequently track through the North Pacific's mid-latitudes (40 to 50 degrees north latitude), often near the Aleutian Islands. These storms generate the well-known large North Pacific swells made famous by the North Shore, that range in direction from west-northwest to northeast and arrive at north-facing Hawaiian shores with little loss of energy. Deepwater wave heights often reach 15 feet and in extreme cases can reach up to 40 feet. Periods vary between 12 and 20+ seconds, depending on the track and intensity of the originating storm. Because of the northerly component, these waves can also have a significant impact on northeast-facing shores of Oahu, including the project sites.

[‡] Wave period is defined as the distance between two successive wave crests passing through a stationary position, measured in time (seconds).

[§] A fetch is the area in which ocean waves are generated by the wind, or simply the length over which the wind is blowing to produce the waves.

South swells are generated by intense storms thousands of miles away in the southern hemisphere's mid latitudes and are most prevalent during the late spring and summer months of April through September. Traveling distances of up to 5,000 miles, these waves arrive with relatively small deep-water wave heights of 1 to 5 feet but characterized with having long periods of 15 to 20+ seconds. South swells' direction of approach to the Islands is typically between southwest to southeast, depending on the originating storm's track across the Southern Ocean. The project sites' shorelines, which face northeast, are fully sheltered from swells from this approach by the island of Oahu itself.9

Wind swell from Kona storms is episodic and relatively infrequent, occurring usually about 10 percent of the time during a typical year. A Kona storm is a seasonal cyclone, generally classified as extratropical (cold core), which typically approaches the Islands with strong westerly to southwesterly winds that can also bring additional hazards such as heavy rain, flash flooding, hail, and even blizzards at high elevations such as on the upper slopes of Mauna Kea or Haleakala. Kona wind waves are typically experienced as short period wind swell, which range in period from 6 to 10 seconds, along with wave heights of 5 to 20 feet from the west to southwest. The project sites are considered to be fully sheltered from Kona storm wind swell, however, the associated high winds that are funneled by the steep mountain slopes and valleys can be very damaging as they blow offshore, sometimes accompanied by torrential downpours that can affect the drainage along portions of the project area.

Severe tropical storms and hurricanes (warm core cyclonic storms) have the capacity to generate extremely large waves, which potentially could result in extreme wave heights at the project site. Since construction of the Waianae Wastewater Treatment Plant and its original 36-inch diameter ocean outfall in the mid-1960's, two powerful hurricanes, *Iwa* (1982) and *Iniki* (1992), have impacted Oahu. In recent years, there have been several close-approach hurricanes, including Category 3 *Hector* (2018) which pounded south and west shores of Oahu with dangerously large surf, and Category 5 *Lane* (2018) which was forecasted to make landfall on Oahu but unexpectedly (and fortunately) weakened rapidly and veered off to open ocean just hours before its predicted impact. Most recently, Category 1 *Douglas* side-swiped the entire project area in July of 2020, generating extremely large surf that battered the shoreline and over-washed Kamehameha Highway in several locations, leaving rocks, sand and debris scattered along the road deck, leaving it impassable in some locations.

Notably, for as long as official records have been kept, tropical storms and hurricanes have had a relatively low probability of occurrence in the vicinity of the Hawaiian Islands; however, the risk of damage to Hawaii's offshore and coastal infrastructure is substantial and likely increasing every year due to rising ocean temperatures and intensifying storms driven by global warming.

3.3 Extreme Wave Height Analysis

Historic wave height measurements obtained from an array of offshore wave buoys, along with meteorological hindcast data, allows for the possibility of a statistics-based prediction of extreme wave events—such events are considered to be large and intense, episodic in nature, low-probability wave events that are typically used for design purposes. For instance, a 25-year event is an extreme event with a 1/25 (4%) chance of occurring in any given year based on historic measurements from the previous 20+ years. This is equivalent to a 25-year *return period* or *recurrence interval* event. And because the project shoreline is vulnerable to waves coming from multiple independent sources (north pacific swell, northeast Tradewind swell, and hurricane waves), it was necessary to consider extreme deep-water wave heights for each independent event source.

Decades of parametric wave data from Hawaii's offshore buoy network were obtained from online sources and used to generate a *Weibull*** *extreme value distribution*, a powerful statistical tool for relating frequency of occurrence to expected wave size. Commonly referred to as *return period* wave heights, the results of the analysis are valid only for the location where the source data were collected, or sites nearby with similar wave exposure windows. To be accurate, the extreme value wave height analysis must be based on a long-term dataset, typically with a record at least one-third as long as the maximum desired return period interval (for example, at least 33 years of wave data would be required to safely predict the commensurate 100-yr wave). During this procedure wave events are sorted by size, and subsequently the frequency of occurrence can then be assessed by how often events of a particular size range occur in the record. The plotted relationship between wave height and return period is logarithmic, and typically a best fit can be established with a linear regression of the data. In practice, not all wave events will plot perfectly along the fit line, however its curve represents the best fitted trend, or general nature of the wave height to frequency relationship of events for a specific location (i.e., the buoy location and adjacent vicinity). In this study, a separate extreme value wave height analysis was performed for waves from each previously identified independent swell source (excluding hurricanes) using the Weibull distribution. It is noted that due to the erratic nature of hurricane tracks and intensities, along with the sporadic availability of data from such storms, classic return period analysis tools are ineffective in predicting frequency of occurrence wave heights. In its place, the analysis relies on a real scenario hurricane that directly impacted the site in 2020, hurricane Douglas.

3.3.1 Northwest Pacific Swell

For extreme deep-water waves associated with north pacific swell, wave buoy data was compiled from two sources, the first being the Coastal Data Information Program (CDIP) buoy station 106 located offshore from Waimea Bay approximately 18 miles to the west-northwest of the project site. This buoy was chosen for its exposure to Northwest Pacific swell and its long record of continuous wave data, which makes it reliable for return period analysis. Wave data for this buoy spans over a 21-year period from December 2001 to April 2022. Extreme wave heights were investigated by filtering the buoy data by direction and period for waves approaching from the northwest sector, with periods of 12 seconds or greater. The resulting relationship of wave height to expected return period based on the Weibull

** Extreme value distributions such as Weibull's are limiting distributions for minima or maxima of a very large collection of random observations from the same arbitrary distribution. Because of its flexible shape and ability to model a wide range of random quantities, the Weibull in particular, has been used successfully in many applications (*Engineering Statistics Handbook, 2020*).

distribution is shown on Table 3-1 and Figure 3-3. The ten largest wave events associated with North Pacific swell during the period of record are shown in Table 3-2.

Table 3-1. Return period wave heights, Waimea Buoy

Return Period	Hs (ft)	Hs (m)
1 Year	17.7	5.38
2 Year	20.0	6.09
5 Year	23.1	7.03
10 Year	25.4	7.74
25 Year	28.5	8.68
50 Year	30.8	9.39
100 Year	33.1	10.10

Table 3-2. Top 10 NW swell events observed at Waimea Buoy

Date - Time	H_s (ft)	T_p (s)	D_p (deg.)
2019-02-11 01:15:45	26.5	15	334
2016-02-22 18:37:45	26.5	17	334
2003-01-05 11:07:16	22.4	18	319
2014-01-23 04:25:45	21.9	18	307
2007-12-04 03:11:16	20.9	15	339
2016-01-16 09:37:45	20.7	17	324
2004-01-10 19:29:07	20.7	18	318
2009-12-08 06:54:48	20.1	18	325
2002-01-07 10:06:57	20.0	18	315
2008-01-13 17:10:57	19.9	18	315

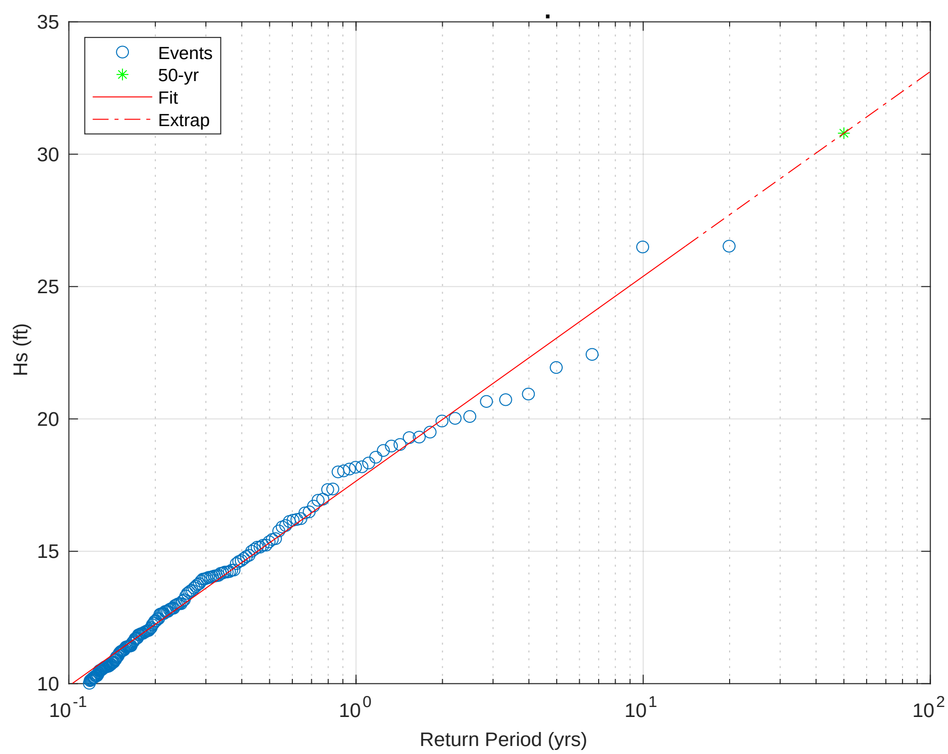

Figure 3-3. Significant wave height vs return period, Waimea Bay (December 2001 to September 2021) – Filtered for swell only

An alternative source of existing wave data for northwest swells comes from the National Data Buoy Center (NDBC), which has deployed and maintains an array of buoys separate from CDIP. The NDBC buoys are generally much further offshore than the CDIP buoys and have the potential to provide an improved picture of the raw incoming swell before interacting with any of the islands, outlying seamounts, or surrounding shoals due to their more distant offshore locations. From the NDBC array, buoy 51001 was selected to best represent the raw incoming wave field representative of the dominant northwest swell wave energy Hawaii receives in the winter. The location of buoy 51001 is approximately 188 nautical miles NW of the island of Kauai, as shown in Figure 3-4. Existing wave data for this location spans more than four decades, from 1981 to the present (2022). Again using the Weibull distribution method, analyzed return period extreme wave heights for this location were found as plotted in Figure 3-5 and summarized in Table 3-3. The ten largest wave events associated with North Pacific swell episodes are listed in Table 3-4. The largest observed wave height on record at this location was 40.3 ft (12.3 m), measured in early November 1988.

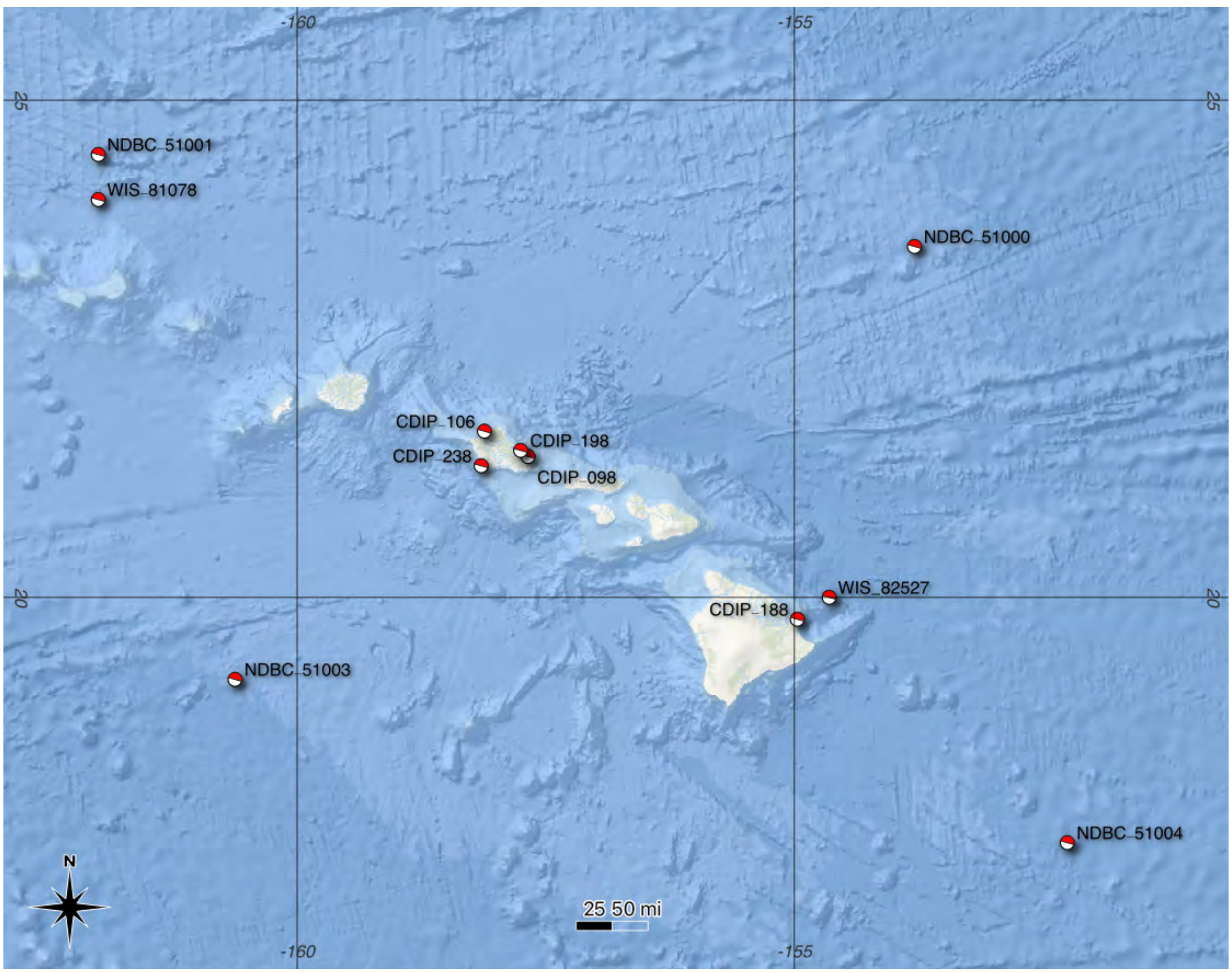

Figure 3-4. Relative locations of select NDBC and CDIP buoys around the Hawaiian Islands

Table 3-3. Return period wave heights, NDBC buoy 51001

Return Period	Hs (ft)	Hs (m)
1 Year	23.5	7.16
2 Year	26.1	7.95
5 Year	29.5	8.99
10 Year	32.1	9.79
25 Year	35.5	10.83
50 Year	38.1	11.62
100 Year	40.7	12.41

Table 3-4. Top 10 NW swell events at NDBC buoy 51001

Date - Time	H_s (ft)	T_p (s)	D_p (deg.)
1988-11-05 04:00:00	40.3	14	--
2019-02-10 16:40:00	35.3	16	355
1985-01-14 20:00:00	33.1	17	--
1986-02-23 08:00:00	31.2	20	--
2003-01-05 08:00:00	30.5	17	--
2016-02-22 07:40:00	30.4	16	328
1998-12-31 23:00:00	30.1	20	--
2000-10-14 09:00:00	29.9	25	--
2007-12-06 01:00:00	28.7	15	357
1989-01-29 03:00:00	27.6	20	--

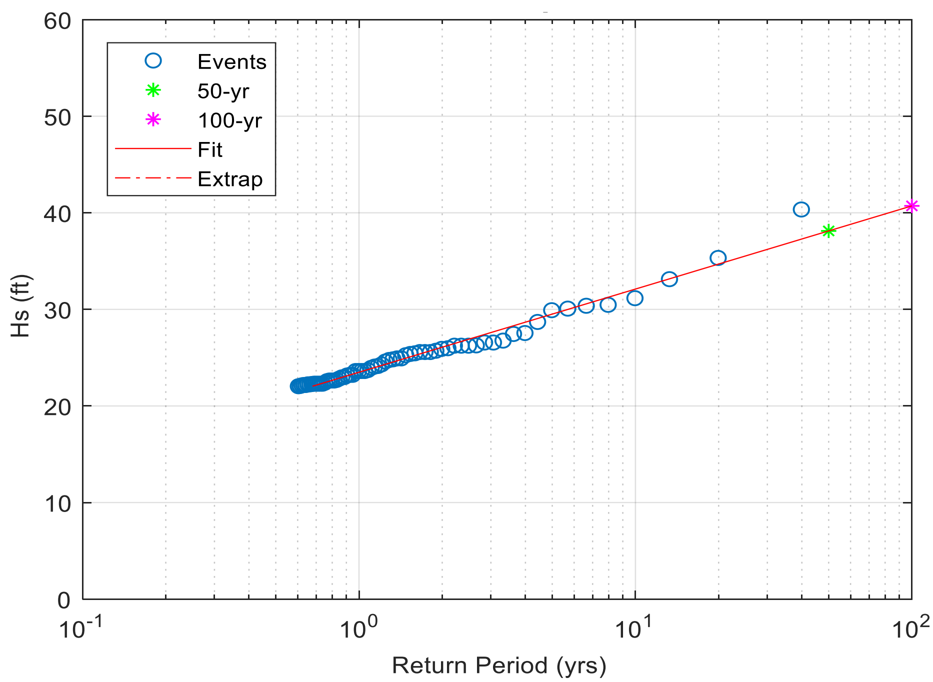

Figure 3-5. Significant wave height vs. return period, NDBC 51001 (February 1981 to April 2020) – Filtered for swell only

3.3.2 Northeast Tradewind Swell

For extreme wave events associated with the persistent Tradewinds blowing from the northeast to southeast sector of the Central Pacific, the Mokapu buoy from the CDIP network (098) was used for analysis as it was deemed to best represent the eastern exposure characteristic of the project area. The Mokapu buoy is located approximately 15 miles southeast of the project area, or 4 miles east-northeast of Kailua, and located in a depth of approximately 285 feet. Refer to Figure 3-4 for buoy locations.

Wave data at this location spans approximately 22 years, from 2000 to the present. This dataset was pre-filtered for wave directions between northeast and southeast, and for wave periods between 4 to 12 seconds in order to isolate wave sources from this directional sector (i.e., filter out long period swell from the north and south). Following data partitioning and analysis, a Weibull distribution was then generated with the dataset. The corresponding return period extreme wave heights are summarized in Table 3-5. The ten largest wave events associated with Tradewind swells at Mokapu are listed in Table 3-6. The largest observed wave on record at this location was 14.1 ft (4.3 m), measured in late January 2017. The associated plot of significant wave height versus return period is presented in Figure 3-6.

Table 3-5. Return period wave heights, Mokapu

Return Period	Hs (ft)	Hs (m)
1 Year	11.9	3.63
2 Year	12.6	3.83
5 Year	13.5	4.10
10 Year	14.1	4.30
25 Year	15.0	4.57
50 Year	15.7	4.78
100 Year	16.3	4.98

Table 3-6. Top 10 NW swell events observed at Mokapu

Date - Time	H_s (ft)	T_p (s)	D_p (deg.)
2017-01-22 08:35:07	14.1	9	36
2002-01-19 07:45:23	13.7	9	66
2003-11-19 20:09:55	13.5	9	38
2018-09-12 22:35:07	13.3	9	81
2001-12-13 14:45:40	13.3	10	73
2013-01-05 16:42:07	13.2	9	69
2000-08-21 01:40:46	13.2	9	61
2018-01-19 07:35:07	12.9	9	60
2001-02-15 11:10:50	12.8	9	69
2018-08-25 00:35:07	12.8	8	71

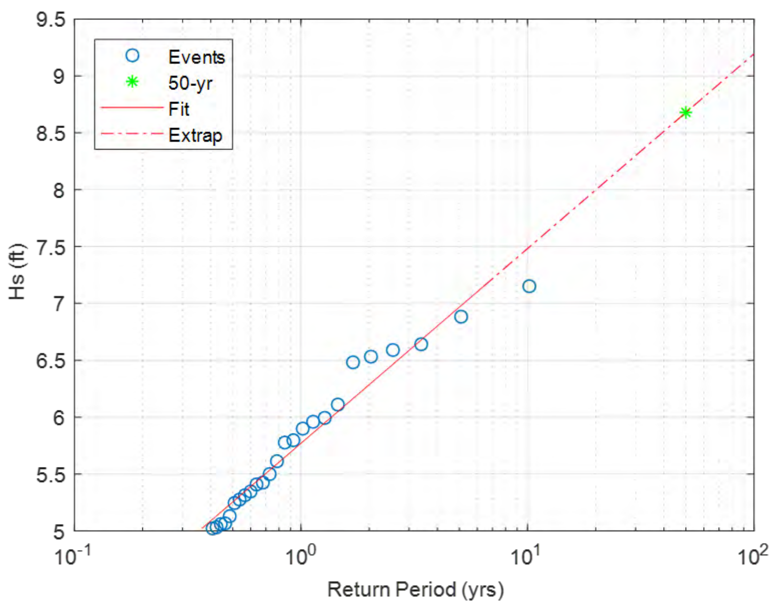

Figure 3-6. Significant wave height vs return period, Mokapu (Aug. 2000 to Apr. 2021) – Filtered for Tradewind swell only

3.3.3 Hurricane Waves

The Hawaiian Islands are exposed on a yearly basis to severe tropical cyclonic storms (hurricanes) and the waves generated by them. Hurricanes are the most severe category of tropical cyclones and are generally formed by intense low-pressure vortices that break off from atmospheric waves in the inter-tropical convergence zone (ITCZ). Tropical storms and hurricanes in the east Pacific are typically, but not exclusively, spawned in the eastern tropical Pacific Ocean, near the coasts of Mexico and Central America, and track westward towards the Central Pacific. Along with damaging winds and torrential rainfall, hurricanes bring the threat of short-term superelevated sea levels, commonly referred to as *storm surge*.

Storm surge is a localized, short-term superelevation of sea levels comprised collectively of three additive components: *wave setup*, *wind setup*, and *pressure setup*. Wave setup is a superelevation of water levels landward (mauka) of the surf zone above the normal still water tide level, which is a result of intensified mass transport of water shoreward, driven by the flow of breaking waves, which then becomes temporarily trapped against the shoreline boundary. Wind setup is a similar increase in local water levels, due specifically to wind shear stress acting on the sea surface which will only occur when the storm's winds are blowing onshore (shoreward). Typically, wind setup components are negligible in Hawaii because the physics of the phenomenon require an extremely long coastline and shallow continental shelf to trap and hold the water against the shoreline. Lastly, pressure setup is temporary increase in local water levels due to the significant drop of atmospheric pressure within the core of the storm. Pressure setup is a function of the central pressure of the storm, and the observation location's distance from the center of the storm.

While it is not uncommon for hurricanes to pass near Hawaii, historically it has been evident that they often change course or devolve in strength by the time they approach coastal Hawaiian waters. Figure 3-7 illustrates the combined set of historical tracks for all named tropical storms and hurricanes recorded in the Central Pacific within 250 miles of Hawaii, from 1949 to 2021.

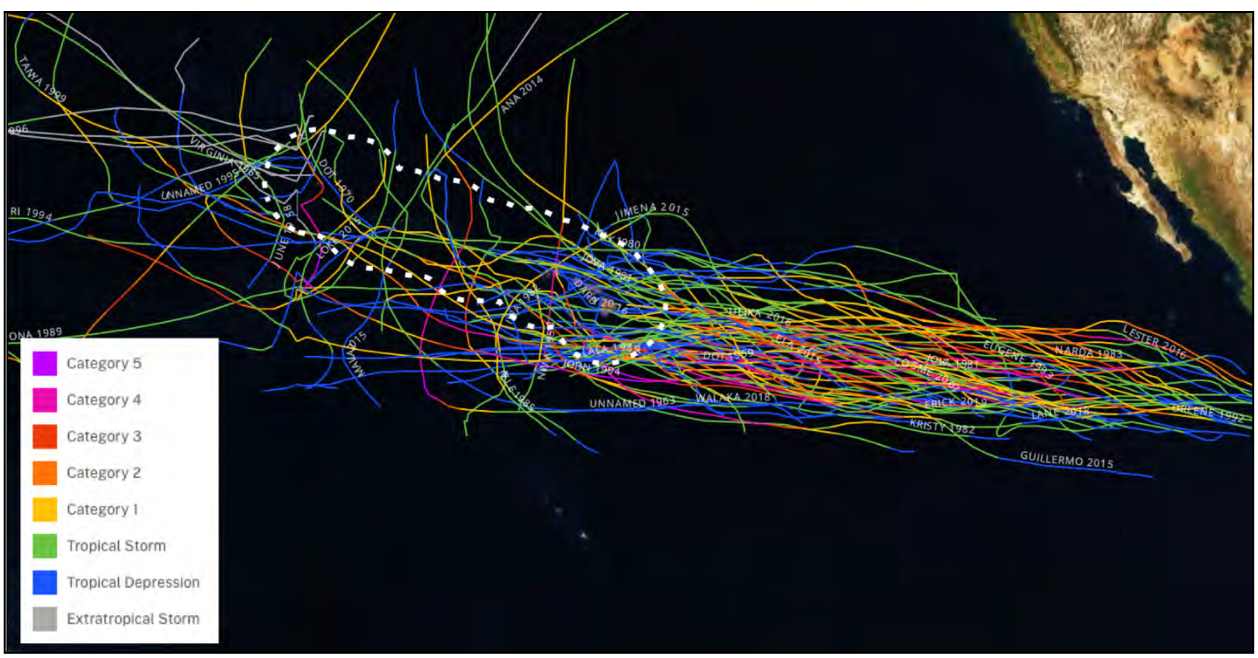

Figure 3-7. Central Pacific historical hurricane tracks, passing within a 250-mile radius from Hawaii (1949 to 2021).

(*Source: https://coast.noaa.gov/hurricanes/*)

While direct strikes or landfall on any of the major populated islands are rare, close-approach hurricane tracks to waters north or south of the Hawaiian Islands are not infrequent, and can still generate large, damaging surf, which can have significant impacts along shorelines throughout Hawaii. Historic hurricane data filtered for only the tracks of close-approach hurricanes (winds > 73 mi/hr or 118 km/hr), passing within 50 miles of Hawaii between 1948 to 2021, reveals the resulting tracks which are illustrated in Figure 3-8. Filtering the data once more for only tropical storms and tropical depressions (winds > 39 mi/hr or 63 km/hr, excluding hurricanes) that have passed near Hawaii results in the tracks shown in Figure 3-9.

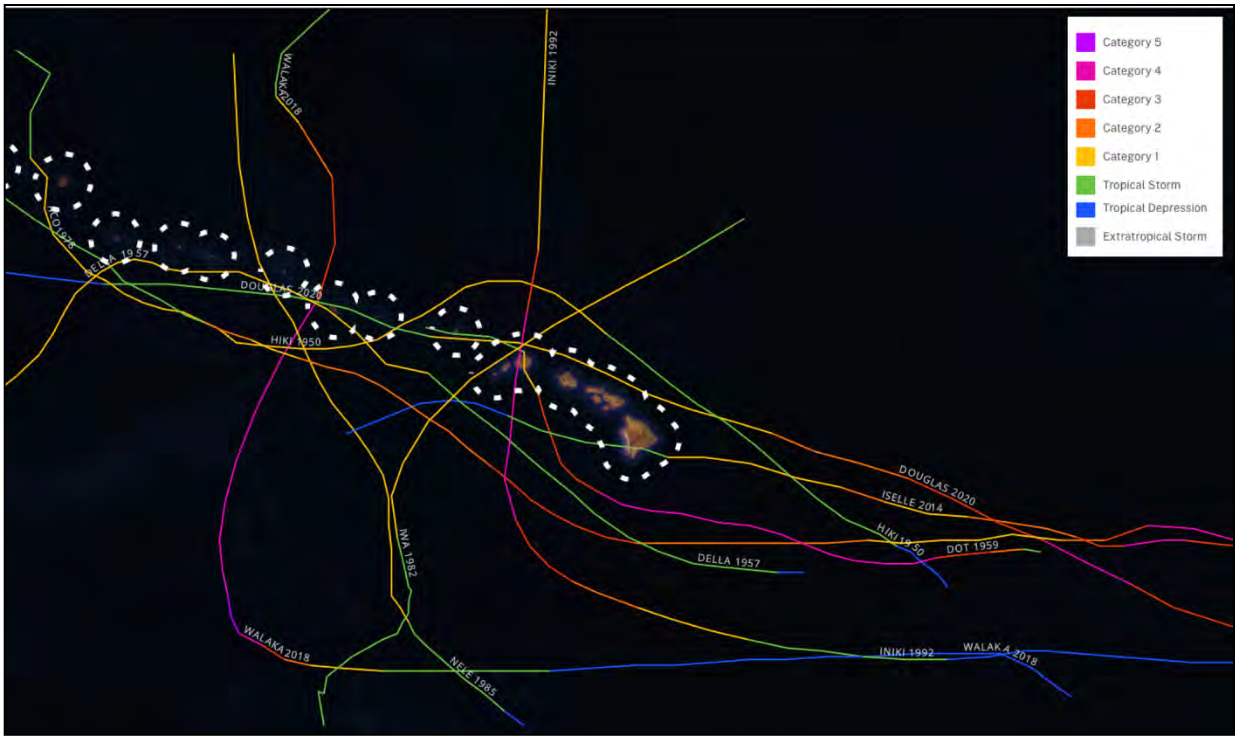

Figure 3-8. Close approach (50-miles) hurricane tracks, 1949 to 2021. (*Source: https://coast.noaa.gov/hurricanes/*)

Because the formation and subsequent trajectory of cyclones (and by extension also the wave fields generated by them) are characteristically erratic and largely unpredictable in movement and strength, conventional statistical distribution models like the Weibull distribution do not effectively or realistically predict the probability of extreme wave heights due to such sources. The scientific study of cyclone probability and prediction is a nascent field and is quite complex and considered beyond the scope of this document. However, it has been noted that within the last 25 years, the most significant or impactful cyclone swell to affect the project shoreline was hurricane *Douglas* in the summer of 2020, which battered the northeast coastline of Oahu with extremely large surf while it transited to the northwest, remaining just offshore as it did so. Therefore, in lieu of a complex probabilistic approach to predicting recurrence interval hurricanes within this basis for design study, a simplified but reasonable assumption was made based on the observation that this, being the largest hurricane swell to impact the collective project sites within the last 25 years, this actual scenario would be assumed as the 25-yr condition for this wave source.

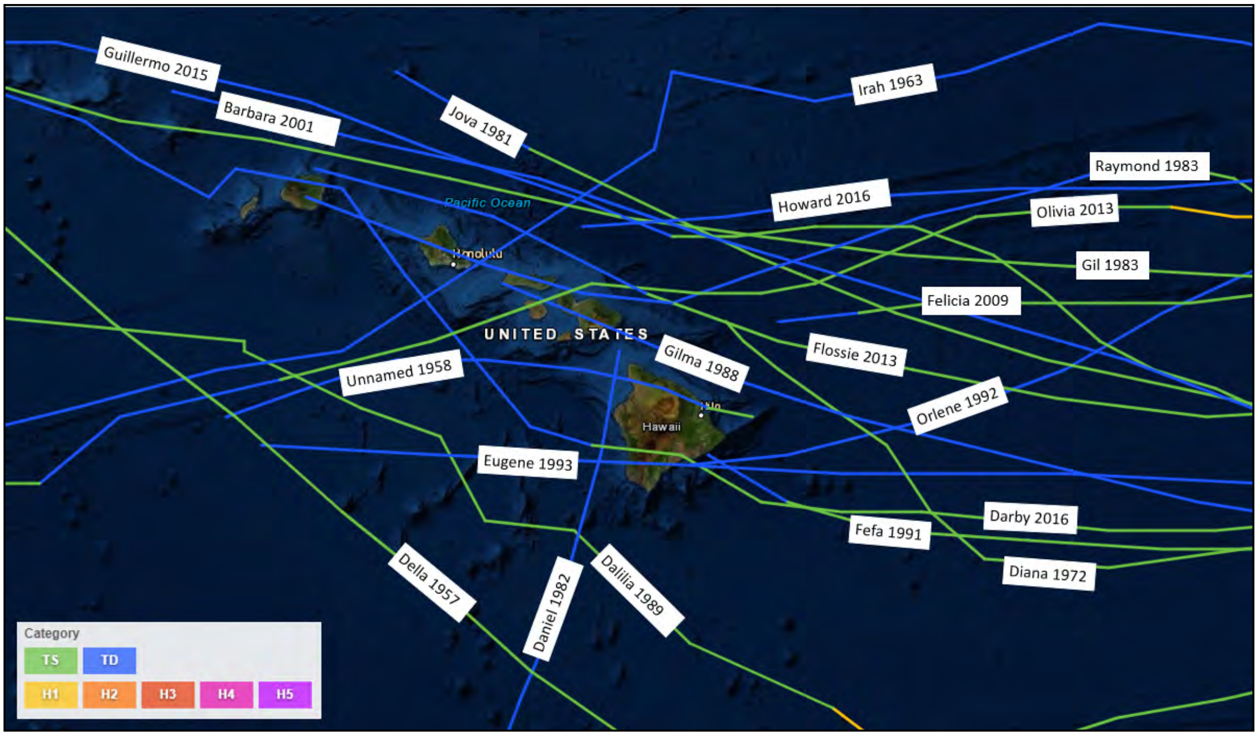

Figure 3-9. Close approach tropical storm and tropical depression tracks (1949 to 2018). (*Source: https://coast.noaa.gov/hurricanes/*)

Together, the wave sources and extreme wave heights presented in Sections 3.3.1 through 3.3.3 above, form the starting point for the numerical deep-water wave modeling process. A final tabulation of extreme wave heights and scenarios that will subsequently be used in the deep-water wave transformation modeling are summarized in Table 3-7. Considering the North Pacific NW swell exposure window, the rationale for providing two sources was to ensure that the most conservative case was identified for use in the modeling. NDBC-51001 is further afield and has a longer measurement record, while CDIP-106 is much closer and with better directional resolution, but in intermediate water depth and with a shorter record. Considering both NW buoys provides additional insights for this critical component.

Table 3-7. Summary of the deep-water maximum wave conditions selected for use in wave modeling

Case	Buoy	Description	H_s		Period	Direction
			ft	*m*	*s*	*deg-N*
1	(CDIP-098)	25-yr Tradewind Swell	15.0	4.6	9.0	62
2	(CDIP-106)	25-yr NW Swell	30.6	9.3	17.0	323
3	(NDBC-51001)	25-yr NW Swell	35.5	10.8	18.0	347
4	(CDIP-098)	Hurricane Douglas	12.5	3.8	14	45

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4. OCEANOGRAPHIC ANALYSIS METHODOLOGY

As discussed in the introduction, the primary purpose of this *basis-for-design* (BOD) document is to assemble and memorialize the development of site-specific oceanographic design conditions from which to base the engineering and design of potential shore protection structures, following the general workflow shown in Figure 4-1. These design criteria were generally based upon seasonal extreme wave events representative of the project vicinity. In initiating this analysis, a set of deep-water source wave conditions was first developed, utilizing decades of historic wave data collected by an array of existing oceanographic and meteorologic buoys stationed far offshore of the site's location and shoreline exposures. In consultation with the State of Hawaii Department of Transportation (HDOT), a mid-level design life of 25 years was assumed for all analyses and calculations.

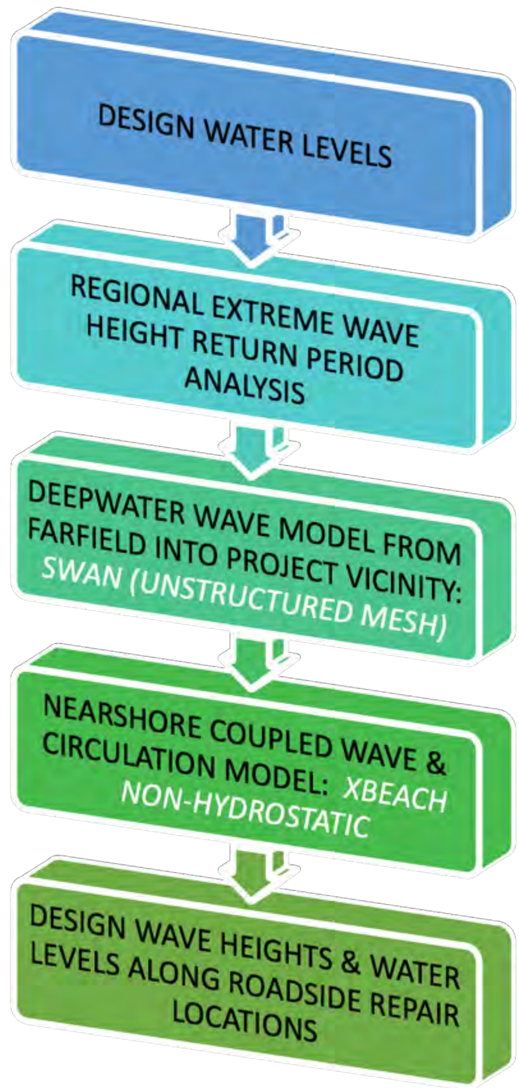

Figure 4-1. Project analysis workflow

The process began with a statistical analysis of expected peak wave conditions (parameters such as significant wave height, peak period, and peak direction) as measured from the principle wave sources known to affect the windward and north-facing shores of the Hawaiian Islands, including: large northwest (NW) swells from winter-time North Pacific storms that generally form near the Aleutian Islands far to the northwest of Hawaii; large northeast (NE) swells from intense extra-tropical storms that track closer from the north and east of the Islands; large easterly (E) wind-swells from prolonged and intensified Tradewind episodes; and, hurricane swells from direct approach tropical cyclones. The peak parametric wave conditions characteristic of each of these primary sources were calculated from multiple decades of historic wave data, acquired from far-field as well as coastal wave observation buoys. The buoy deployment locations were situated closer to the swell generation sources, and unaffected by island shadowing or other shallow water interference. These deep-water wave conditions were then used to initialize a series of deep-water phase-averaged wave models for each unique source.

Each deep-water wave model required its own custom-tailored computational grid that covered the area from buoy observations to the project site; and the further the source buoy location, the larger the model domain needed to be in order to complete the analysis. The computational grid in the case of the large-scale deep-water models was an unstructured finite-element mesh, with mesh element sizes ranging from kilometers in the deepest open ocean locations, down to tens of meters in nearshore shallow waters. Areas of interest, such as the island of Oahu and the project vicinity, were further resolved by defining a sequential series of nested areas of refinement within user-specified coordinates. Mesh elements within these regions were refined to much smaller element sizes compared with the surrounding base mesh, allowing model computation to focus on areas of interest to the project without wasting computation time on unimportant areas outside. The process essentially replaces the *nesting* procedure required by bulky cartesian model grids.

These finite-element computational meshes were essential for accurately transforming incipient peak wave conditions from their respective points of origin, into and over the complex bathymetry surrounding the Hawaiian Islands. The large-scale *phase-averaged*[††] numerical modeling process accounted for the effects of island shadowing and the complex pattern of wave refraction that occurs over the highly varied bathymetry, resulting in numerical output that reveals the expected wave-height (expressed as significant wave height) field at locations of interest from deep to transitional depths just offshore of the project vicinity.

Following the transformation modeling of deep-water wave conditions from source to the vicinity of coastal waters in the offshore region of the project location, a series of higher resolution *phase-resolving* wave models were then developed to bring the waves into the shoreline. The higher resolution *Boussinesq*-type wave models accurately simulate the complex transformations occurring in transitional depths as energy loss from wave breaking becomes an important factor, yielding important insights into refractions patterns and wave-generated currents as the waves propagate from nearby offshore waters into the complex nearshore project bathymetry. The high-resolution nearshore wave models were nested (one-way coupling) into the large-scale phase-averaged wave models via 2D wave spectra recorded at multiple pre-established monitoring locations, and subsequently utilizing that spectral data to drive the offshore wave generation boundary conditions for the nearshore wave models. This coupled process allows for a detailed and accurate understanding of the resulting high-frequency wave field and low-frequency infragravity waves (surge) at points of interest along the project shoreline. Nearshore model results provided data such as time-varying water surface elevations (WSE), depth averaged currents, wave energy spectra, surge, and wave setup elevations.

Design wave parameters and other related criteria for use in developing conceptual shore protection alternatives were obtained from subsequent processes derived from the various modeling results.

[††] *A phase-resolving wave model is one which additionally calculates the water surface elevation as a function of time—resolving the visual wave form from trough to crest, as opposed to a phase-averaged model which reports only the maximum wave height parameters and is non-temporal in its solution (no crest patterns).*

5. DESIGN CONDITIONS MODELING

The design of shore protection or other coastal structures requires thoughtful determination of maximum water levels and wave heights at the project site. Wave behavior is complex, with deep-water wave conditions determined by growth and decay factors acting in the wave-generating regions such as far-away North Pacific winter storms near the Aleutian Islands, or conversely in nearby waters by passing hurricanes. As the waves approach land, the transformative shallow water behavior becomes dramatically influenced by approach direction and bathymetry.

A *deep-water* wave is defined in oceanographic terms as a wave which is propagating in water depths greater than one-half its *wavelength*, where wavelength is the distance measured from crest to crest of the same wave in the direction of propagation. As deep-water waves propagate toward a shoreline, they will at some point begin to encounter and be transformed by the seafloor topography or *bathymetry* as depth decreases, at which point they are known as *transitional waves*. As waves propagate over uneven bathymetry or around obstacles, they are *refracted* and *diffracted* into new orientations and heights. The phenomenon of wave refraction is caused by differential wave speed along a wave crest as the wave passes over varying bottom contours and can cause wave crests to converge or diverge and may locally increase or decrease wave heights. Not strictly a shallow water phenomenon, wave diffraction is the lateral transmission of wave energy along the wave crest and would cause the spreading of waves in a shadow zone, such as occurs behind a breakwater or other barrier.

Once in *shallow water*, oceanographically defined as a depth less than 1/20th a particular wave's wavelength, a shallow-water wave's *celerity* (speed) becomes a direct function of water depth. As wave speed slows down with decreasing depth, the process of wave shoaling steepens the face of the wave while at the same time increasing wave height. Wave *breaking* occurs when the wave's forward slope (face) becomes too steep to remain stable, with the peak then collapsing into the wave's trough as a *breaker*. This has generally been observed to occur when the ratio of wave height to water depth is approximately 0.78. The process of wave breaking is by far the primary mechanism for dissipation of wave energy, however, some lesser factors such as bottom friction and strong currents can also contribute to energy loss in waves.

Two leading numerical wave models, known as *SWAN* and *XBeach,* were utilized during this study to predict and simulate the complex wave conditions from far-field deep-water generation regions, and transforming them accurately into the project site.

SWAN

Simulating Waves Nearshore (SWAN) is a third-generation wave model developed by Delft University of Technology (Delft, Netherlands) that computes random, short-crested wind-generated waves in coastal regions and inland waters (*Booij, et al, 1999*). The SWAN model can be employed as a steady state or non-steady state (transient) model and is fully spectral over the total range of wave frequencies. Wave propagation computations are based on linear wave theory and include the effects of wave generated currents.

SWAN provides many output quantities, including two-dimensional spectra at points of interest, and field calculations for significant wave height, peak and average period, peak and mean wave direction and directional spreading. For this project, the SWAN model was used to transform far-field source wave conditions from deep water and bring them into intermediate water depths just offshore from the project shoreline. A series of spectral reporting stations were included in the SWAN models, spaced approximately every 200 meters following along the 30 m depth contour, providing an indirectly coupled 'nesting' capability for the subsequent nearshore XBeach models (discussed in the next section).

XBeach

As waves move into shallow water, bathymetry has a greater influence on wave behavior. As depth decreases, the velocity field beneath a wave interacts with the bottom, dissipating increasingly more energy through depth-induced breaking and bottom friction. In this region extending from transitional depth to shallow water, where a significant fraction of wave energy is lost due to wave breaking, the equations utilized in SWAN are of limited use. To effectively continue simulations into the shallower waters of the project site, the XBeach model was employed to make use of its capability for accurately handling wave energy loss from breaking.

As discussed in the previous section, two-dimensional spectral results from the SWAN model's deep-water wave conditions were loosely coupled to the higher-resolution nearshore model region developed using the XBeach non-hydrostatic (XBeach-NH) wave model. XBeach is an open-source numerical wave model originally developed to simulate hydrodynamic and morphological (seabed change) processes along mostly sandy shorelines. The XBeach-NH module (*Stelling and Zijlema, 2003*) computes the depth-averaged flow due to waves and currents using non-linear shallow water equations and includes a non-hydrostatic pressure term. The governing equations are valid from intermediate to shallow water and can simulate most of the phenomena of interest within the nearshore zone and in harbor basins, including shoaling and refraction over variable bathymetry, reflection and diffraction near structures, energy dissipation due to wave breaking and bottom friction, wave setup/setdown, breaking-induced longshore/cross-shore currents (colloquially known as *rip currents*), and stationary waves or harbor oscillations. XBeach-NH is a phase resolving model, meaning that wave crests and troughs are simulated as a continuous water surface elevation record, and propagated in time and space—resulting in an accurate or 'visually realistic' representation of wave heights and wave patterns across the model domain.

5.1 Static Water Levels

Normal water level fluctuations along Hawaii's ocean shorelines vary hour-by-hour and location to location, and are largely driven by *astronomical tides* (i.e., gravitational pull primarily of the sun and moon, along with that of Jupiter and the other planets in our solar system). The tides are a familiar aspect of coastal life that the general public is typically aware of, and where it is understood that the monthly cycles of high and low tides are principally tied to the phases of the moon, and most importantly are predictable.

5.1.1 Astronomical Tides

Tides in the Central Pacific are considered *semi-diurnal* with pronounced diurnal inequalities (i.e., two high and low tides each 24-hour period with different tidal heights). Variation of the tidal range results from the relative position of the moon, sun, and the planets. During full moon and new moon phases, the gravitational pull of the sun and moon combines as the align, acting together to produce the larger *spring* tides. When the moon is at a maximum dis-alignment from the sun with respect to the earth, the moon is in its first or last quarter, and is when the smaller *neap* tides occur. The cycle of spring to neap tides and back is half the 27-day period of the moon's orbit around the earth and is sometimes called the *fortnightly cycle*. The combination of diurnal, semi-diurnal and fortnightly cycles dominate the tidal variations in sea level throughout the Hawaiian Islands. Current values for commonly used tidal reference levels, observed at the NOAA tide station on Moku O Loe (Coconut Island) within Kaneohe Bay, are presented in Table 5-1. A conceptual illustration of the primary tidal water levels and datums, including mean sea level (MSL), mean lower low water (MLLW), and mean higher high water (MHHW), as measured at the Kaneohe Moku O Loe tide station, is presented in Figure 5-2.

5.1.2 Sea Level Rise

Separate from ordinary tidal sea level variations, scientists and researchers have brought increasing attention to an emerging 'across-the-board' rise in sea levels that is gradually gaining momentum. And although there is general consensus within the scientific community on the fact that this is happening, there remains significant uncertainty as to the rate at which it is happening.

In terms of defining design water levels for coastal engineering projects, the additional water level component due to this phenomenon is known as sea level rise (SLR). Historic sea level trends are a good first look to discern what current trends are—the Moku O Loe tide station in Kaneohe Bay has a record only spanning from the 1950's to the present, but the Honolulu tide station has a record almost twice as long, starting just after the turn of the century in 1905. The historical sea level trend for Honolulu Harbor, NOAA Tide Station 1612340, is shown in Figure 5-1 (NOAA, 2017). The present rate of global mean sea level rise has been recently calculated at +3.4 ± 0.4 mm/year (Sweet, 2017), where a positive value represents rising levels and negative value lowering levels. The average historical rate of sea level change (RSLC) is +1.55 ± 0.21 mm/yr based on monthly data for the period 1905 to 2022. Importantly, SLR appears to be accelerating when compared to the mean rate of rise for the 20th Century, as shown in Figure 5-1. Sea levels, however, are still highly variable as shown in the plot.

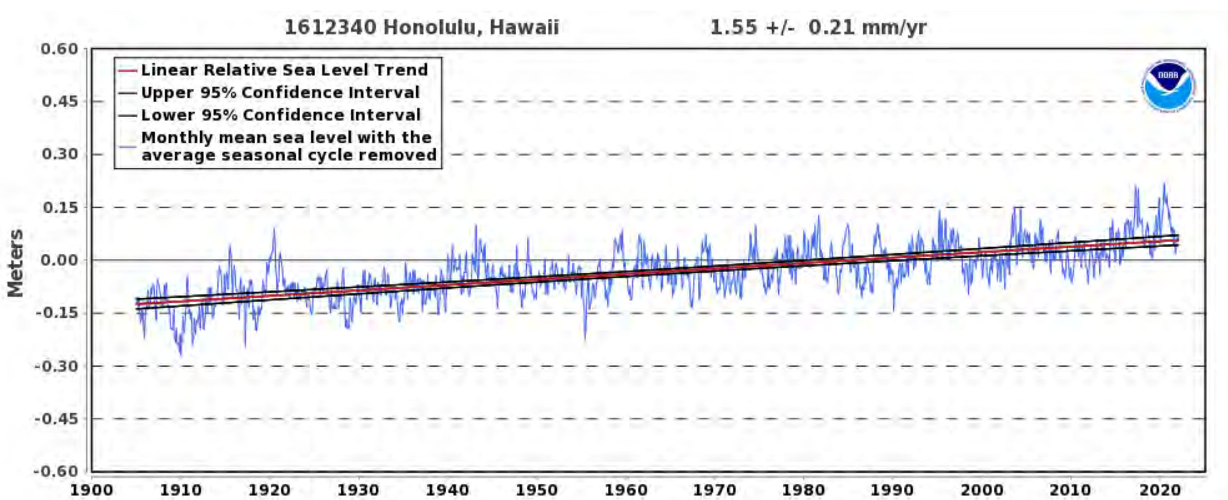

Figure 5-1. Mean sea level trend, Honolulu Harbor, Station 1612340, 1905 to present (NOAA, 2017)

SLR as a quantity is a result of several components including melting of land ice (polar ice caps, glaciers, etc.) and thermal expansion of the ocean — all of which are additive, and tied to global warming, which in turn is a result of global greenhouse gas emissions. Accurate prediction of SLR into the future is therefore linked to accurate prediction of future greenhouse gas emissions, the latter of which being extremely difficult to accurately forecast due to the complexities of global economies and geopolitics. However, regardless of difficulty it becomes essential that some form of future SLR predictions be available when planning for or designing coastal structures, and particularly true for those structures intended to last for many decades. Design life for large civil projects can often be somewhere between 50 to 100 years.

Future projections based on historic data are always more reliable the closer they are to the present day, and this is because uncertainty always increases with time or distance into the future. The 25-year design life assumed for this project lies on the shorter end of that spectrum and subsequently should be a slightly more reliable figure when compared with the 50-yr and certainly 100-yr estimates that are sometimes required. The 25-year estimated sea level rise prediction presented in Table 5-1 is based on an interpolated value from the NOAA 2017 online SLR model shown in Figure 5-3, using their 'intermediate-high' scenario curve for a level of conservativity in light of the road being considered critical infrastructure.

Table 5-1. Reference Water Levels (*Based on NOAA Tide Station 1612480, Kaneohe Bay*)

WL Name	Abbrev.	Vert Datum	Value (ft)	Value (m)
Mean Lower Low Water	MLLW	LMSL	-1.05	- 0.32
Local Mean Sea Level	LMSL	LMSL	0.00	0.00
Mean Higher High Water	MHHW	LMSL	1.07	0.33
Sea Level Rise - 25 year (Year 2047)*	SLR-25	LMSL	1.67	0.51

**NOTE: Interpolation Based on 'intermediate-high' scenario curve.*
Source: {http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html}

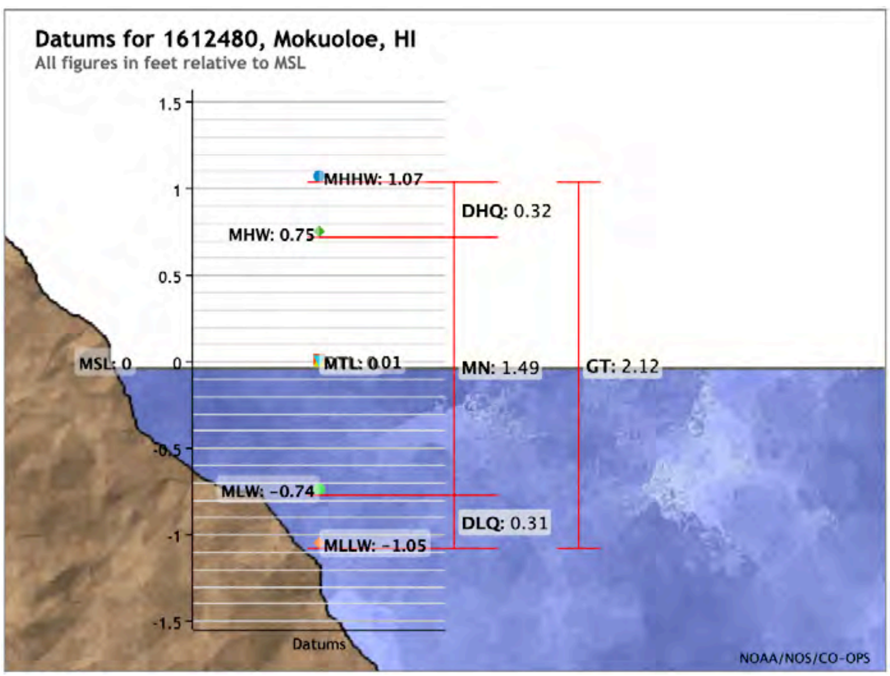

Figure 5-2. Graphic representation of tidal datums at NOAA tide station, Honolulu Harbor (NOAA, 2020)

NOAA has recently revised their sea level change projections through 2100 considering more up-to-date scientific research, observations, and measurements. NOAA is currently projecting that global sea level rise as shown by their "Extreme" scenario could be as high as about 8 feet by 2100. NOAA's recent report also identifies specific regions that are susceptible to a higher-than-average rise in sea level. Hawaii has thus far experienced a rate of sea level rise that is less than the global average; however, this is expected to change. Hawaii is in the "far field" of the effects of melting land ice. This means that those effects have been significantly less in Hawaii compared to areas closer to the ice melt. Over the next few decades, this effect is predicted to spread to Hawaii, which will then experience sea level rise greater than the global average.

Figure 5-3 presents mean sea level rise scenarios for Hawaii based on the revised NOAA projections, taking into account those far-field effects. While the projections are based on the most current scientific models and measurements, discretion is necessary in selecting the appropriate scenario. Selecting the appropriate sea level rise projection is a function of many parameters, including topography, coastal setting, criticality of infrastructure, potential for resilience, budget, and function.

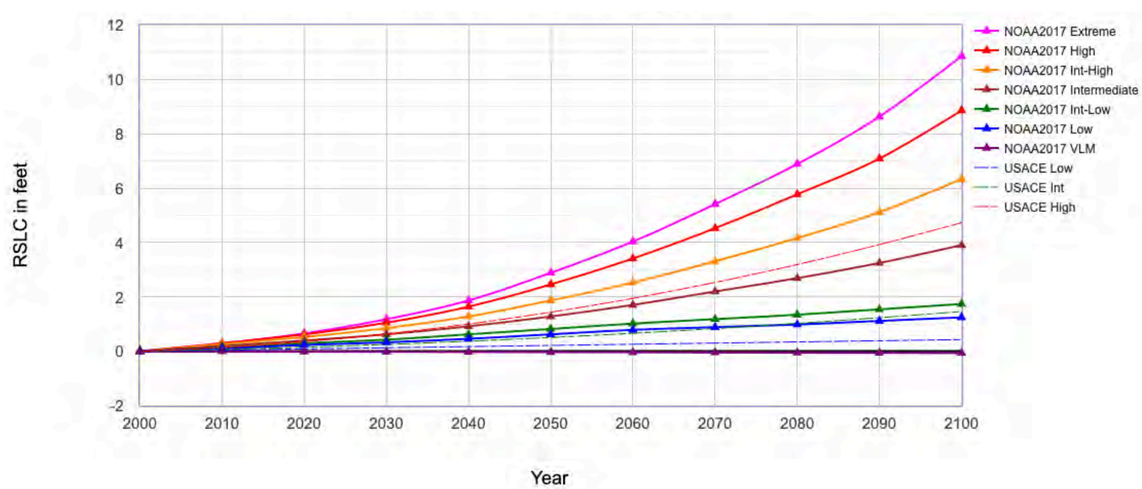

Figure 5-3. Hawaii sea level rise projections (Moku O Loe Island, NOAA, 2017)

Table 5-2. Hawaii Local Mean Sea Level rise scenarios (feet)

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	**NOAA2017 Int-High**	NOAA2017 High	NOAA2017 Extreme
2010	-0.01	0.1	0.13	0.2	0.26	0.3	0.3
2020	-0.01	0.23	0.3	0.39	0.52	0.62	0.66
2030	-0.02	0.33	0.43	0.62	0.85	1.05	1.18
2040	-0.03	0.46	0.62	0.92	1.28	1.64	1.87
2050	-0.03	0.62	0.82	1.28	1.87	2.46	2.89
2060	-0.04	0.79	1.02	1.71	2.53	3.41	4.04
2070	-0.05	0.89	1.18	2.2	3.31	4.53	5.41
2080	-0.05	0.98	1.35	2.69	4.17	5.77	6.89
2090	-0.06	1.12	1.54	3.25	5.12	7.09	8.63
2100	-0.07	1.25	1.74	3.9	6.33	8.86	10.86

5.1.3 Sea Level Anomaly – Mesoscale Eddies

Around the Hawaiian Islands, the presence of large-scale sea surface signatures known as *sea level anomalies* (SLA) has recently been identified and investigated by the scientific and oceanographic community. SLAs are defined by oceanographic researchers as the difference between the measured and predicted tides recorded at a known location, such as NOAA's Honolulu Harbor tide station, and are thought to be primarily due to an oceanographic phenomenon known as *mesoscale eddies*. As the name suggests, these large (order of 100 km diameter) and slowly rotating masses of superelevated water that propagate around the boundaries of the Hawaiian Islands are thought to be the result of such processes as the *El Niño* weather pattern, global warming, and *geostrophic* currents due to the rotation of the earth, which together generate the mesoscale eddies that propagate across the ocean. Hawaii is subject to periodic extreme tide levels that are exacerbated by these mesoscale eddies that have only recently been recognized. Mesoscale eddies or SLAs may boost normal tide levels to ones that can be up to 0.5 – 0.75 feet higher than predicted for periods up to several weeks (Firing and Merrifield, 2004).

The end of 2019 marked an extended period of a large SLA event. Figure 5-4 is a plot of measured tide (green curve) and predicted tide (blue curve) and is illustrative of the extreme water levels from December 24 through 26, 2019. During this period, a sea level anomaly of approximately 0.7 to 1.1 feet was superimposed on the already quite high winter king tides, resulting in the highest recorded water level at Honolulu Harbor to date at an impressive 3.4 ft MLLW.

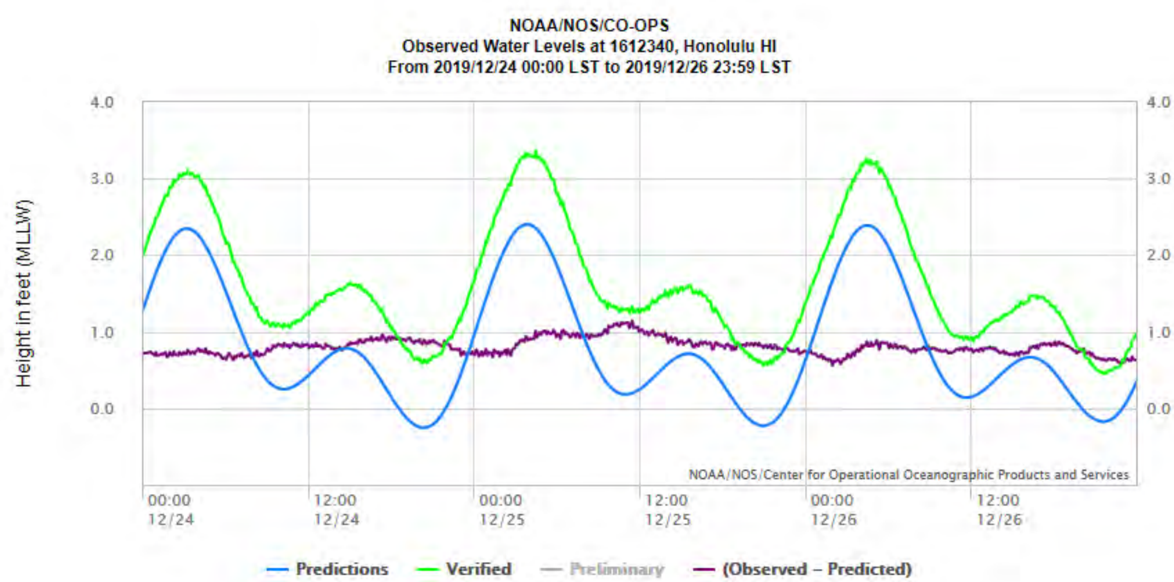

Figure 5-4. Predicted and measured tides at Honolulu Harbor (December 24-26, 2019)

5.1.4 Combined Sea Level (Static Water Level Rise) for Design

The accuracy and validity of numerical wave models depends, in part, on an accurate estimation of the still water level (SWL) within the numerical domain for the modeled conditions. This usually means considering a series of applicable steady state high water factors for exploring maximum wave height conditions and inundation limits at the proposed structure's shoreline location, known collectively as *design still water level rise*. For a typical analysis such as this, the design still water level rise is considered to be an additive combination of the following components, measured with respect to MSL:

Astronomical tide: An astronomical tide component will be taken as **+1.1 feet MSL**, which is equivalent to the mean higher high water (MHHW) level as measured at the Moku O Loe tidal station. MHHW is typically used for modeling of design wave conditions and will be assumed the same for this study.

Sea level anomaly (SLA): A local SLA value of **+0.5 feet** was also included as part of the design water level. This is a typical value commonly used for planning and design purposes in Hawaii.

Sea level rise (SLR): A SLR value of **+1.67 feet** was selected, which corresponds to the NOAA 2017 intermediate-high scenario by the year 2047 (25-yr from 2022).

An additional design water level component is *wave setup*, which is the term for a complex water level phenomenon that occurs along the shoreline due to periods of high surf. Wave setup is basically described as a localized superelevation of the average water surface height developed along a hard shoreline boundary due to the mass flux of water developed from breaking waves. Wave setup can be estimated empirically based on design wave conditions but is more accurately estimated using non-hydrostatic numerical modeling techniques, like employing an advanced wave model such as XBeach. Wave setup is not considered a part of the design still water level components discussed in Sections 5.1.1 through 5.1.3 due to the transient nature of the phenomenon and will be discussed in more detail in later sections examining design dynamic water levels. In summary, the total still water level rise assumed for design conditions was calculated to be 3.27 feet above MSL, as shown in Table 5-3, and may be considered a probable worst-case scenario.

Table 5-3. Still Water Levels for Design

Component	**25-year**	
	(ft)	*(m)*
Astronomical Tide Above MSL (MHHW)	1.10	0.34
Mesoscale Eddy	0.50	0.15
Sea Level Rise, SLR	1.67	0.51
Total SWL (referenced to MSL)	**3.27 MSL**	**1.00 MSL**

5.2 Deep Water Wave Model

For this study, SWAN was employed to simulate four deep-water wave condition scenarios developed from the extreme wave height analysis presented in Section 3.3, propagating the wave fields from their deep-water source locations in to nearshore transitional waters adjacent to the project site. The source conditions include the 25-year return period northwest (NW) from the far-field Buoy 51001 location roughly 200 miles northwest of Kauai, and similarly the 25-yr NW from near-field buoy CDIP-106 offshore from Waimea Bay; the 25-yr return period Tradewind swell event from the east, using nearby CDIP-098 offshore of Mokapu Peninsula (Marine Corps Base Hawaii); and, a 25-year hurricane swell represented by the actual maximum wave heights recorded at CDIP-098 for Hurricane Douglas. In developing this procedure, it was decided to take advantage of SWAN's relatively new capability for computation on an unstructured mesh. The primary benefit of utilizing SWAN with unstructured meshes, in contrast to conventional rectilinear orthogonal grids, is that the variable sized cells of the unstructured mesh allow for coarser model resolution (and thus faster computation time) over the vast majority of the model domain which consists of deep offshore regions—regions where waves are not influenced by the seafloor and remain relatively unchanged. Similarly, the mesh transitions to increasingly finer resolution for increasingly shallower waters nearshore, where wave transformations become of a function of water depth. In terms of the spatial extents of the model, creation of the unstructured mesh covered the region from the source buoy location to the project area, decreasing in element size as a function of depth and slope, with successive zones of refinement as the domain focuses in on the project area. For example, the far-field NW swell domain is presented in Figure 5-5, illustrating the telescoping refinement stages highlighted by red boxes. Nominal size of the individual mesh elements varies throughout the domain, ranging from a maximum size of 16,400 ft (5,000 m) in full ocean depth waters (as shown in the upper left areas of the top left panel of Figure 5-5), and decreasing by a factor of 100, down to 164 ft (50 m) in nearshore intermediate depth waters, as shown in the lower right panel of Figure 5-5.

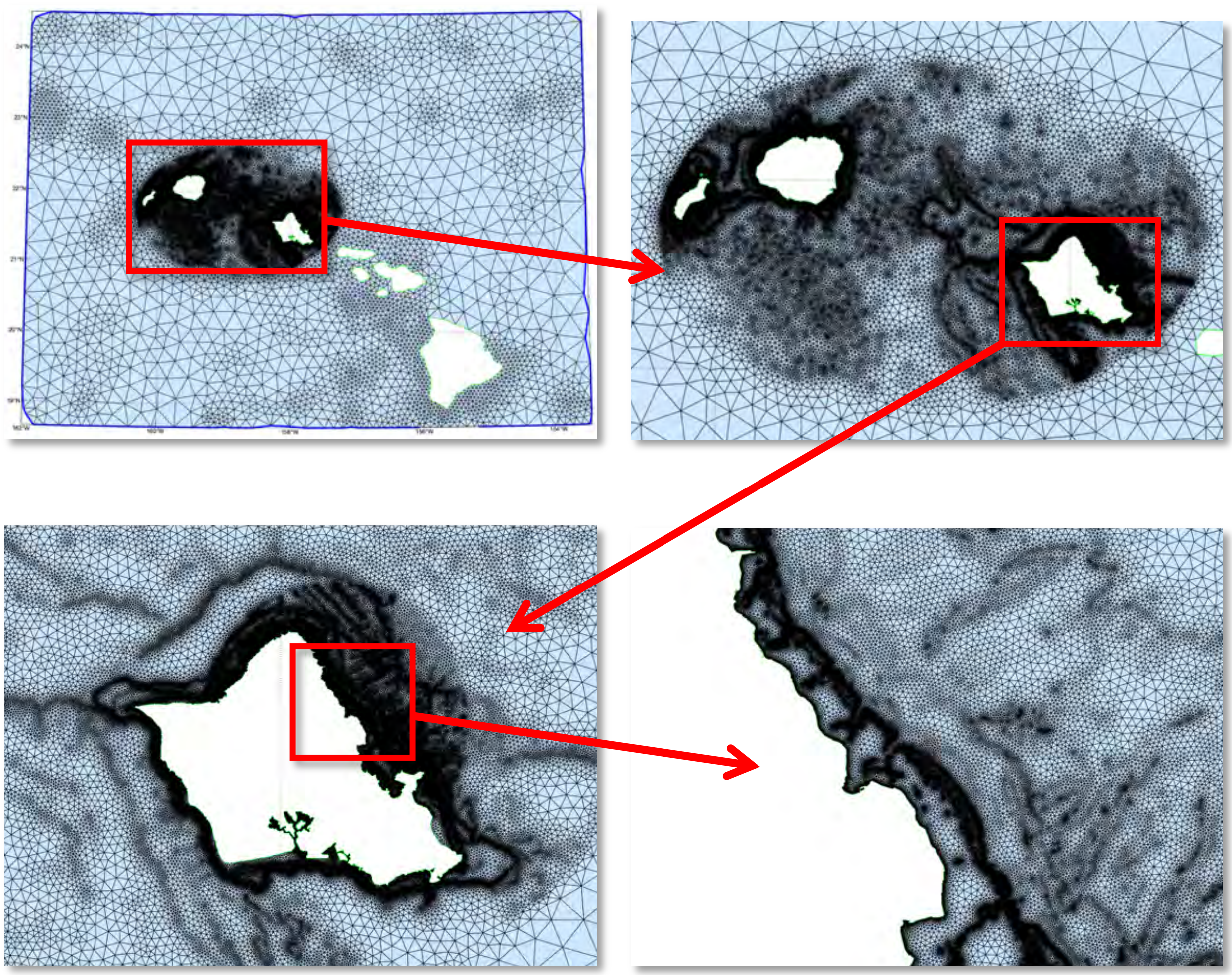

Figure 5-5. Examples of telescoping mesh size based on depth, for SWAN unstructured mesh - NW Far-field Swell

Results of the deep water wave transformation modeling for the NW Far-field, NW Near-field, Tradewind swell, and hurricane wave conditions are presented in Figure 5-6, Figure 5-7, Figure 5-8, and Figure 5-9 respectively. Calculated wave height is represented in these figures by the provided color scale, where dark blue is zero, navy blue is 5 ft (1.5 m), cyan is 15 ft (4.6 m), orange is 25 ft (7.6 m), and dark red is 35 ft (10.7 m). The direction of wave propagation is indicated by the black arrow vector-field overlay. For the 25-yr NW Far-field swell in Figure 5-6, the effects of island shadowing from all the islands is distinctly revealed in the regional view (*left image*), while wave heights near the KKPH project site are fairly undiminished from their original size offshore, but lose energy quickly as the refract into the northeast-facing shoreline (*right image*). Two areas of significant wave focusing can be seen as 'fingers' of red projecting in towards the shoreline at the north and south ends of Kaaawa and Kualoa. The 25-yr NW near-field case exhibits results that resemble the far-field case but with less energy available due to losses from propagating around Kahuku Point with the more westerly angle of the swell, leaving much of northeast Oahu in the wave shadow, shown in Figure 5-7 (*left image*). Similar focal areas to that seen in the far-field case are observed again for Kaaawa (cyan/green finger-like extensions of higher color), however with some decrease in overall wave height (*right image*). With full exposure to the north and east, the project coastline is directly open to the 25-yr Tradewind swell condition in Figure 5-8. Some distinct regions of local focusing are revealed along the outer reefs, particularly offshore from Kualoa near the ship channel, Punaluu on the north side of Kahana Bay and in front of Hauula (Figure 5-8, *right image*). The 25-yr hurricane swell (*Douglas*) approaches the project coastline with a similar direction, however with a little more easterly angle. As with the Tradewind swell, due to direct exposure the hurricane wave height field is fairly homogenous throughout until reaching the outer reefs of the Windward coastline, were some localized focusing occurs as shown in Figure 5-9.

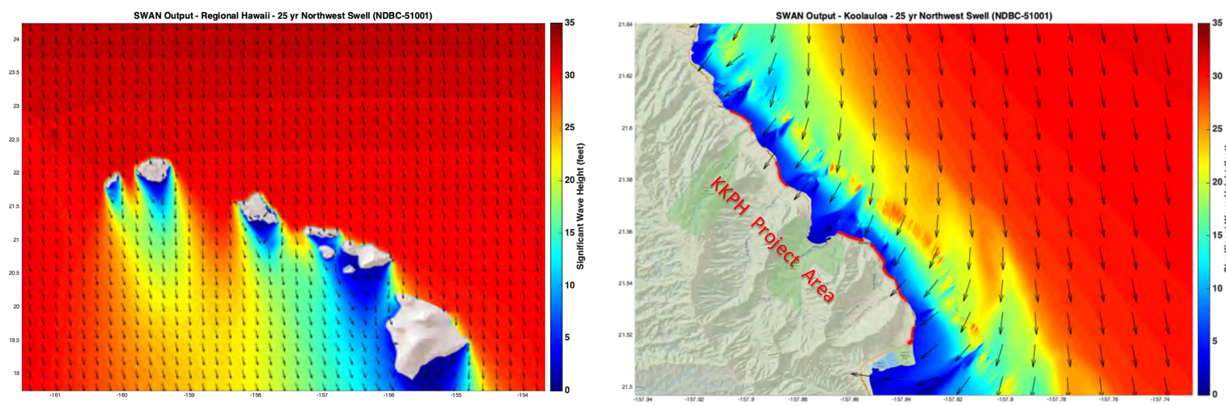

Figure 5-6. Regional (*left*) and local (*right*) wave heights and directions for the 25-yr NW Swell (Far-field)

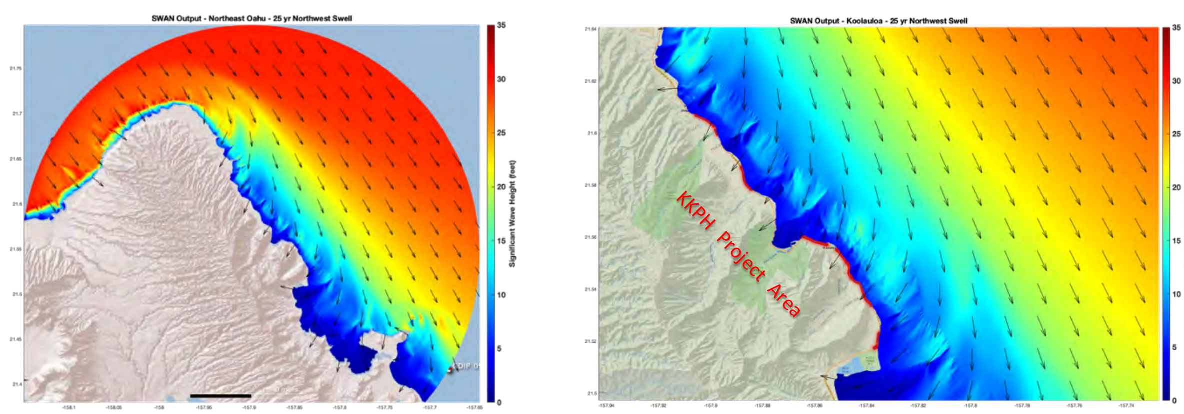

Figure 5-7. Regional (*left*) and local (*right*) wave heights and directions for the 25-yr NW Swell (Near-field)

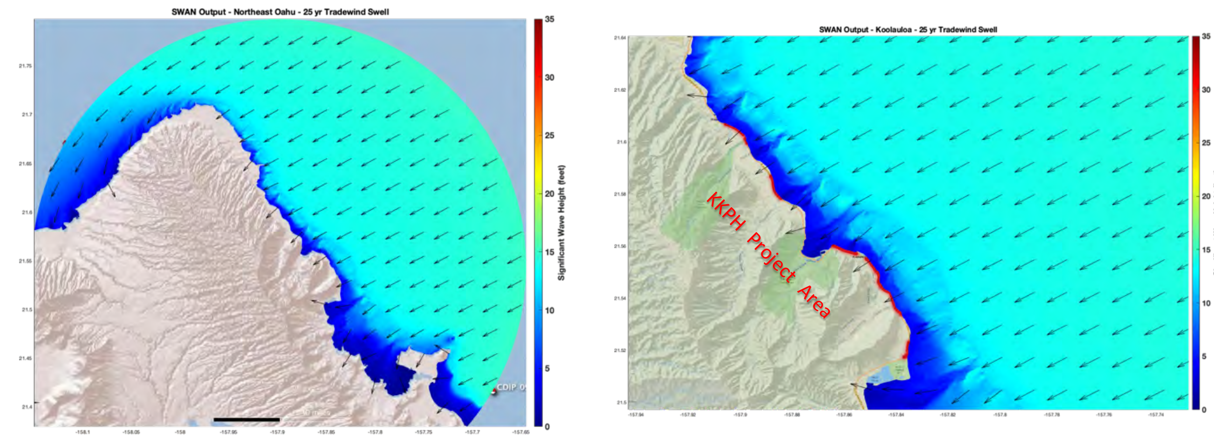

Figure 5-8. Regional (*left*) and site-localized (*right*) wave heights and directions for 25-yr Tradewind swell

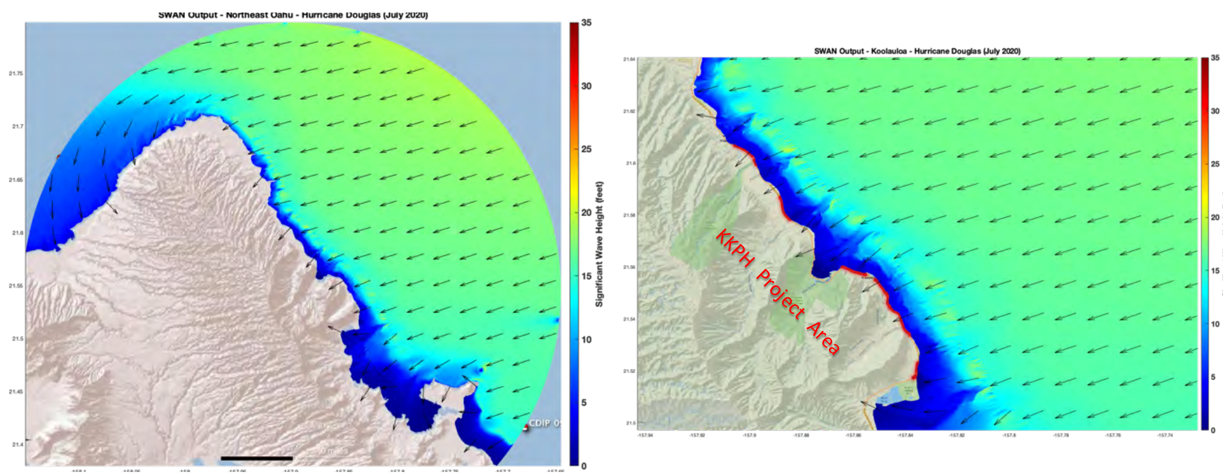

Figure 5-9. Regional (*left*) and site-localized (*right*) wave heights and directions for 25-yr hurricane

5.3 Nearshore Wave Model

Higher resolution, non-hydrostatic, nearshore wave modeling using XBeach was required in the shallow shoreline vicinity to adequately quantify energy losses and other complex effects of wave shoaling and braking in and around the surf zone—areas where SWAN's performance is limited. The surf zone itself varies spatially with water depth and is dependent on wave direction, height, and period (and additionally with any localized water level fluctuations). The nearshore XBeach models were *nested* within the larger parent model (SWAN) domain by linking 2D wave spectra placed at spatially varying stations roughly 600 ft apart, following approximately along the 30 m (~100 ft) depth contour within the SWAN model. The wave characteristics from these spectra were then used to drive the offshore wave boundary of the nearshore models. The spectral reporting station locations used in this process are illustrated in Figure 5-10. Individually tailored model domains were developed for each of four cases for the nearshore wave modeling, with Kualoa through Kaaawa separated into one domain and Punaluu to Hauula grouped into another, for a total of eight unique model domains. The alignment step was essential to satisfy the requirement for XBeach that necessitates a rectilinear (orthogonal) model grid, with the x-axis oriented in the general direction of wave approach. Typically, each of the resulting XBeach grids consisted of a cell size varying between 16.4 ft (5 m) to 32.8 ft (10 m). Gridded bathymetry (depth information) for the models was developed from a fusion of bathymetry data sets including the U.S. Army Corps of Engineers' coastal LiDAR dataset from 2017 and the University of Hawaii's Multibeam Bathymetry Synthesis dataset.

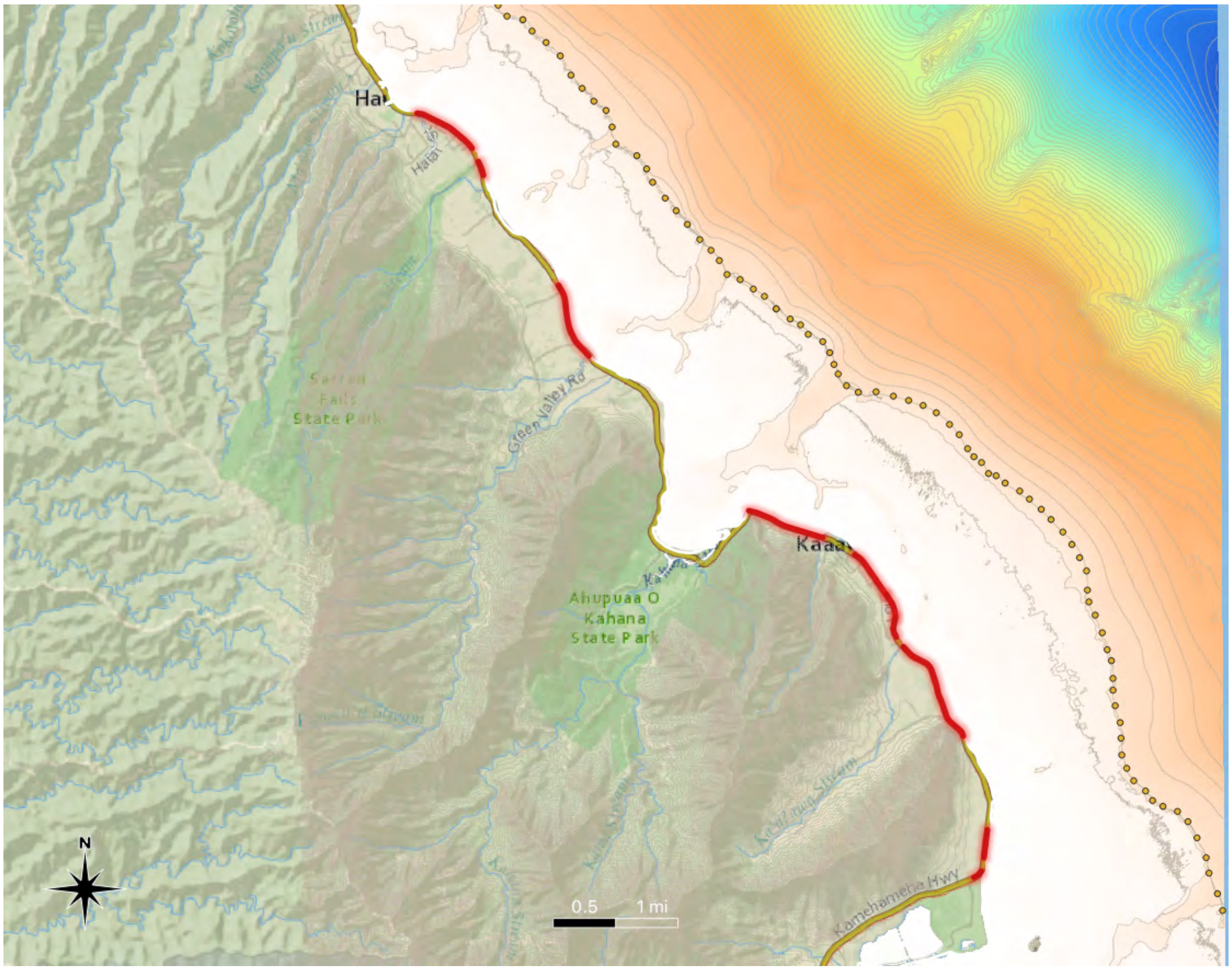

Figure 5-10. Locations of SWAN 2D-spectral reporting stations, used to drive XBeach models (along 30 m contour)

A series of three-dimensional visualizations from the nearshore modeling are presented in Figure 5-11 through Figure 5-18, illustrating wave field refraction patterns for the 25-yr far-field NW swell, 25-yr near-field NW swell, 25-yr Tradewind swell, and equivalent hurricane Douglas swell, respectively. The figures reveal expected refraction/diffraction patterns and wave crest heights for each scenario, based on a snapshot of the water surface elevation (WSE) roughly halfway through the model duration. Color-scale of WSE is in meters, with the wave trough represented in darker shades and wave crests represented by lighter colors. The WSE scale ranges from -4 m to +4 m above still water, as shown in the provided color scale included with the figures. The shorter period Tradewind wave field is visibly distinguishable from the longer period NW swells and hurricane swell (all T > 12 s), with characteristic short broken crestlines and greater directional variability in clear contrast to the long-crested and more organized wave fields for long period swells. Complex reflection and focusing patterns on the outer reefs are visible in all results.

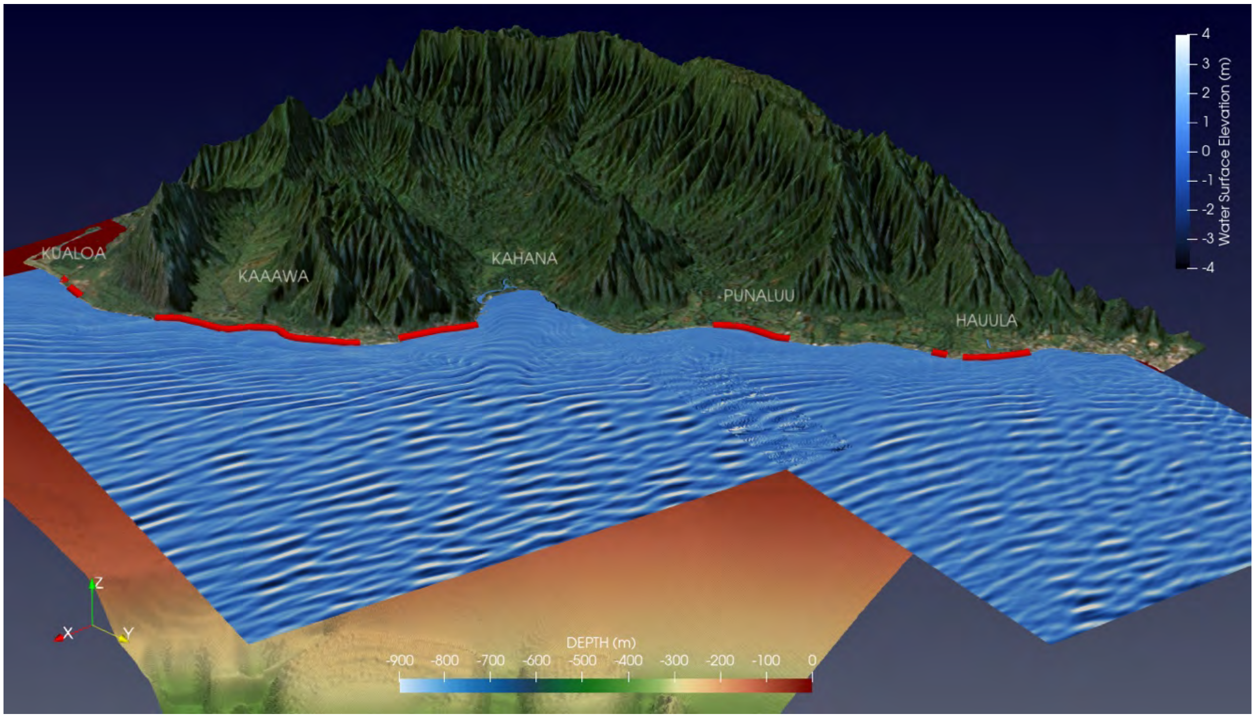

Figure 5-11. Phase-resolving XBeach results for the 25-yr NW (far-field source) swell condition (looking SW)

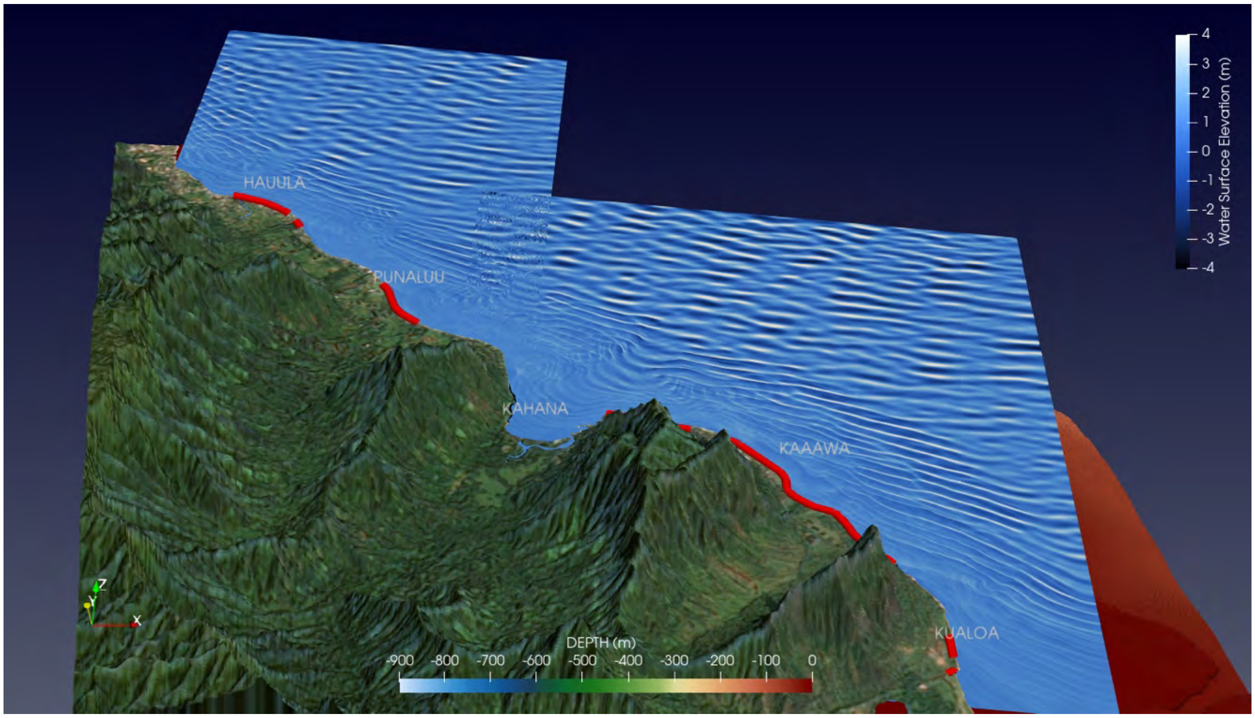

Figure 5-12. Phase-resolving XBeach results for the 25-yr NW (far-field source) swell condition (looking N)

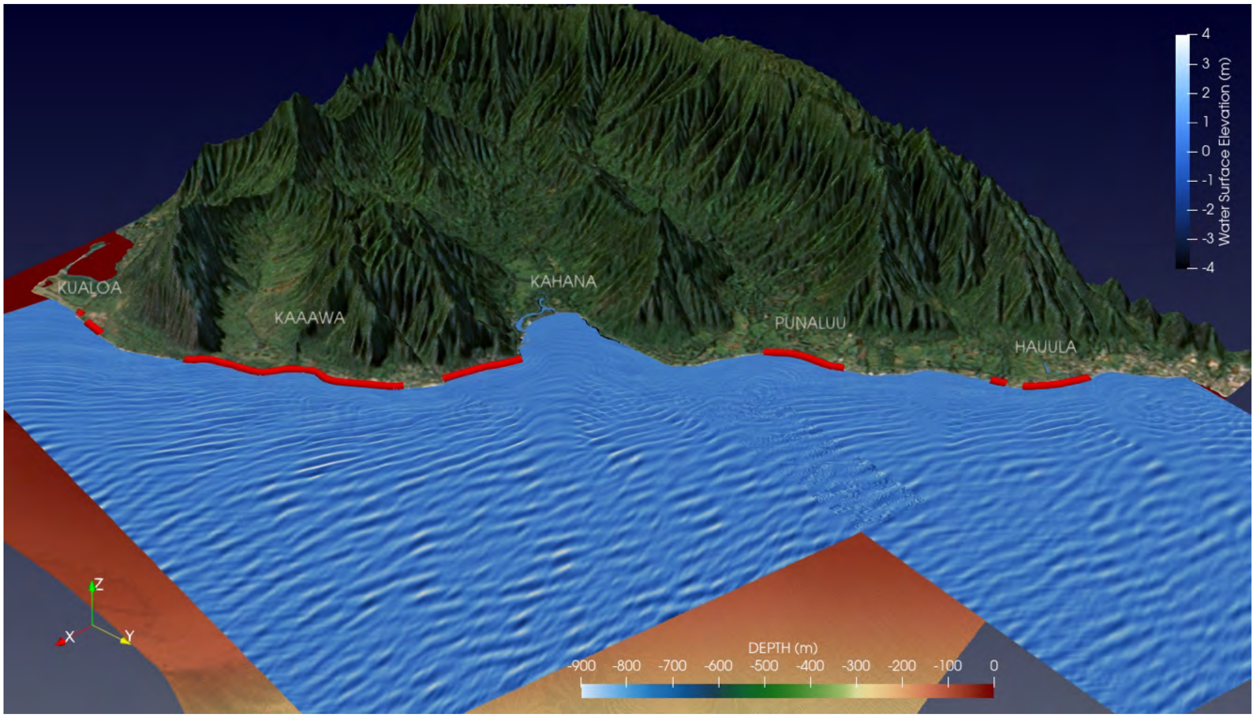

Figure 5-13. Phase-resolving XBeach results for the 25-yr NW (near-field source) swell condition (looking SW)

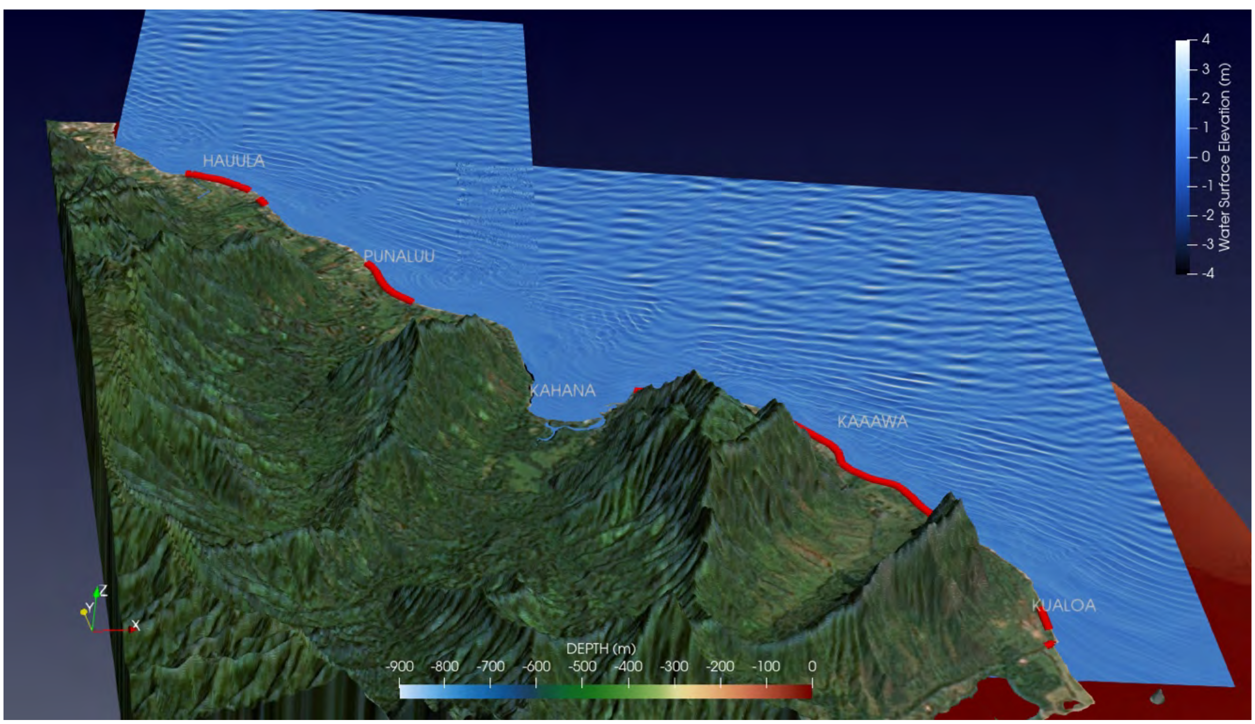

Figure 5-14. Phase-resolving XBeach results for the 25-yr NW (near-field source) swell condition (looking N)

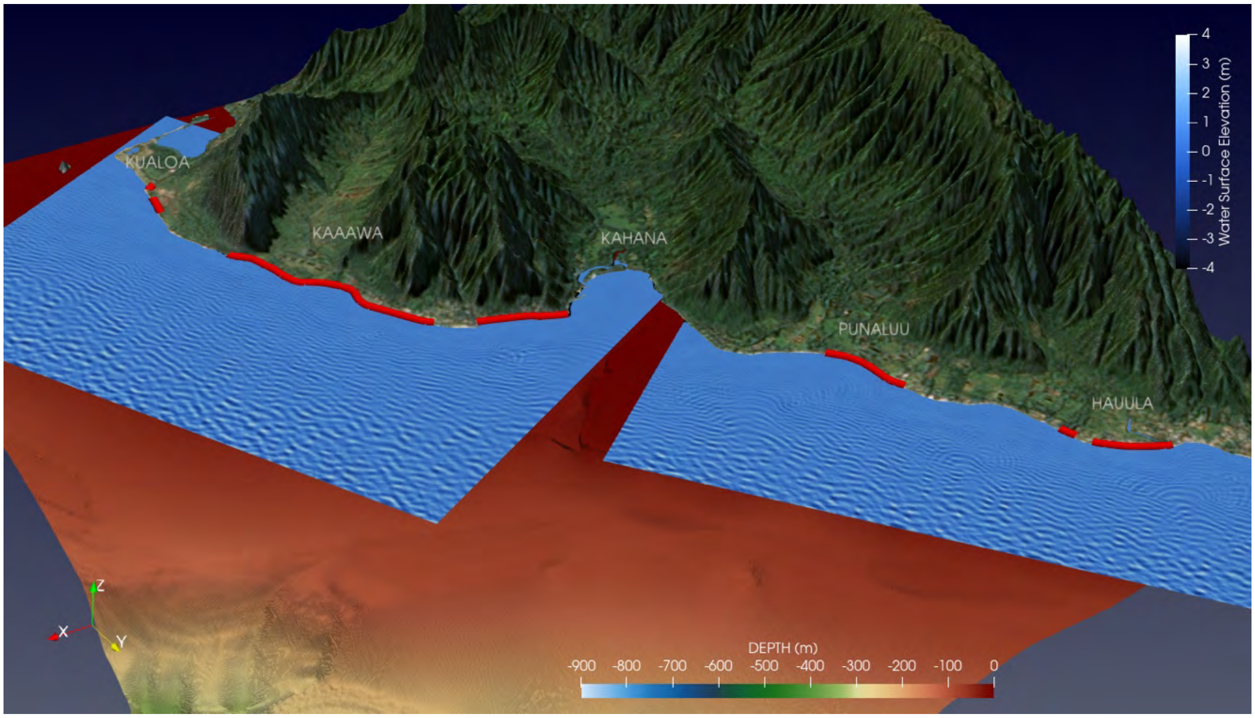

Figure 5-15. Phase-resolving XBeach results for the 25-yr Tradewind swell condition (looking SW)

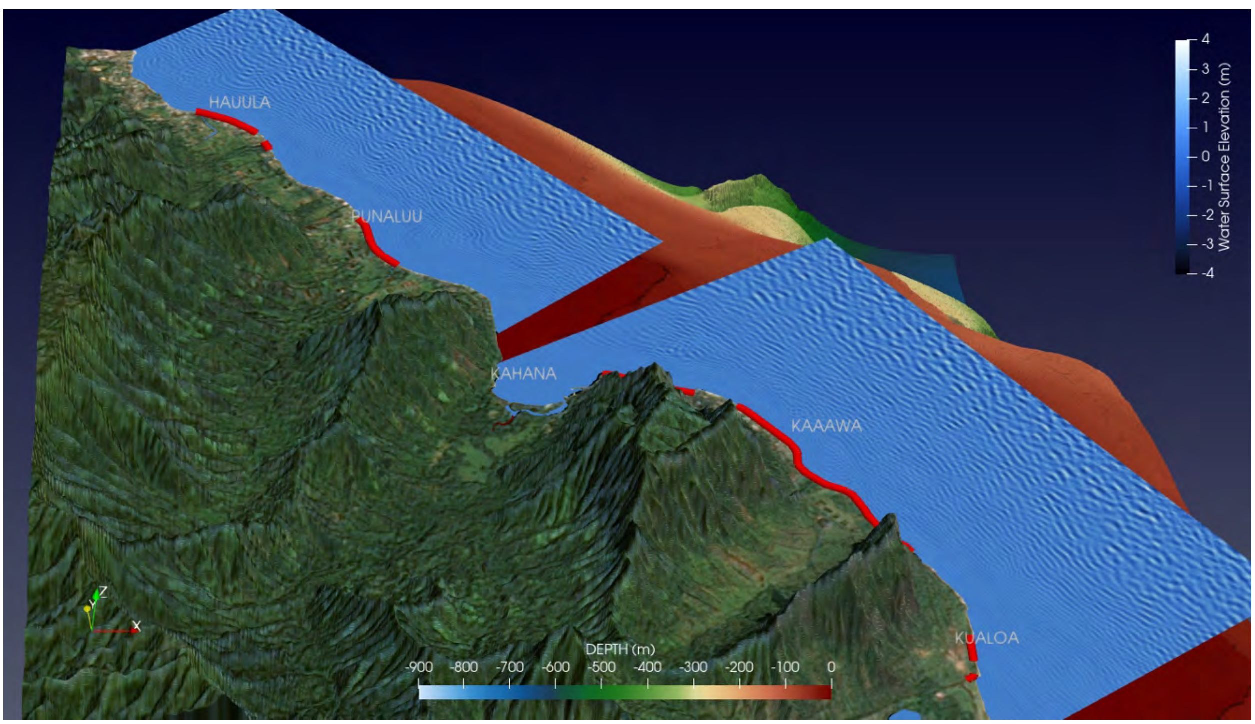

Figure 5-16. Phase-resolving XBeach results for the 25-yr Tradewind swell condition (looking N)

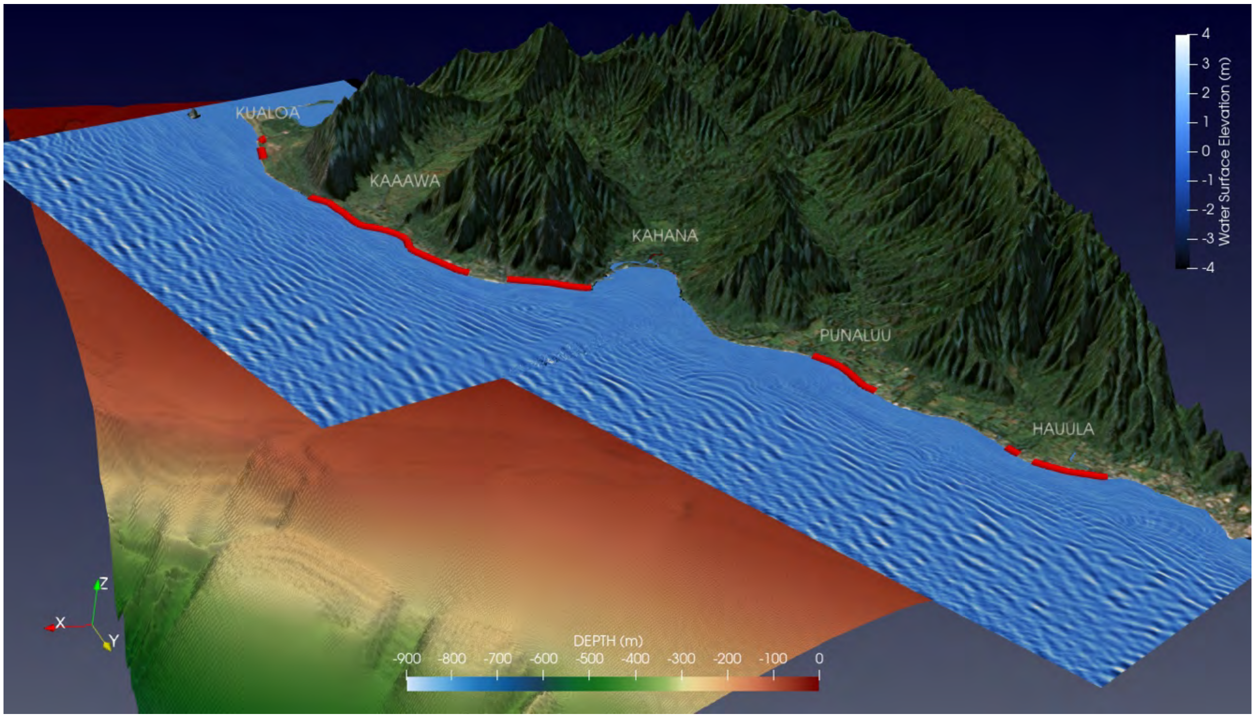

Figure 5-17. Phase-resolving XBeach results for the equivalent hurricane Douglas swell condition (looking S)

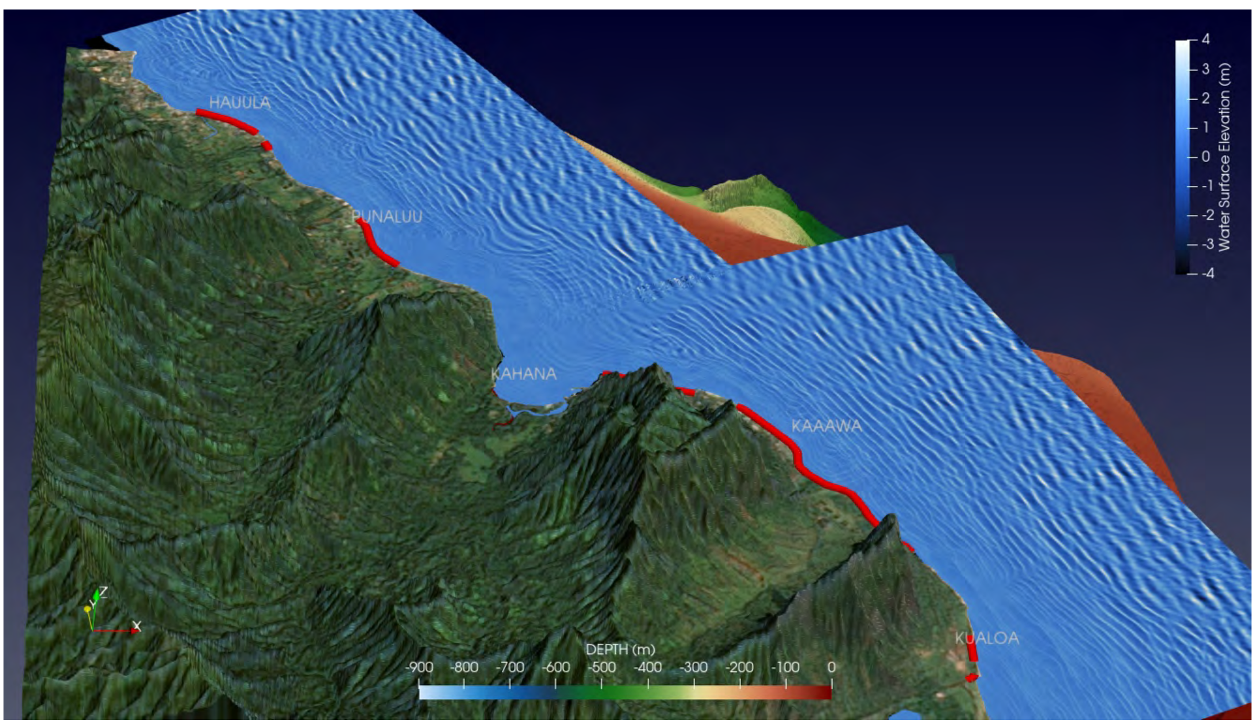

Figure 5-18. Phase-resolving XBeach results for the equivalent hurricane Douglas swell condition (looking N)

The illustrations presented in Figure 5-11 through Figure 5-18 represent a snapshot in time, one instant of a wave field record that is 4,300 seconds in length and containing up to 600 individual waves (depending on swell period). The snapshots nicely visualize individual wave crests of various sizes and periods within the full spectrum of waves, as they propagate through the domain. And although useful for revealing large scale refraction and diffraction patterns as the waves move towards shore, those types of illustrations are less informative for understanding the spatial distribution of particular wave heights.

Utilizing the nearly 1.2 hour-long time-dependent water surface elevation data illustrated by the previous set of figures, a statistical processing operation was then employed to calculate phased-averaged maps of *significant wave height*, a statistical quantity which is defined as the average of the highest one-third of waves in the record (represented by the variable H_s or $H_{1/3}$). This operation was completed on a cell-by-cell basis for every wet grid cell in the computational domain. The resulting wave height maps are presented in Figure 5-20 through Figure 5-25, illustrating the spatial distribution of significant wave height that correlates to each wave condition scenario shown in the wave field refraction maps in Figure 5-11 through Figure 5-18. Because H_s is a phase-averaged value, it does not provide much insight into the patterns of individual wave propagation, however it does provide very useful understanding of the distribution of wave heights within the domain. For example, maps of H_s may reveal particular areas that exhibit exceptional focusing and enhanced exposure, or conversely areas of sheltering and dispersion.

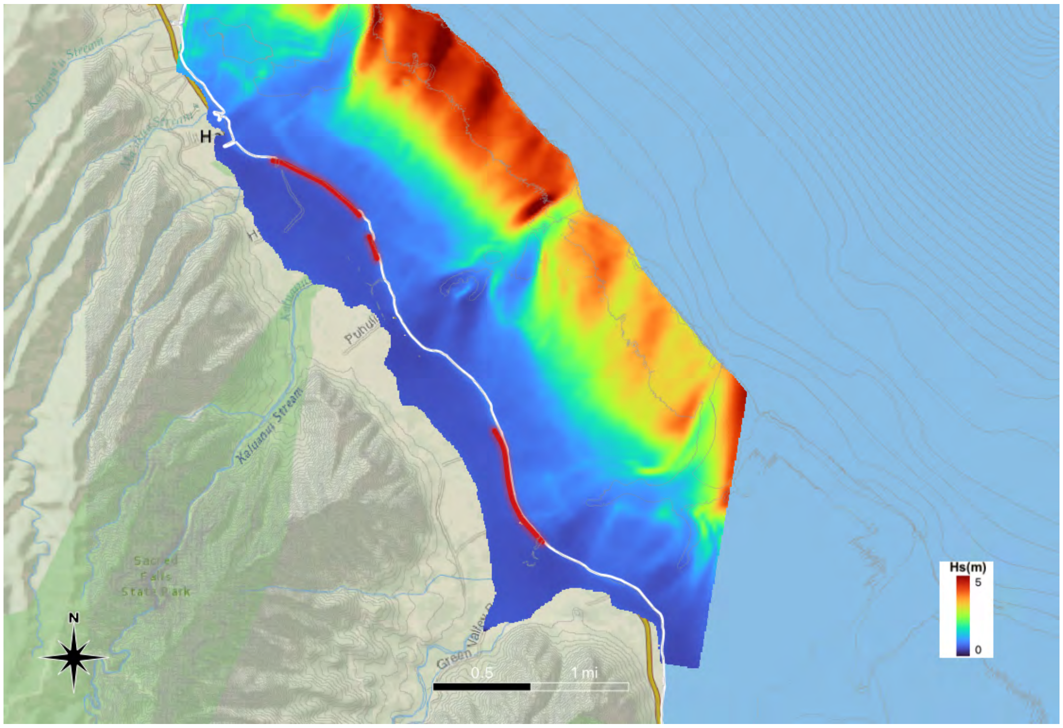

Figure 5-19. Phase-averaged XBeach results for H_S at Punaluu to Hauula, 25-yr NW Swell (far-field)

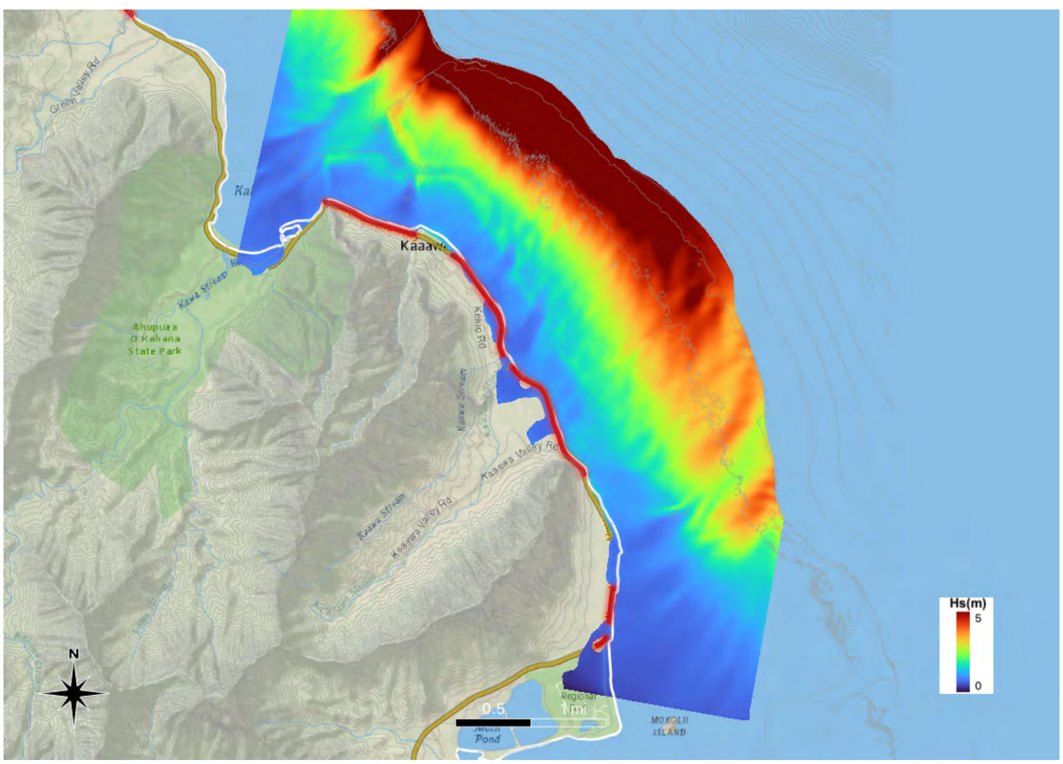

Figure 5-20. Phase-averaged XBeach results for H_S at Kualoa to Kaaawa, 25-yr NW Swell (far-field)

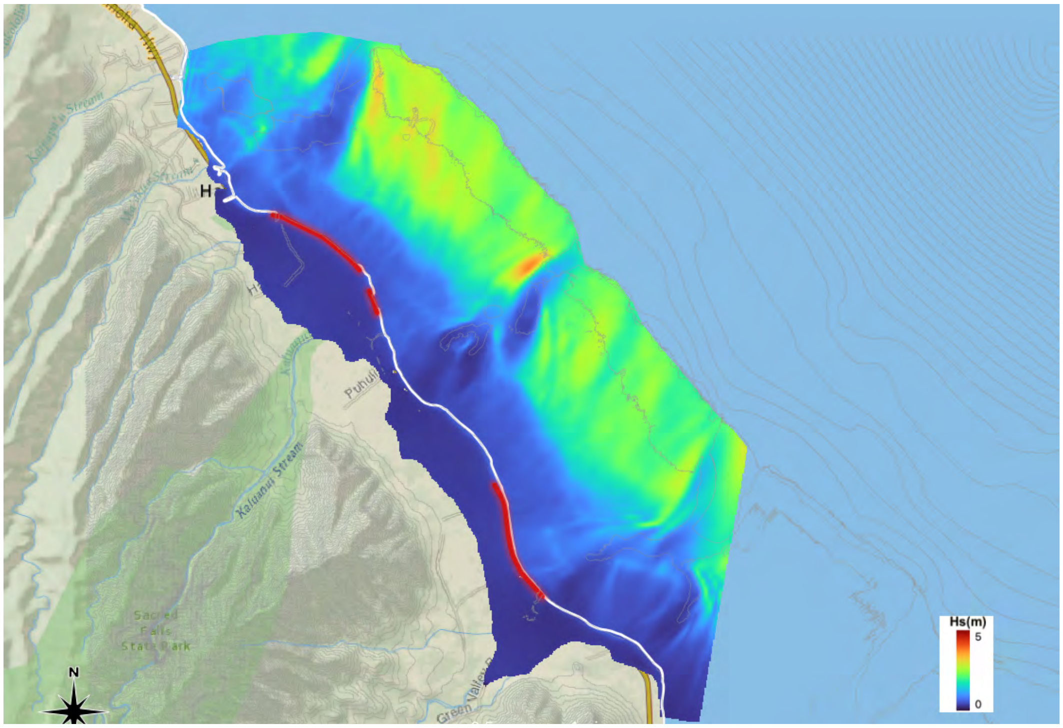

Figure 5-21. Phase-averaged XBeach results for H_s, Punaluu to Hauula, 25-yr NW Swell

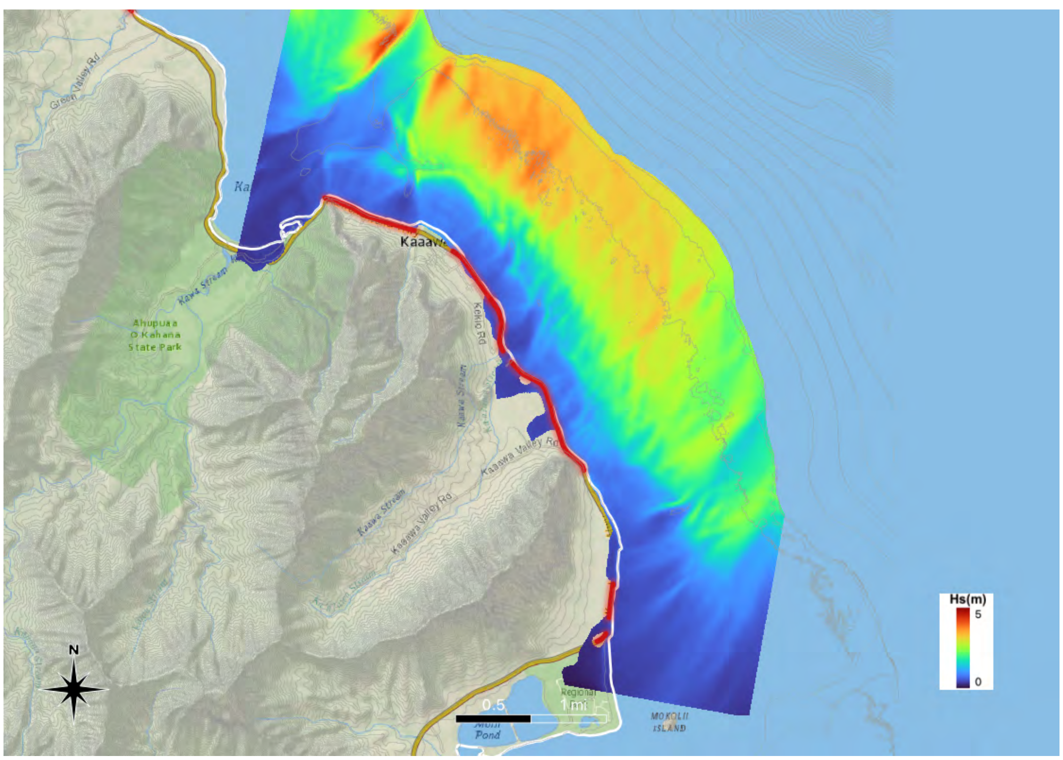

Figure 5-22. Phase-averaged XBeach results for H_S at Kualoa to Kaaawa, 25-yr NW Swell

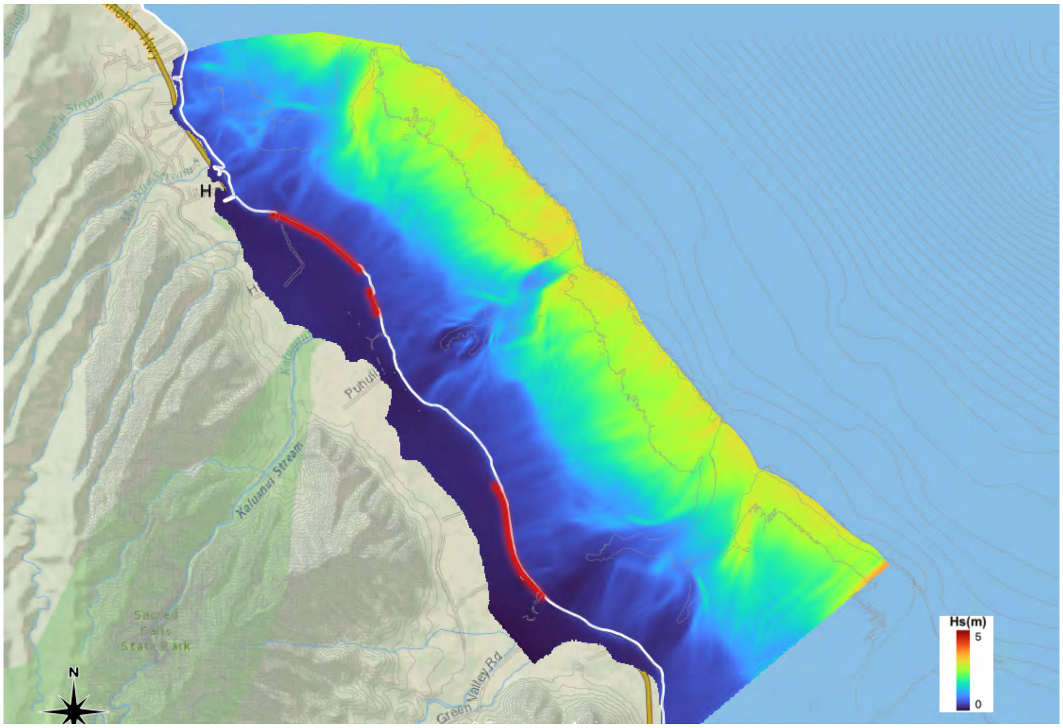

Figure 5-23. Phase-averaged XBeach results for H_S at Punaluu to Hauula, 25-yr Tradewind Swell

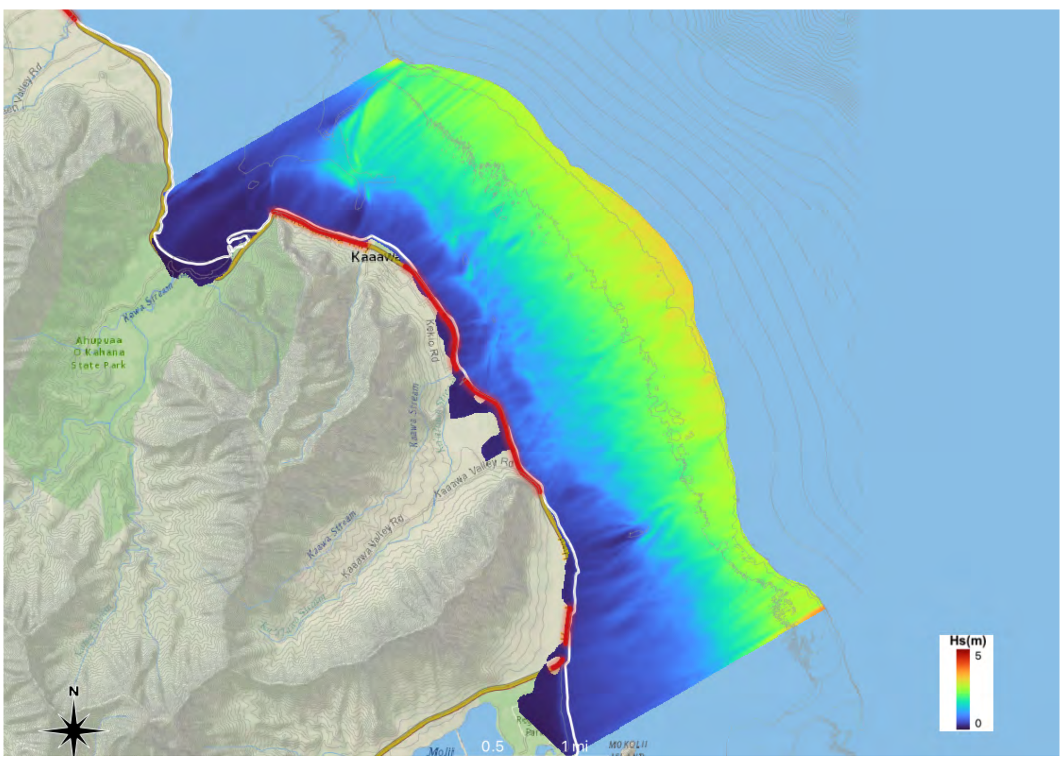

Figure 5-24. Phase-averaged XBeach results for H_S at Kualoa to Kaaawa, 25-yr Tradewind Swell

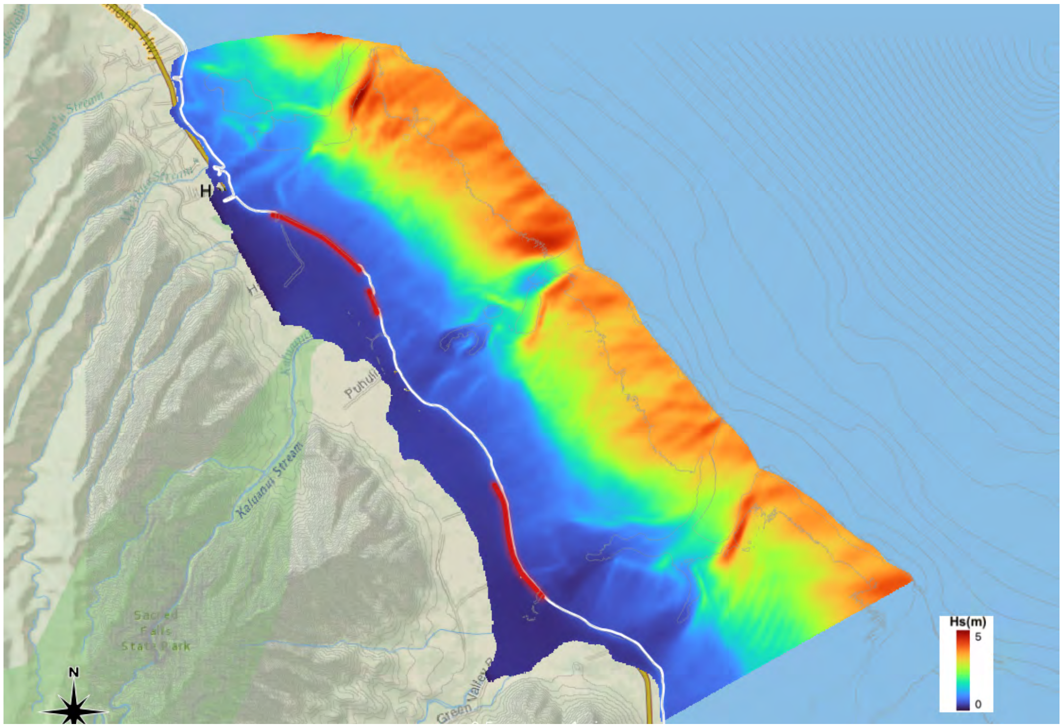

Figure 5-25. Phase-averaged XBeach results for H_S at Punaluu to Hauula, hurricane Douglas swell

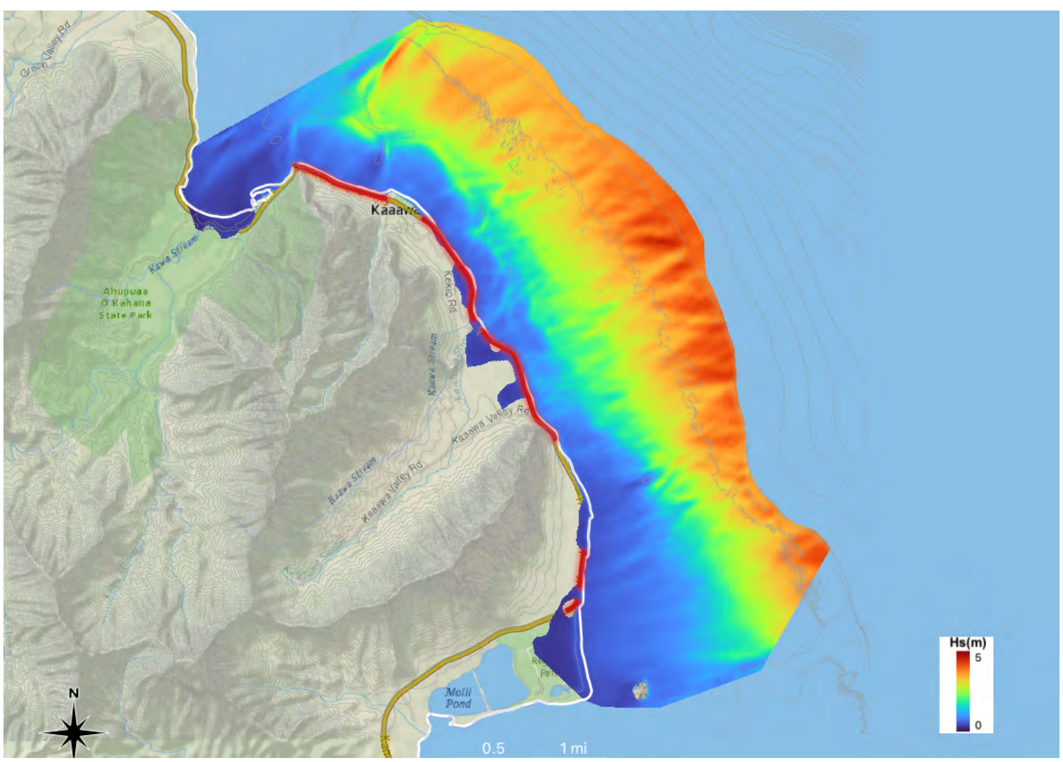

Figure 5-26. Phase-averaged XBeach results for H_S at Kualoa to Kaaawa, hurricane Douglas swell

Numerical probes were set within the simulations at several arbitrary station locations, chosen for their general proximity to the individual repair reaches, with their relative positions illustrated in Figure 5-27. From the approximately 1.2 hours of probe data for each location, *zero up-crossing* analyses combined with additional *FFT* mathematical operations were conducted to calculate the wave *energy spectrum* for each location. A wave energy spectrum provides the distribution of wave energy over the range frequencies of waves present on the sea surface at a particular location for a discrete range of time. Spectral frequency (*f*) is measured in Hertz, [Hz] which is equivalent to the inverse of wave period, *T* in seconds (T = [s]), or (*f* = 1/T = 1/[s]).

Spectral plots are an important visual tool for assessing the characteristics of a swell at a particular location and time; the plots do this by relating wave *energy density* (units of m^2/Hz) to wave *frequency* (units of Hz), where the quantity of wave energy is proportional to wave height squared (as implied by the units). The combined wave energy spectra plots presented in Figure 5-28 through Figure 5-35 are the results for each of the four wave condition scenarios, grouped by locations Kualoa/Kaaawa and Punaluu/Hauula: the 25-yr NW swell (far-field), 25-yr NW (near-field), 25-yr Tradewind swell, and the hurricane Douglas swell, respectively. Peaks in the data indicate the frequency band(s) on which the local wave field is focused, as well as how energetic (i.e., how big) the swell is. In general, the amplitude of this curve is related to wave height, and narrowness of the energy peak curve implies a focused or well-organized swell with frequencies/periods tightly banded near the peak period. A wider peak or series of peaks would indicate a more complex wave field composed of waves with more varied periods and directions, or a mix of swells from multiple sources. The dashed vertical line near the left axis of all the plots (at 0.05 Hz, equivalent to a period of 20 s) represents an assumed cut-off between normal wind-driven surface gravity waves (i.e., ordinary ocean wind-generated waves consisting of *sea* and *swell*), and long period infra-gravity waves like *surge*, or other long-period water surface *oscillations*. A simplified illustration of the relationship between various wave periods on the ocean wave spectrum was adapted from Munk (1950) and presented in Figure 5-36, where the primary waves of interest in this study are labeled "*ordinary gravity waves*" with periods ranging from 1 to 20 seconds, and "*infra-gravity waves*" with periods ranging from 20 seconds to 5 minutes. For the combined spectra in Figure 5-28 through Figure 5-35, "ordinary gravity waves" corresponds to everything to the right of the dashed vertical line, while "infra-gravity waves" or surge are to the left of this line. In general, the deeper probe stations (3, 6, 9, 12, and 15 for Kualoa/Kaaawa and 2, 5, and 8 for Punaluu/Hauula) for both of the NW scenarios, the spectral plots are tightly banded around approximately 0.055 to 0.06 Hz (17-18 s) as would be expected, while the shallower stations begin to exhibit some spreading and reduction in energy as the waves break, reform and are otherwise transformed by the complicated shallow reef structures. The near-shoreline stations (1, 2, 5, 8, 11, and 14 for Kualoa/Kaaawa and 1, 4, and 7 for Punaluu/Hauula) appear to transform a significant fraction of incident wave energy from ordinary gravity waves into long-period surge, revealed by a distinct peak to the left of the dashed vertical line for those respective plots.

The same pattern generally holds true for all wave scenarios, however the 25-yr Tradewind swell has a peak with wider spread at the offshore probe locations centered near 0.125 Hz (8 s), with a wider range of frequencies within the wave field—a typical characteristic of fully developed wind swells. The hurricane swell appears as a blend between the NW and Tradewind swells, with a slightly wider peak than the NW swells, but is more tightly banded than the Tradewind spectra, with hurricane peak frequencies centered around 0.07 Hz (14 s). In some cases, for the NW and hurricane swells in particular, many of the near-shoreline stations suggest an almost total transformation of the incoming wave energy from ordinary waves into infra-gravity waves or surge at the shoreline. From the modeling, the maximum wave heights and surge amplitudes resulting along the shoreline at the nine designated repair areas are summarized in Table 5-4, and colorized by wave height value from green (lowest) to red (highest) to provide a quick visual que, along with a notation of which wave scenario was responsible for that maximum value.

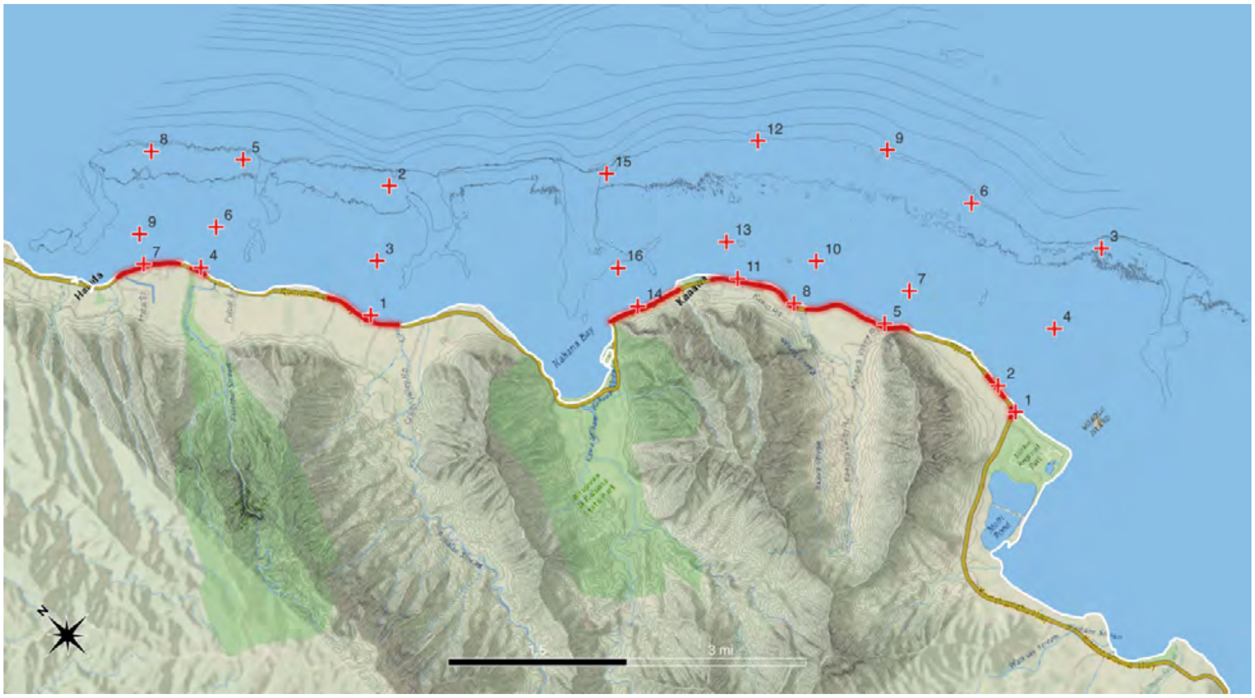

Figure 5-27. XBeach probe stations (Hauula to Punaluu use separate numbering from Kaaawa to Kualoa)

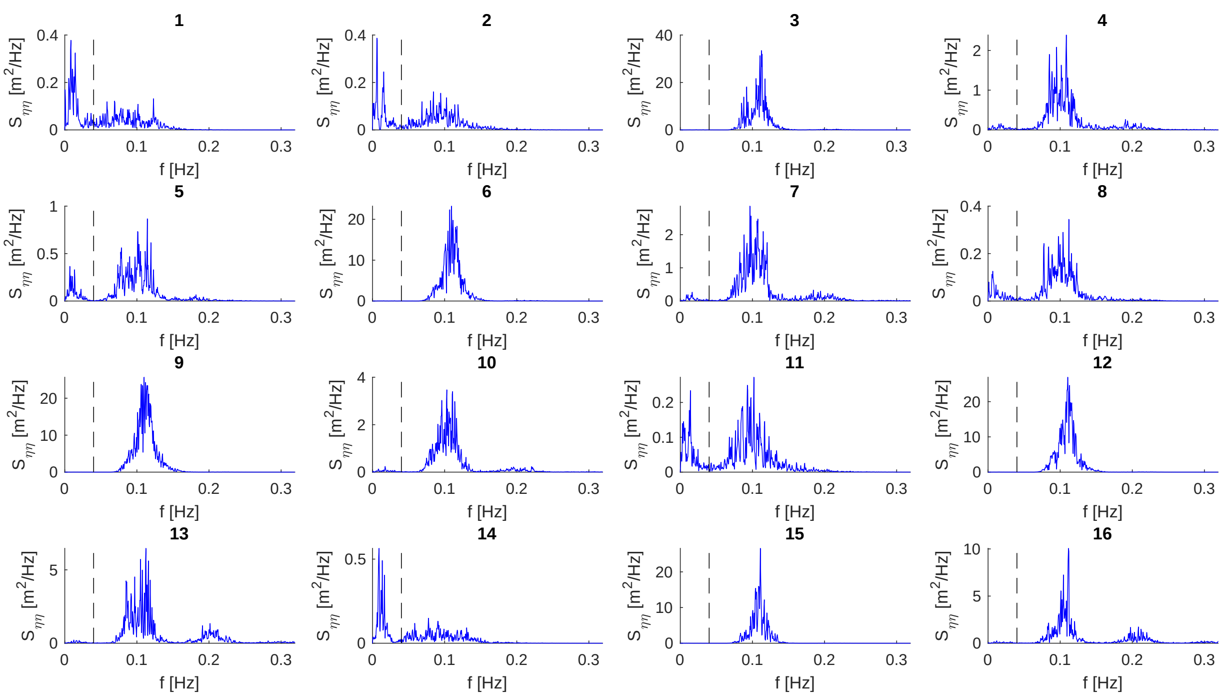

Figure 5-28. Wave energy spectra at XBeach Kualoa/Kaaawa probe locations for the 25-yr Tradewind swell

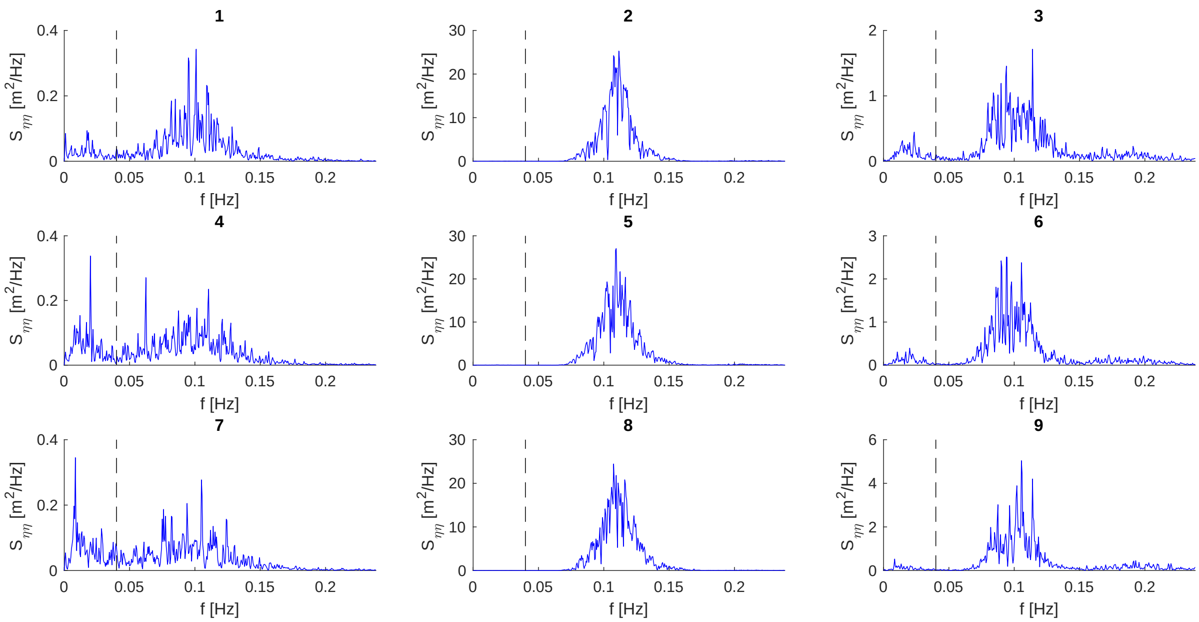

Figure 5-29. Wave energy spectra at XBeach Punaluu/Hauula probe locations for the 25-yr Tradewind swell

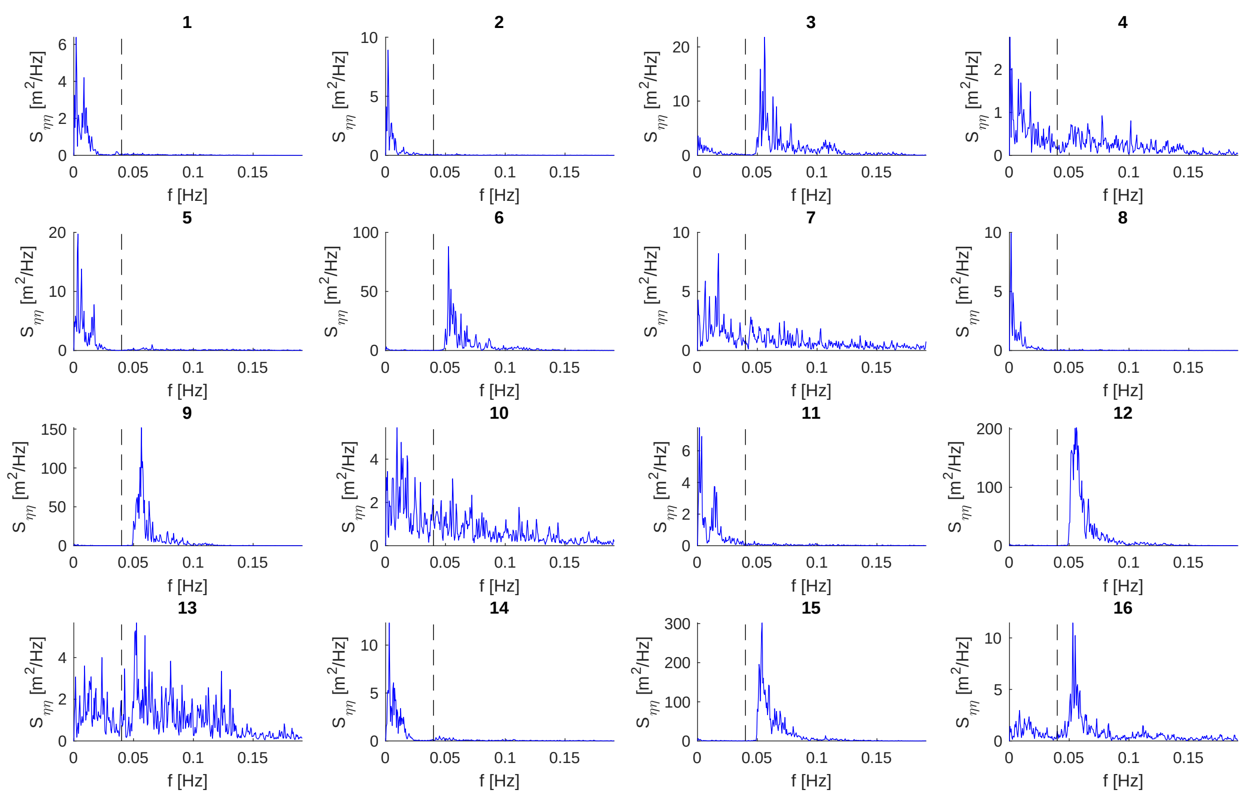

Figure 5-30. Wave energy spectra at XBeach Kualoa/Kaaawa probe locations for the 25-yr NW swell (far-field)

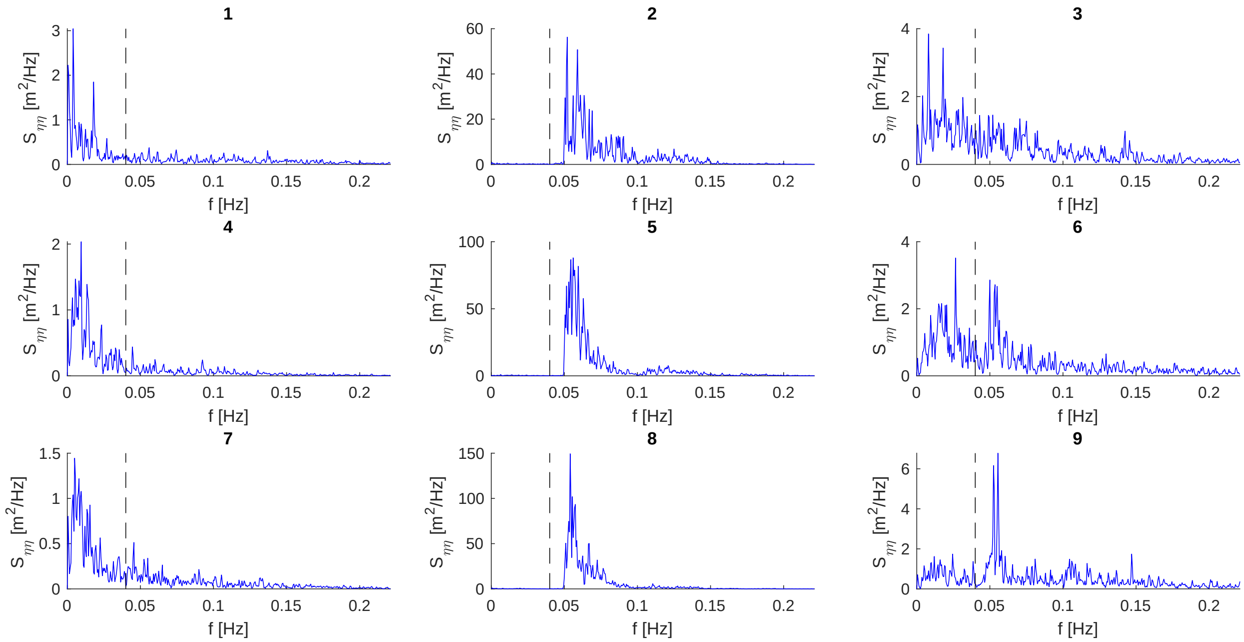

Figure 5-31. Wave energy spectra at XBeach Punaluu/Hauula probe locations for the 25-yr NW swell (far-field)

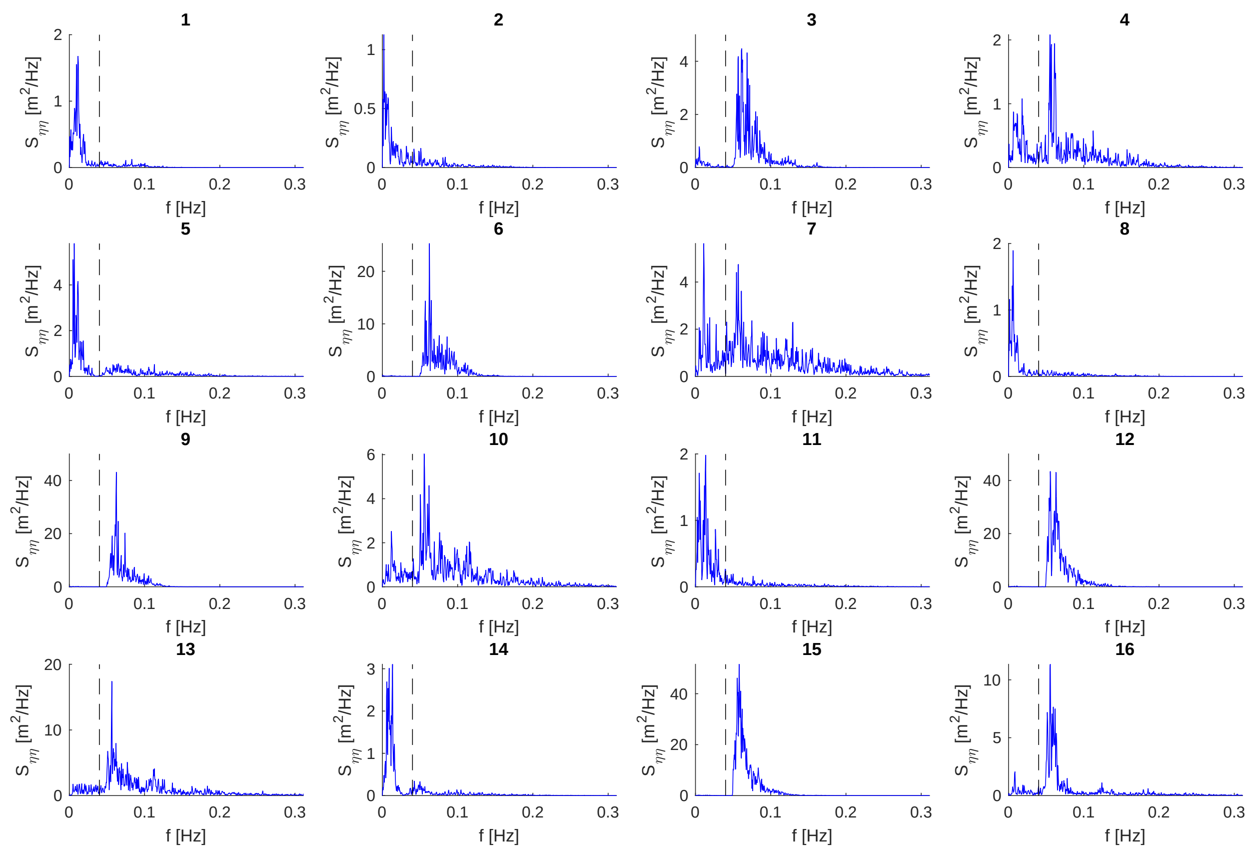

Figure 5-32. Wave energy spectra at XBeach Kualoa/Kaaawa probe locations for the 25-yr NW swell (near-field)

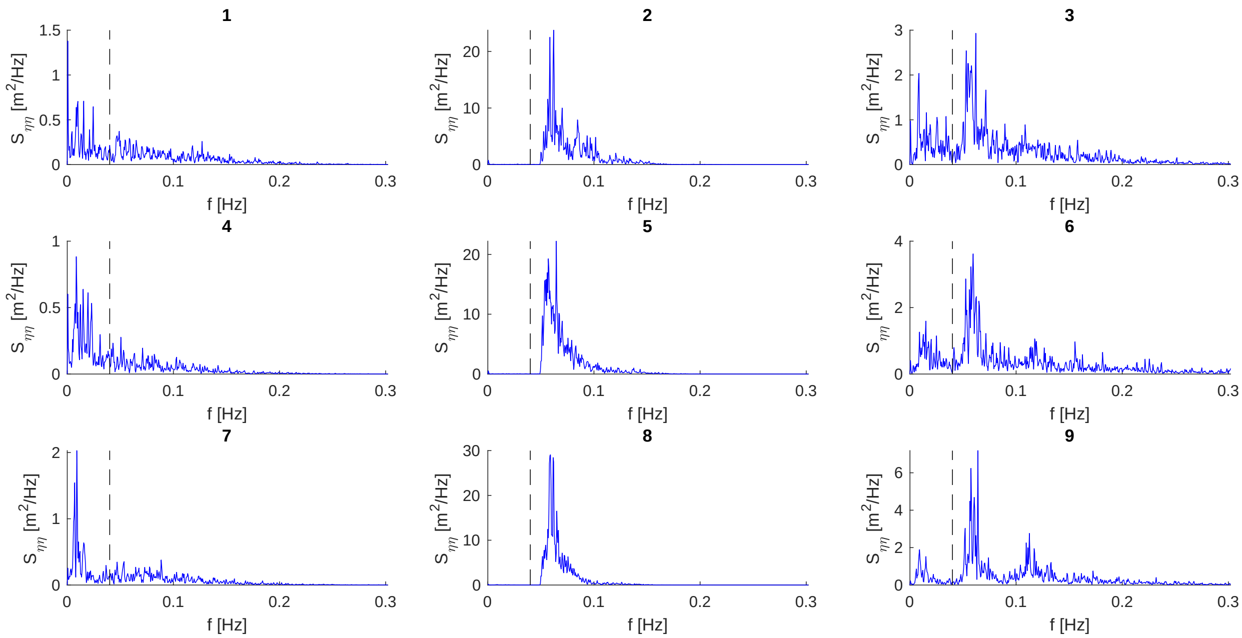

Figure 5-33. Wave energy spectra at XBeach Punaluu/Hauula probe locations for the 25-yr NW swell (near-field)

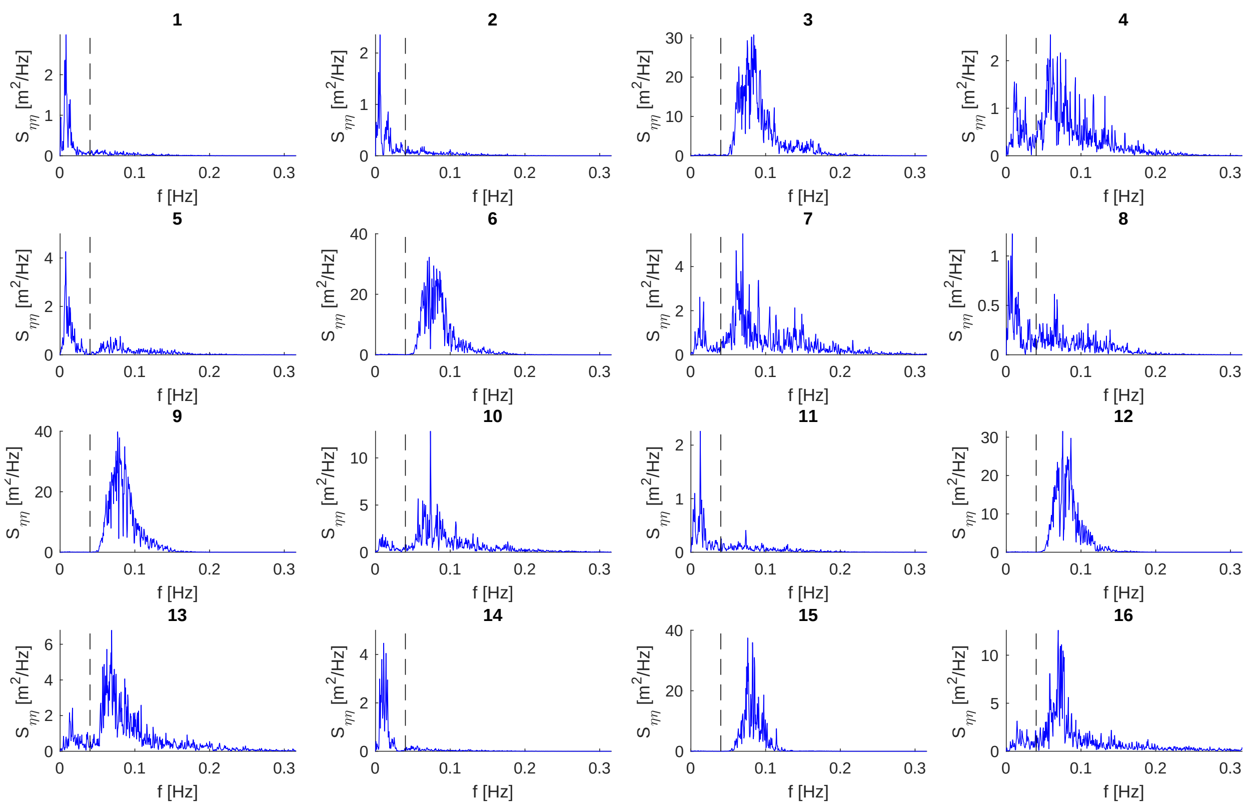

Figure 5-34. Wave energy spectra at XBeach Kualoa/Kaaawa probe locations for 25-yr hurricane (Douglas) swell

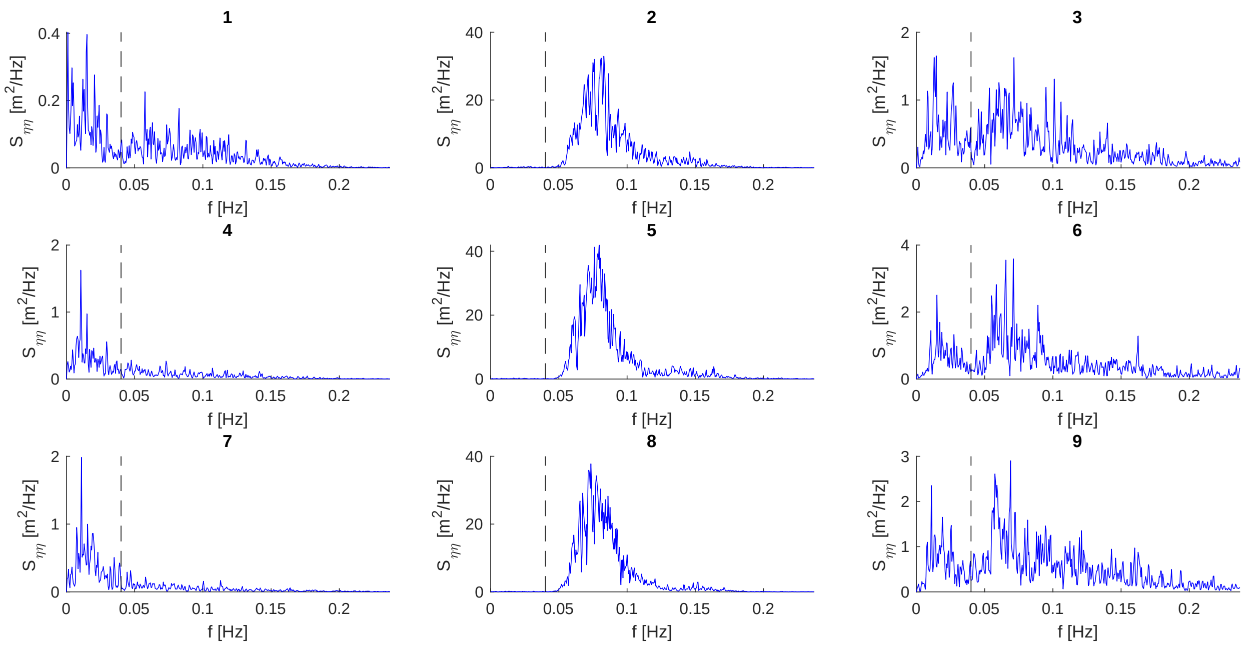

Figure 5-35. Wave energy spectra at XBeach Punaluu/Hauula probe locations for 25-yr hurricane (Douglas) swell

Table 5-4. Maximum wave conditions at shoreline probe locations

	wave height		surge height	
Probe Station	**H_s** feet	Max Ord. Wave - source -	**H_s (IGW)** feet	Max Surge - source -
(1) Kualoa Park	2.36	NW Far-field	0.86	hurricane
(2) Kualoa Ranch	2.21	NW Far-field	0.91	hurricane
(5) Kaaawa Kaoio Pt	4.29	NW Far-field	1.93	hurricane
(8) Kaaawa Stream	2.40	NW Far-field	1.55	hurricane
(11) Kaaawa 711	2.94	NW Far-field	1.15	hurricane
(14) Crouching Lion	3.37	NW Far-field	1.14	NW Far-field
(1) Punaluu P2	2.40	NW Far-field	1.53	NW Far-field
(4) Punaluu P1	2.15	NW Far-field	1.16	hurricane
(7) Hauula	2.02	NW Far-field	1.44	NW

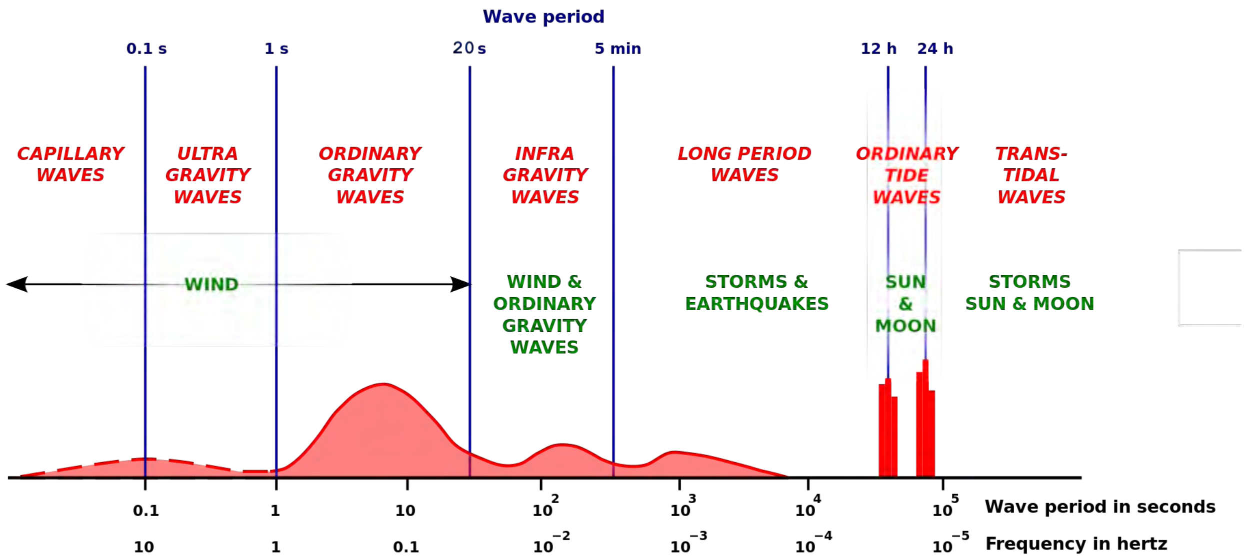

Figure 5-36. Types of ocean waves within the full spectrum according to wave period and frequency. (*Adapted from Munk, 1950*)

As shown in Table 5-4, modeled wave heights (e.g., significant wave height) varied somewhat among the different repair locations, but in general were found to be under 5 ft for all shoreline sites. Nearshore depth also varied between the sites, and in fact was found to vary widely within each site in some instances. Depth at the shoreline can have an important effect on final design wave heights, which will be discussed in more detail in Section 5.

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6. SHORE PROTECTION ALTERNATIVES

6.1 Introduction

The key objectives of the Kamehameha Highway KKPH shore protection project are to:

- Ensure that the existing alignment of Kamehameha Highway is sufficiently protected from advancing coastal erosion, allowing it to remain open and serviceable for commuters, commerce, emergency services, and all motorists for the next 25 years—a period during which a long-term permanent solution shall be developed and implemented.
- Reduce or minimize wave overtopping onto the highway under design wave conditions through 2047.
- Increase the resilience of the highway to coastal hazards and sea level rise through 2047.

Several alternatives were considered in terms of their suitability and performance under the project site conditions, and determinations were made in relation to achieving the project objectives. Those alternatives include:

- No Action
- Managed Retreat
- Beach Nourishment
- Revetment
- Hybrid Seawall with Armor Stone Apron

Alternatives were evaluated based on the following criteria:

- Effectiveness (i.e. capable of achieving the project objectives)
- Design Considerations (i.e. suitability, durability, design life)
- Costs (relative)
- Feasibility (i.e. constructability, regulatory requirements, community support/opposition)
- Potential Impacts (i.e. coastal processes, marine habitat, shoreline access, adjacent properties)

Ideally, the recommended engineering alternative would satisfy the project objectives, while minimizing potential negative impacts to the environment and adjacent shorelines.

6.2 No-Action

The No-Action alternative would involve leaving the highway in its existing condition with no repairs or modifications. This approach would do nothing to protect the condition or functionality of the highway. The highway is approximately 100 years old and is exposed to near constant erosional forces along with rising sea levels. If the highway is not protected, this critical transportation link can be expected to quickly continue deteriorating, with wave action undermining large sections of the roadway in multiple locations leaving them unsupported and partially collapsing. If the roadway deteriorates to a point that it is no longer serviceable, the entire road deck may fail, collapsing completely and leaving large sections of exposed earth along the erosion scarp, generating significant plumes of discolored water in the nearshore regions due to suspended clays and mud.

Advantages

- No cost.

Disadvantages

- Does not increase the resilience of the project sites to sea level rise.
- Does not address protection of the highway or keeping it open and serviceable.
- Does not reduce wave overtopping under design wave conditions.

No-Action would have no immediate impacts to the project sites, adjacent nearshore waters, marine habitat, or adjacent properties. However, the likelihood of future failure or collapse would increase significantly over time. If no mitigative action is taken to strengthen or protect the highway, damage will continue and the level of deterioration of the highway could eventually result in significant negative impacts to the project sites, their nearshore waters, marine habitats, and adjacent properties. No-Action would not increase the resilience of the project site to sea level rise. No action is therefore not a preferred alternative.

6.3 Managed Retreat

Managed retreat (also referred to as adaptive realignment) is a coastal management strategy that is intended to allow an eroding shoreline to naturally migrate inland, in contrast to fixing the shoreline position with engineered shore protection structures. Managed retreat typically involves modification, relocation, or removal of existing structures to reduce hazard exposure and maintain a natural shoreline. Managed retreat strategies can be horizontal or vertical in nature. *Horizontal* retreat strategies seek to reduce hazard exposure by moving structures further inland. *Vertical* retreat strategies seek to reduce hazard exposure by elevating structures above the hazard.

The KKPH project is composed of a series of discontinuous individual sites located within Oahu's Koolauloa District, strung along the coastal highway from Kualoa in the south through Kaaawa and Punaluu, and finally Hauula in the north. Landward of the shoreline in these locations, the terrain is characterized by a narrow low-elevation coastal plain which typically abuts the steeply rising slopes of the Koolau Mountains. For most of the project sites identified along Kamehameha Hwy, this coastal plain is fully occupied by developed residential communities. A managed retreat for these sites would require realignment of the highway through existing homes and private properties, or alternately, through steep mountainous terrain at the base of the coastal slopes currently designated as a preservation district.

Advantages

- Reduces vulnerability of transportation infrastructure to coastal hazards and sea level rise.
- Avoids costs and requirements associated with shore protection or beach restoration.
- Allows the shoreline to migrate naturally.

Disadvantages

- Requires government acquisition of large areas of private property and forcible displacement of local residents within the realigned highway corridor.
- Expected to be extremely costly, due to combination of required land acquisitions, new highway engineering and construction costs.

- Likely to incur widespread opposition from local communities.
- Does not address the condition of the existing highway, and if left in place with no action the potential ruins and debris along shoreline from abandonment of those portions of highway will be problematic.
- Currently there are no existing rules, programs, or policies in place to manage or facilitate the retreat process.

Managed retreat is a relatively new concept that is being evaluated for applicability in Hawaii. The State Office of Planning recently published a report entitled, "Assessing the Feasibility and Implications of Managed Retreat Strategies for Vulnerable Coastal Areas in Hawaii." The study evaluated options to establish policies, regulations, tools, and programs to support a managed retreat strategy in response to sea level rise. The study found that *retreat* is one of three primary adaptation strategies, along with *accommodation* and *protection*, and that, prior to deciding upon retreat, accommodation and protection must be examined to determine which strategy is the best for the area of interest in dealing with coastal hazards, climate change and sea level rise. The study also found that retreat is only effective when done voluntarily, and that economic incentive programs designed to fund retreat like buyouts, transferrable development rights, rolling easements, and so on, are unlikely to be effective due to the high value of real estate in Hawaii. Importantly, the report noted that retreat from chronic coastal hazards like erosion and sea level rise is an incremental process and typically takes decades to complete.

Managed Retreat at the KKPH project site would likely involve removal of the existing highway, which would allow the current shoreline area to erode and any present beach material to migrate naturally along the coast. Managed Retreat would avoid the costs associated with design, permitting, and construction of shore protection measures or beach restoration; however, combined costs associated with realigning, relocating, and removing the existing highway would be substantial. In the absence of the existing highway, the terrestrial area in the vicinity would be exposed to erosion and flooding, creating many sources for large mud plumes in the nearshore waters due to newly exposed earthen embankments created from the collapsing roadway corridor, and the project site would generally be more vulnerable to coastal hazards and sea level rise.

Managed retreat may turn out to be a component of the long-term solution—possibly the only long-term solution—but it is not recommended at this time. The existing highway is generally in a good and serviceable condition and can be maintained, repaired, and protected to increase the resilience of this critical roadway to coastal hazards and sea level rise for the next two to three decades. Until retreat is determined to be feasible, desirable, or necessary; and rules, programs and policies are in place to facilitate the retreat process, other appropriate solutions should be considered for the near to mid-term range. Managed retreat is therefore not the preferred alternative.

6.4 Beach Nourishment

Beaches naturally absorb and dissipate wave energy. *Beach nourishment* involves the placement of additional beach material sourced offshore or off-site and graded to specified elevations and profiles that are designed to augment the natural morphology of the existing beach, which is carried out to offset the effects of chronic, seasonal, or episodic beach erosion. Regulatory agencies and the public are generally supportive of beach nourishment because it has minimal environmental impacts and is consistent with State and County policies that seek to preserve and enhance beach resources.

Beach nourishment projects are regulated by Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act, which regulate discharges of fill material into waters of the United States. These regulations all consider any potential beach nourishment material to be *fill*. Placement of fill material seaward of the mean higher high water (MHHW) line is generally prohibited by regulators. Often, placement of fill material is limited only to those areas where an existing beach is typically present and additional fill is required to maintain a stable beach profile. Although some portions of the KKPH repair sites do have a stable beach, many of the shoreline areas in consideration under this project are not known to have significant beach formations along much of their lengths.

A major constraint that can diminish the effectiveness of beach nourishment projects is the attrition of newly placed beach material due to natural processes such as suspension and transport via longshore and cross-shore currents, particularly during higher tides and periods of elevated surf. Some areas have natural features such as headlands, harbors, or reefs that disrupt sediment transport and naturally stabilize the beach material. However, in many other cases, it may be necessary to construct engineered beach containment structures such as groins or jetties, which serve to trap and maintain a stable beach within their vicinity.

Advantages

- Provides a temporary increase in beach volume and width (without groins);
- Provides a more permanent increase in beach volume and width (with groins).
- Increases wave absorption and provides additional protection against wave overtopping.
- SSBN authorizations may allow for periodic renourishment.
- Agencies and the public are generally supportive of beach restoration projects.

Disadvantages

- Offshore sand borrow sites are expensive to explore and difficult to exploit, particularly for windward exposures.
- Terrestrial sand sources are scarce and often not viable.
- Much of the project area does not have existing beach material in significant volumes and would therefore not be an applicable location for beach nourishment.
- Requires an adequate quantity of compatible beach quality sand.
- With respect to environmental regulations, nourishment requires discharge of a large volume of fill material (sand or stone for groins) in waters of the United States.
- Sand is unlikely to remain stable without engineered stabilizing structures.
- Recurring costs for periodic renourishment could be high without engineered stabilizing structures.
- Construction costs for required array of groins would be high.
- Regulatory requirements are onerous.

Beach nourishment would increase beach width along the project sites. Some of the project areas, at least in part, already exhibit a stable beach. However, without engineered stabilizing structures like groins, the beach profile would be unstable and likely transient, and the sand would eventually be redistributed along the shoreline or transported offshore into one of the many channeled areas bisecting the fringing reef. Beach nourishment with stabilizing structures would create a stable beach, improve lateral shoreline access, and provide long-term protection for the terrestrial area and roadway. However, the project would require a large array of costly groin or breakwater structures along the highway's shoreline and would have a combined footprint that was very large, particularly in the water. Beach nourishment with or without stabilizing structures is therefore not a preferred alternative.

6.5 Revetment

A revetment is a sloping, un-cemented rubble mound structure constructed of wave-resistant material, often including stone or concrete units. The most common method of revetment construction is to place a layer of armor stone sized according to site-specific design wave height, installed over an inner layer of smaller stone (underlayer) that rests on a core or prepared slope covered with filter fabric. The underlayer is designed to distribute the weight of the outer armor layer and to prevent erosion and loss of fine material from the supporting embankment or core through voids in the revetment stone. An example of a rock revetment is provided in Figure 6-1, which illustrates the porous irregular surface of the revetment's outer armor layer.

Figure 6-1. Example of rock (rubble mound) revetment, Kahului Harbor, Maui

Properly designed and constructed rock revetments are durable, flexible, and highly resistant to wave damage. If scour threatens to undermine the base or *toe* of the revetment, the structure is able to accommodate moderate displacements and settle into the scoured-out region, allowing readjustment of the upper armor units without major failure. Damage from excessive wave heights is typically not catastrophic, and the revetment remains functional even if damage does occur.

A significant advantage of rock revetments is derived from their rough, porous, and permeable rock layers along with the sloping seaward face of the structures which combine effectively to absorb wave energy and reduce wave reflection. When designed appropriately revetments may even promote local accretion of beach material when sufficient sand volume is available in the littoral environment. Additional advantages of rock revetments include: the stone materials are readily available; localized damage can be rapidly repaired by placement of additional stone; and, the natural appearance of the rock structures is often visually pleasing. Properly designed and constructed rock revetments are durable, flexible, and highly resistant to wave damage.

A disadvantage of revetments is that they require a relatively large horizontal footprint, which can be problematic in a coastal setting due to strict regulatory constraints. Revetments are typically constructed in areas where the shoreline area is already threatened by erosion, such as along roadways. In these locations, the erosion threat is typically so severe that there is no room to maneuver; shifting revetment placement landward is constrained by the existing road, and so it can only be constructed seaward of the shoreline, which often has eroded up to the base of the road.

Revetments are generally known to be more effective in reducing wave reflection, runup, and overtopping, by gradually absorbing the moving water's momentum and thereby increasing the potential for sand accumulation seaward of the structure. The rough and porous surface and sloping face of revetments effectively absorb and dissipate wave energy, in contrast to sea walls whose smooth vertical surfaces are highly reflective and often inhibit beach accretion in dynamic environments. Due to its durability, flexibility, and reduced reflectivity, a revetment—or similar form of rubble mound structure—is often considered the best shore protection measure for sites where shoreline hardening is considered appropriate. Based on the above characteristics, an engineered rock revetment is generally the preferred alternative for the KKPH project sites.

Advantages

- Increases resilience to coastal hazards and sea level rise.
- Provides additional protection against wave overtopping and over-wash onto the road deck.
- Better wave energy dissipation characteristics than a seawall.
- Less reflective than a seawall and may facilitate sand accretion seaward of the structure.
- Does not negatively impact shoreline access compared to existing conditions.
- May be possible to leverage existing stone or riprap on site installed as part of previous emergency repairs.

Disadvantages

- Largest structural footprint of the options considered.
- Moderate to high costs for design, permitting, and construction.
- Regulatory requirements are onerous.

An engineered revetment is an appropriate solution for the KKPH project sites and would satisfy project objectives to protect the existing highway against coastal erosion forces, reduce or minimize wave overtopping and wave over-wash onto the road, and increase the resilience of the highway to sea level rise for the next quarter century while longer-term solutions are developed.

A revetment would not fundamentally alter the character of the project shoreline in this area, which already incorporates many discontinuous stretches of non-engineered riprap and rock repairs along its length. An in-depth discussion with details for the preferred rock revetment alternative are provided in the following section (Section 7).

6.6 Hybrid Seawall With Armor Stone Apron

Another shoreline hardening solution applicable to certain limited areas of the project is a *hybrid seawall* combined with an armor stone toe apron. The hybrid seawall is a shore protection structure that combines the small footprint of a vertical wall with the absorptive properties of a revetment in a low-height sloping rock apron at its base—used for protection of the wall's foundation from scour and undermining. A hybrid seawall would be constructed from two primary elements, including a seawall (which could include sheet pile, reinforced concrete, or cemented rock masonry), and an uncemented armor stone rubble-mound apron installed over a geotextile filter layer. An existing example of what a hybrid seawall might look like is illustrated in Figure 6-2 below, from a site which is located in Kapaa on the island of Kauai.

Figure 6-2. Example of existing hybrid seawall with rock apron (armored toe), Kapaa, Kauai

The key benefit of a hybrid seawall is that it combines the effectiveness and minimal disturbance footprint of a vertical wall, with the dissipative and absorptive characteristics of a rock revetment—which is more consistent with strategies to promote beach preservation.

Hybrid seawalls can also be designed as adaptable, to withstand increasing wave conditions as sea level rise progresses, by incrementally increasing wall crest height and correspondingly augmenting the rock apron with larger stone and raising the apron's crest height. Other advantages of a hybrid seawall are that construction materials are readily available, and localized damage to the armored apron can be easily repaired by placement of additional armor stone. Properly designed and constructed hybrid seawalls are durable, flexible, and highly resistant to wave damage. On the other hand, because the hybrid seawall is a compromise between size and function, its performance does not match that of an equivalent rock revetment in terms of wave absorption and reflectivity.

Advantages

- Reduced horizontal footprint.
- Increases resilience of highway to coastal hazards and sea level rise.
- Provides additional protection against wave overtopping.
- Structure could be adapted to withstand future design water levels.
- Better wave energy dissipation characteristics than a conventional seawall.
- Less reflective than a conventional seawall.
- May facilitate sand accretion seaward of the armor stone apron.
- Appropriate for project sites with low wave energy environments.
- Appropriate for project sites with low elevations.

Disadvantages

- Although smaller than for a revetment, a hybrid seawall still has a significant horizontal footprint when compared to a conventional wall.
- Highest costs for design, engineering, permitting, construction, and future modifications.
- Not appropriate for higher energy wave environments.
- Not appropriate for large vertical spans.
- Regulatory requirements are onerous.

A hybrid seawall with armor stone apron is an appropriate engineering solution for the lowest elevation project sites with the smallest design wave heights and would satisfy the project objectives to protect the highway from existing coastal erosion forces, reduce wave overtopping, and increase the resilience of the highway to sea level rise.

Optionally, a recurved wall crest cap may also be a useful addition in the future with higher water levels, to deflect wave over-wash and debris back away from the road.

It is not recommended to utilize conventional seawalls alone, without additional absorptive or dissipative features, anywhere in the project area due to their reflective characteristics. These types of vertical structures by themselves are not consistent with beach preservation.

7. ROADSIDE SHORE PROTECTION DESIGN

7.1 Introduction

Kamehameha Highway hugs the coast of northeast Oahu's Koolauloa district, particularly for stretches in Kualoa, Kaaawa, Punaluu and Hauula, where there is frequently little-to-no buffer between the road shoulder and the open waters of the Pacific Ocean. Unsurprisingly, over the years the highway has become threatened by chronic and progressive erosion occurring at increasing rates along numerous stretches of this critical transportation link. In several of the worst-affected locations, the seaward edge of the road deck has been significantly undermined causing failure and collapse, with temporary 'emergency-repairs' having been required for near-term stability just to keep the roadway open. This assemblage of non-engineered stopgap emergency repairs has been completed ad-hoc and as needed in a rapid manner in order to keep traffic flowing and communities connected. These emergency repairs were not intended to serve as long-term solutions. To address the mid-to-longer-term needs, development of site-specific design criteria was necessary to engineer and design conceptual roadside shore protection measures that would be sufficiently durable to keep the road in a safe and serviceable condition for the next quarter century. The following sections of this document address these criteria in greater detail.

7.2 Design Depth

In terms of engineering shore protection structures, *design depth* (local depth as measured from the base or seaward toe of the structure) is an important quantity not just for the physical dimensions of the structure itself, but also for its implications on design wave height and scour considerations. For some locations, like those with relatively flat surroundings or gently sloping relief, assigning a design depth is clearly a straightforward process. However, for other locations that happen to reside in complex or convoluted terrain with many ups and downs—as is the case for several of the KKPH project repair sites—arriving at a fair and representative design depth can be more of a challenge. For these situations, a reasonable, repeatable, and quantifiable method of developing a representative design depth was desired for project sites with long variable stretches of shoreline. This depth assessment method should minimize bias and eliminate excessively conservative over-estimates or overly liberal under-estimates.

With that goal in mind, a design depth assessment method was formulated for this project based on a simple statistical analysis of high-resolution LiDAR topo-bathy data (NOAA, 2013). The method uses a 100, 200, or 300-ft highway centerline offset (depending on location and beach width), to drape a road-parallel offset line on the LiDAR-based digital terrain model (DTM) to produce an elevation profile along this seaward parallel offset. Take for example, the repair site designated with the ID "Kaaawa.school," represented by the magenta line in Figure 7-1. This reach of Kamehameha Hwy was initially considered as one repair site, however, based on the depth analysis it appears to contain two distinctly different nearshore depth environments—one being quite shallow and protected directly by a fringing reef; the other being significantly deeper and adjacent to a large channel that cuts through the reef complex. To ascertain the representative depths along the shoreline for this stretch, a nearshore profile was developed by offsetting the road centerline by 200 ft seaward in this case, as illustrated in the figure. Further, the parallel profile was divided at an approximate inflection point to separate the two distinctly different bottom types, labeled "Kaaawa.school.south" (purple/white line) and "Kaaawa.school.north" (yellow/red line), respectively. Draping the offset profile lines onto the LiDAR bathymetry results in the elevation plots presented in Figure 7-2, where the left plot represents depth (negative elevation = depth below MSL) for the northern profile which lies on the shallow reef, and where the right plot reveals the deeper channel section fronting the southern profile, which is nearly twice as deep. The discontinuity in depth is clearly visible in the satellite imagery shown in Figure 7-1, where the shallow reef drops into the sand channel.

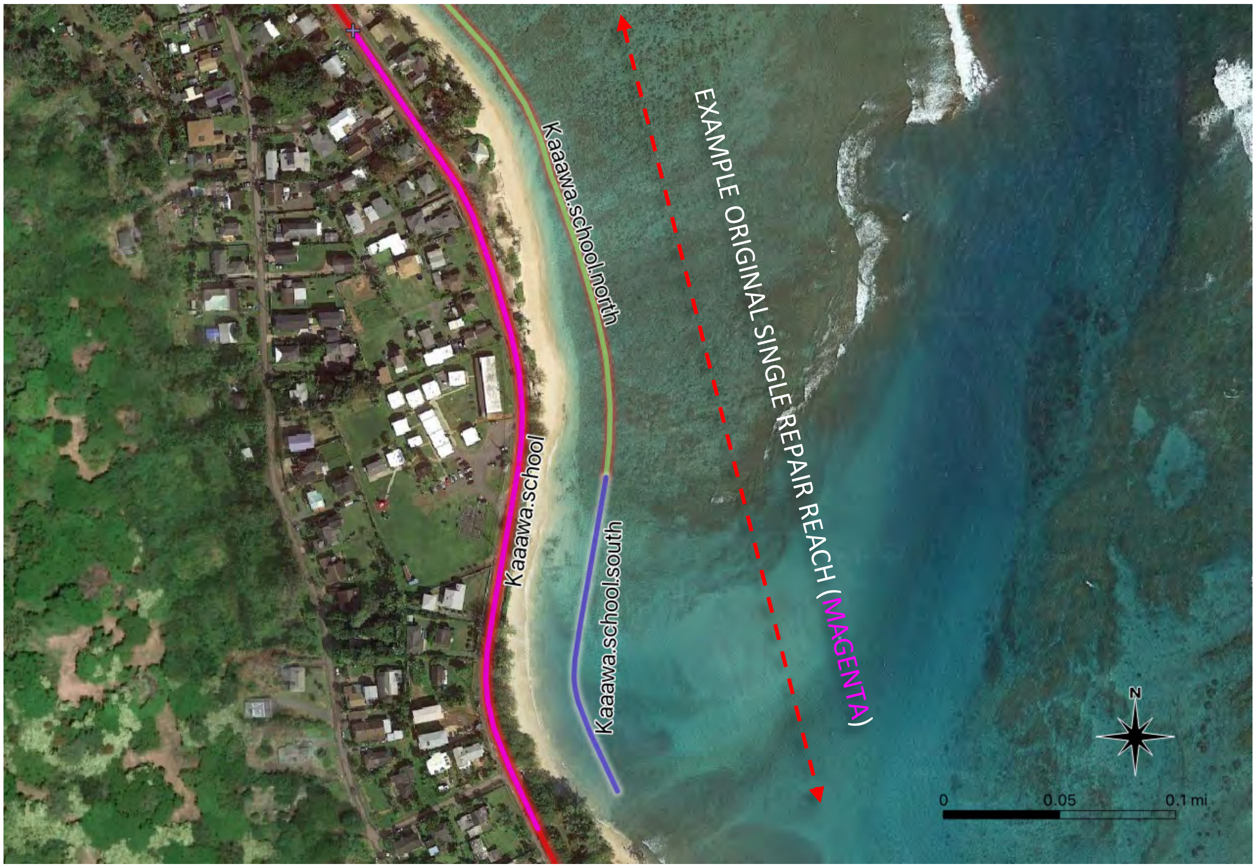

Figure 7-1. Repair reach partitioning example, for "Kaaawa.school" – new partitions in dark purple and yellow

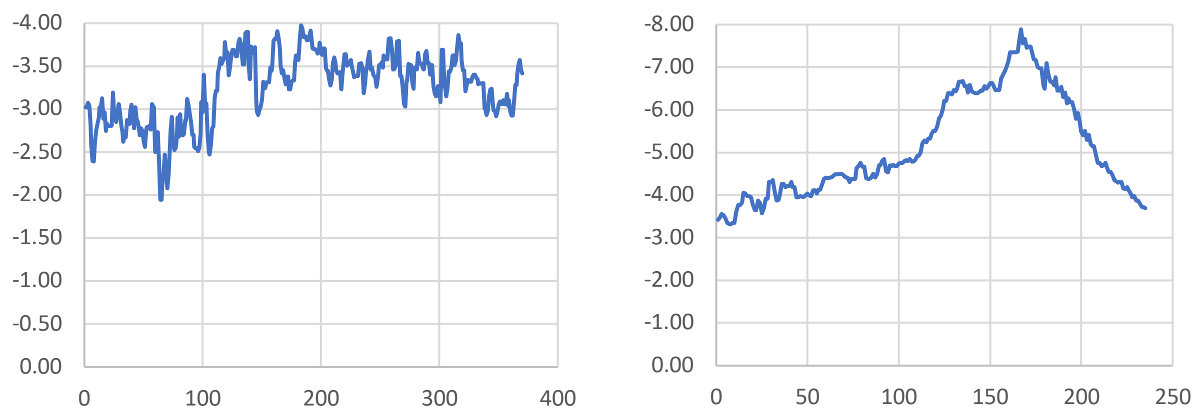

Figure 7-2. Depth profiles for "Kaaawa.school" nearshore partitions for north (*left*) and south (*right*). Vertical axis for elevation and horizontal axis for distance along profile from north end.

Similar depth profiles were developed for each of the identified repair reaches shown in Figure 1-12 and were partitioned as necessary based on the results. In total, three of the originally designated repair areas required partitioning. A summary of repair reach partitions is provided in Table 7-1 below, where they are listed by reach ID, along with the average nominal depth (in feet below MSL) for each partition. Additionally, the *standard deviation*, σ (sigma), of depth along profile is also given for each partition. Due to the variation of depth along each profile, with many high and low spots for each area, the final nominal design depth for each partition was taken to be the average profile depth plus one standard deviation, as shown in the last column of Table 7-1. The additional term of 1σ was added to profile design depth in order to reasonably accommodate a more conservative estimate for depth by weighting the deeper sections of each profile, where the deeper waters are capable of yielding larger wave heights and thus more conservative forces for design. Design wave heights are discussed in detail in Section 7.4.

Table 7-1. Summary of repair areas with depth partitioning and average nominal depths

Repair Site Name	Depth-based Partition (*Partition in parentheses*)	Avg. Depth (MSL) *fronting structure*		Depth + 1σ
		depth (ft)	σ *(ft)*	*(ft)*
Kualoa.Npark	Kualoa.Npark	1.77	0.23	2.0
Kualoa.ranch	Kualoa.ranch	1.91	0.28	2.2
Kaaawa.surf	Kaaawa.surf (*south*)	4.95	0.86	5.8
	Kaaawa.surf (*mid*)	2.47	0.70	3.2
	Kaaawa.surf (*north*)	7.02	0.40	7.4
Kaaawa.school	Kaaawa.school (*south*)	5.13	1.20	6.3
	Kaaawa.school (*north*)	3.25	0.40	3.6
Kaaawa.710	Kaaawa.711	2.13	0.69	2.8
Kaaawa.CL	Kaaawa.CL (*south*)	1.86	0.69	2.6
	Kaaawa.CL (*north*)	2.97	0.63	3.6
Punaluu.P2	Punaluu.P2	4.46	1.03	5.5
Punaluu.P1	Punaluu.P1	3.57	0.75	4.3
Hauula	Hauula	3.07	0.89	4.0

7.3 Design Water Levels (Dynamic & Static)

In addition to the still water level components discussed in Sections 5.1.1 through 5.1.3 and shown in Table 5-3, there are also dynamic water level contributions that must be considered as part of any water level analysis for the design of shore protection structures. These dynamic components of water level are characterized as transient and can change significantly within time periods much shorter than a tidal cycle. Examples of dynamic water level components include wave setup (or set-down), infra-gravity waves (wave-generated surge), and storm surge due to cyclonic tropical storms. However, since the design standard for this effort does not encompass designing specifically for a hurricane-level event, storm surge will be excluded from the analysis, leaving wave setup and infra-gravity wave (IGW) surge.

Wave setup and wave surge are both acutely site-specific phenomenon and depend heavily on the surrounding nearshore bathymetry as much as the source wave conditions—because of this, some locations may be greatly affected, while nearby adjacent locations may not be, depending on the submerged terrain. Consequently, numerical wave modeling becomes invaluable for its ability to quantify these phenomena effectively and efficiently. The series of nearshore wave models presented in Section 5.3 of this analysis provided site-specific results for these components, reported at the model's shoreline probe station locations shown in Figure 5-27. The aggregate total of water level components, both static and dynamic, have been gathered in Table 7-2 and listed by repair site. Wave setup and surge heights were derived from the numerical modeling scenarios, using the largest of the resulting values per site. The values used for MHHW, 25-yr SLR, and sea level anomaly are constants, and given in Table 5-3 in Section 5.1.4. Final design depth reported by repair reach is provided in the last column of Table 7-2, which represents the depth of water at the toe or base of the planned shore protection structure.

Table 7-2. Summary of water level components for design water levels, listed by repair area

Repair Site Identifier	**Nom. Depth (MSL)**		**Depth +1σ**	**MHHW** *cumulative*	**SLR-25** *cumulative*	**SLA** *cumulative*	**Wave Setup** *site-specific*	**IGW Surge** *site-specific*	**Design Depth** *cumulative*
	depth (ft)	*σ (ft)*	*(ft)*	*(ft)*	*(ft)*	*(ft)*	*(ft)*	*(ft)*	*(ft)*
Kualoa.Npark	1.77	0.23	2.0	3.09	4.76	5.26	0.17	0.86	6.30
Kualoa.ranch	1.91	0.28	2.2	3.29	4.96	5.46	0.19	0.91	6.56
Kaaawa.surf (south)	4.95	0.86	5.8	6.91	8.58	9.08	0.22	1.93	11.24
Kaaawa.surf (mid)	2.47	0.70	3.2	4.27	5.94	6.44	0.22	1.93	8.60
Kaaawa.surf (north)	7.02	0.40	7.4	8.52	10.19	10.69	0.22	1.93	12.85
Kaaawa.school (south)	5.13	1.20	6.3	7.43	9.10	9.60	0.24	1.55	11.39
Kaaawa.school (north)	3.25	0.40	3.6	4.75	6.42	6.92	0.24	1.55	8.71
Kaaawa.711	2.13	0.69	2.8	3.92	5.59	6.09	0.28	1.15	7.53
Kaaawa.CL (south)	1.86	0.69	2.6	3.66	5.33	5.83	0.29	1.14	7.26
Kaaawa.CL (north)	2.97	0.63	3.6	4.71	6.38	6.88	0.29	1.14	8.31
Punaluu.P2	4.46	1.03	5.5	6.59	8.26	8.76	0.20	1.53	10.49
Punaluu.P1	3.57	0.75	4.3	5.42	7.10	7.60	0.23	1.16	8.99
Hauula	3.07	0.89	4.0	5.06	6.74	7.24	0.20	1.44	8.87

7.4 Design Wave

Determination of design wave height is typically a key consideration for coastal engineering projects—wave loads often dictate the maximum forces used for design, and consequently wave height needs to be assessed thoughtfully. Due to the significance of waves, extensive numerical modeling of peak deep-water wave conditions was employed for this effort in order to conduct a detailed assessment for the roughly 13-mile discontinuous project shoreline—a shoreline that along its length includes great variation in exposure and terrain. Results of the modeling analysis are detailed in Section 4, with key values summarized in Table 5-4, which records maximum significant wave height ($H_{1/3}$) and surge for each repair site, along with indication of which out of the four wave source scenarios was responsible for the listed maximum value. Extensive wave stability tests performed in wave flumes under random and regular wave fields have shown that equivalent regular wave height for random wave spectra may actually vary between $H_{1/5}$ and $H_{1/10}$.[‡‡] Therefore, model output $H_{1/3}$ wave heights were converted to equivalent $H_{1/10}$ values for use in design calculations. Lastly, actual determination of design wave heights from the raw modeling data requires further consideration: In this case, it was necessary to compare the modeled nearshore wave heights with the theoretical *depth-limited* wave height, defined as the maximum wave height that may physically exist at a specified depth and bottom slope before breaking. For stable and progressive regular waves over a generic bottom, the *breaker index*—a ratio of wave height to water depth—has a theoretical value of 0.78. However, depth-limited wave height for flat or low-sloped foreshore areas (a nearshore characteristic that exists for much of the project length) has been shown to average 0.55 for irregular (mixed sea and swell) wave fields (Rattanapitikon and Shibayama, 2000). Design depths from Table 7-1 are subsequently used to calculate depth-limited wave heights for each site, and are paired with respective modeled wave heights, as shown in Table 7-3.

Table 7-3. Summary of design wave heights, by repair site

(1)	(2)	(3)	(4)	(5)	(6)
Repair Site Name	**Design - MSL** *depth* *(ft)*	H_{DL} Wave *depth-limited* *(ft)*	$H_{1/3}$ Wave *modeled* *(ft)*	$H_{1/10}$ Wave *1.27 $H_{1/3}$* *(ft)*	**Design Wave** *(ft)*
Kualoa.Npark	3.67	2.99	2.36	3.00	**3.0**
Kualoa.ranch	3.74	3.11	2.21	2.81	**3.1**
Kaaawa.surf (south)	4.36	5.12	4.29	5.45	**5.5**
Kaaawa.surf (mid)	4.20	3.67	4.29	5.45	**5.5**
Kaaawa.surf (north)	3.90	6.01	4.29	5.45	**6.0**
Kaaawa.school (south)	4.71	5.41	2.40	3.05	**5.4**
Kaaawa.school (north)	3.92	3.94	2.40	3.05	**3.9**
Kaaawa.711	4.25	3.51	2.94	3.73	**3.7**
Kaaawa.CL (south)	4.26	3.37	3.37	4.29	**4.3**
Kaaawa.CL (north)	4.20	3.94	3.37	4.29	**4.3**
Punaluu.P2	4.50	4.93	2.40	3.04	**4.9**
Punaluu.P1	4.25	4.30	2.15	2.73	**4.3**
Hauula	4.37	4.09	2.02	2.57	**4.1**

[‡‡] $H_{1/5}$ and $H_{1/10}$ represent the average wave height of the highest one-fifth of waves, and of the highest one-tenth of waves, respectively. They are both higher than the significant wave height, which is the average of the highest one-third of waves, $H_{1/3}$.

The final design wave height shown in the last column on the right (6) of Table 7-3, was determined as the greater of the two columns, (3) the depth-limited wave and (5) the modeled wave height, $H_{1/10}$. By setting the design wave height as the greater result of two independently calculated methods, a measure of conservatism is added to the design criteria, in an attempt to account for real world complexities and complicated non-linear phenomenon that occur in nearshore hydrodynamics that might not be captured by the modeling analysis. The values in column (2) represent the design depth in feet above MSL (e.g., design depth minus depth at MSL).

7.5 Armor Unit (Rubble Mound Shore Protection Structures)

Rubble mound structures, such as breakwaters or revetments, are protective and dissipative structures that are built around an impermeable core of small diameter stone or gravel, armored against waves and other peak hydraulic forces by a cover layer of much larger stone or concrete units. Voids formed within a rubble mound revetment's slope, including the interstitial spaces between the individual armor stone units and between the underlayer, act to gradually absorb the water's energy and motions, while the core or underlayer protects the underlying embankment from erosion.

Rubble mound revetment design is reliant on known peak wave conditions and/or current velocities to which the armor units will be subject. For typical coastal applications, determination of these parameters is a well-documented process, based on established empirical relationships between required armor unit weight for given wave conditions, structure depth and dynamic water levels, which are presented in detail in Sections 3 and 4 of this report. With this information in hand, it is now possible to design a rubble mound shore protection structure with appropriately sized armor units, structure slope, embedment depth, and other requirements, on a site-by-site basis.

7.5.1 Armor Stone

Design of conceptual roadside shore protection revetments applied methods and procedures in accordance with national standards provided by the US Army Corps of Engineers (USACE), primarily from the Coastal Engineering Manual (CEM), EM 1110-2-1614, *Design of Coastal Revetments, Seawalls, and Bulkheads*.

Typically, a rubble mound structure such as a breakwater or revetment is composed of several layers of randomly shaped and randomly placed small diameter stones or riprap forming a permeable core, protected with a highly permeable cover layer of armor units which may be either quarry stone or precast concrete units. The core layer is defined by the CEM as an inner, much less permeable portion of a breakwater or revetment; the cover layer is defined as the outer layer of armor units used in a rubble mound system as protection against external hydraulic loads (USACE, 2003).

7.5.1.1 Stone Size

Revetment stone sizing is based on the water levels, wave heights, and additional parameters shown in Table 7-2, Table 7-3 and Table 7-4, respectively, where armor unit *weight* is considered the primary criterion for stability. Determination of appropriate stone weight and nominal diameter was accomplished through use of an empirical formula that relates the required mass of armor stone units to the design wave height and structure slope. For this calculation, the Coastal Engineering Manual recommends use of *Hudson's Formula*, which computes the individual armor unit weight, W (or for graded riprap, W_{50}, the median weight) from the following relationship:

$$W = W_{50} = \frac{\gamma_r H^3}{K_D\left(\frac{\gamma_r}{\gamma_w} - 1\right)^3 \cot\theta}$$ ***Equation 1.*** *(Eq. 2-15, CEM)*

where,

W	Individual armor stone weight; becomes W_{50}, median stone weight, for graded riprap
H	Design wave height, varies, see Table 7-3 (assumes 25-yr life)
γ_r	Specific weight of rock, assumed as 160 lbf/ft^3 (Hawaiian quarry stone)
γ_w	Specific weight of sea water, 64.2 lbf/ft^3
n	Nominal number of layers forming revetment armor layer, typically 2
K_D	Stability coefficient, which is 2.0 for rough angular quarry stone, 2.2 for riprap; also depends on value of *n*. From Table 2-3, EM 1110-2-1614 (USACE).
$\cot\theta$	Cotangent of structure slope, varies from 1:1.5 to 1:3 (V:H), therefore $1.5 \leq \cot\theta \leq 3$

Table 7-4. Summary of additional stone sizing parameter values

Parameter	Description	Value	Units
H	Design wave height	Table 7-3	ft
γ_w	Density of seawater	64.2	lbf/ft^3
$\cot\theta$	Cotangent of structure slope	1.5 to 3	--
γ_r	Density of stone	160	lbf/ft^3
n	Number of armor layers	2	--

Using the formula shown in Equation 1 and the additional parameters in Table 7-4, and assuming for the moment a minimized structure horizontal footprint for a slope of 1:1.5, the resulting stone weight, *W* required for a revetment cover layer, per repair site, is summarized in Table 7-5. In general, the table shows that required stone weights vary between 606 and 5,672 lbf among the various sites, with the smallest units with a nominal diameter of 1.6 ft needed in Kualoa, while the largest at 3.3 ft would be necessary in Kaaawa. Median underlayer stone weights similarly varied from 61 to 567 lbf, equivalent to nominal diameters of approximately 0.7 to 1.5 ft. The 'unit type' column in Table 7-5 indicates whether the design weight refers to an *armor unit* or *graded riprap* type of cover layer, where riprap is only applicable to those sites with a design wave height less than 5 ft. Riprap is often more desirable when conditions allow, as it is generally easier to construct and materials more readily available. However, it has been noted during recent construction activities for revetment and breakwater projects on Oahu, that obtaining from local quarries or contractors the desired volume of stone with the necessary gradations of stone sizes required for the riprap specification has been difficult to impossible. For this reason, all riprap sections shown in Table 7-5 may alternatively be replaced by an equivalent two-layer armor stone cover layer if it is later determined that the stone gradation supply issue persists.

For armor unit cover layers, the CEM states that armor stones may vary in weight within the cover layer from 0.75W to 1.25W (may be increased to 2.0W) as long as 50 percent of the units weigh at least *W,* and the gradation is uniform across the revetment's surface. Associated nominal stone diameter, *d* was calculated in Table 7-5 from the design weight, *W* using the relationship presented by Van der Meer (1987), which equates stone diameter to the cube root of stone weight divided by specific weight, or:

$$d = \sqrt[3]{\left[\frac{W}{\gamma_r}\right]}$$ ***Equation 2.*** *(Van der Meer, 1987)*

Table 7-5. Summary of example revetment armor stone sizes, for 1:1.5 slope

Repair Site Name	Design Depth (ft)	Design Wave (ft)	Unit Type	K_D *stability coeff.*	W (W_{50}) *nom. wt.* (lbf)	d (d_{50}) *nom. dia.* (ft)	W_{UL} *underlayer* (lbf)	d_{UL} *underlayer* (ft)
Kualoa.Npark	1.8	3.46	Riprap	2.2	606	1.56	61	0.72
Kualoa.ranch	1.9	3.61	Riprap	2.2	686	1.62	69	0.75
Kaaawa.surf (south)	5.0	6.18	RA Quarry	2	3,795	2.87	380	1.33
Kaaawa.surf (mid)	2.5	5.45	RA Quarry	2	2,602	2.53	260	1.18
Kaaawa.surf (north)	7.0	7.07	RA Quarry	2	5,672	3.28	567	1.52
Kaaawa.school (south)	5.1	6.26	RA Quarry	2	3,944	2.91	394	1.35
Kaaawa.school (north)	3.2	4.79	Riprap	2.2	1,604	2.16	160	1.00
Kaaawa.711	2.1	4.14	Riprap	2.2	1,036	1.86	104	0.87
Kaaawa.CL (south)	1.9	4.29	Riprap	2.2	1,149	1.93	115	0.90
Kaaawa.CL (north)	3.0	4.57	Riprap	2.2	1,394	2.06	139	0.96
Punaluu.P2	4.5	5.77	RA Quarry	2	3,079	2.68	308	1.24
Punaluu.P1	3.6	4.94	Riprap	2.2	1,761	2.22	176	1.03
Hauula	3.1	4.88	Riprap	2.2	1,696	2.20	170	1.02

7.5.1.2 Underlayer Stone

Underlayer stone size is calculated as one-tenth the weight of the corresponding armor stone weight, *W*, as shown in the second to last column in Table 7-5, with the nominal underlayer stone diameter provided in the last column, using Equation 2. The underlayer's nominal layer thickness is equivalent to at least three-times the median underlayer stone diameter for riprap, and at least two-times the median underlayer stone diameter for use under quarry stone armor layers, per Section 2-20 (b) of EM 1110-2-1614 (CEM).

7.5.1.3 Crest Height

The design *crest* elevation for a revetted shore protection structure is typically a function of the calculated *wave run-up* elevation plus some desired amount of freeboard to prevent overtopping during design conditions. Wave run-up is defined as the maximum vertical height of water (above SWL) that propagates up the slope of the structure due to wave breaking. However, for the situation along Kamehameha Hwy, where revetment crest heights are physically limited by the existing road deck elevation and usable horizontal footprint seaward of the highway, crest heights are constrained, forcing any revetment to be designed as a submerged structure during peak design conditions. For this reason, it was found infeasible to fully protect the backshore area or other adjacent dry land areas from peak wave overtopping conditions. Rather, the revetment is intended very specifically to armor and protect the erodible foundation material directly supporting the highway travel lanes, adjacent road shoulder and seaward earthen embankment. Consequently, estimations of run-up elevation and overtopping were omitted at this time. Road deck elevations range from approximately 8 to 10 feet above MSL along this reach of highway, with revetment design crest elevations following at 1-ft above existing road deck elevation.

7.5.1.4 Development of Concepts

The range of shore protection concepts considered by this effort consists primarily of varying slopes of either riprap or armor layer revetments, contingent on site-specific design wave heights. Additionally, for a select few locations that were found to exhibit the smallest design wave heights in combination with the lowest road deck elevations, consideration was also given to a low-crested hybrid seawall combined with an armor stone toe apron. The collection of concepts presented in this document are intended to bookend a reasonable spectrum of options, per site, ranging from better performance (reduced wave overtopping and increased wave energy absorption) to least intrusive and likely more readily approvable by regulators (minimized horizontal footprint, at the cost of increased slope and reflectivity). In a few areas where it is well known that wave overtopping frequently washes onto the road deck at higher tides or periods of high surf, an extreme low slope revetment configuration is presented for its enhanced ability to absorb incoming wave energy for a limited crest height. The complete set of concept drawings is provided in the Appendix of this document. For all concepts, the following points apply:

- Crest heights of the shore protection options are limited to elevations of one to two feet above existing road deck elevation;
- All shore protection options presented herein are intended specifically to armor and protect the existing highway and supporting earthen embankment from coastal erosion, undermining and collapse, and are considered as submersible during peak conditions—the structures are <u>not</u> intended to mitigate backshore flooding due to overtopping during design wave events;
- Although a few years longer than the 25-year design life adopted for this effort, the University of Hawaii Coastal Geology Group's (UH-CGG) predicted shoreline retreat for 2050 on the island of Oahu (obtained as a vector shapefile from their website [University of Hawaii, 2022]) was generally used as the basis for horizontal limits for the alongshore extents of the shore protection structures at each site. Typically, the location where this vector line passes landward or mauka of the existing road location, would correlate to structure start/stop locations; and,
- The seaward (makai) white line edge marking (a.k.a., fog line) along the northbound lane of Kamehameha Hwy was utilized as the baseline alignment for each site, as the location of this line should never meaningfully change unless the roadway is significantly realigned.

7.5.1.5 Armor Stone Revetment: Typical Plan and Section Views, 'Minimized Footprint' Option

Assuming that the concept best positioned for regulatory approval is preferential, the more steeply sloped, smallest-footprint revetment option using the 1:1.5 (V:H) slope is presented here, using the Kaaawa "Kaoio Point to Kalaeoio" repair reach as a representative example. Based on the design criteria discussed in the preceding sections, along with results from the stone sizing and stability calculations above, typical plan and section drawings for the 'minimized footprint' revetment concept have been developed to best fit the given geometric limitations, as illustrated in Figure 7-4 thru Figure 7-8. The existing condition plan and profile views are presented in Figure 7-4 and Figure 7-6, respectively. The 1:1.5 slope revetment concept plan view is presented in Figure 7-5, and its associated typical section in Figure 7-7, along with an alternate profile with additional toe apron for use in areas of soft bottom or fractured substrate, shown in Figure 7-8. Full sized drawings are provided in the appendix of this report, included as part of the larger concept drawing set.

Revetment armor stone is specified by weight (*W*), calculated to withstand a site-specific design wave height. For the example given at the location specified above, the corresponding design wave height of 5.5 ft results in a required armor stone weight of 2,602 pounds, with an allowable range of 1,952 to 3,253 pounds (0.75*W* to 1.25*W*). From Equation 2 in Section 7.5.1.1, the corresponding nominal stone diameter equivalent to *W* is 2.53 ft, with a corresponding allowable size range from 2.3 to 2.7 ft. Additionally, the suitable weight range requires that at least 50% of all armor stones must weigh at least *W* and that the gradation of allowable stone must be uniform across the revetment's surface. The armor stones are to be used in constructing the revetment's outer *cover layer*, which is to be composed of a two-stone thick armor layer, placed over a filter stone underlayer, all of which to be installed over a geotextile filter cloth layer on a prepared slope at 1:1.5.

Although the 1:1.5 revetment option is considered as most readily permittable (from the standpoint of environmental regulators), it should also be noted that its overall performance would be ranked last of the three slopes considered in the attached drawing set. The steeper 1:1.5 slope is more reflective in terms of incoming wave energy, as demonstrated by the reflectivity plot in Figure 7-3, and consequently least absorptive of the three slope options presented (1:2 and 1:3 slopes are included with the 1:1.5 slope, in the concept drawing set attached in the appendix). Minimizing wave reflection and increasing wave absorption corresponds directly to an improved ability of the structure to reduce problematic wave run-up and overtopping onto the highway road deck, as well as providing increased potential for accretion of beach material (if naturally present) along the structure's length.

The heavy black curve in Figure 7-3 portrays the empirical reflection coefficient of a typical rubble mound revetment with impermeable core, as a function of structure slope, based on the equations of Van Der Meer and Zanuttigh (2006). The light grey curve, for comparison, indicates the empirical reflection from an equivalent slope composed of a smooth and impermeable surface like concrete. The plot is instructive in that it illustrates the benefit of two important characteristics of effective shore protection structures, which are slope and permeability. Steep to vertical smooth surfaces like seawalls have increased reflectivity, which is associated with increased near-structure water velocities, which generally equates to an environment of enhanced sediment suspension and transport and impaired beach growth. As structure slopes recline from vertical, and structure surfaces become more porous and permeable, wave energy is more effectively absorbed by the structure, resulting in a lower energy near-field environment with greater potential for sand accretion, while also reducing the level of wave run-up on the structure's face and minimizing overtopping. In essence, the lower the slope and more porous or permeable the surface, the better the performance of the shore protection structure will be.

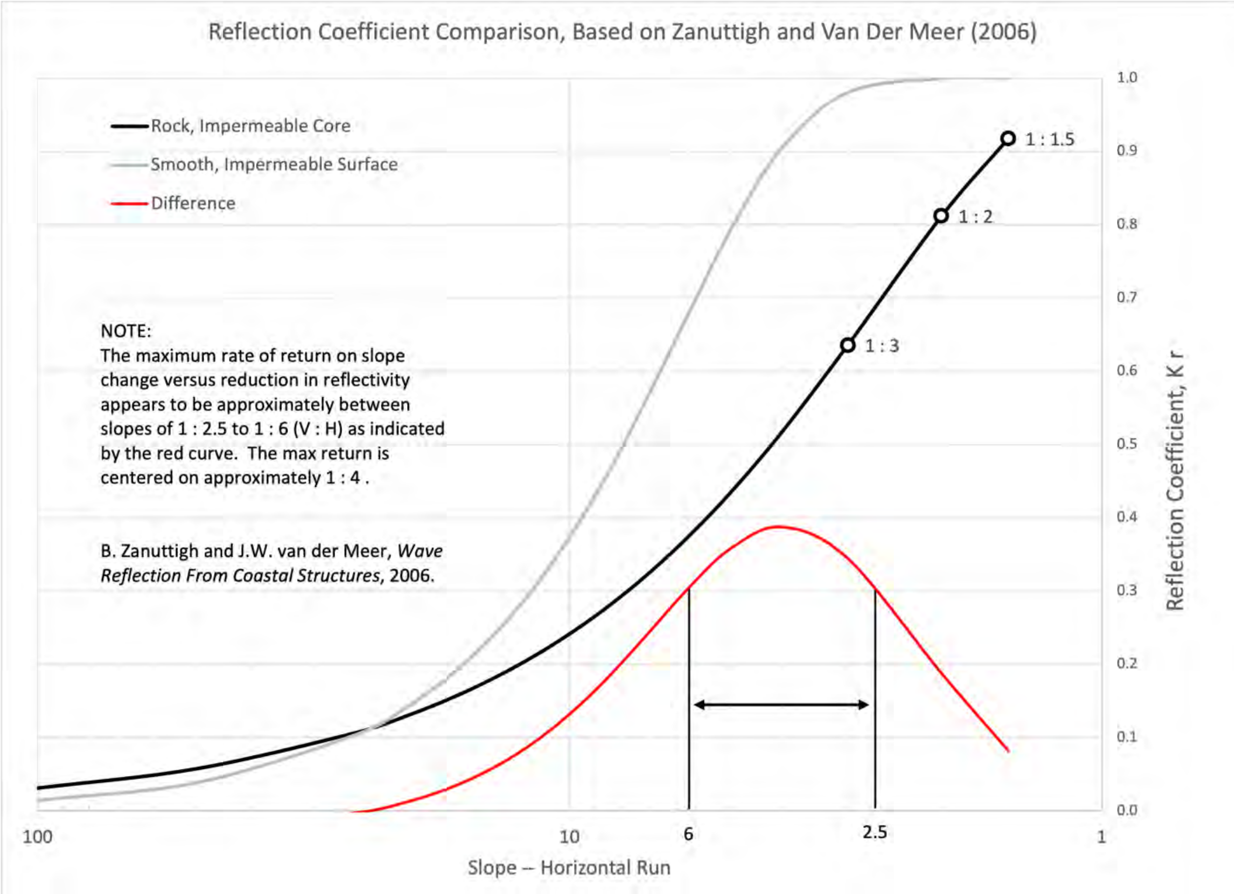

Figure 7-3. Reflection coefficient values for typical rock revetment at varying slopes

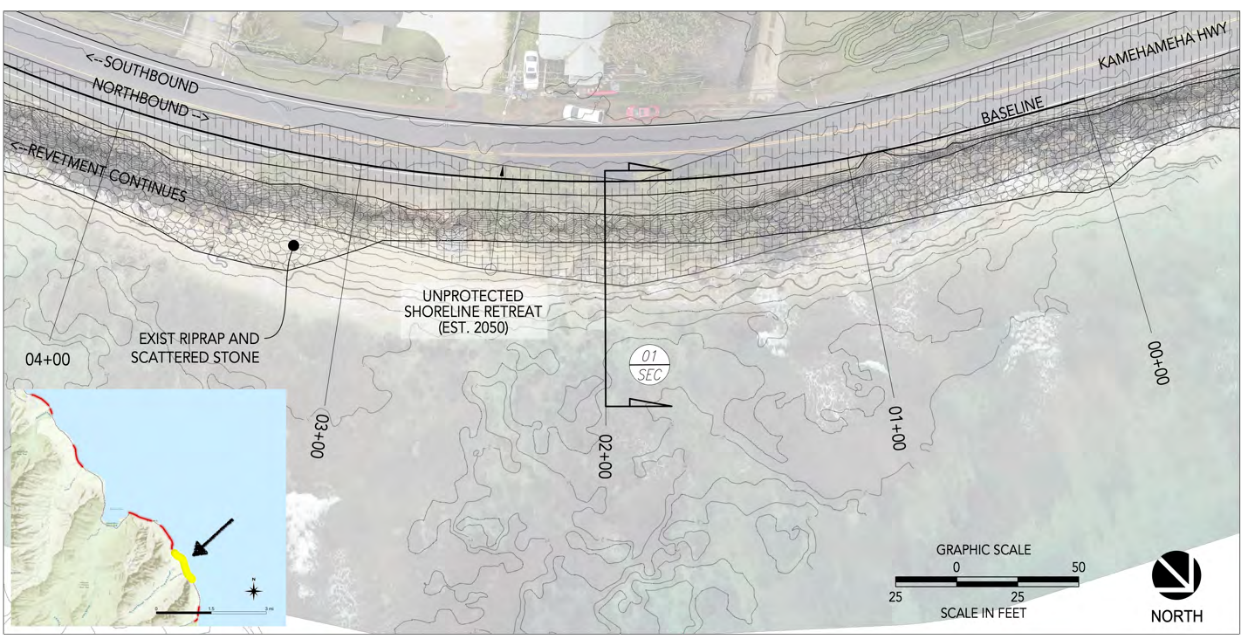

Figure 7-4. Existing condition (plan), Kaaawa repair reach “Kaoio Pt to Kalaeoio”

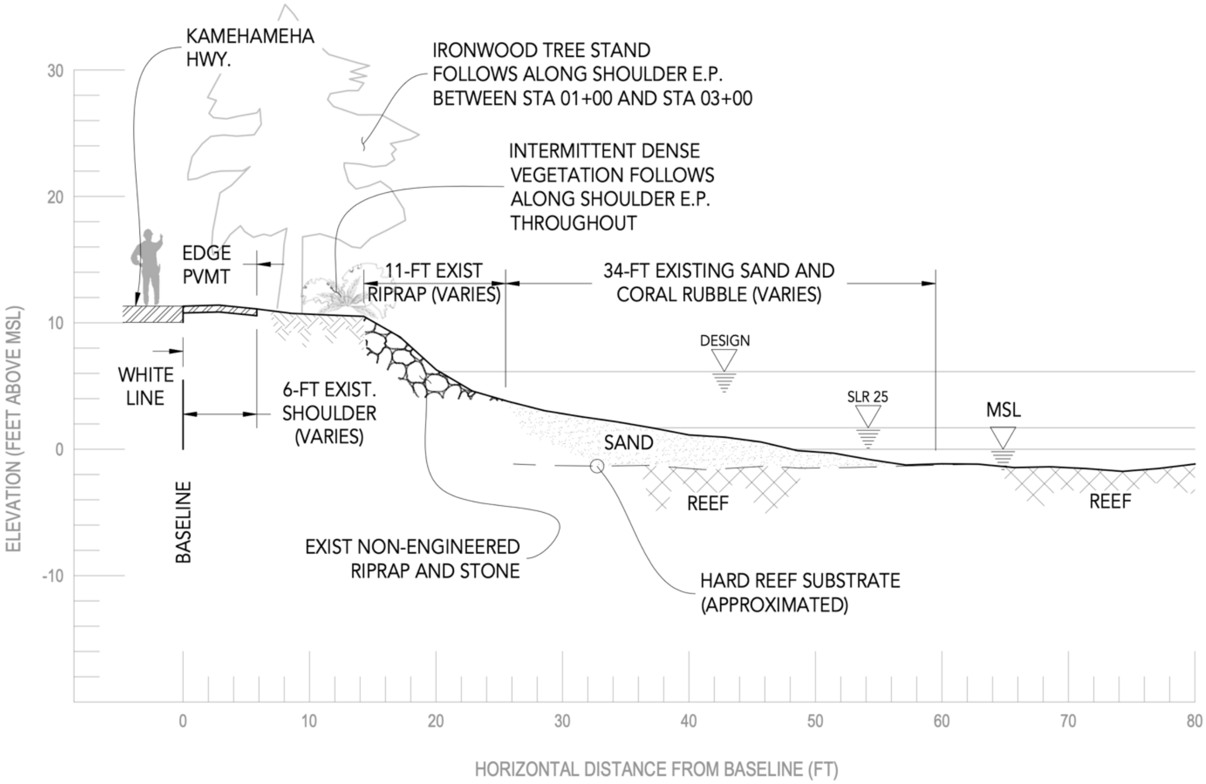

Figure 7-5. Existing condition (typical section at Sta. 02+00), Kaaawa repair reach “Kaoio Pt to Kalaeoio”

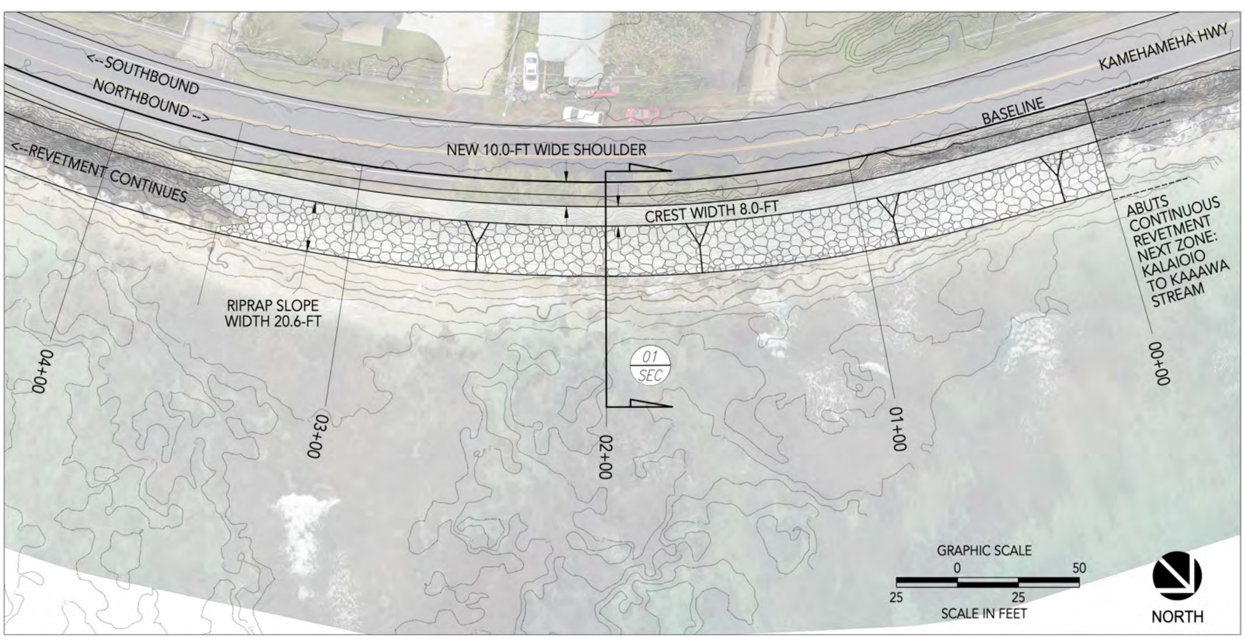

Figure 7-6. Small footprint 1:1.5 slope revetment (plan), Kaaawa repair reach “Kaoio Pt to Kalaeoio”

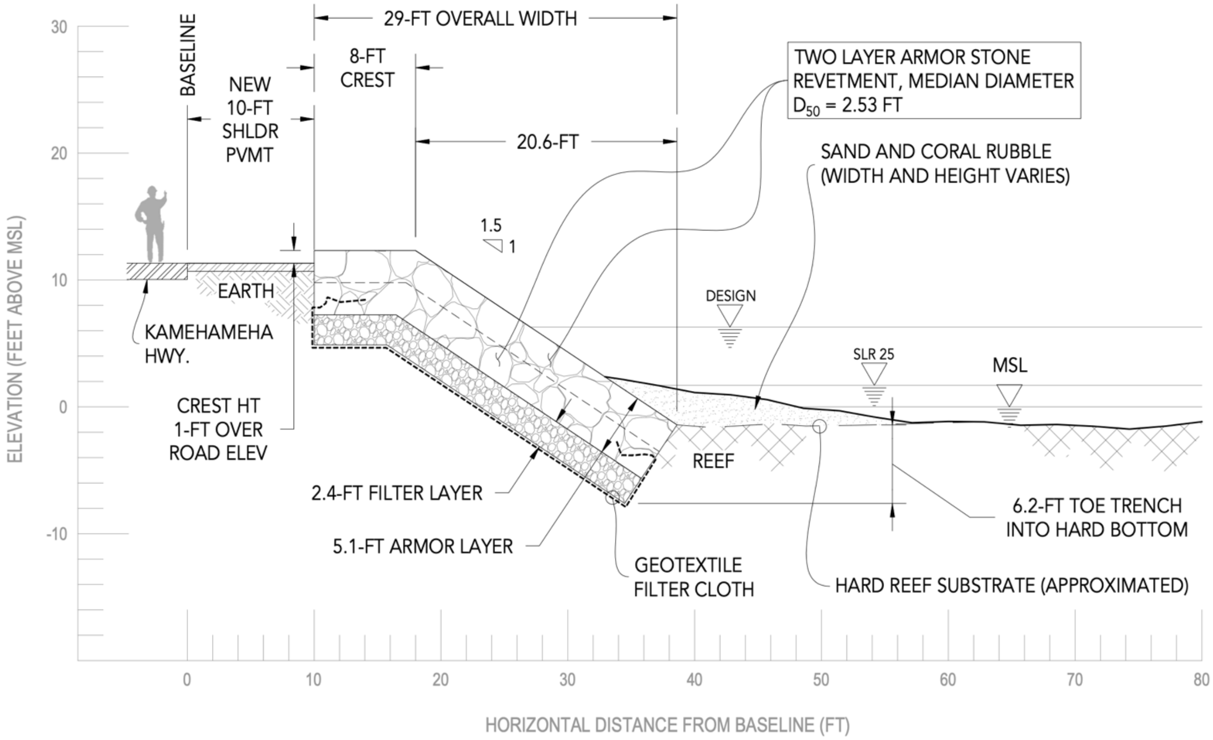

Figure 7-7. Small footprint 1:1.5 slope revetment (typical section at Sta. 02+00), Kaaawa "Kaoio Pt to Kalaeoio"

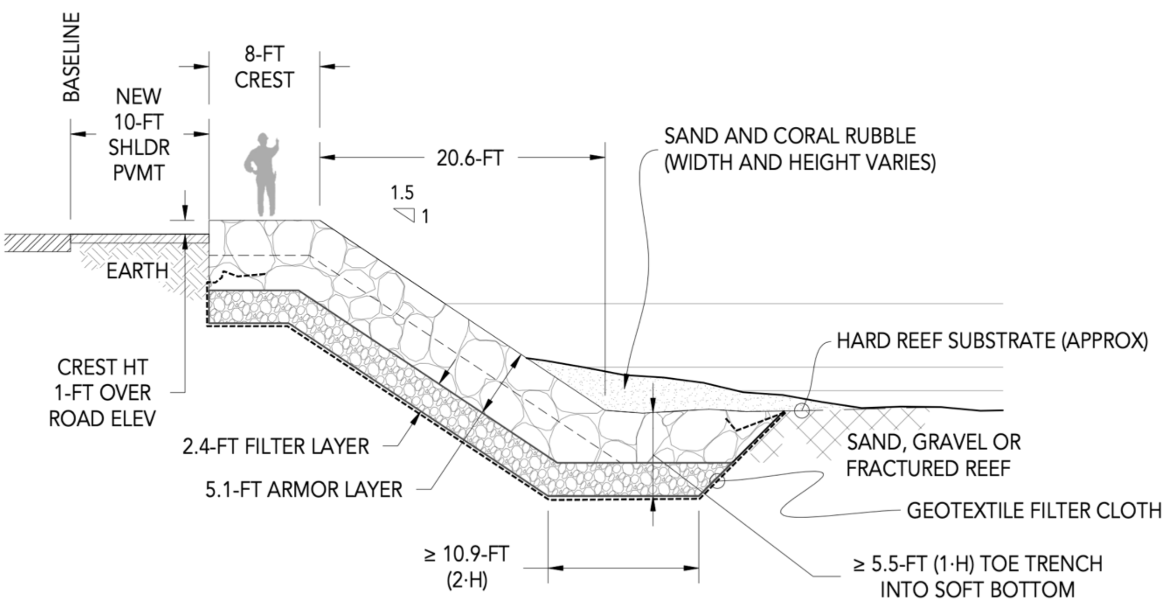

Figure 7-8. Small footprint revetment, alternate 'no-hard-bottom' configuration, Kaaawa "Kaoio Pt to Kalaeoio"

7.5.2 Alternative Concrete Armor Unit

In recent years, a growing number of shore protection construction projects on Oahu—projects that have required significant volumes of similar sized stone—have reportedly encountered difficulty in either sourcing adequate volumes of the necessary sizes of armor stone, or in producing the required gradations of stone for riprap layers. In considering this potential material supply issue, which is pertinent to any revetment's local constructability in the near term, it is advised that concrete armor units may be the only reasonable contingency option for substituting the stone armor layer if it becomes necessary to do so.

Concrete armor units are commonly used to protect coastal rubble mound shore protection structures such as revetments or breakwaters, and typically employed in high-energy wave environments. The molded concrete units are individually placed on the structure face in a regular pattern or in a quasi-random layer, depending on the type of unit. Concrete armor units are frequently used as the armor layer on shore protection structures when stone of a sufficient size to resist wave action is unavailable or uneconomical to source locally. Concrete armor units can be made into a number of shapes and sizes depending on the application, and some have several recommended placement configurations such as random, semi-random, or uniformly placed within the armor layer. Some of the more common shapes used for concrete armor units are illustrated in Figure 7-9, with *dolos* and *tribar* being among the most popular. One additional concrete unit thought to be potentially useful but not listed on Figure 7-9 is the newer *xbloc* and *xbloc-plus*, which were also considered for this effort, however, it became difficult to obtain the necessary performance specifications from the manufacturer leading to a later omission from consideration. In the end it was decided to rely on the tribar unit, which has a known track record in Hawaii and elsewhere in the Pacific including Saipan and American Samoa. The tribar unit's dimensions and volume are as illustrated in Figure 7-10, where the unit is sized by weight much in the same way as armor stone, using Hudson's Formula shown in Equation 1. The method of sizing is similar to that presented in Section 7.5.1.1, except that the value for K_D for a single layer of tribar becomes 12. A table providing the minimum required weight for tribar armor units per site is presented in Table 7-6.

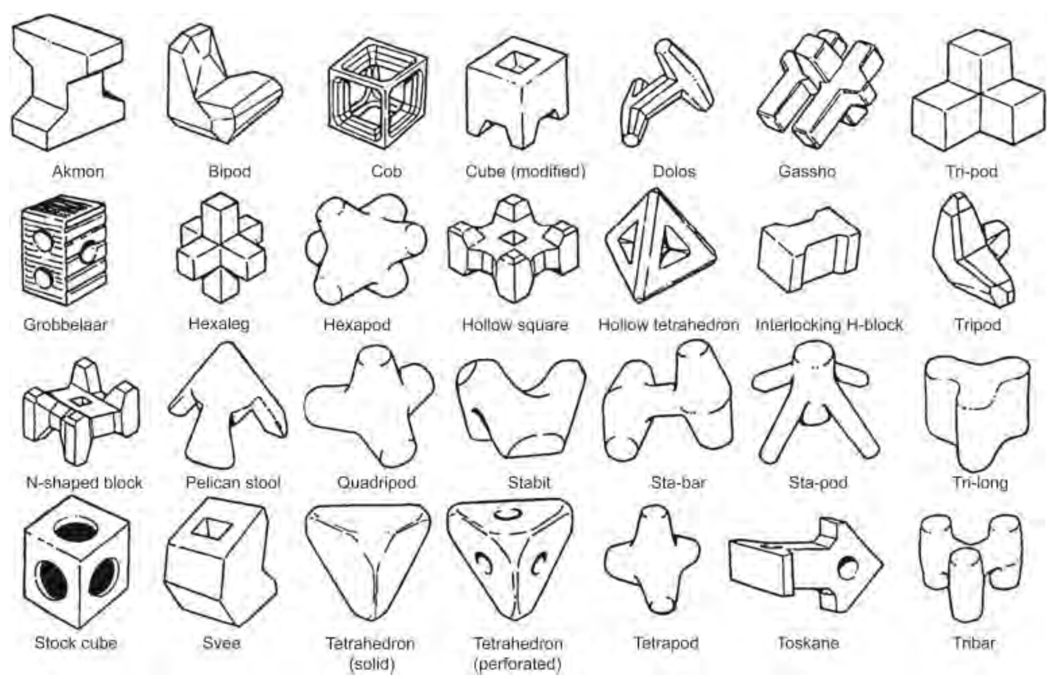

Figure 7-9. Assortment of common shapes for concrete armor units used in shore protection projects

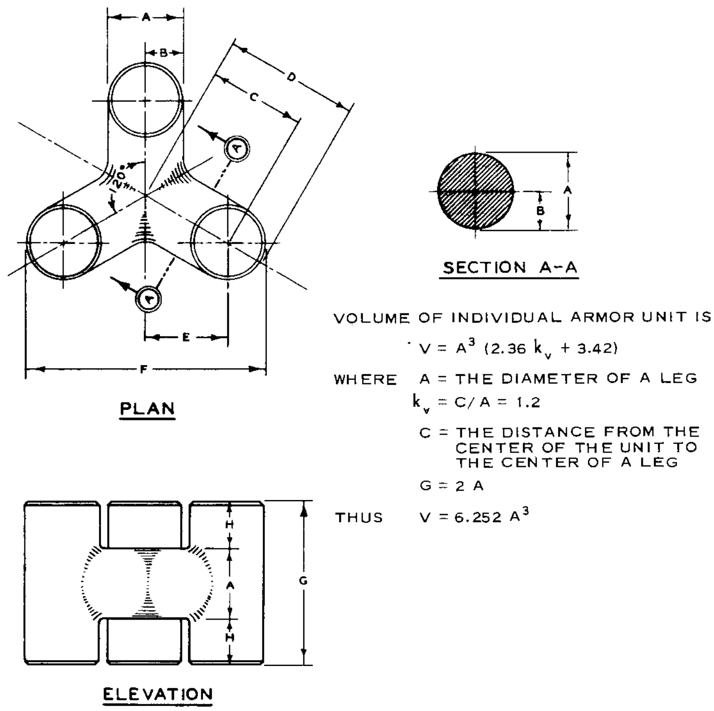

Figure 7-10. Primary dimensions for the tribar concrete unit

Table 7-6. Summary of minimum tribar unit weights and key dimensions per repair site (for 1:1.5 slope)

Repair Site Name	Design Wave *(ft)*	Unit Type	K_D *stability coeff.*	W *nom. wt. (lbf)*	V *volume (ft)*	A *dim (ft)*	C *dim (ft)*	G *dim (ft)*
Kualoa.Npark	3.00	Tribar	12	109	0.75	0.49	0.62	0.99
Kualoa.ranch	3.11	Tribar	12	122	0.84	0.51	0.64	1.02
Kaaawa.surf (south)	5.45	Tribar	12	655	4.52	0.90	1.12	1.79
Kaaawa.surf (mid)	5.45	Tribar	12	655	4.52	0.90	1.12	1.79
Kaaawa.surf (north)	6.01	Tribar	12	875	6.04	0.99	1.24	1.98
Kaaawa.school (south)	5.41	Tribar	12	641	4.42	0.89	1.11	1.78
Kaaawa.school (north)	3.94	Tribar	12	247	1.70	0.65	0.81	1.30
Kaaawa.711	3.73	Tribar	12	210	1.45	0.61	0.77	1.23
Kaaawa.CL (south)	4.29	Tribar	12	318	2.19	0.71	0.88	1.41
Kaaawa.CL (north)	4.29	Tribar	12	318	2.19	0.71	0.88	1.41
Punaluu.P2	4.93	Tribar	12	483	3.33	0.81	1.01	1.62
Punaluu.P1	4.30	Tribar	12	322	2.22	0.71	0.89	1.42
Hauula	4.09	Tribar	12	276	1.90	0.67	0.84	1.35
Generic Half-ton	6.28	Tribar	12	1,000	6.90	1.03	1.29	2.07
Generic One Ton	7.91	Tribar	12	2,000	13.79	1.30	1.63	2.60

Based on the site-specific design wave heights, the resulting minimum weight for the tribar units ranged from a minimum of just over 100 pounds at Kualoa, to a maximum of nearly 900 pounds at Kaaawa. It is, however, economically infeasible to construct varying tribar unit sizes for each site due to the need for building an estimated 50 to 100 forms or molds per tribar unit size in order to cast sufficient numbers of concrete units for construction. For this reason, it was decided to 'round up' and use an even half-ton (1,000 lbf) unit everywhere, which would end up being slightly oversized for the sites with the highest design waves and well into the conservative range for the remainder of the sites. This will minimize construction costs by allowing the contractor to use just one set of forms during construction, while providing an increased factor of safety for structure stability.

Basic dimensions for the half-ton unit were calculated as follows: 2.07 ft in leg height (G in Figure 7-10), 1.03 ft leg diameter (A), 3.26 ft overall horizontal width (F), and 1.29 ft radial spoke length (C). Using units of these dimensions, a typical plan and section view for the Kaaawa "Kaoio Point to Kalaeoio" repair reach is provided in Figure 7-11 and Figure 7-12.

The required number of individual armor units, N_R for a given surface area, A can be estimated by the following formula from the Coastal Engineering Manual:

$$\frac{N_R}{A} = nk_{\Delta}\left(1 - P/100\right)\left(\frac{w_r}{W}\right)^{2/3}$$ ***Equation 3.*** *(CEM)*

where:

- n = number of units composing the layer thickness, use 1
- k_{Δ} = layer coefficient, use 1.13
- P = armor layer porosity, 47% for tribar (CEM)
- W = weight of tribar (half-ton, 1,000 lbf)
- w_r = specific weight of concrete (145 lbf/ft^3)

From Equation 3, a total of 165 half-ton tribar armor units would be required per 1,000 square feet of revetment surface area. Constructing the tribar revetment with a 1:1.5 slope, the revetment would consist of 0.5-ton (1,000 lbf) tribar armor units installed in a single layer in a regularly spaced pattern as illustrated by the example in Figure 7-13. The installation pattern consists of alternating columns of units stacked two-legs-down with adjacent columns stacked one-leg-down and repeating as needed, as illustrated in Figure 7-14. The tribar armor layer will be constructed on a stone filter layer with median stone weight of 260 lbf, installed over a prepared slope covered with geotextile filter fabric. At the revetment crest, top row tribar units will be secured in position by cast-in-place concrete between the seat wall and the top row of tribar units as shown in Figure 7-12 and Figure 7-13. Flexible formwork will be used to mold around the tribar crest units and contain the wet concrete. Landward of the crest seat wall, a layer of riprap will be used to cover the 8-foot-wide horizontal filter layer at the structure crest as illustrated in Figure 7-12 and Figure 7-13. The tribar slope toe will be embedded approximately 3.7 feet into the excavated toe trench cut into the reef substrate and locked in place with a pour of tremie concrete following tribar installation. It is noted that tribar units are of uniform size and must be placed as whole units, thus the revetment crest and toe configuration at any specific location will have to be adjusted in the field to account for changes in the finish elevation at the crest and the existing ground elevation at the toe. The number of tribar units required to span the slope length may vary with location. An existing tribar revetment installation is shown for example in Figure 7-15, which is located in American Samoa.

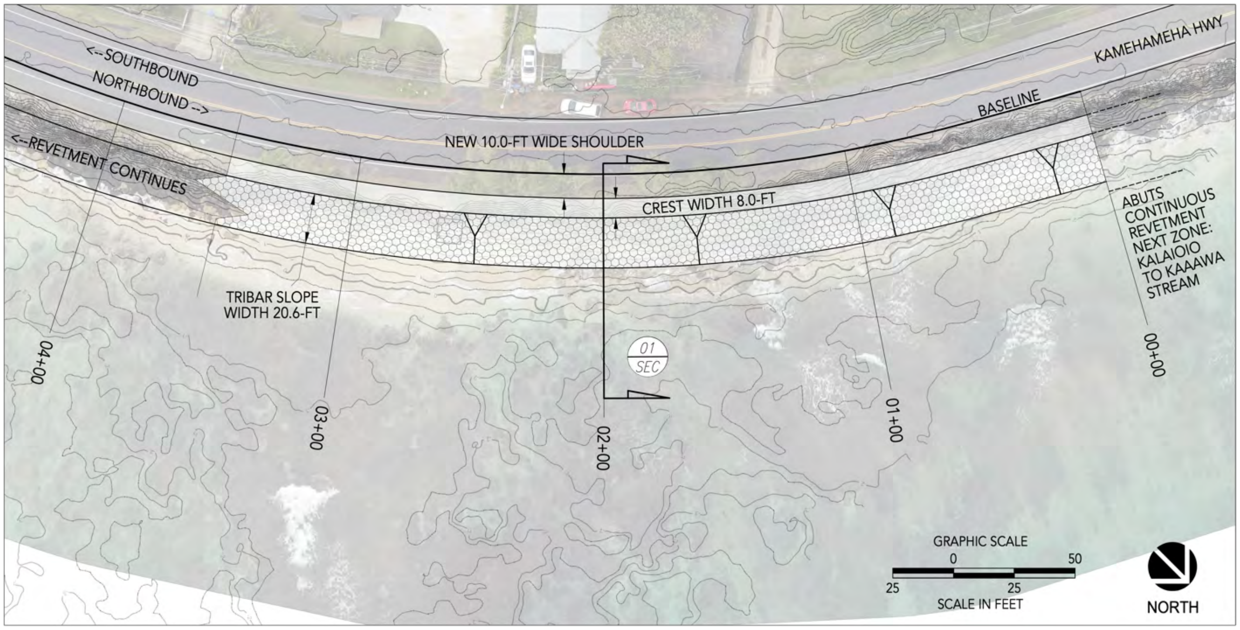

Figure 7-11. Tribar 1:1.5 slope revetment footprint (plan), Kaaawa repair reach "Kaoio Pt to Kalaeoio"

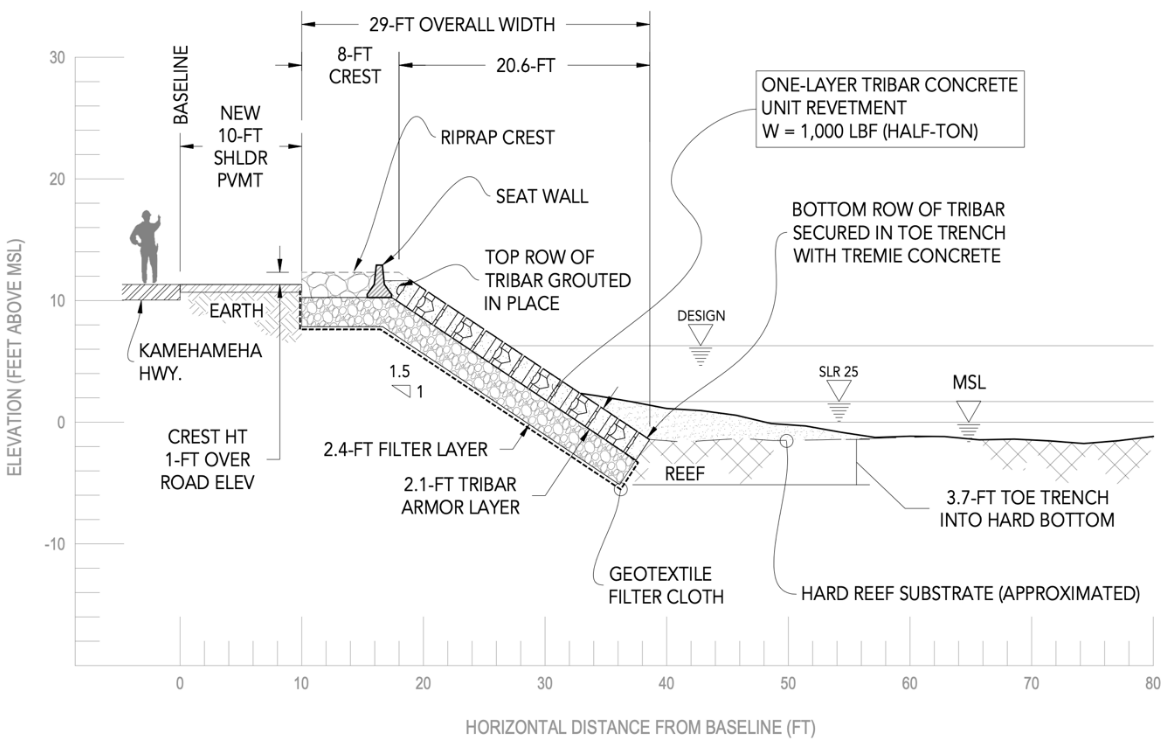

Figure 7-12. Tribar 1:1.5 slope revetment (typical section at Sta. 02+00), Kaaawa "Kaoio Pt to Kalaeoio"

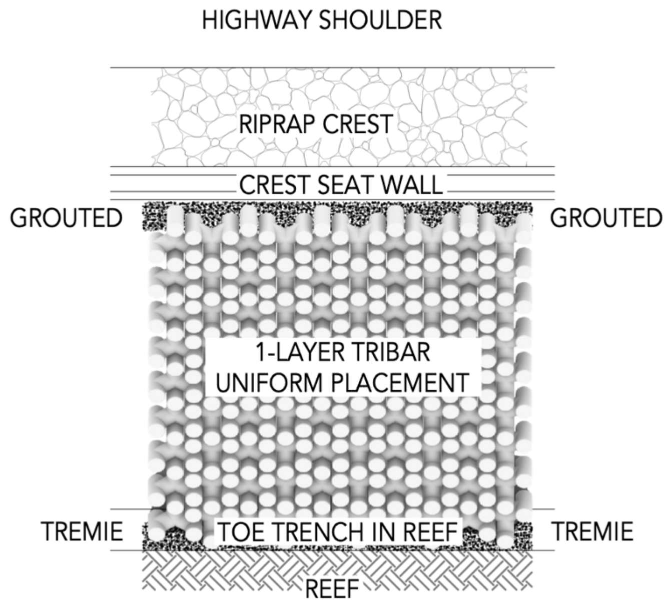

Figure 7-13. Tribar 1:1.5 slope revetment, plan view example of unit placement

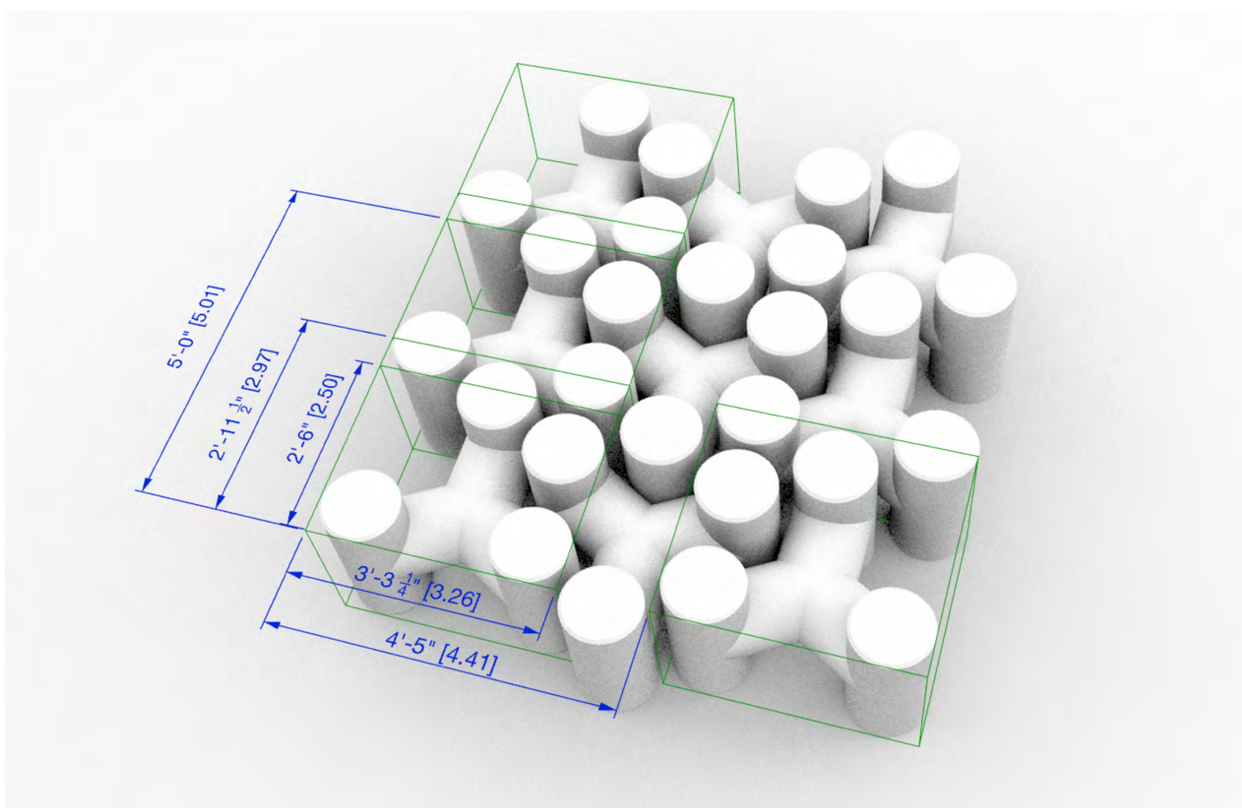

Figure 7-14. Example of tribar uniform placement pattern, looking up-slope

Figure 7-15. Example tribar installation, American Samoa

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8. SUMMARY & CONCLUSION

The purpose of this document is to provide a site-specific, engineering-based, basis of design for urgently needed roadside shore protection along a series of discontinuous sections of highly eroded lengths of Kamehameha Hwy between Kualoa and Hauula. Sea level rise along with intensifying tropical storm activity from global warming are a clear and present danger to the future stability of this critical yet vulnerable transportation link. Decision-making regarding what to do with the future of this highway, including possible roadway realignments, is a complex and hotly contested issue that will require community, political, technical, and engineering involvement and take years if not decades to arrive at a long-term future solution. At the same time, the highway is under threat by active erosion on a daily basis, requiring an intermediate solution. The material presented in this document represents the start of this intermediary effort—intended to keep Kamehameha Hwy open to motorists and protected from advancing erosion for the next two to three decades until a long-term solution is in place.

The alternative shore protection concepts presented during this effort consist generally of rubble mound armor stone or riprap revetments at varying slopes; for a limited number of areas with the lowest wave energy environments, a low-crested hybrid seawall with armor stone apron is also included. And although the revetment option with the smallest horizontal footprint and therefore steepest slope (1:1.5) is presented in the example within the body of the report, with an eye towards regulatory limitations, it is recommended that sober consideration also be given to performance where possible. As discussed within this report, significant improvement in revetment performance—both in reducing wave overtopping and increasing potential for beach material accretion—can be gained by reducing structure slope. Thoughtful and detailed deliberation by stakeholders and regulators is encouraged to weigh the tradeoffs between a better performing shore protection structure with a larger footprint versus the actual resources that will be lost by occupation of this shoreline space by the structure. Taking that into consideration, it is possible that a suitable compromise between minimizing seafloor disturbance and maximizing revetment performance may end up being closer to the 1:2 slope.

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APPENDIX

SHORE PROTECTION CONCEPTS – FULL SIZED DRAWING SHEETS

(CONFIDENTIAL, NOT FOR CONSTRUCTION)

KKPH Kamehameha Highway Shore Protection:

Conceptual Alternatives Development

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CONFIDENTIAL

NOT FOR CONSTRUCTION

CONCEPTUAL ONLY

Sheet Name
Title Sheet

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	21 Mar 2022	C-001
Scale	NTS	

INDEX OF DRAWINGS

INDEX & OVERVIEW

SHEET	TITLE
C-001	TITLE SHEET
C-002	INDEX OF SHEETS
C-003	PROJECT OVERVIEW MAP (ISLAND OF OAHU)
C-004	PROJECT SITE MAP (KUALOA TO HAUULA)

KUALOA PARK (NORTH)

SHEET	TITLE
C-005	EXISTING CONDITION - PLAN
C-006	ARMORED SEAWALL - PLAN - CONCEPTUAL
C-007	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-008	LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-009	EXISTING CONDITION - SECTION (TYPICAL)
C-010	ARMORED SEAWALL - SECTION - CONCEPTUAL
C-011	HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-012	LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

KUALOA RANCH

SHEET	TITLE
C-013	EXISTING CONDITION - PLAN
C-014	ARMORED SEAWALL - PLAN - CONCEPTUAL
C-015	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-016	LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-017	EXISTING CONDITION - SECTION (TYPICAL)
C-018	ARMORED SEAWALL - SECTION - CONCEPTUAL
C-019	HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-020	LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

KAOIO POINT TO KALAEOIO

SHEET	TITLE
C-021	EXISTING CONDITION - PLAN (OVERVIEW)
C-022	STA. 02+00 AND 27+00 - EXISTING CONDITION - PLAN
C-023	STA. 02+00 AND 27+00 - HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-024	STA. 02+00 AND 27+00 - MILD SLOPE REVETMENT - PLAN - CONCEPTUAL
C-025	STA. 02+00 AND 27+00 - LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-026	STA. 02+00 (ZONE A) - EXISTING CONDITION - SECTION (TYPICAL)
C-027	STA. 02+00 (ZONE A) - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-028	STA. 02+00 (ZONE A) - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-029	STA. 02+00 (ZONE A) - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL
C-030	STA. 27+00 (ZONE B) - EXISTING CONDITION - SECTION (TYPICAL)
C-031	STA. 27+00 (ZONE B) - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-032	STA. 27+00 (ZONE B) - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-033	STA. 27+00 (ZONE B) - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

KALAEOIO TO KAAAWA STREAM

SHEET	TITLE
C-034	EXISTING CONDITION - PLAN
C-035	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-036	MILD SLOPE REVETMENT - PLAN - CONCEPTUAL
C-037	LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-038	STA. 07+00 - EXISTING CONDITION - SECTION (TYPICAL)
C-039	STA. 07+00 - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-040	STA. 07+00 -MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-041	STA. 07+00 - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

KAAAWA STREAM TO KAAAWA BEACH PARK

SHEET	TITLE
C-042	EXISTING CONDITION - PLAN - CONCEPTUAL
C-043	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-044	MILD SLOPE REVETMENT - PLAN - CONCEPTUAL
C-045	LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-046	STA. 10+00 (ZONE B) - EXISTING CONDITION - SECTION (TYPICAL)
C-047	STA. 10+00 (ZONE B) - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-048	STA. 10+00 (ZONE B) - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-049	STA. 10+00 (ZONE B) - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

KAAAWA VICINITY OF PUAKENIKENI ROAD

SHEET	TITLE
C-050	EXISTING CONDITION - PLAN
C-051	ARMORED SEAWALL - PLAN - CONCEPTUAL
C-052	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-053	MILD SLOPE REVETMENT - PLAN - CONCEPTUAL
C-054	STA. 09+00 - EXISTING CONDITION - SECTION (TYPICAL)
C-055	STA. 09+00 - ARMORED SEAWALL - SECTION - CONCEPTUAL
C-056	STA. 09+00 - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-057	STA. 09+00 - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL

KAAAWA VICINITY OF CROUCHING LION

SHEET	TITLE
C-058	VICINITY OF CROUCHING LION - EXISTING CONDITION - PLAN (OVERVIEW)
C-059	STA. 03+00 AND 18+00 - EXISTING CONDITION - PLAN
C-060	STA. 03+00 AND 18+00 - HIGH SLOPE REVETMENTS - PLAN - CONCEPTUAL
C-061	STA. 03+00 AND 18+00 - MILD SLOPE RIPRAP REVETMENT & ARMORED SEAWALL - PLAN - CONCEPTUAL
C-062	STA. 03+00 LOW SLOPE REVETMENT AND 18+00 HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-063	STA. 03+00 (ZONE A) - EXISTING CONDITION - SECTION (TYPICAL)
C-064	STA. 03+00 (ZONE A) - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-065	STA. 03+00 (ZONE A) - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-066	STA. 03+00 (ZONE A) - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

KAAAWA VICINITY OF CROUCHING LION (CONTINUED)

SHEET	TITLE
C-067	STA. 18+00 (ZONE B) - EXISTING CONDITION - SECTION (TYPICAL)
C-068	STA. 18+00 (ZONE B) - ARMORED SEAWALL - SECTION - CONCEPTUAL
C-069	STA. 18+00 (ZONE B) - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-070	STA. 18+00 (ZONE B) - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL

PUNALUU SOUTH (HALEAHA ROAD)

SHEET	TITLE
C-071	REACH OVERVIEW - PLAN
C-072	EXISTING CONDITION - PLAN
C-073	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-074	MILD SLOPE REVETMENT - PLAN - CONCEPTUAL
C-075	LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-076	STA. 02+00 - EXISTING CONDITION - SECTION (TYPICAL)
C-077	STA. 02+00 - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-078	STA. 02+00 - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-079	STA. 02+00 - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

PUNALUU NORTH (KALUANUI)

SHEET	TITLE
C-080	EXISTING CONDITION - PLAN
C-081	HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL
C-082	MILD SLOPE REVETMENT - PLAN - CONCEPTUAL
C-083	LOW SLOPE REVETMENT - PLAN - CONCEPTUAL
C-084	STA. 01+00 - EXISTING CONDITION - SECTION (TYPICAL)
C-085	STA. 01+00 - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-086	STA. 01+00 - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-087	STA. 01+00 - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

HAUULA

SHEET	TITLE
C-088	EXISTING CONDITION - OVERVIEW - PLAN
C-089	VICINITY OF STA. 13+00 - EXISTING CONDITION - TYPICAL PLAN (2013)
C-090	VICINITY OF STA. 13+00 - EXISTING CONDITION - TYPICAL PLAN (2021)
C-091	VICINITY OF STA. 13+00 - HIGH SLOPE REVETMENT - PLAN - CONCEPTUAL (TYPICAL)
C-092	VICINITY OF STA. 13+00 - MILD SLOPE REVETMENT - PLAN - CONCEPTUAL (TYPICAL)
C-093	VICINITY OF STA. 13+00 - LOW SLOPE REVETMENT - PLAN - CONCEPTUAL (TYPICAL)
C-094	STA. 13+00 - EXISTING CONDITION - SECTION (TYPICAL)
C-095	STA. 13+00 - HIGH SLOPE REVETMENT - SECTION - CONCEPTUAL
C-096	STA. 13+00 - MILD SLOPE REVETMENT - SECTION - CONCEPTUAL
C-097	STA. 13+00 - LOW SLOPE REVETMENT - SECTION - CONCEPTUAL

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NOTES:

1. Project repair reaches are indicated by thick red line segments along the shoreline.
2. Nine identified repair reaches along Kamehameha Hwy, between Kualoa Beach Park and Hauula, are labeled with a unique identifier printed to the right of the repair reach on the map.
3. Repair reaches Kaaawa.surf, Kaaawa.school, and Kaaawa.CL were further divided into 2 to 3 subdivisions due to varying design conditions.
4. A naming and identification cross reference is provided in Table 1 on this sheet.

Sheet Name: **Sheet Index**

Project Name: **KKPH Kamehameha Highway Shore Protection**

Project No. 25853
Date 21 Mar 2022
Scale NTS
Sheet C-002

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NOTES:

1. Approximate project repair reaches denoted by thick red line segments within project area box.

Sheet Name: **Project Overview Map (Island of Oahu)**

Project Name: **KKPH Kamehameha Highway Shore Protection**

Project No. 25853	Sheet C-003
Date 21 Mar 2022	
Scale NTS	

Mon Mar 21 14:31:04 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***

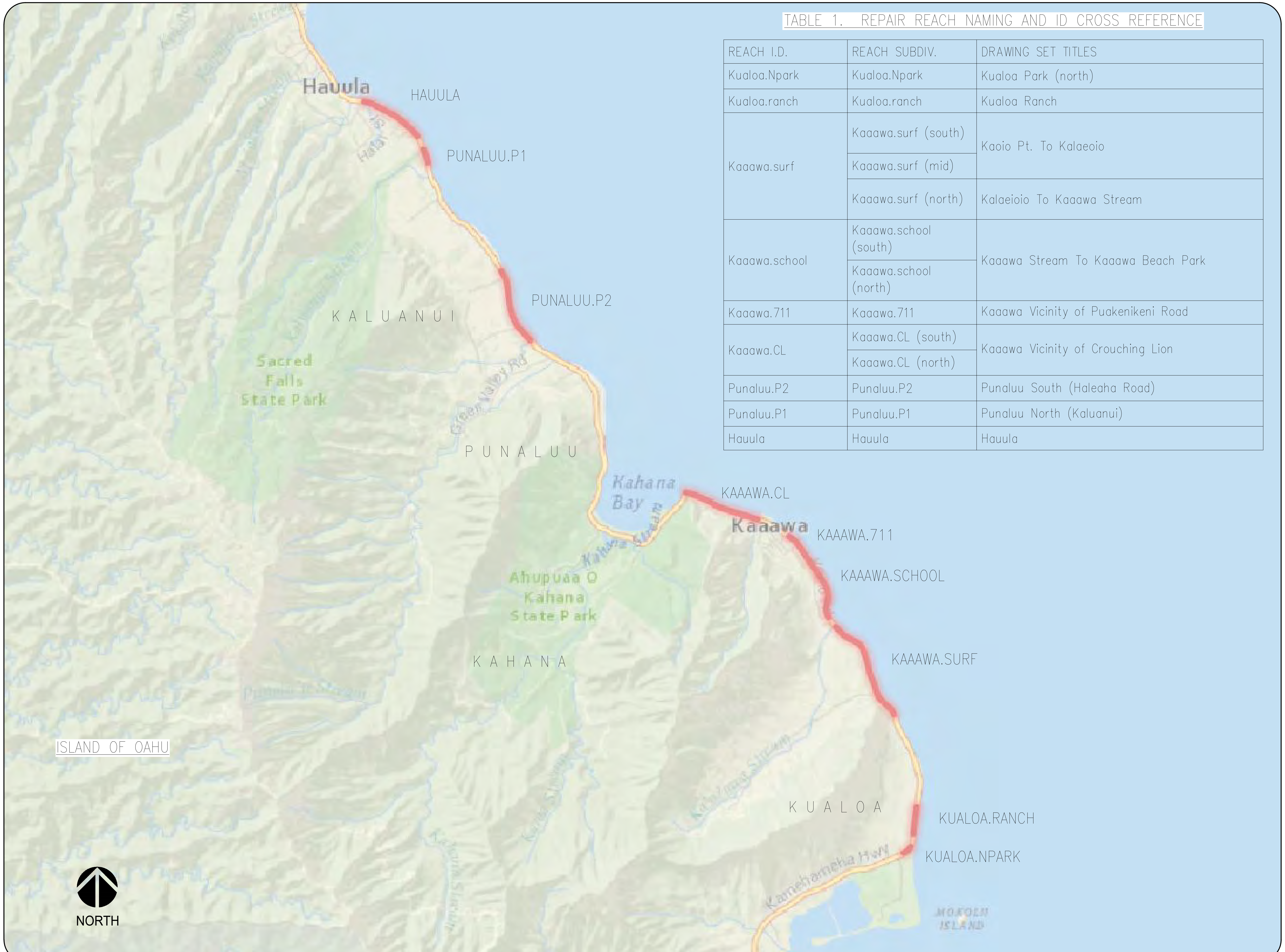

TABLE 1. REPAIR REACH NAMING AND ID CROSS REFERENCE

REACH I.D.	REACH SUBDIV.	DRAWING SET TITLES
Kualoa.Npark	Kualoa.Npark	Kualoa Park (north)
Kualoa.ranch	Kualoa.ranch	Kualoa Ranch
Kaaawa.surf	Kaaawa.surf (south)	Kaoio Pt. To Kalaeoio
	Kaaawa.surf (mid)	
	Kaaawa.surf (north)	Kalaeioio To Kaaawa Stream
Kaaawa.school	Kaaawa.school (south)	Kaaawa Stream To Kaaawa Beach Park
	Kaaawa.school (north)	
Kaaawa.711	Kaaawa.711	Kaaawa Vicinity of Puakenikeni Road
Kaaawa.CL	Kaaawa.CL (south)	Kaaawa Vicinity of Crouching Lion
	Kaaawa.CL (north)	
Punaluu.P2	Punaluu.P2	Punaluu South (Haleaha Road)
Punaluu.P1	Punaluu.P1	Punaluu North (Kaluanui)
Hauula	Hauula	Hauula

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NOTES:

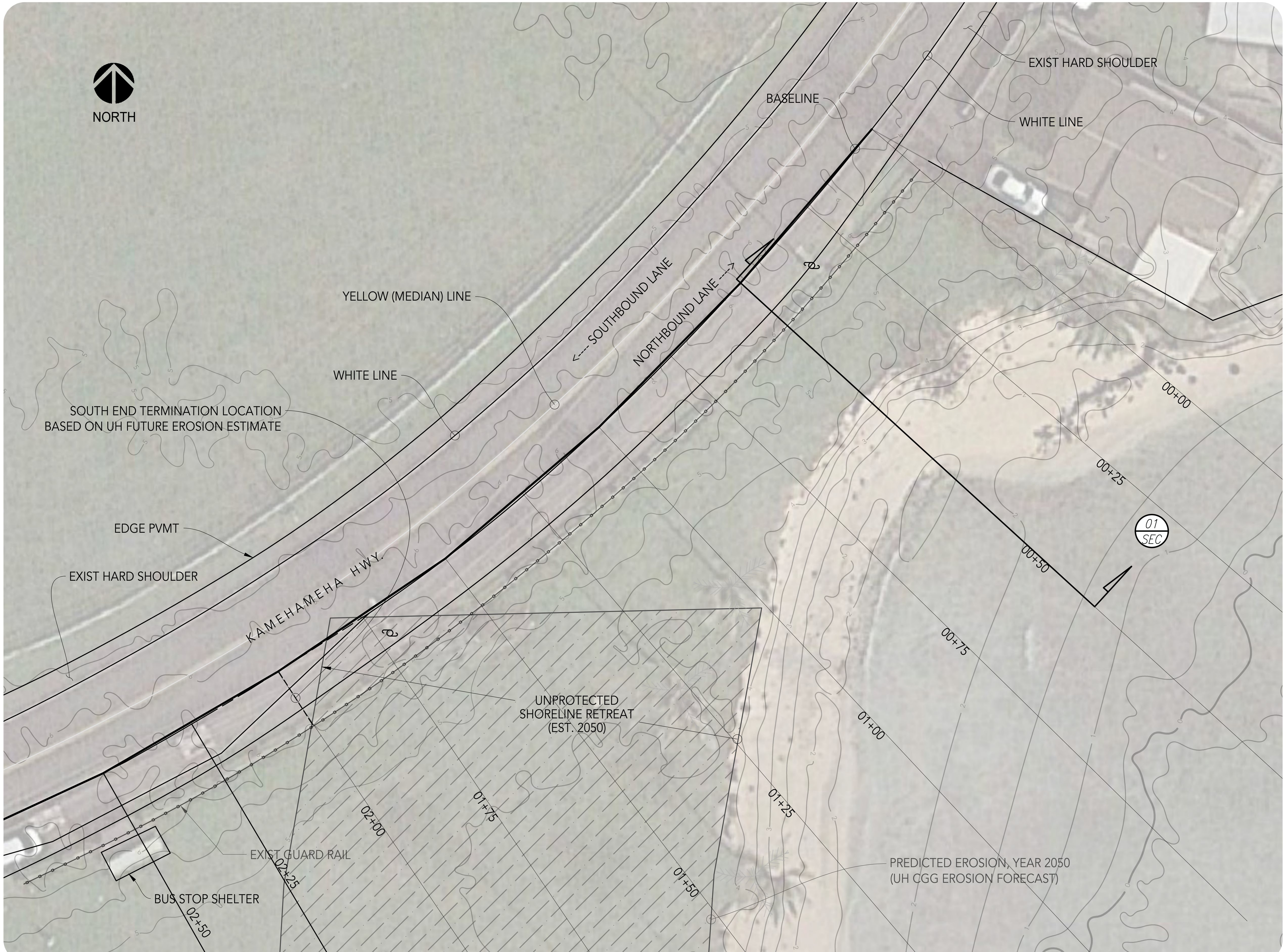
1. Project repair reaches are indicated by thick red line segments along the shoreline (approximate).
2. Nine identified repair reaches along Kamehameha Hwy, between Kualoa Beach Park and Hauula, are labeled with a unique identifier printed to the right of the repair reach on the map.
3. Repair reaches Kaaawa.surf, Kaaawa.school, and Kaaawa.CL were further divided into 2 to 3 subdivisions as shown due to varying design conditions.
4. A naming and design identification cross reference is provided in Table 1 on this sheet.

Sheet Name
Project Site Map (Kualoa to Hauula)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	21 Mar 2022	C-004
Scale	NTS	

Mon Mar 21 14:31:05 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***



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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name

Kualoa Park (North) Existing Condition Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-005
Date 21 Mar 2022	
Scale $\frac{1}{2}$" = 1' - 0"	

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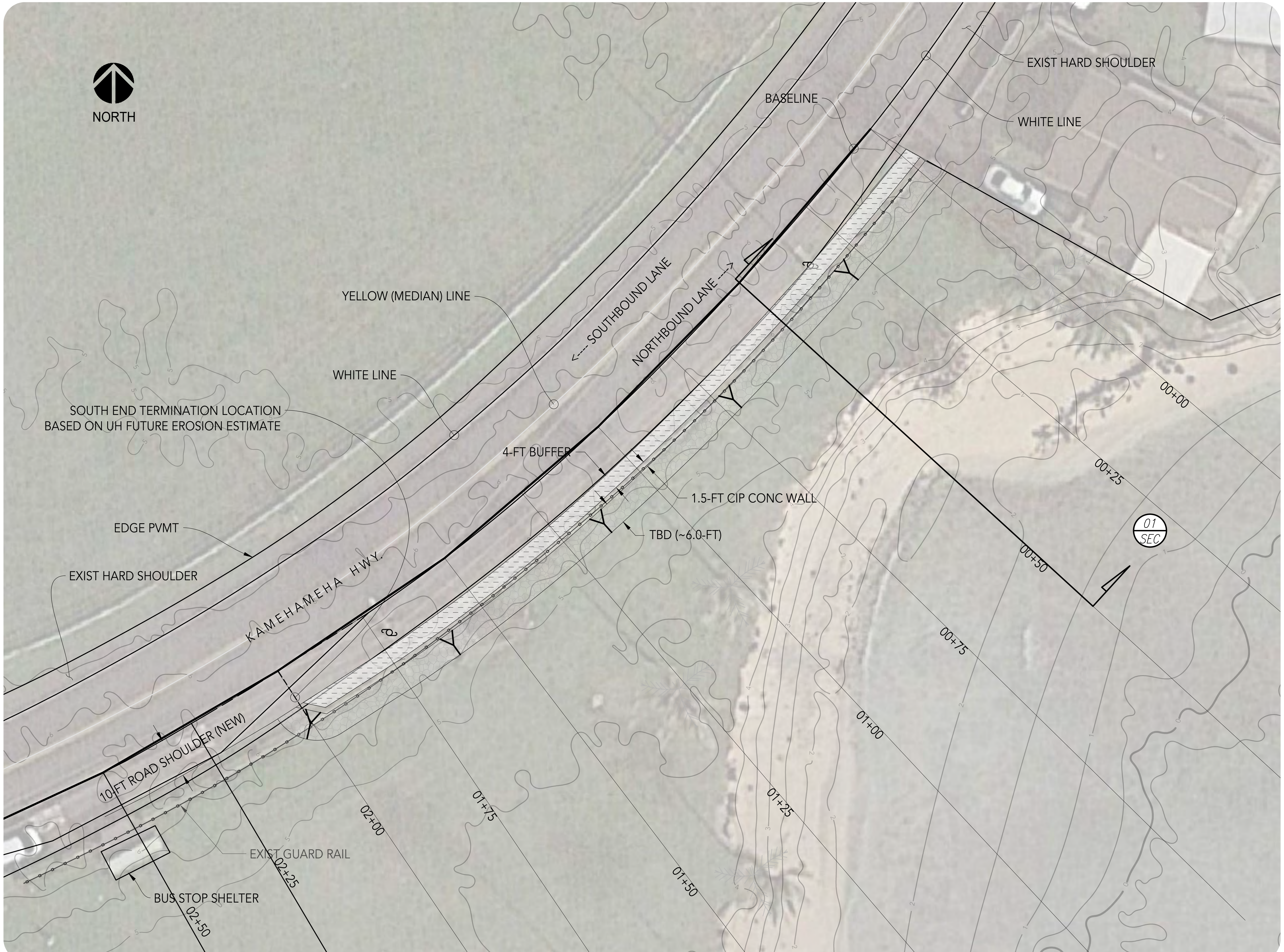

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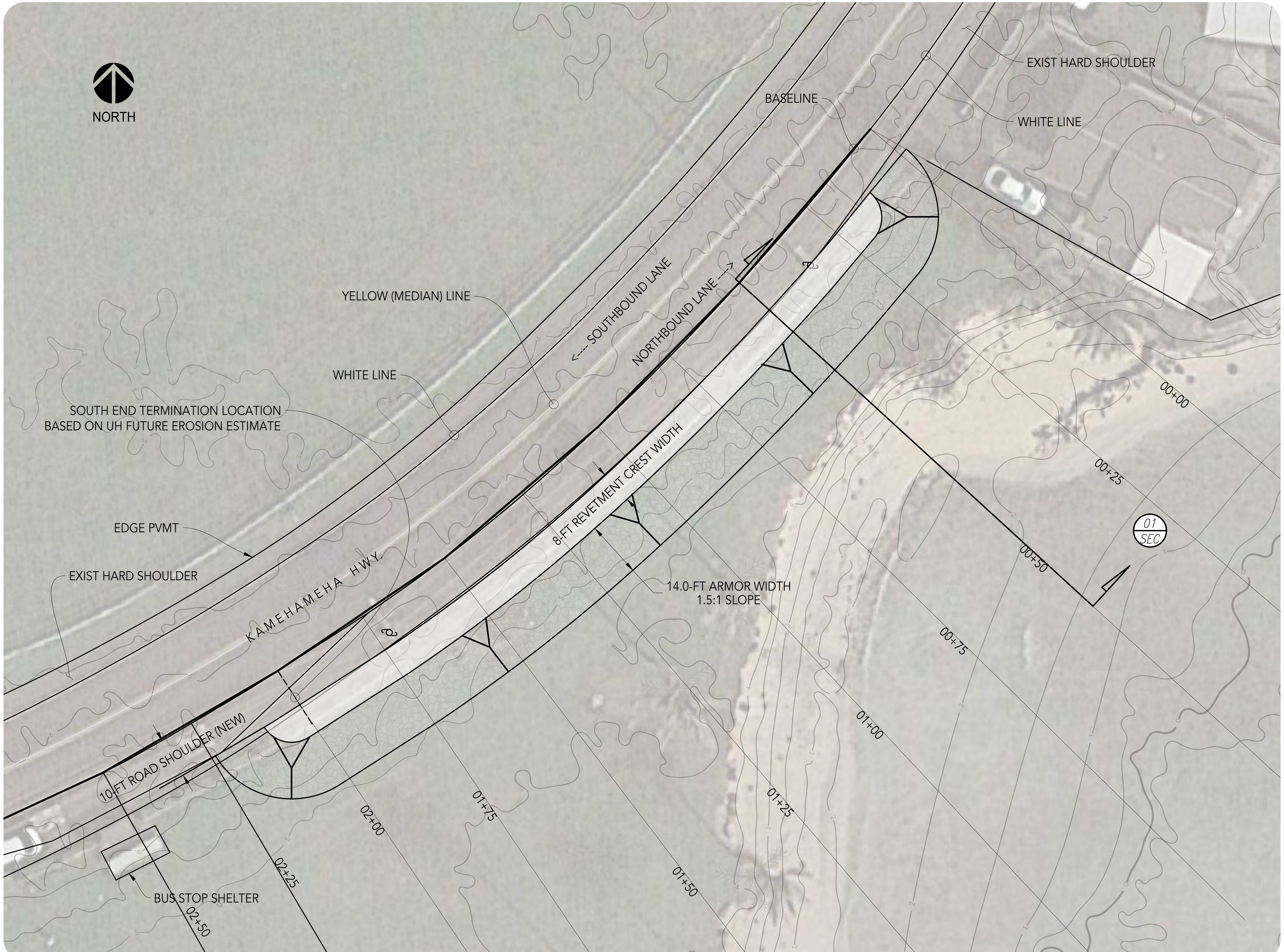
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Top of wall elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Wall toe apron ends to terminate by turning back into slope to prevent flanking erosion.
5. Wall to tie into bridge or culvert wing walls where present.

Sheet Name
Kualoa Park (North) Armored Seawall Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-006
Date 21 Mar 2022	
Scale $\frac{1}{2}$" = 1' - 0"	



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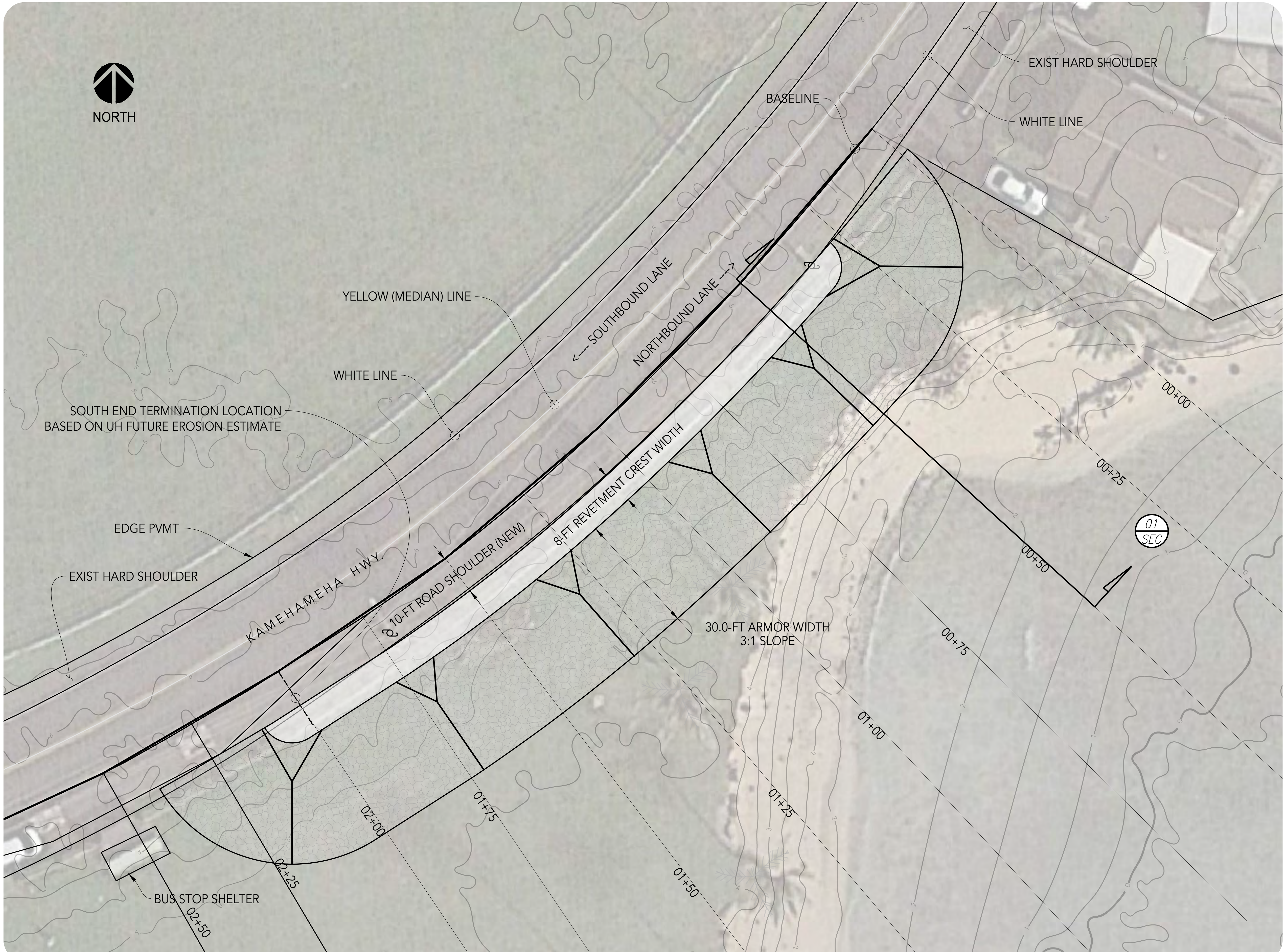
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert wing walls where present, using revetment toe detail for drainage swale.

Sheet Name
Kualoa Park (North) High Slope Riprap Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-007
Date 21 Mar 2022	
Scale $\frac{1}{2}$" = 1' - 0"	



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NOTES:

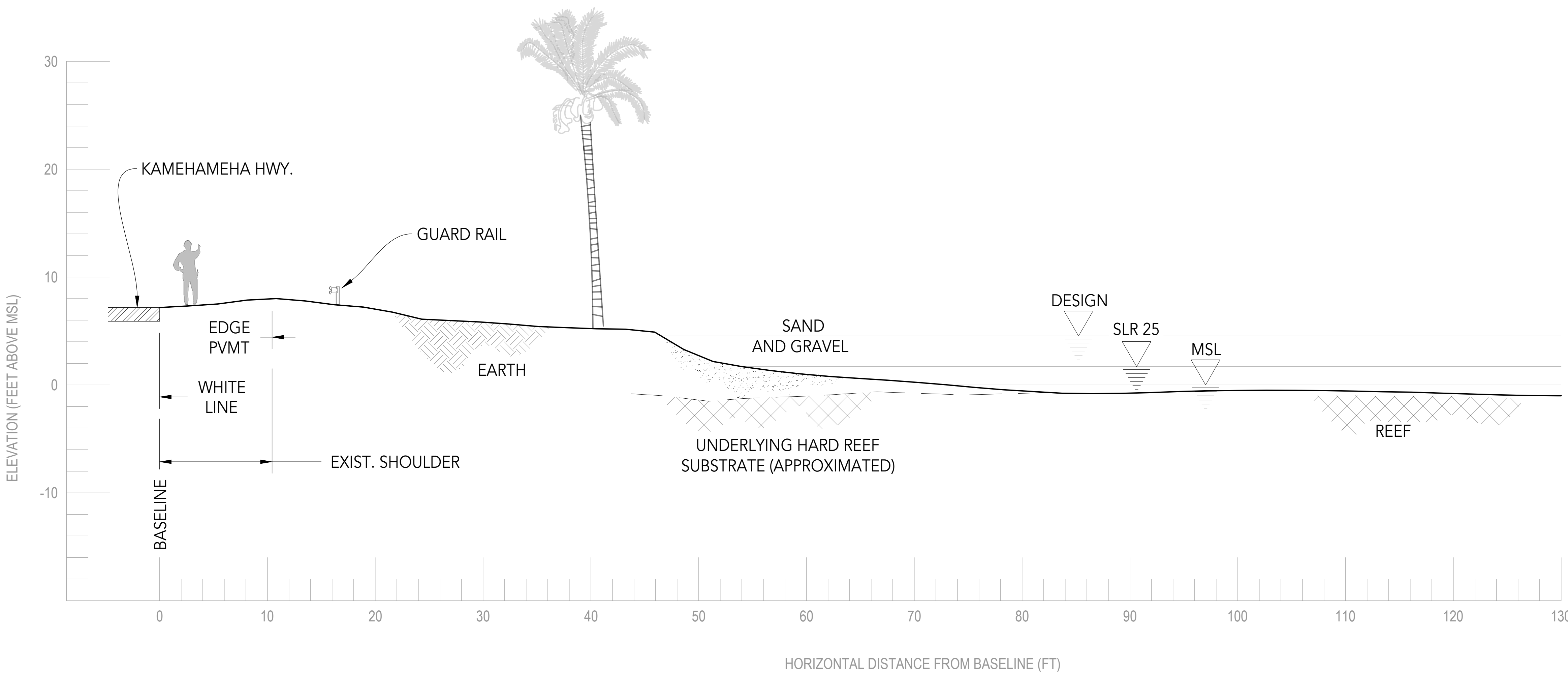
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.

Sheet Name
Kualoa Park (North) Low Slope Riprap Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-008	
Date 21 Mar 2022		
Scale $\frac{1}{2}$" = 1' - 0"		

Mon Mar 21 14:54:23 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***



01 EXISTING (2013) CROSS SECTION AT STATION 00+50
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 4.53 ft MSL

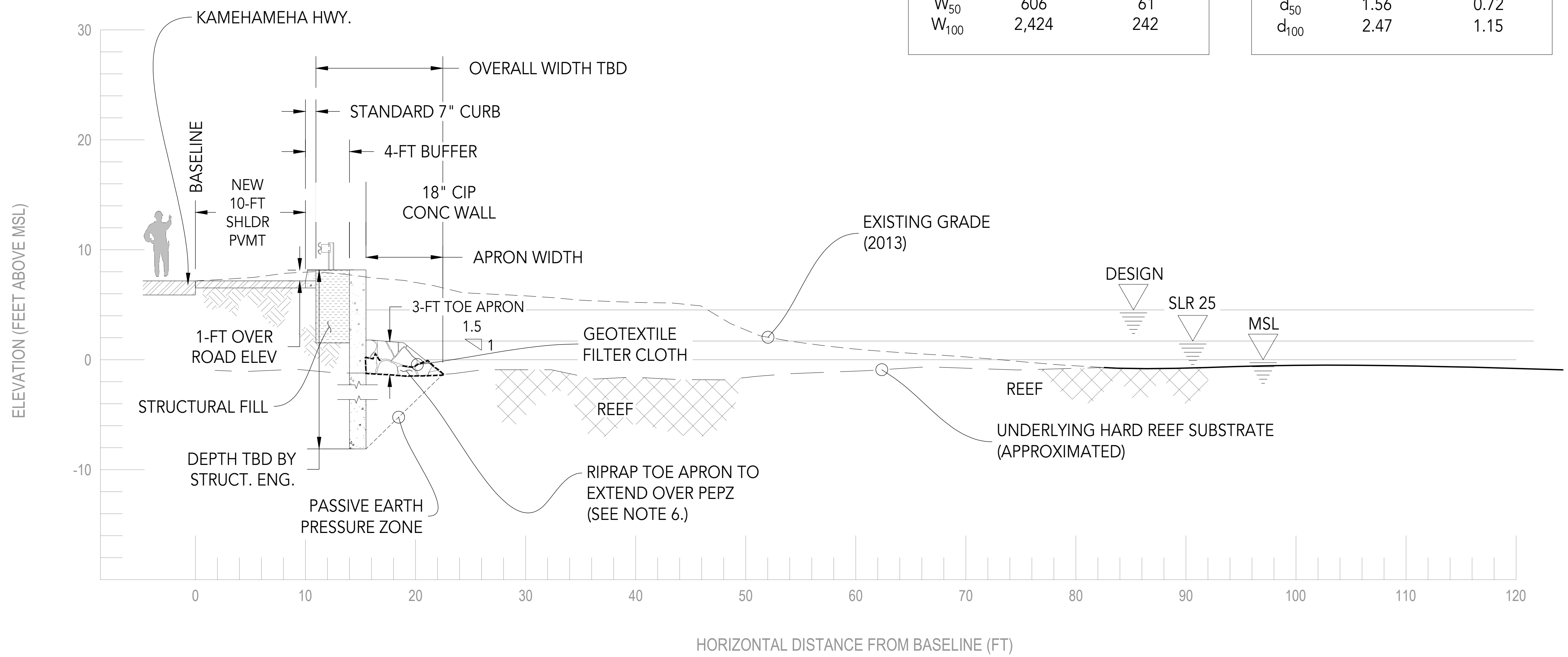
Sheet Name
Kualoa Park (North) Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	21 Mar 2022	C-009
Scale	1" = 1' - 0"	

STONE SIZE GRADATION		
-- BY WEIGHT (LBF) --		
	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
W_{15}	76	8
W_{50}	606	61
W_{100}	2,424	242

STONE SIZE GRADATION		
-- NOMINAL DIAMETER (FT) --		
	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
d_{15}	0.78	0.36
d_{50}	1.56	0.72
d_{100}	2.47	1.15



01 SEAWALL CROSS SECTION AT STATION 00+50
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Passive earth pressure (PEP) zone and wall depth to be determined by geotechnical and structural engineers as appropriate.
7. Toe apron riprap properties are provided in the stone size gradation tables above.
8. Thickness of toe apron is two-times median stone diameter, or 3 ft.

Sheet Name

Kualoa Park (North) Armored Seawall Section - Conceptual

Project Name

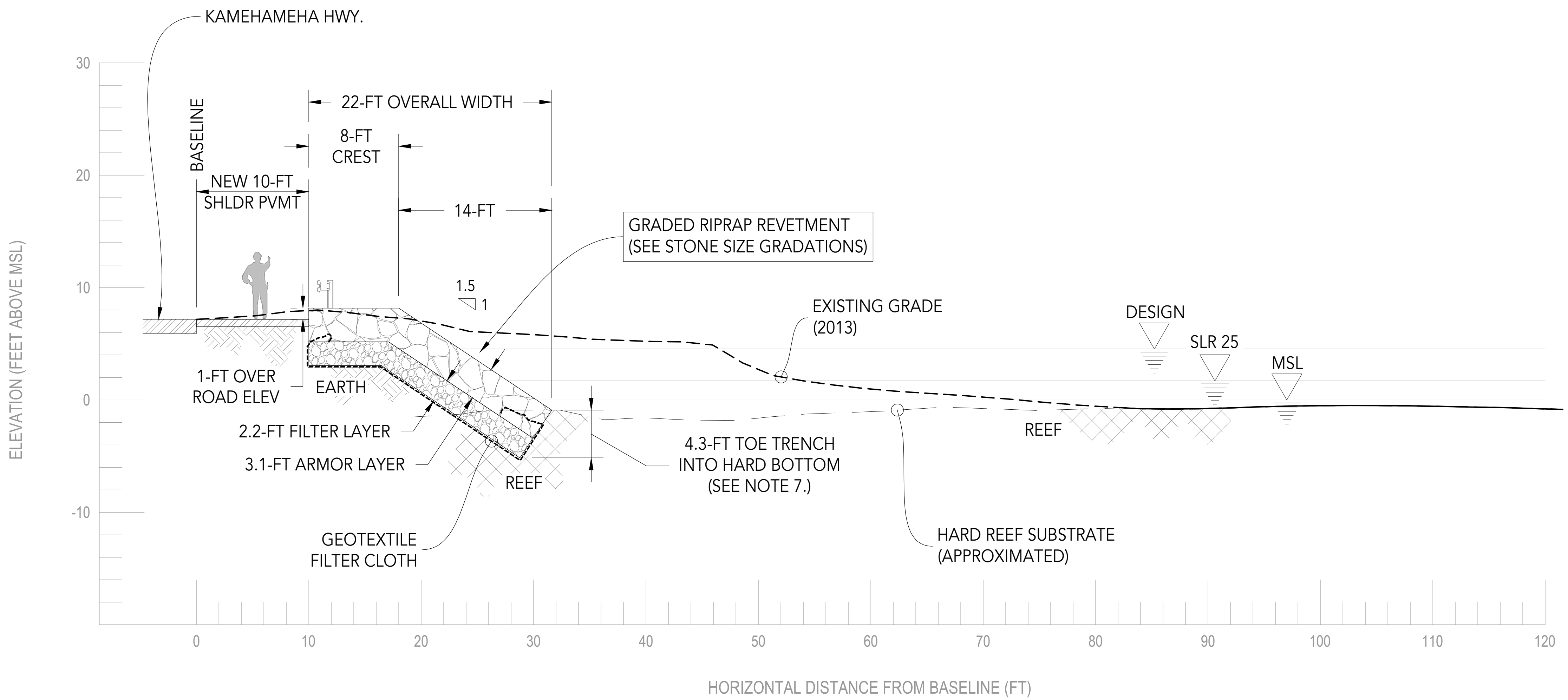
KKPH Kamehameha Highway Shore Protection

Project No. 25853

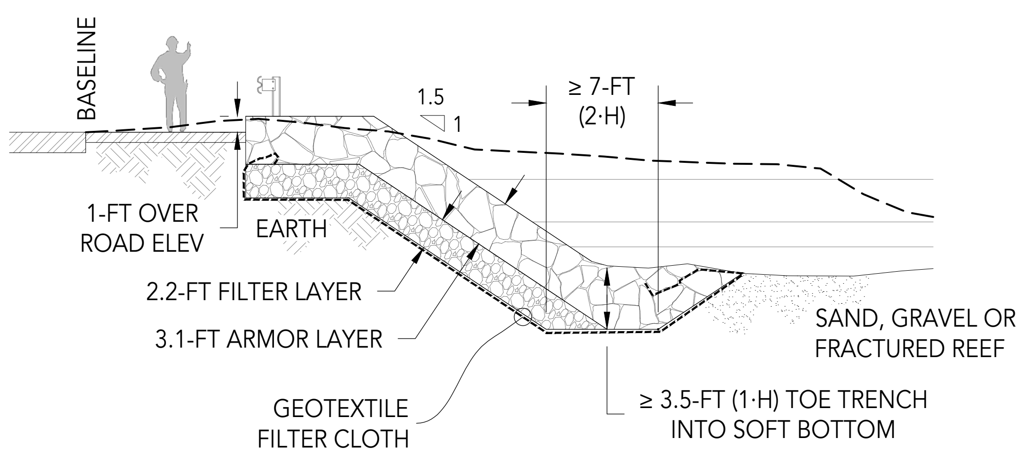
Date 21 Mar 2022

Scale 1" = 1' - 0"

Sheet C-010



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 00+50
NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	76	8
W_{50}	606	61
W_{100}	2,424	242

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.78	0.36
d_{50}	1.56	0.72
d_{100}	2.47	1.15

GRADED RIPRAP STONE SIZE GRADATION TABLES

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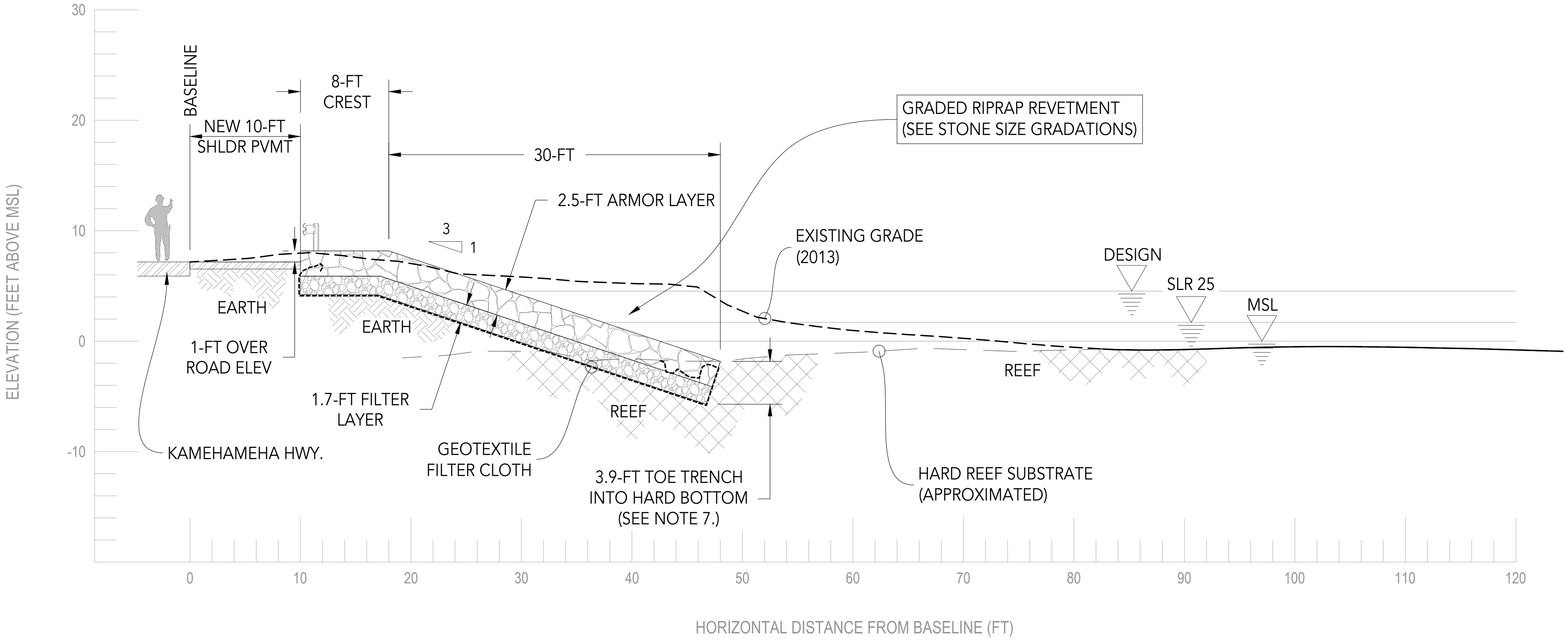
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables above.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 3.5 ft, for this location.

Sheet Name
Kualoa Park (North) High Slope Riprap Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-011



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 00+50
NTS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	38	4
W_{50}	303	30
W_{100}	1,212	121

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.62	0.29
d_{50}	1.24	0.57
d_{100}	1.96	0.91

GRADED RIPRAP STONE SIZE GRADATION TABLES

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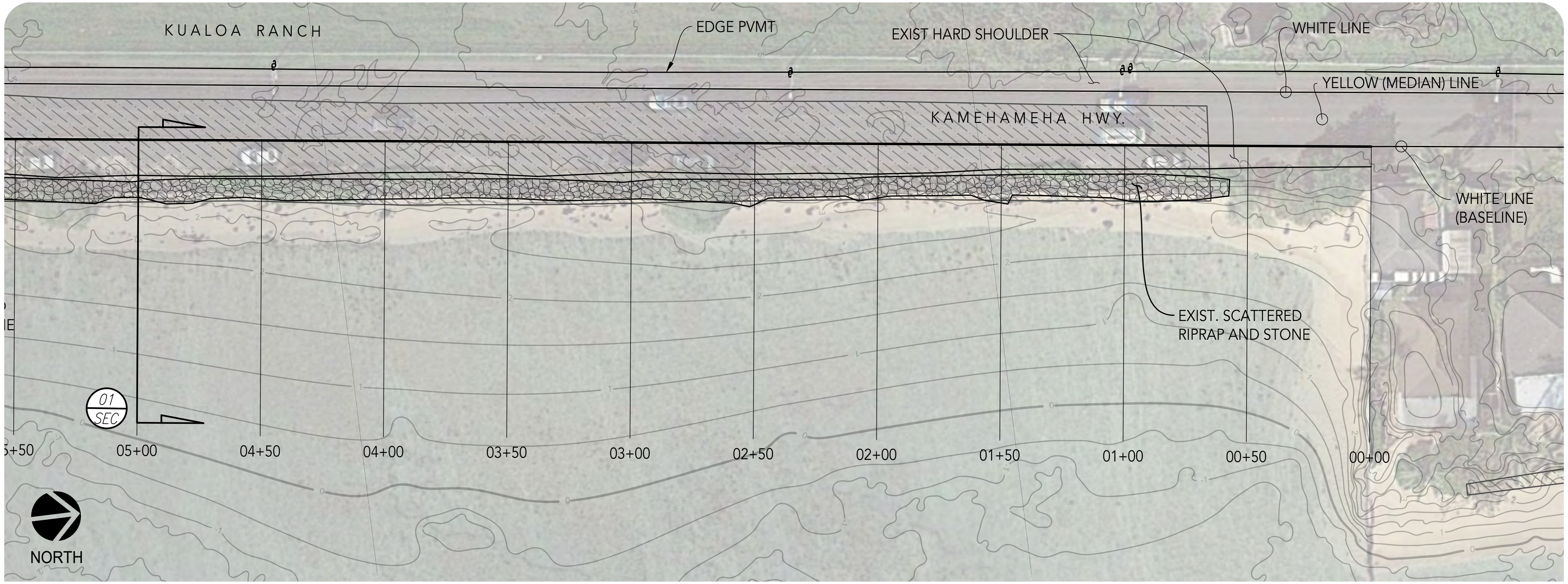
NOTES:

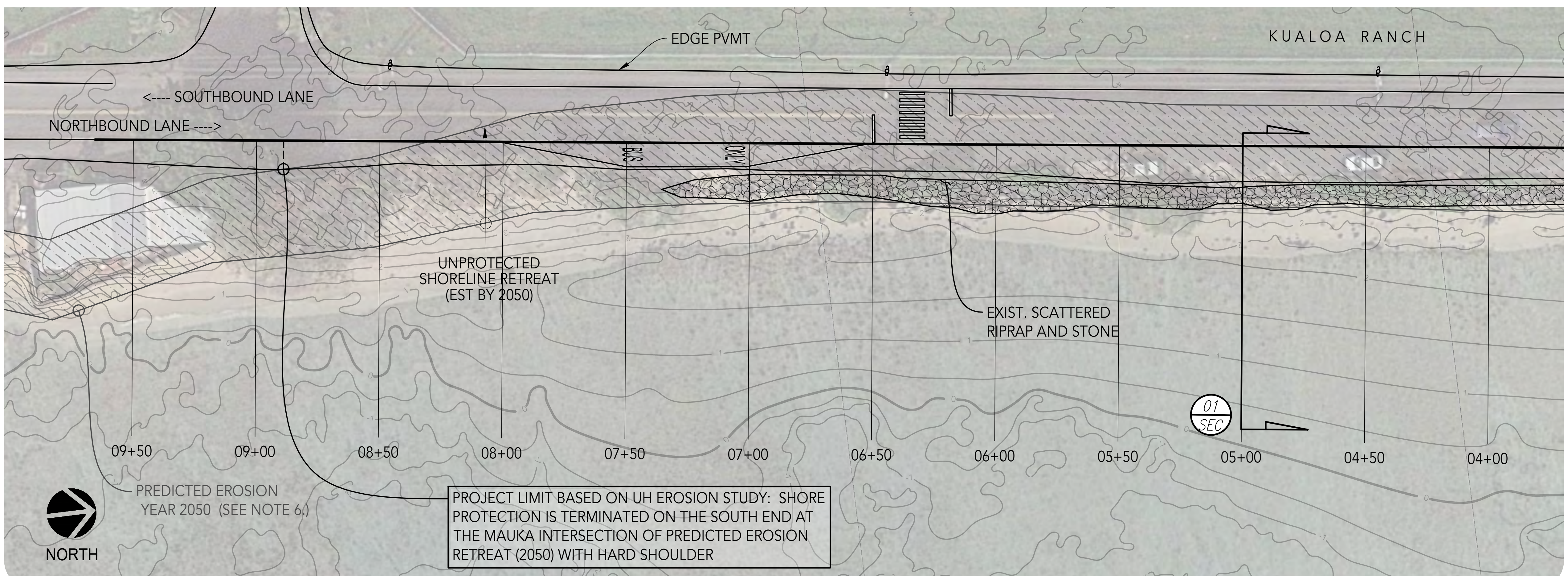
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables above.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 3.5 ft, for this location.

Sheet Name
Kualoa Park (North) Low Slope Riprap Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-012





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

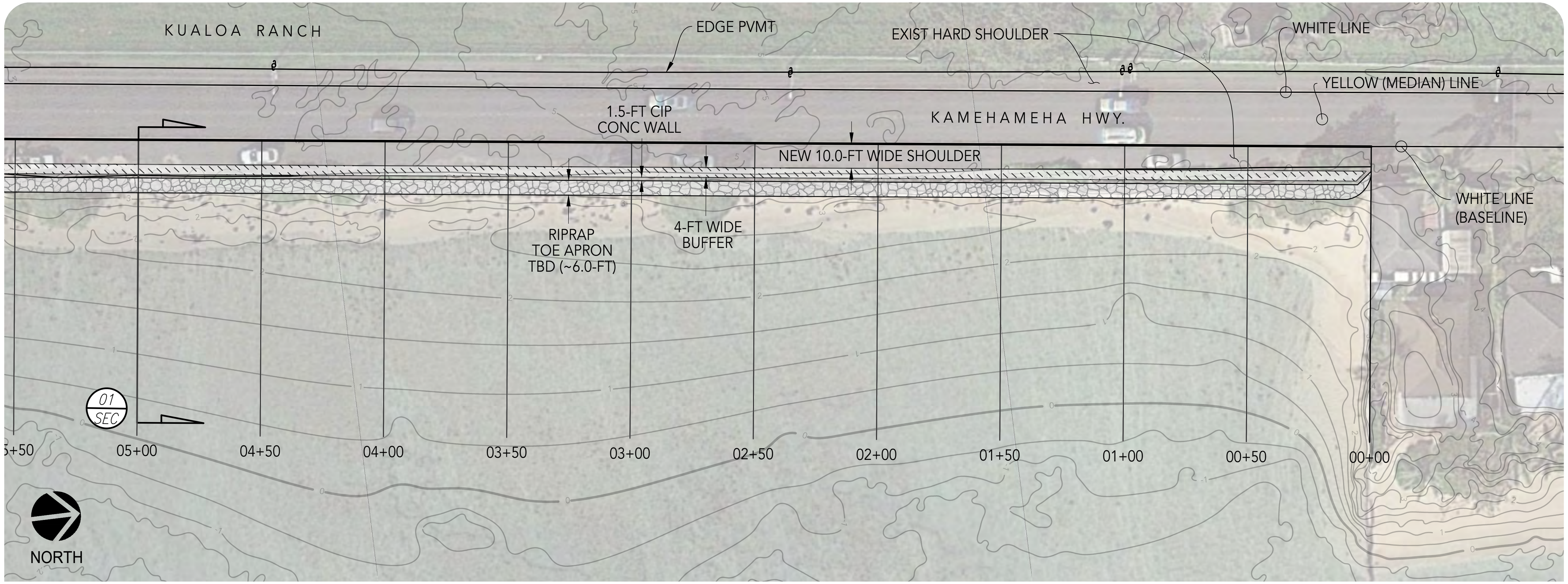
Sheet Name

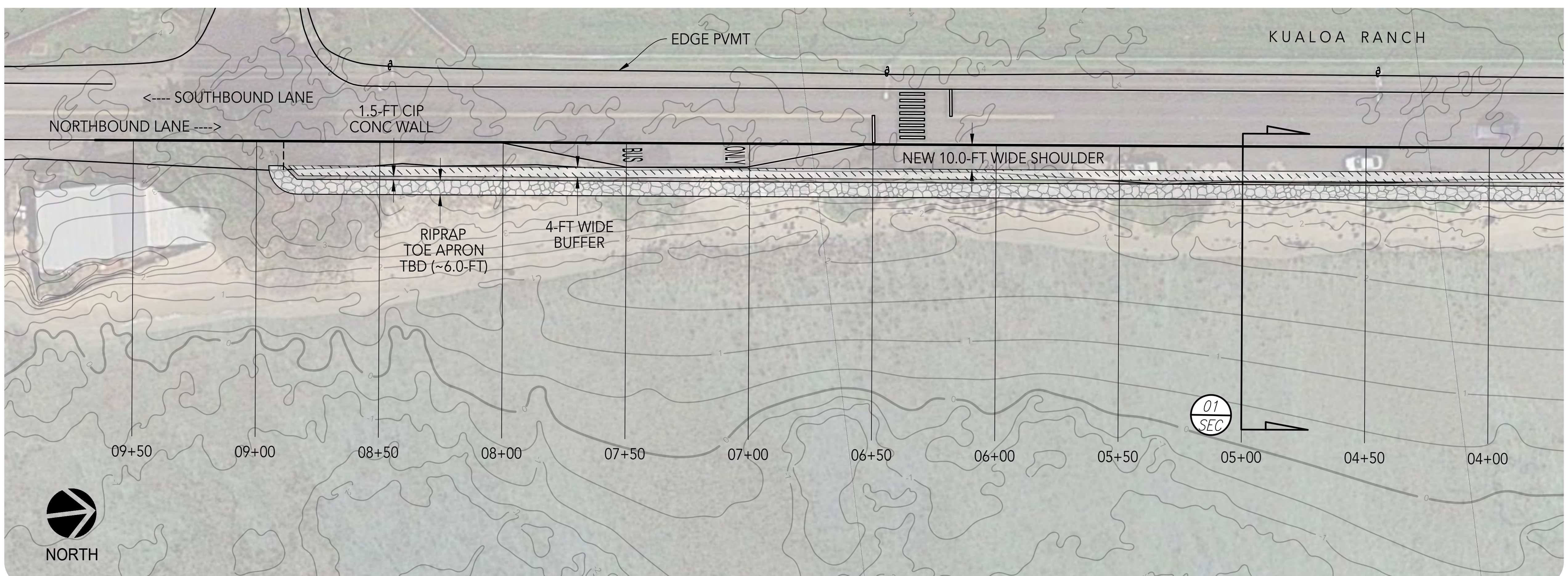
Kualoa Ranch Existing Condition Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-013
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Top of wall elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Wall and toe apron terminate by turning back into slope to prevent flanking erosion or use lateral end wall.
5. Wall to tie into culvert or bridge wing walls where present.

Sheet Name

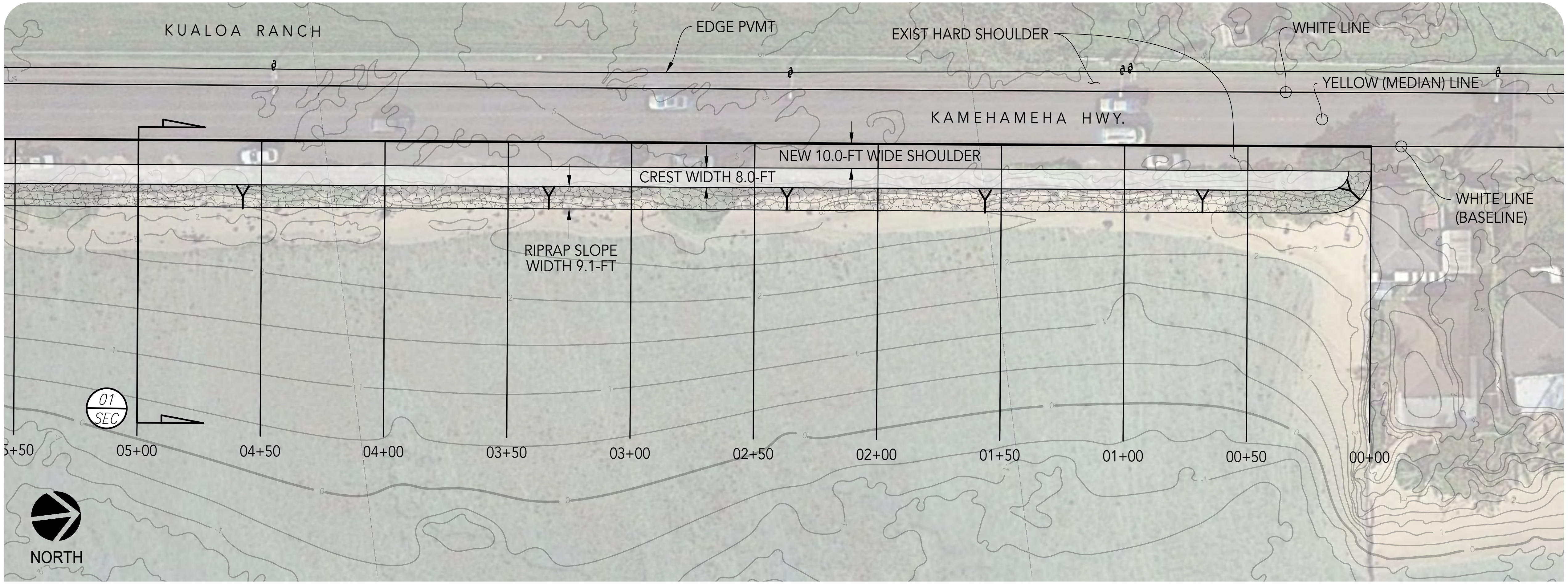
Kualoa Ranch Armored Seawall Plan - Conceptual

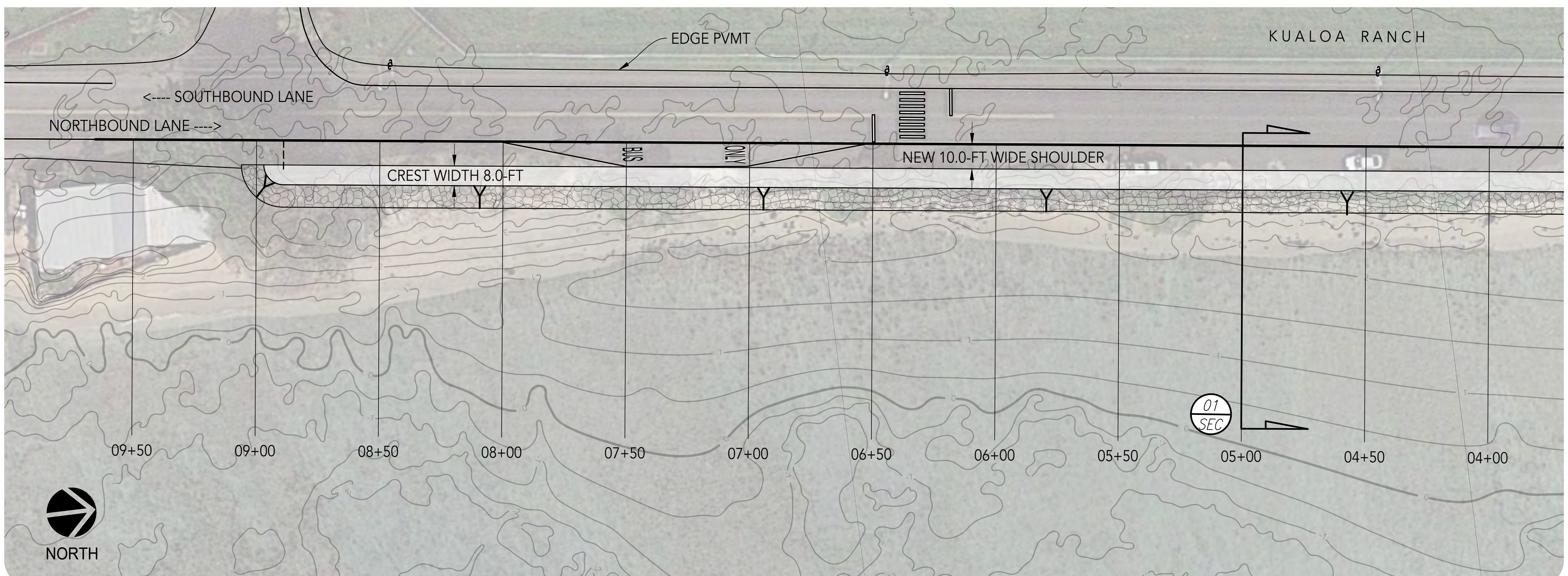
Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-014
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

Mon Mar 21 14:57:38 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Kualoa Ranch High Slope Riprap Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-015
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

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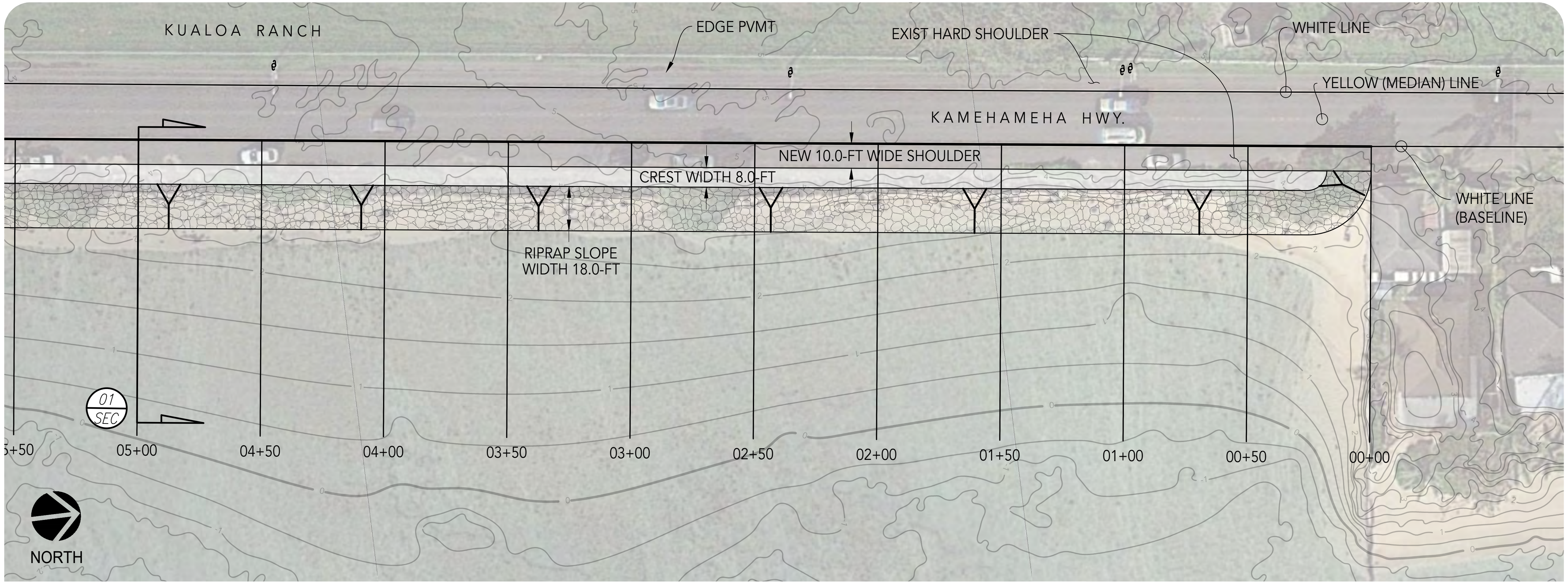

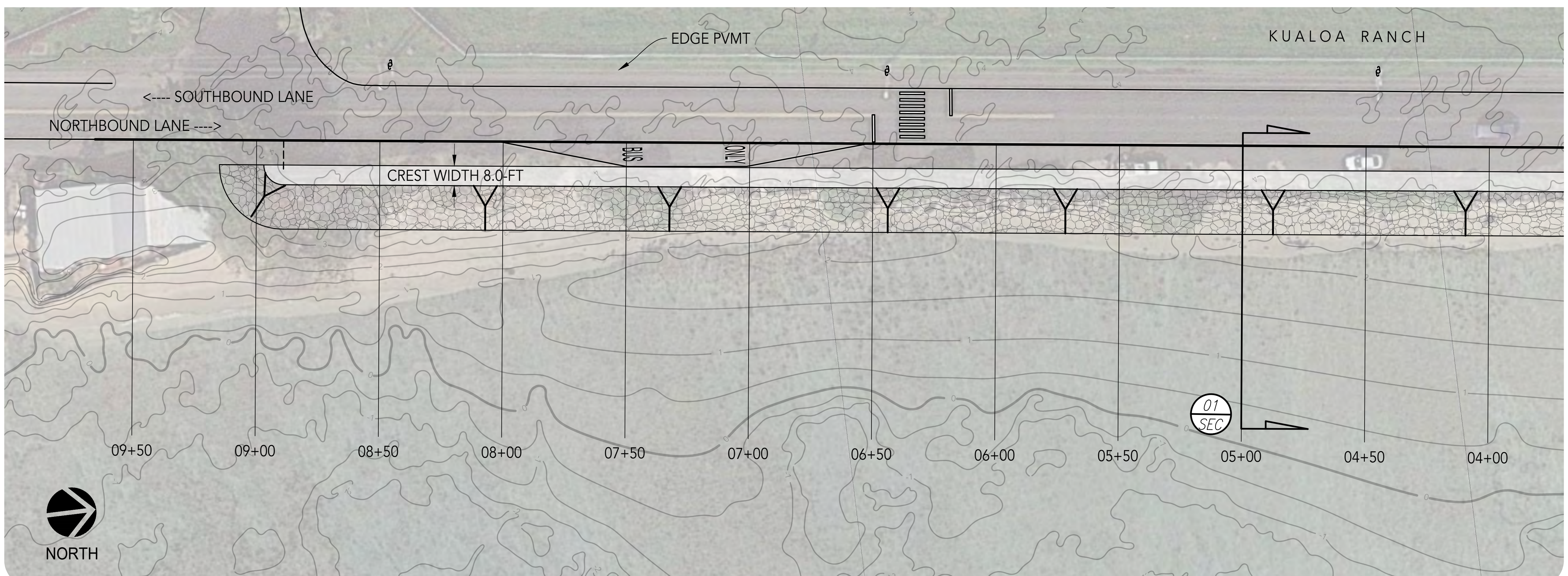

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NOTES:

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2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
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5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

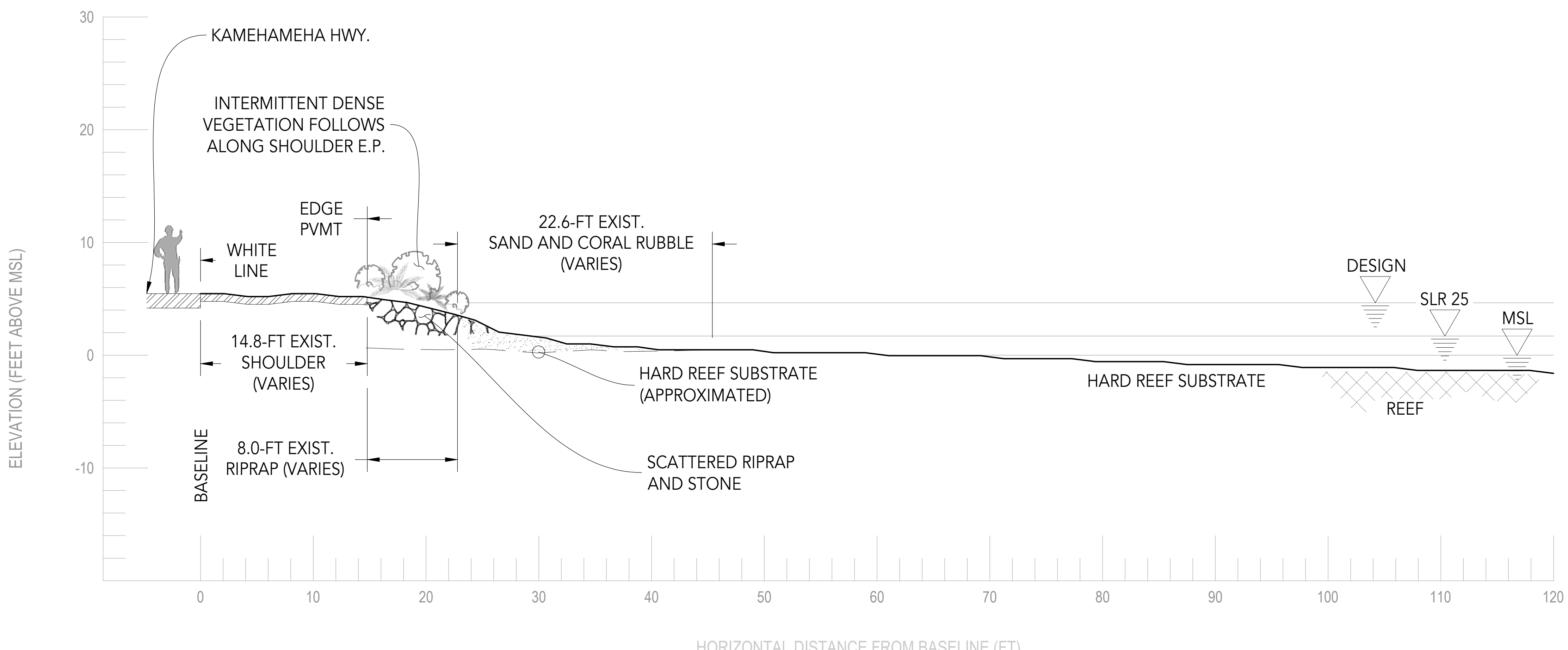
Sheet Name

Kualoa Ranch Low Slope Riprap Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-016
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	



01 EXISTING (2013) CROSS SECTION AT STATION 05+00
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

   MSL = Mean Sea Level

   SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

   Design = Design Water Level, including storm surge, SLR and astronomical tide, 4.65 ft MSL

Sheet Name
Kualoa Ranch Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-017
Date 21 Mar 2022	
Scale 1" = 1' - 0"	

GRADED RIPRAP STONE SIZE GRADATION TABLES

STONE SIZE GRADATION

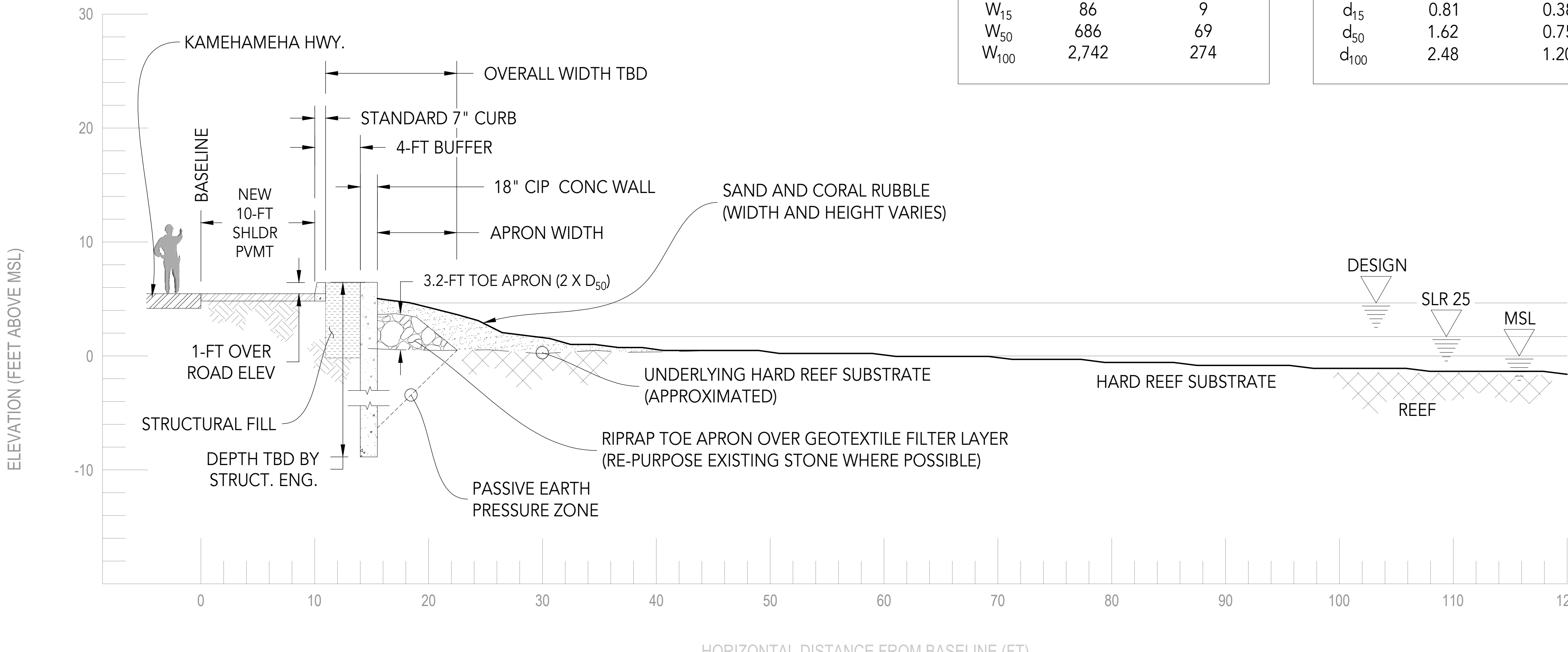
-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	86	9
W_{50}	686	69
W_{100}	2,742	274

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.81	0.38
d_{50}	1.62	0.75
d_{100}	2.48	1.20



01 SEAWALL CROSS SECTION (TYPICAL) AT PROFILE 05+00

NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Passive earth pressure (PEP) zone and wall depth to be determined by geotechnical and structural engineers as appropriate.
7. Toe apron riprap properties are provided in the stone size gradation tables above.
8. Thickness of toe apron is two-times median stone diameter, or 3.2 ft.

Sheet Name

Kualoa Ranch Armored Seawall Section - Conceptual

Project Name

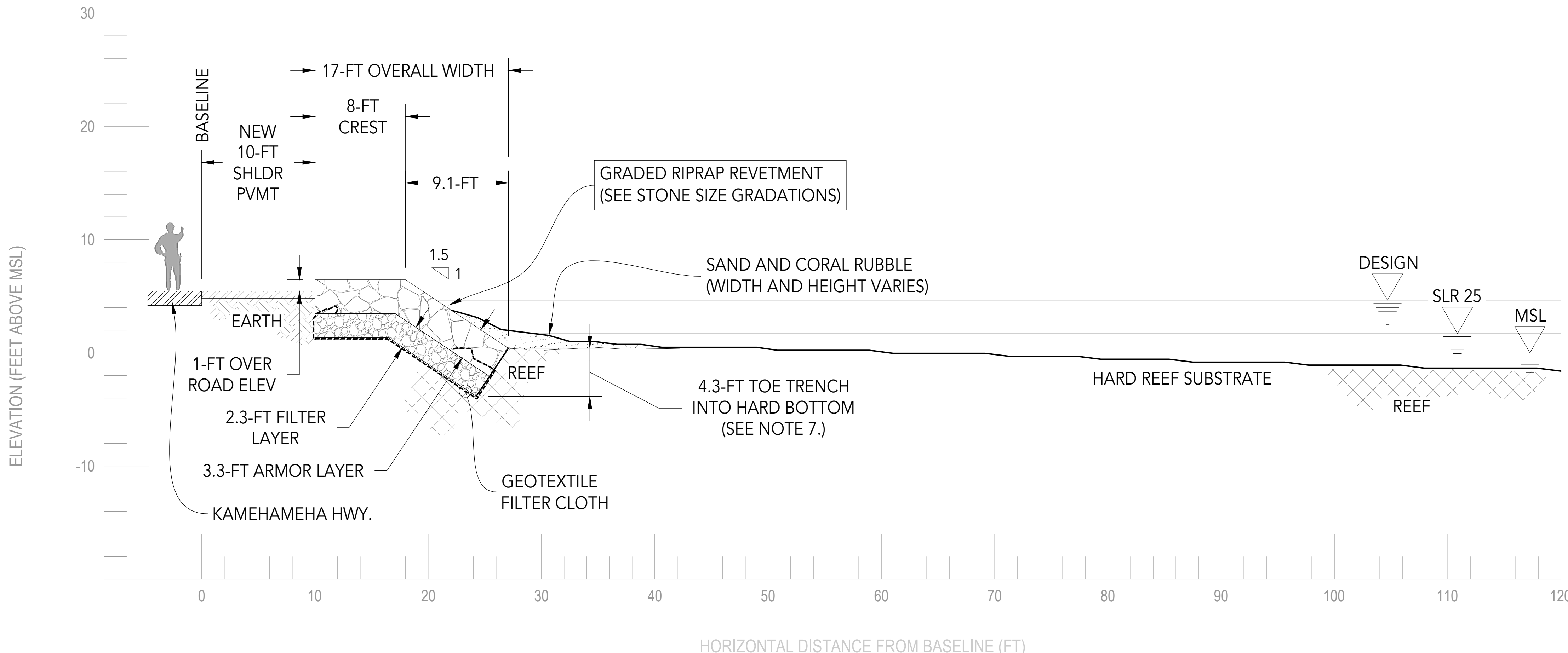
KKPH Kamehameha Highway Shore Protection

Project No. 25853

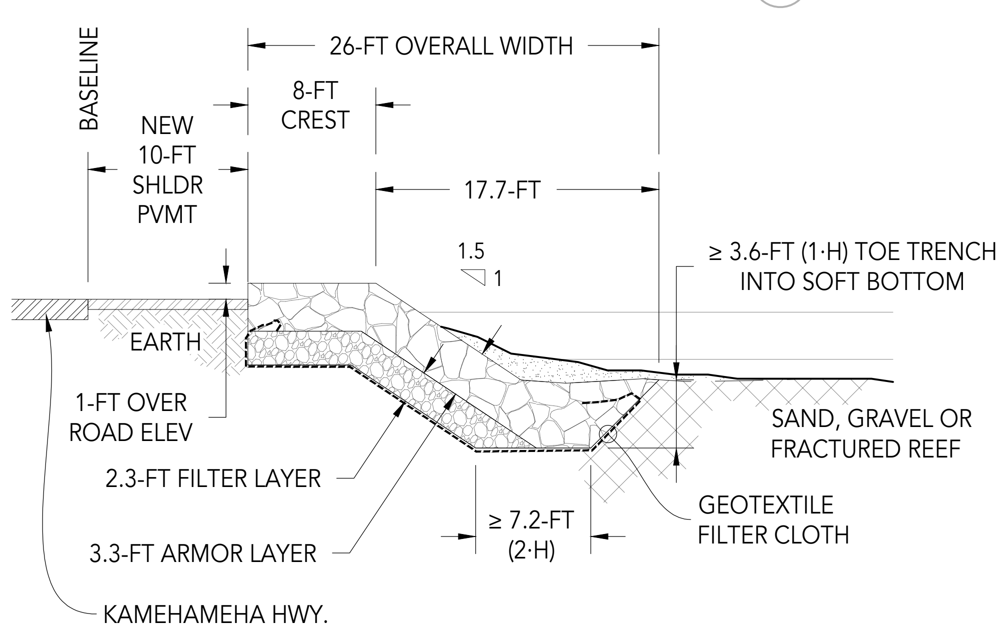
Date 21 Mar 2022

Scale 1" = 1' - 0"

Sheet C-018



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 05+00
NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	86	9
W_{50}	686	69
W_{100}	2,742	274

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.81	0.38
d_{50}	1.62	0.75
d_{100}	2.48	1.20

GRADED RIPRAP STONE SIZE GRADATION TABLES

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NOTES:

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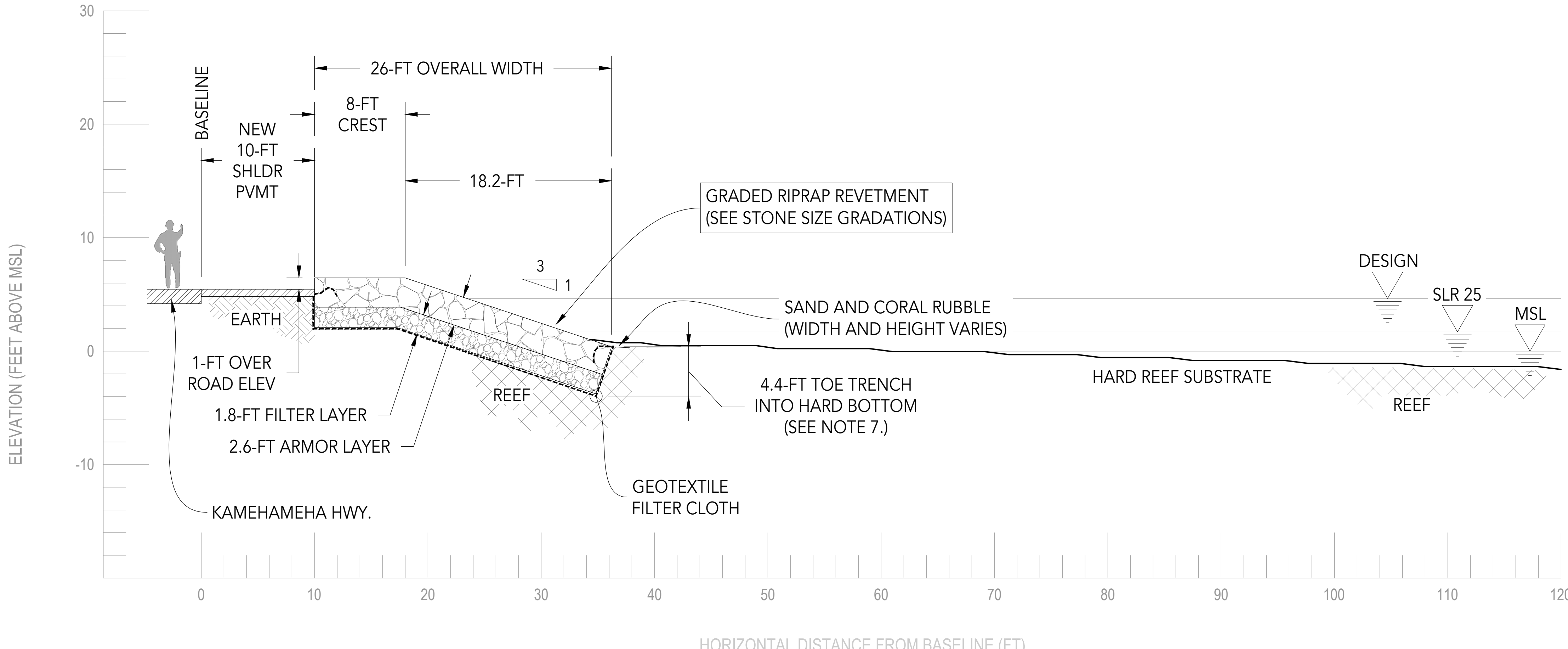
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 3.6 ft, for this location.

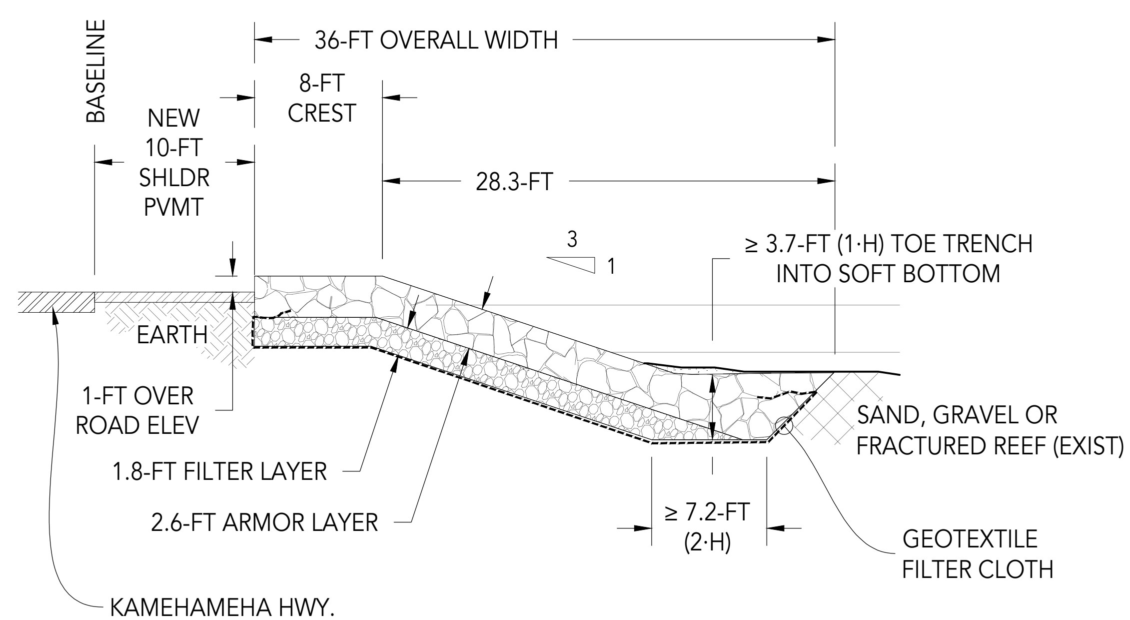
Sheet Name
Kualoa Ranch High Slope Riprap Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-019



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 05+00
NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	43	4
W_{50}	343	34
W_{100}	1,371	137

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.64	0.30
d_{50}	1.29	0.60
d_{100}	2.05	0.95

GRADED RIPRAP STONE SIZE GRADATION TABLES

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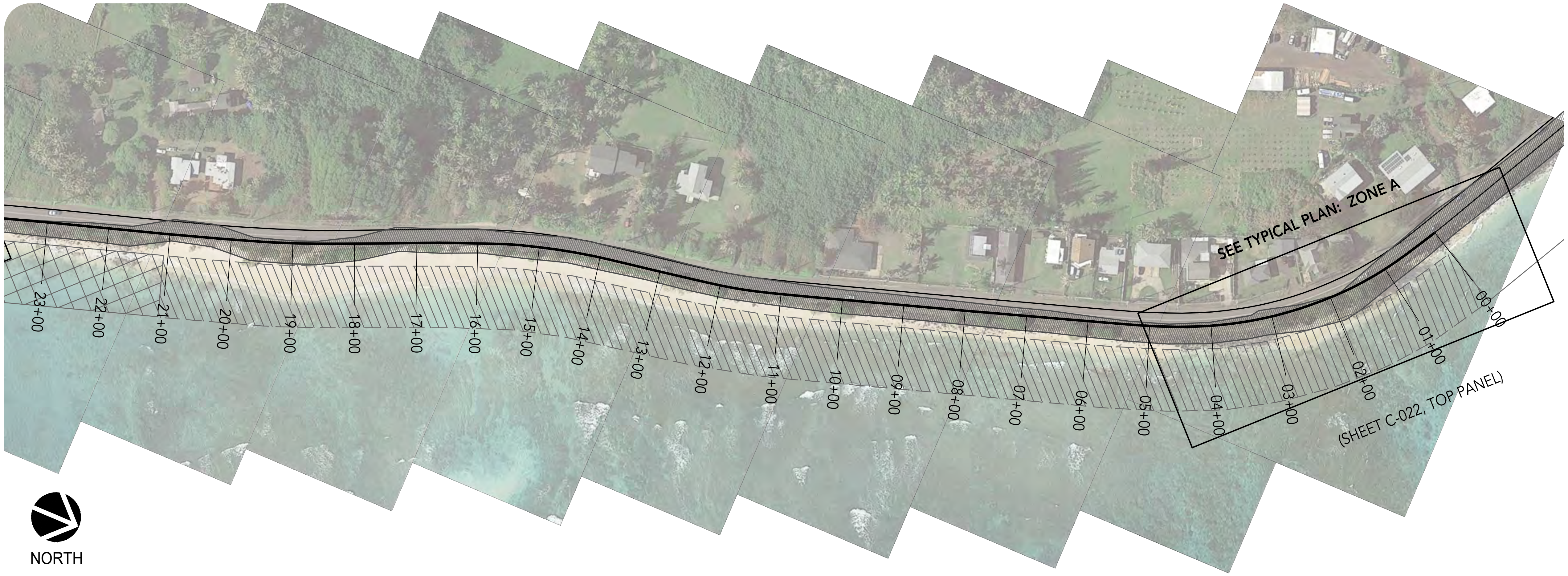
NOTES:

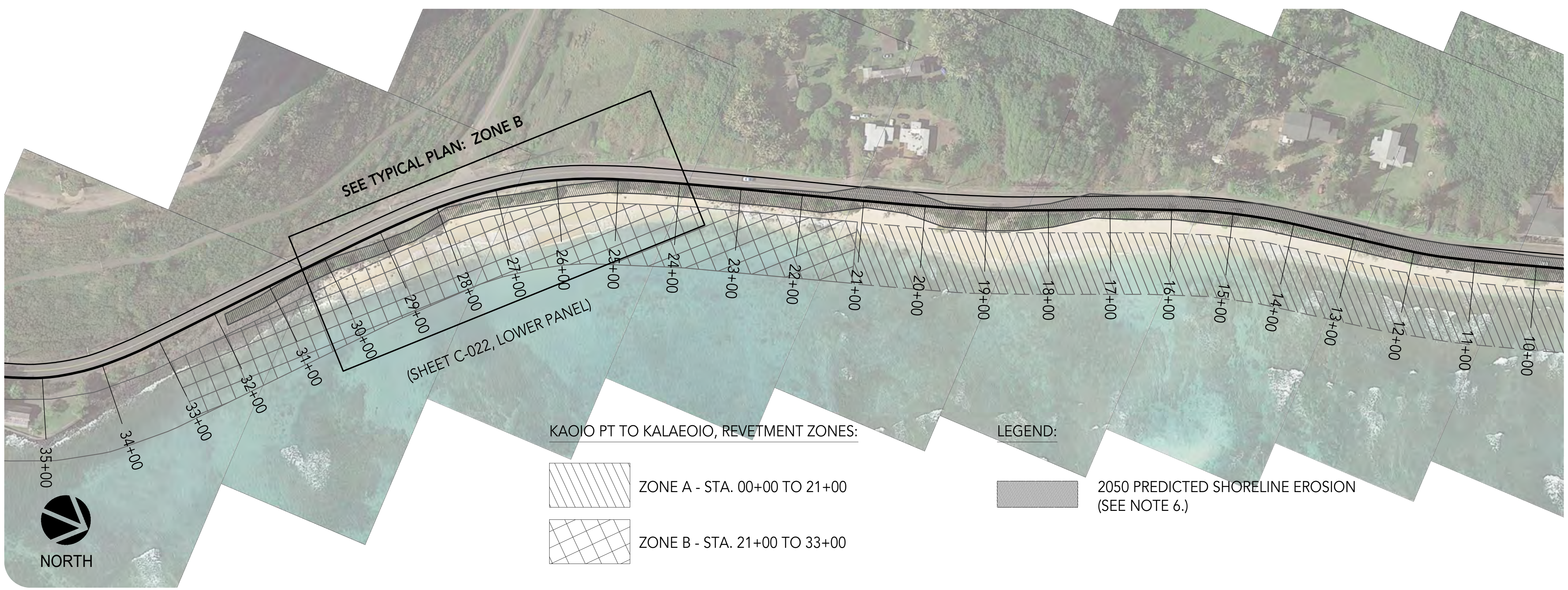
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 3.6 ft, for this location.

Sheet Name
Kualoa Ranch Low Slope Riprap Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	21 Mar 2022	C-020
Scale	1" = 1' - 0"	





KAOIO PT TO KALAEOIO, REVETMENT ZONES:

ZONE A - STA. 00+00 TO 21+00

ZONE B - STA. 21+00 TO 33+00

LEGEND:

2050 PREDICTED SHORELINE EROSION (SEE NOTE 6.)

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NOTES:

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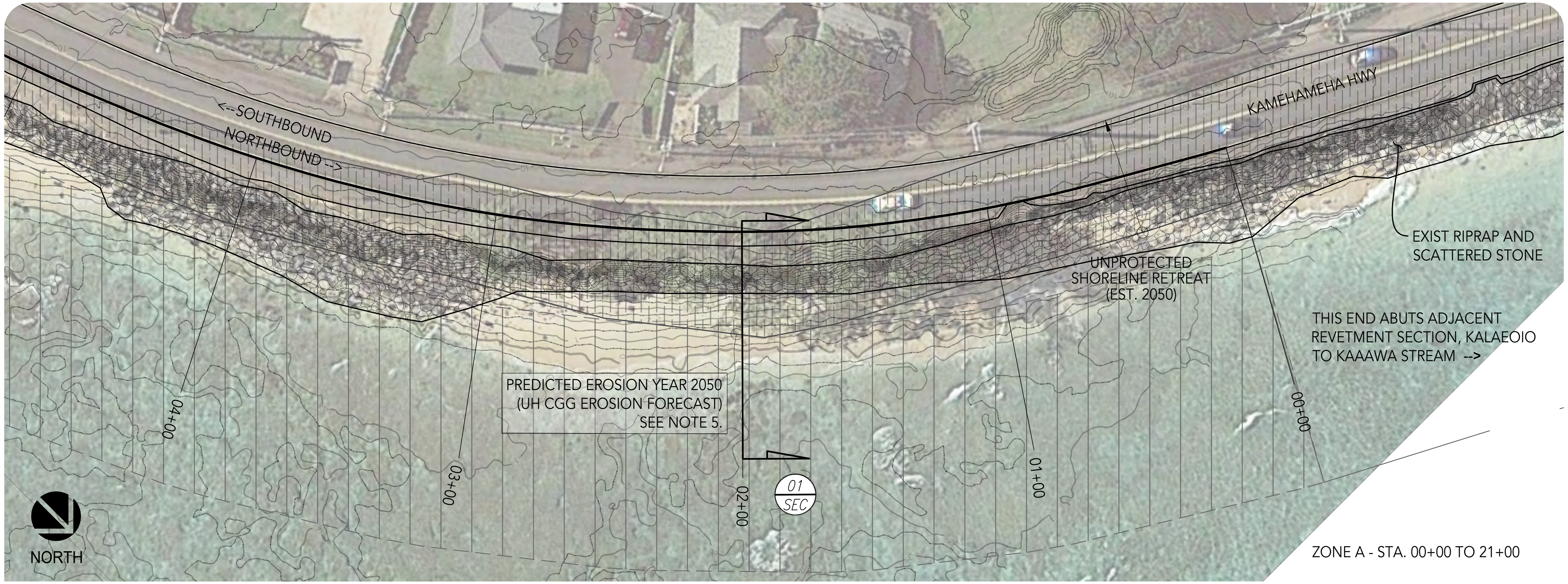
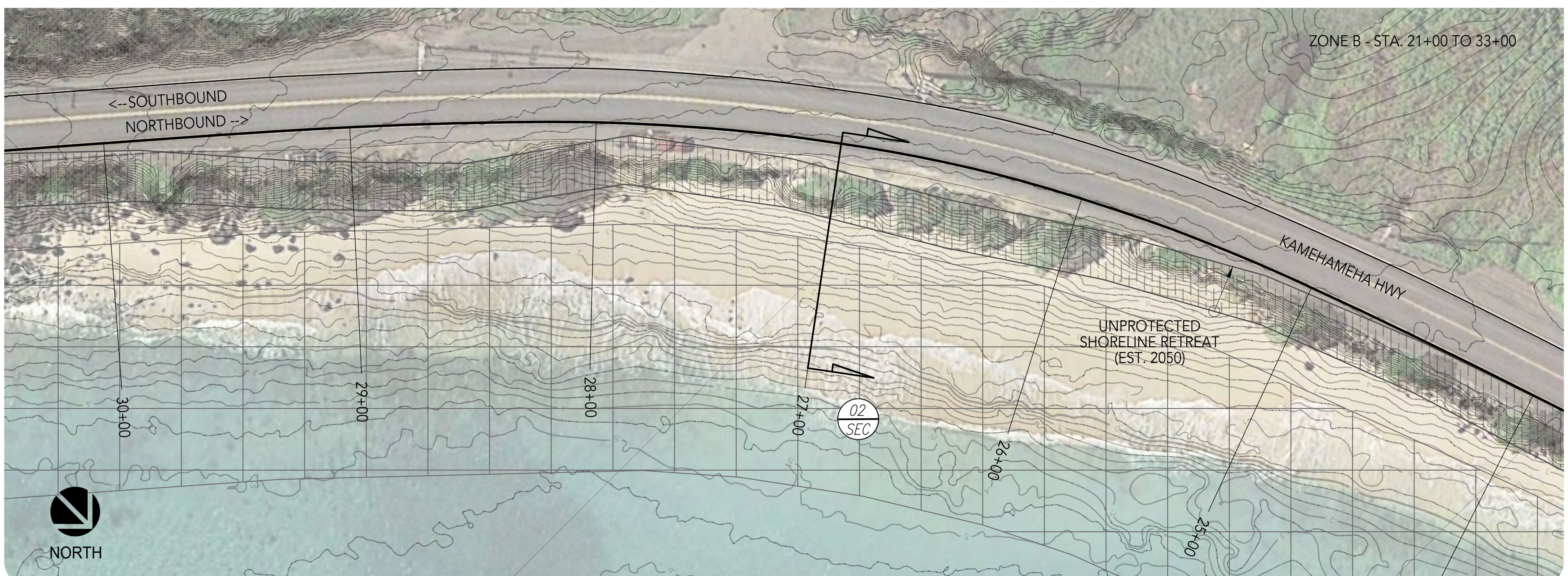
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai white "fog line" lane marking along Kamehameha Hwy as shown. Revetted length is approx. 3,300 ft, from Sta 00+00 to 33+00.

Sheet Name
Kaoio Pt. To Kalaeoio Existing Condition Plan

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-021
Date 21 Mar 2022	
Scale $\frac{1}{16}$" = 1' - 0"	





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NOTES:

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6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Kaoio Pt. To Kalaeoio Sta. 02+00 and 27+00 Existing Condition Plan

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-022
Date	21 Mar 2022	
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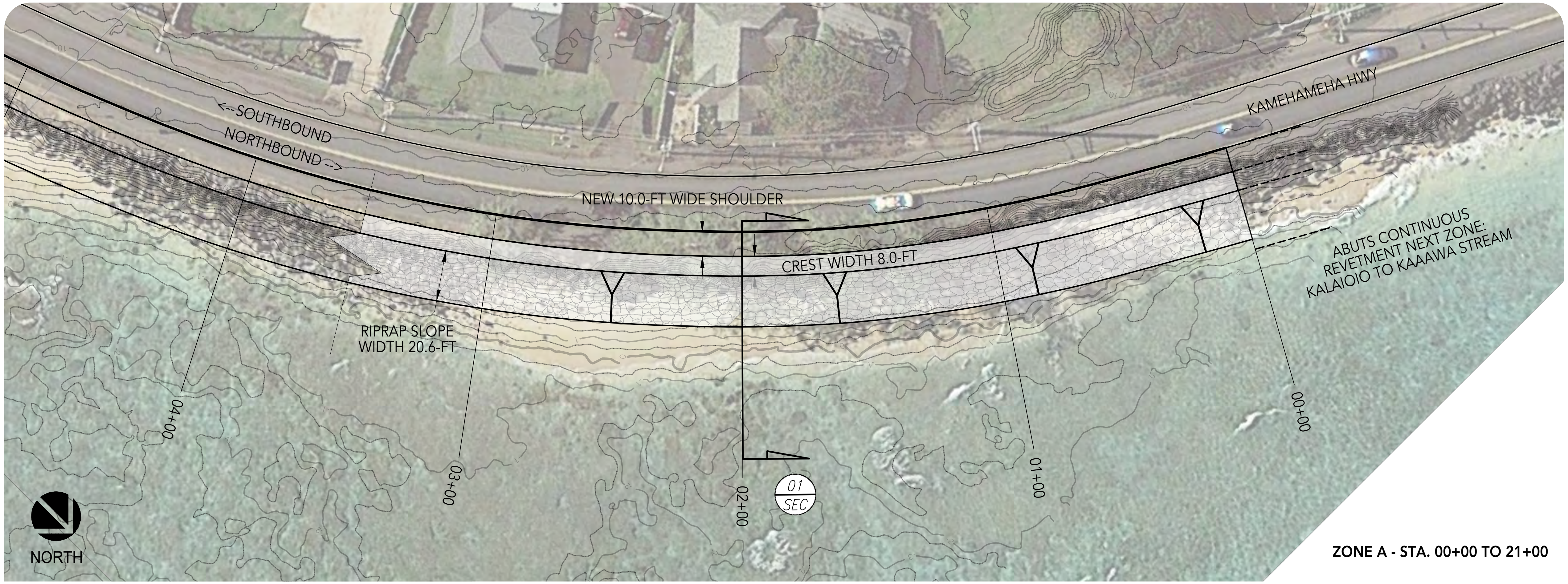

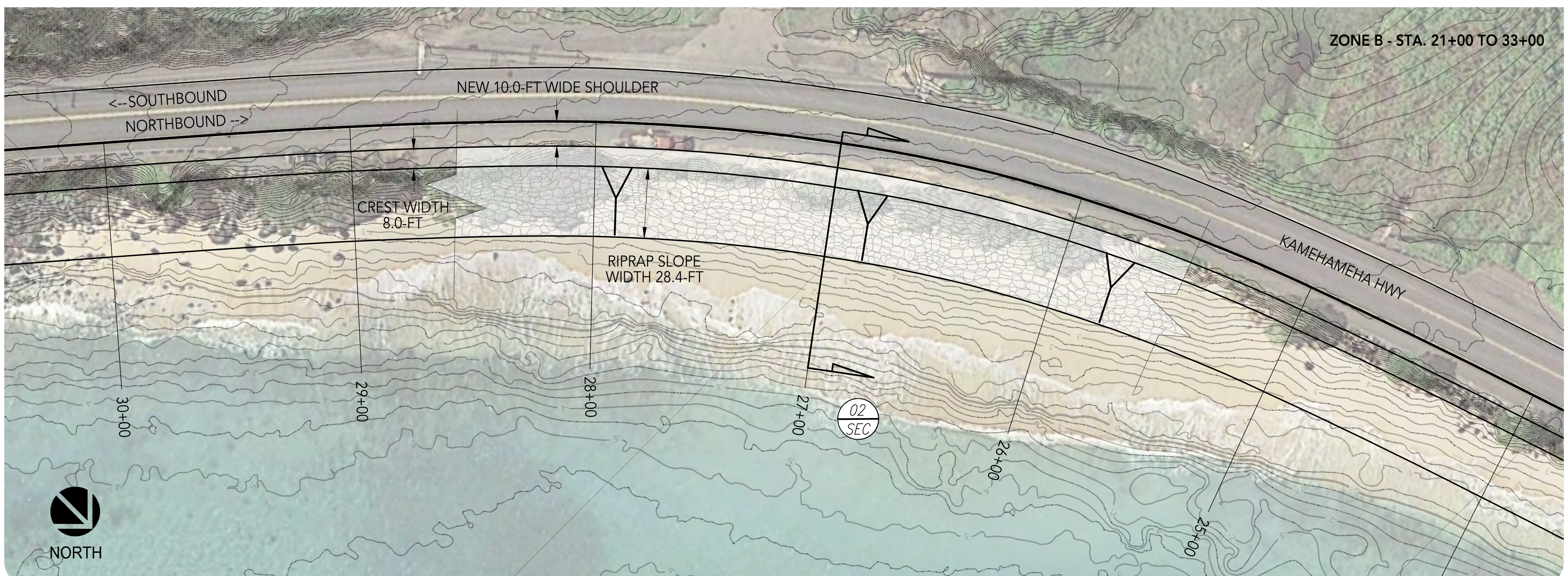

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NOTES:

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5. Revetment to tie into culvert or bridge wing walls where present.
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7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

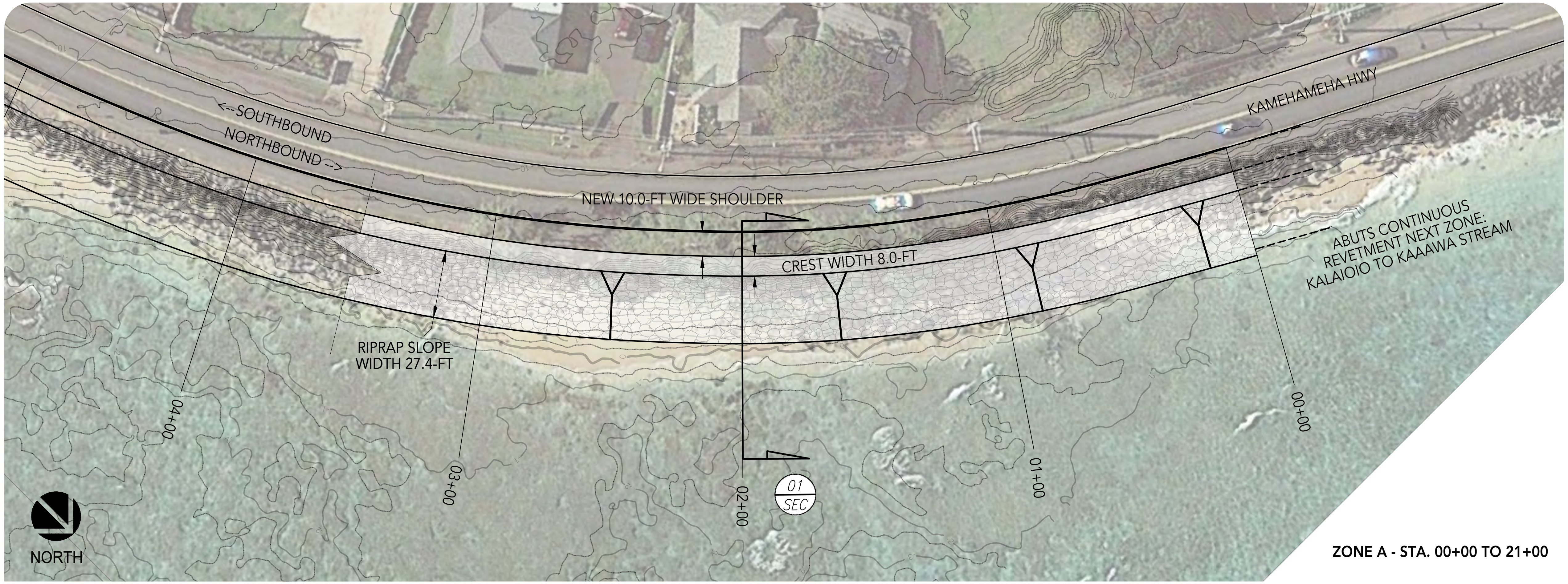
Sheet Name

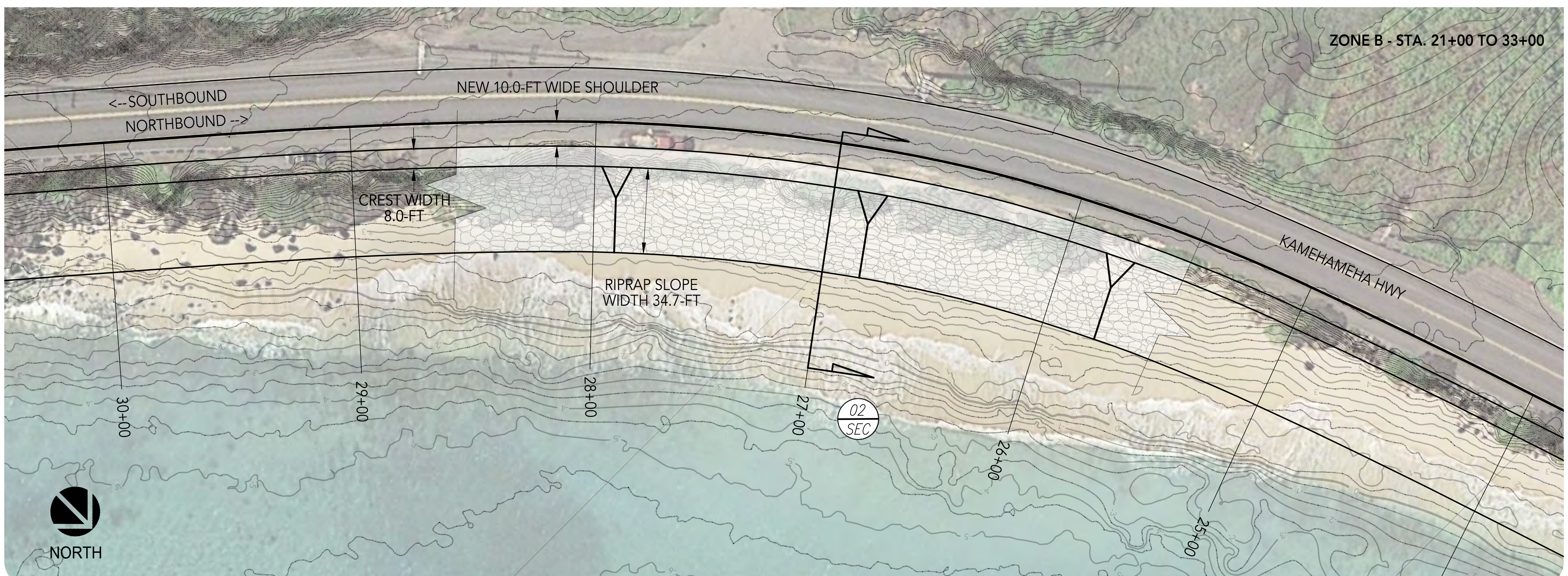
Kaoio Pt. To Kalaeoio Sta. 02+00 and 27+00 High Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-023
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





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NOTES:

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4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

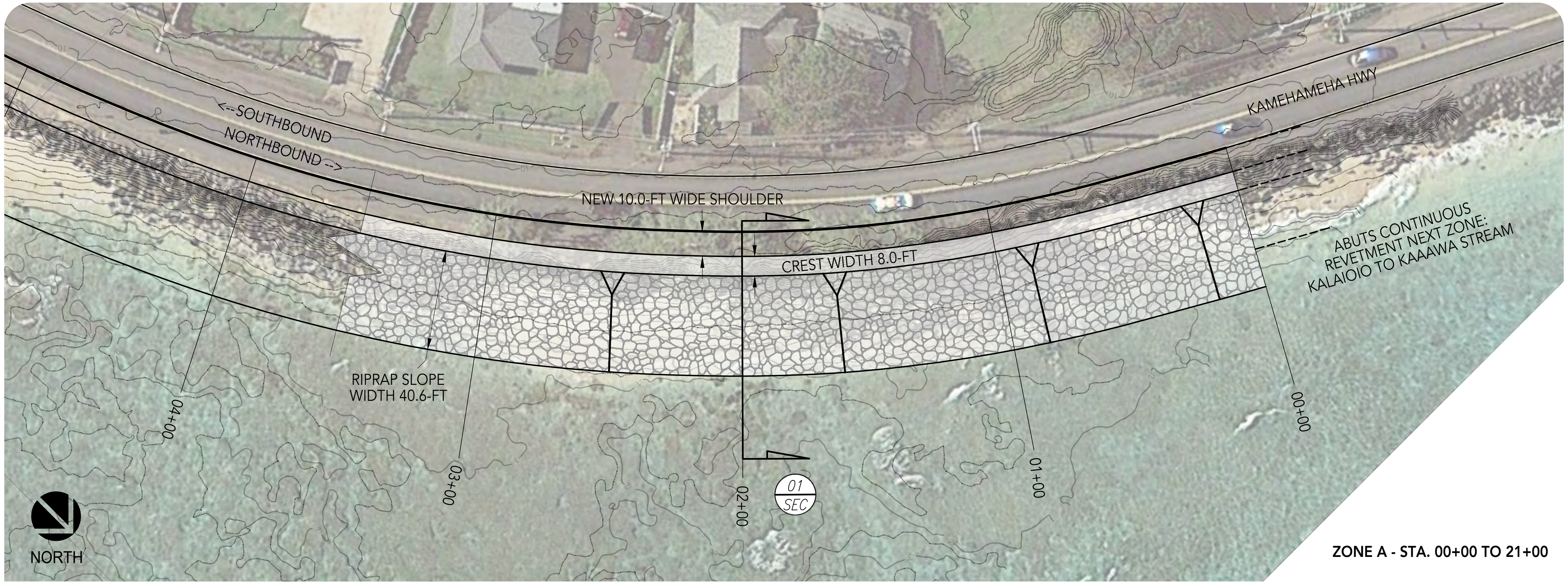
Sheet Name

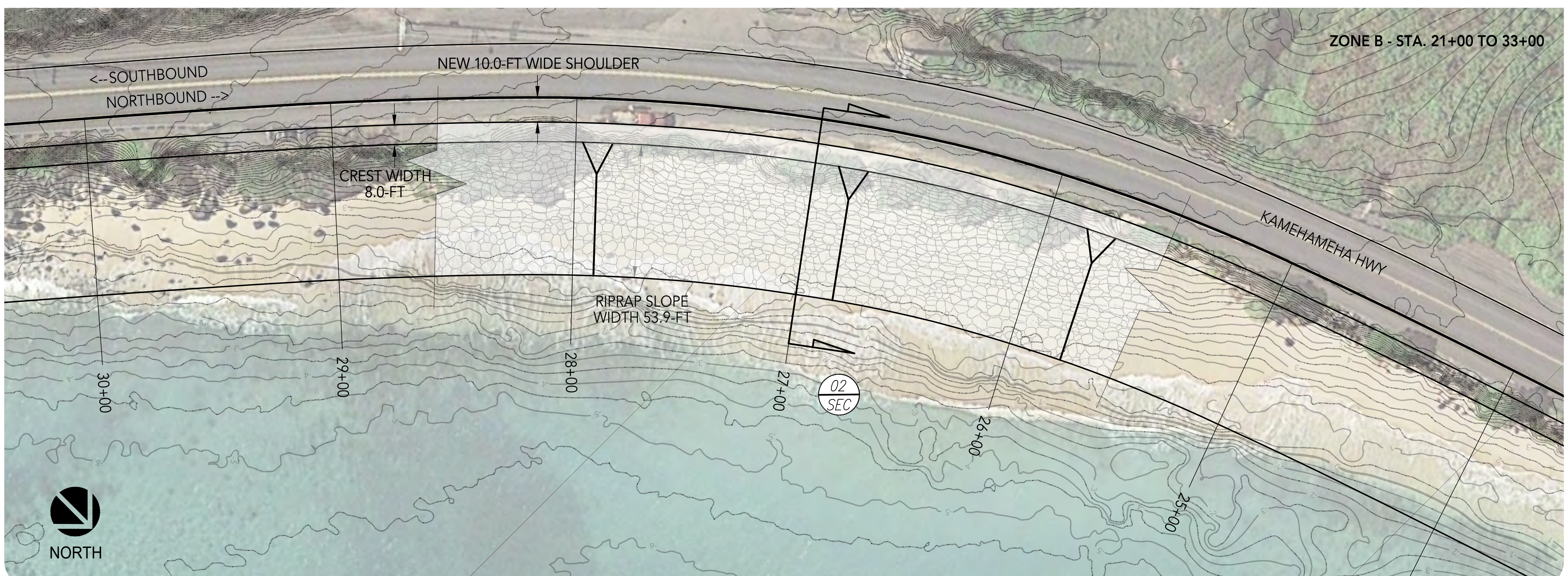
Kaoio Pt. To Kalaeoio Sta. 02+00 and 27+00 Mild Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-024
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





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NOTES:

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5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

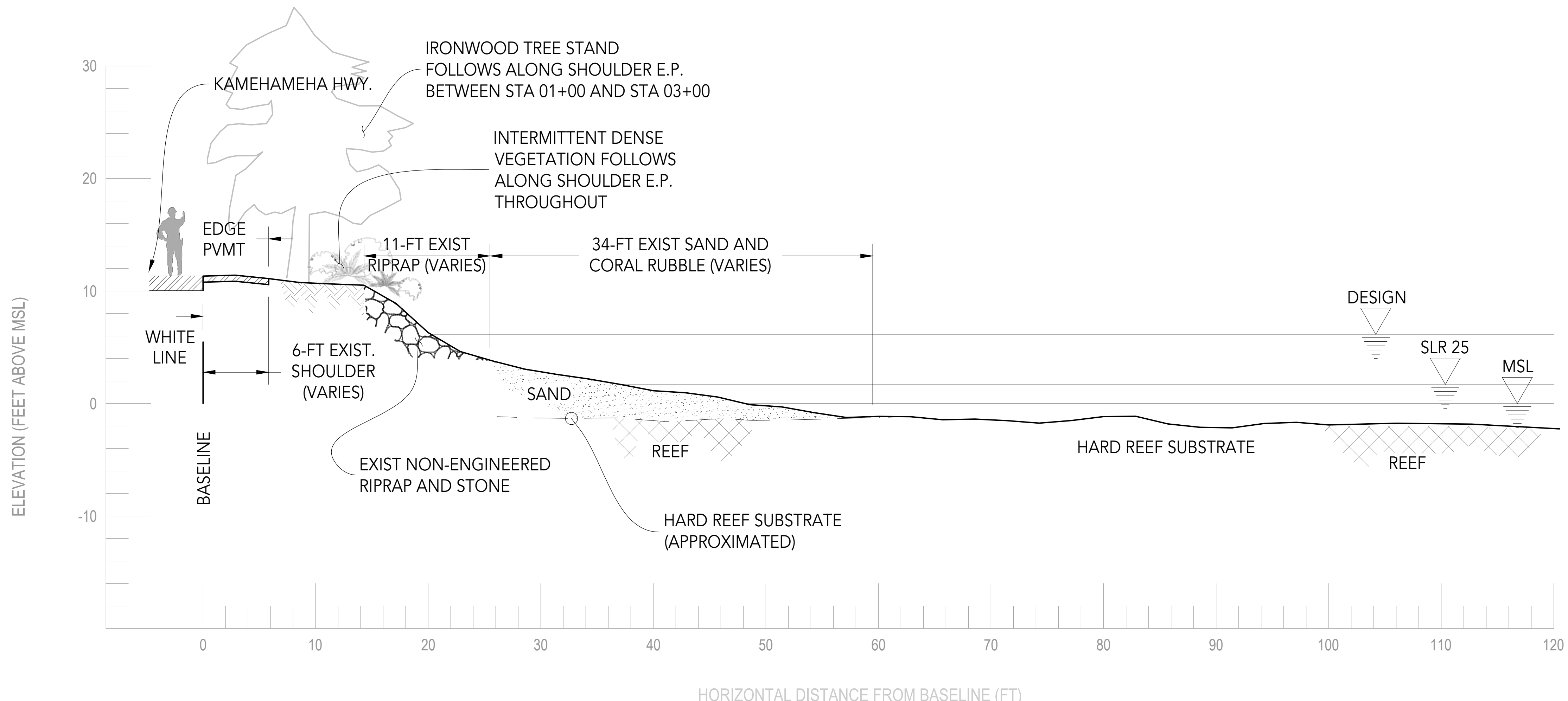
Sheet Name

Kaoio Pt. To Kalaeoio Sta. 02+00 and 27+00 Mild Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-025
Date	21 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	



01 EXISTING (2013) CROSS SECTION AT STATION 02+00
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

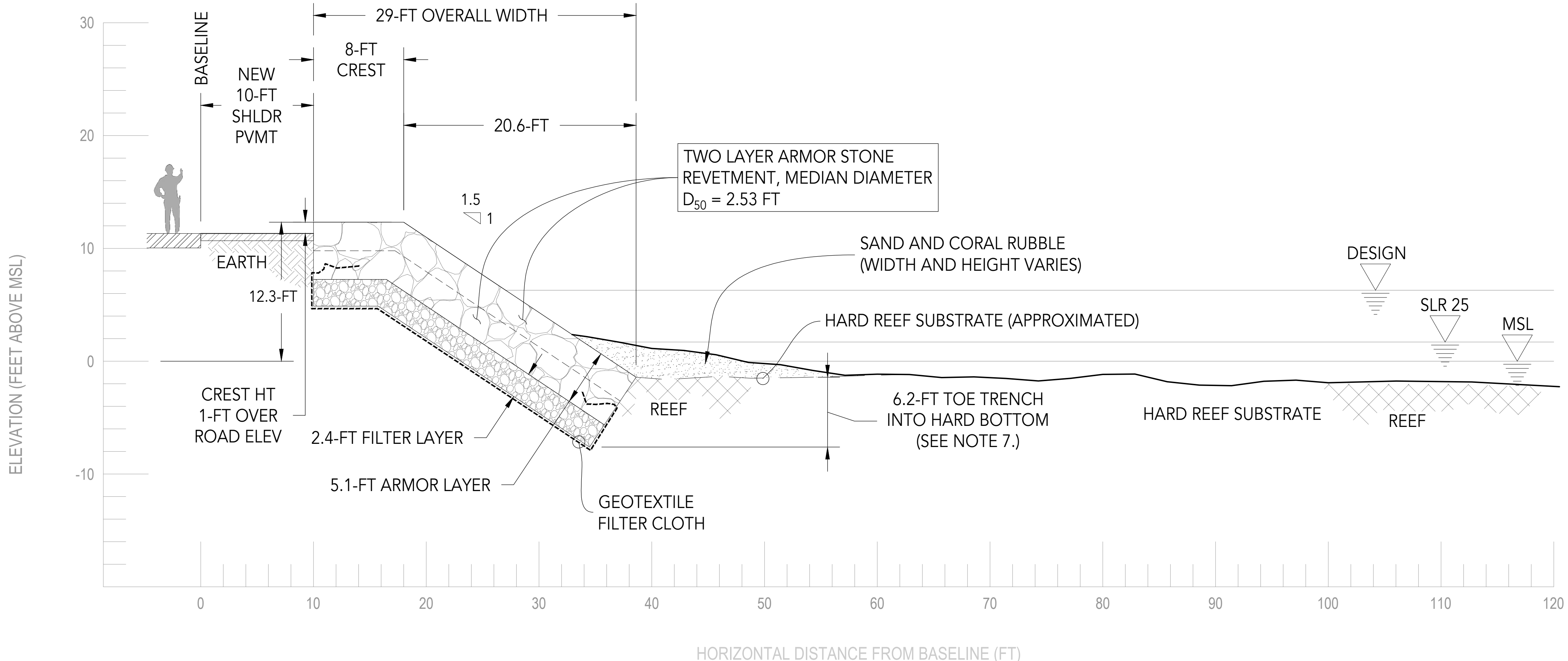
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 6.14 ft MSL

Sheet Name
Kaoio Pt. To Kalaeoio Station 02+00 (Zone A) Existing Condition Section (Typical)

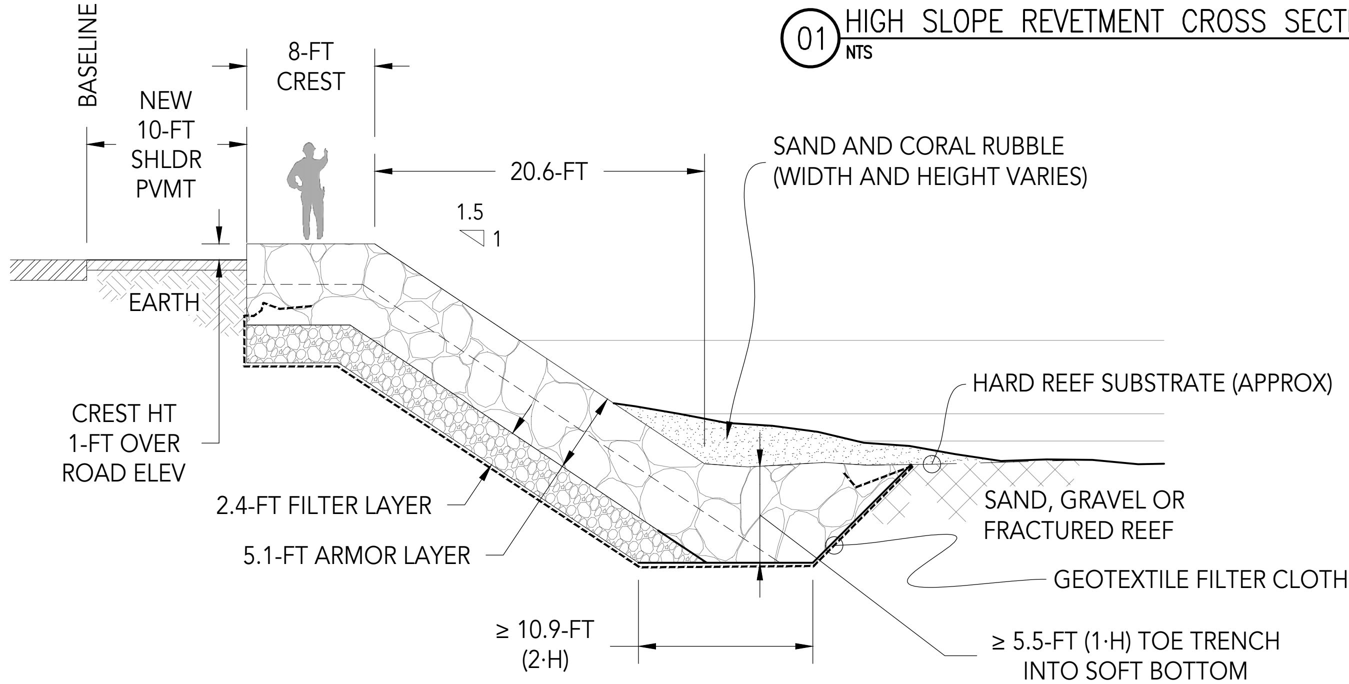
Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-026
Date 21 Mar 2022	
Scale 1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 02+00

NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	1,952	W_{15}	33
W_{50}	2,602	W_{50}	260
W_{max}	3,253	W_{100}	1,421

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.30	d_{15}	0.59
d_{50}	2.53	d_{50}	1.18
d_{max}	2.73	d_{100}	1.87

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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NOTES:

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4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 5.5 ft, for this location.

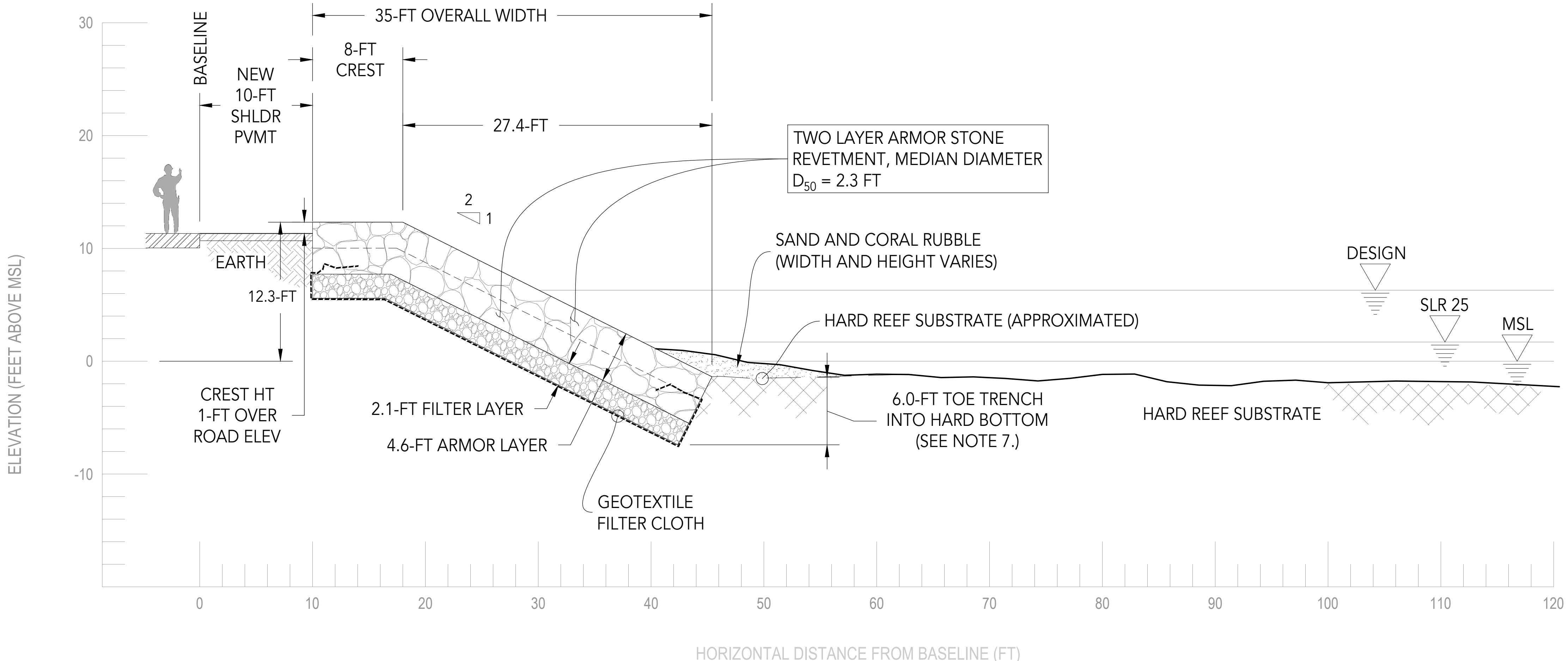
Sheet Name

Kaoio Pt. To Kalaeoio Station 02+00 (Zone A) High Slope Revetment Section - Conceptual

Project Name

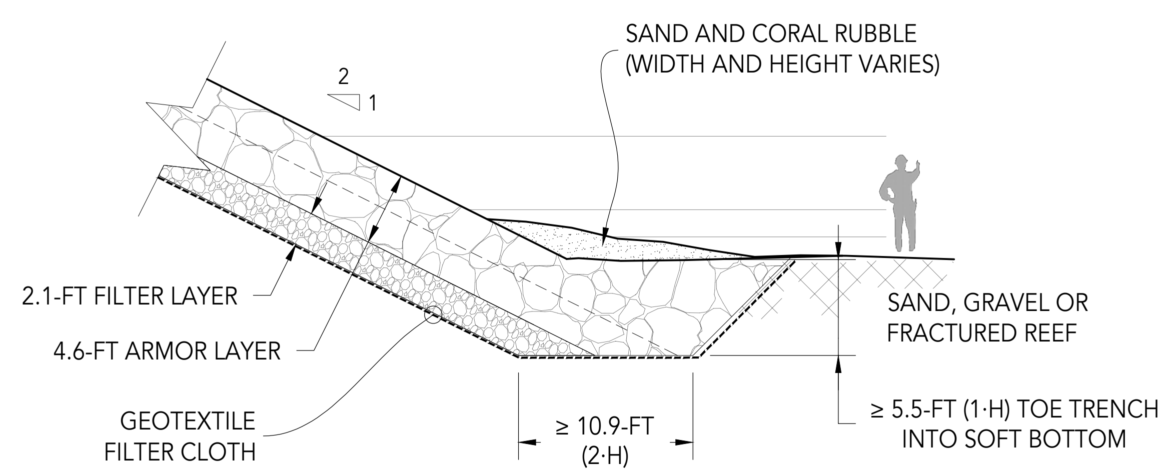
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	21 Mar 2022	C-027
Scale	1" = 1' - 0"	



(01) MILD SLOPE REVETMENT CROSS SECTION AT STATION 02+00

NTS



ALTERNATE TOE DETAIL FOR NON-HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
W_{min}	1,464	W_{15}	24
W_{50}	1,952	W_{50}	195
W_{max}	2,439	W_{100}	781

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
d_{min}	2.09	d_{15}	0.53
d_{50}	2.30	d_{50}	1.07
d_{max}	2.48	d_{100}	1.70

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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NOTES:

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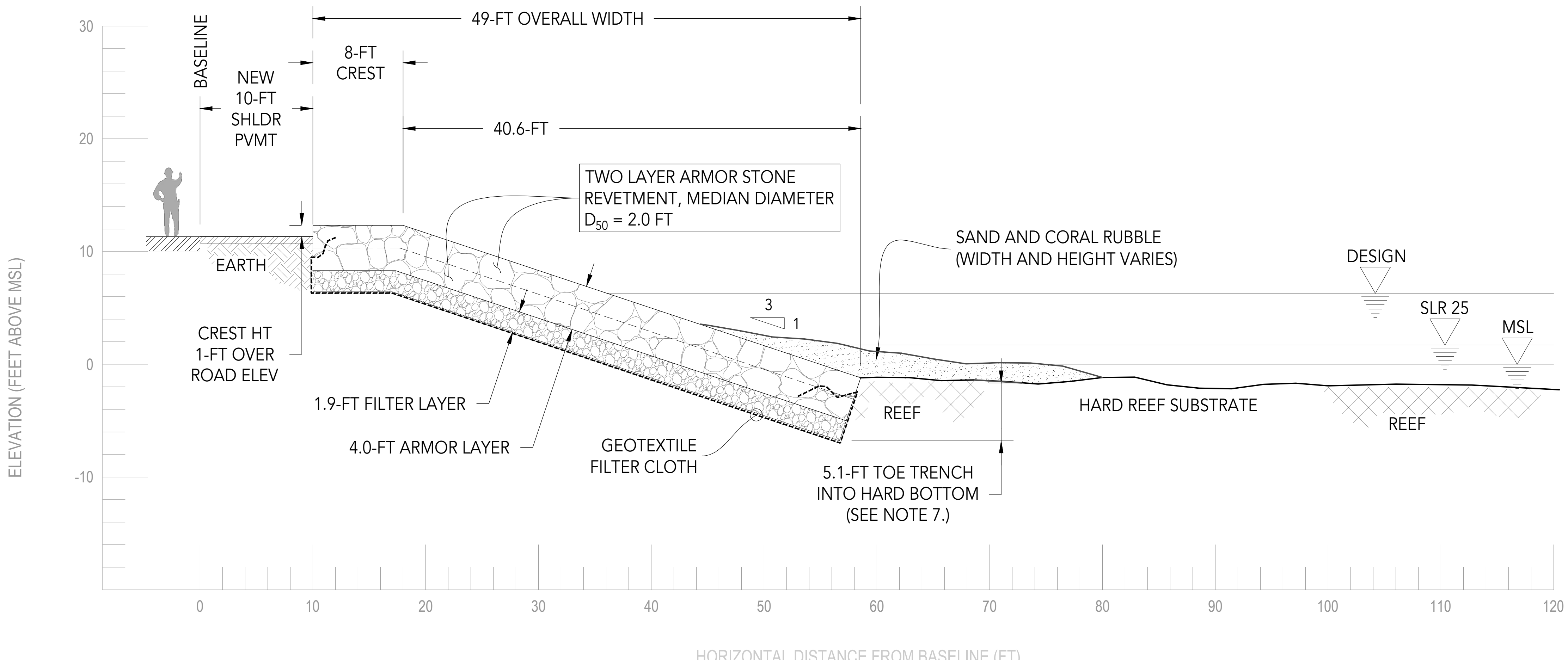
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 5.5 ft, for this location.

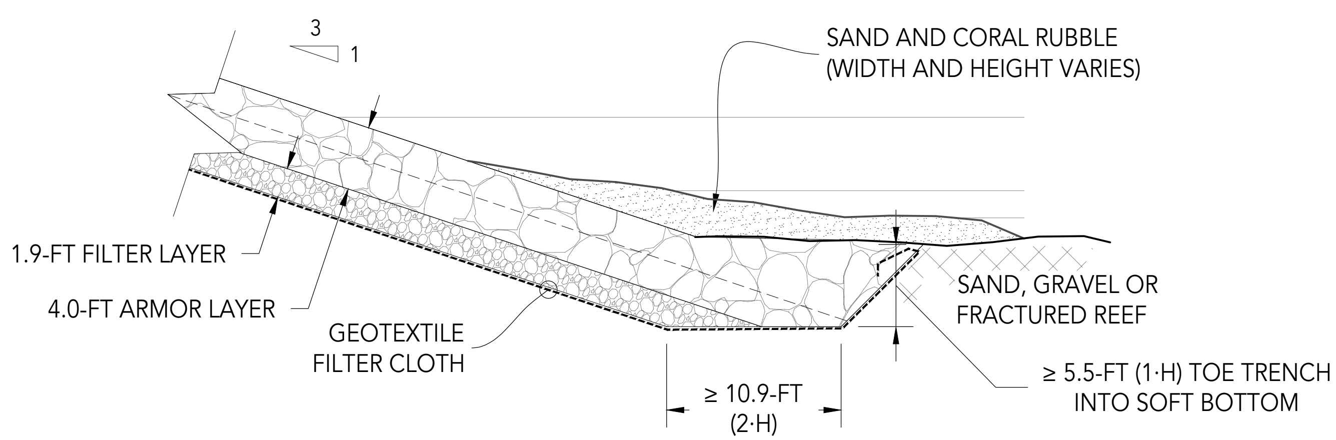
Sheet Name
Kaoio Pt. To Kalaeoio Station 02+00 (Zone A) Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-028



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 02+00
NTS



ALTERNATE TOE DETAIL FOR NON-HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
W_{min}	976	W_{15}	16
W_{50}	1,301	W_{50}	130
W_{max}	1,626	W_{100}	520

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
d_{min}	1.83	d_{15}	0.47
d_{50}	2.01	d_{50}	0.93
d_{max}	2.17	d_{100}	1.48

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

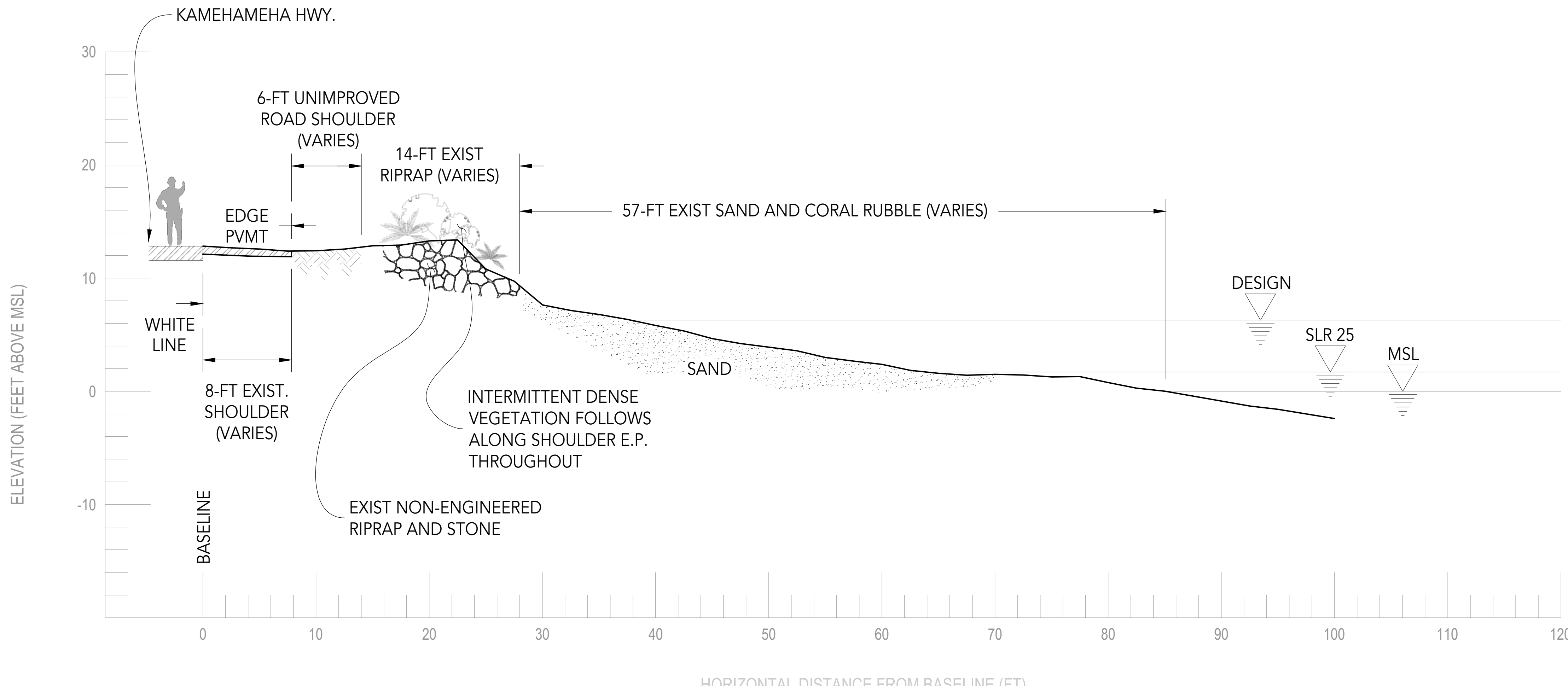
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 5.5 ft, for this location.

Sheet Name
Kaoio Pt. To Kalaeoio Station 02+00 (Zone A) Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-029



01 EXISTING (2013) CROSS SECTION AT STATION 27+00
NTS

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PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

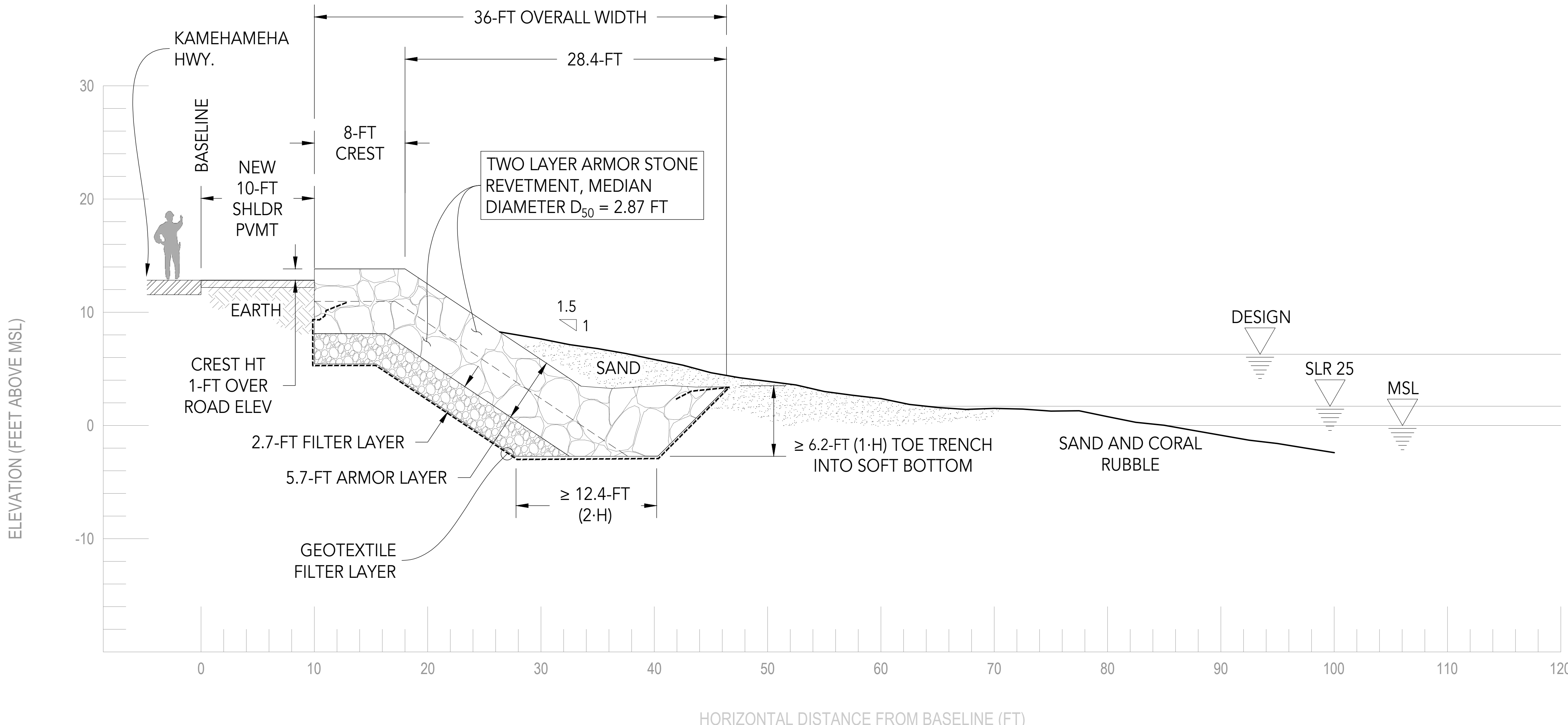
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 6.29 ft MSL

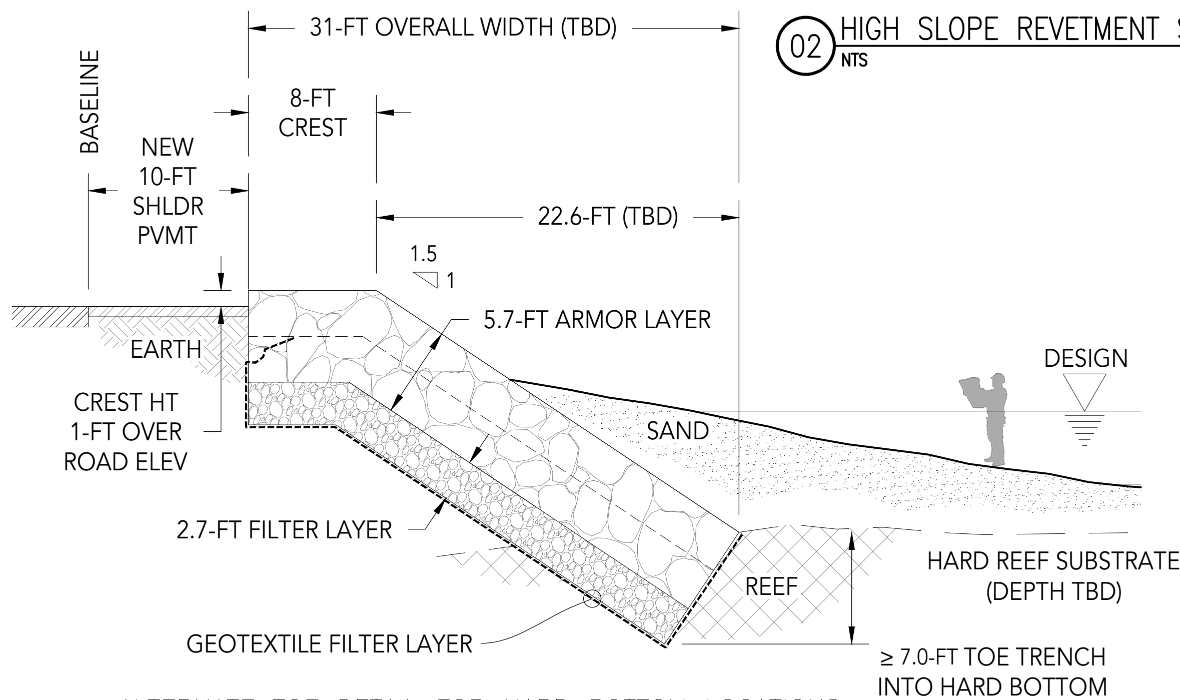
Sheet Name
Kaoio Pt. To Kalaeoio Station 27+00 (Zone B) Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-030
Date 21 Mar 2022	
Scale 1" = 1' - 0"	



02 HIGH SLOPE REVETMENT SECTION AT STATION 27+00
NTS



ALTERNATE TOE DETAIL FOR HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	2,846	W_{15}	47
W_{50}	3,795	W_{50}	380
W_{max}	4,744	W_{100}	1,518

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.61	d_{15}	0.67
d_{50}	2.87	d_{50}	1.33
d_{max}	3.10	d_{100}	2.12

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

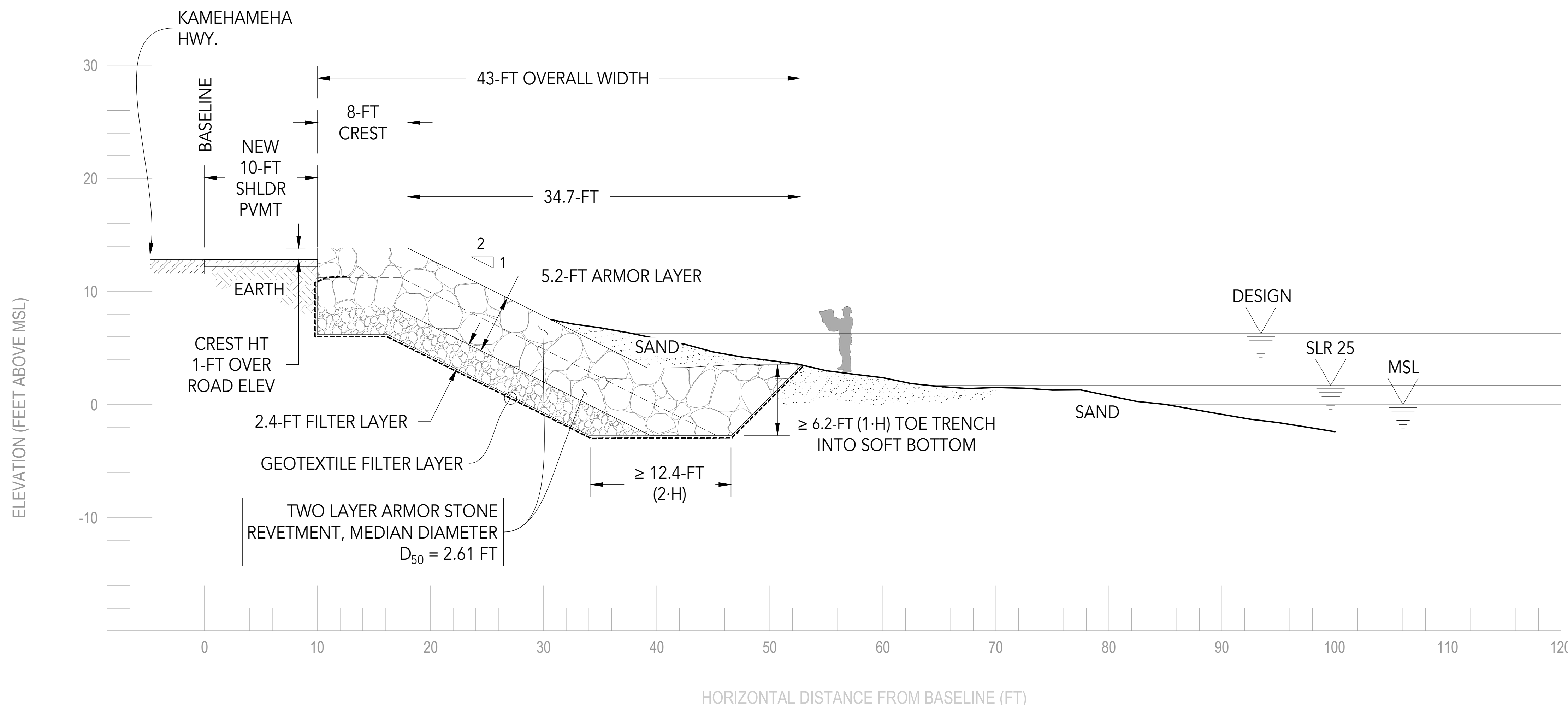
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 6.2 ft, for this location.

Sheet Name
Kaoio Pt. To Kalaeoio Station 27+00 (Zone B) High Slope Revetment Section - Conceptual

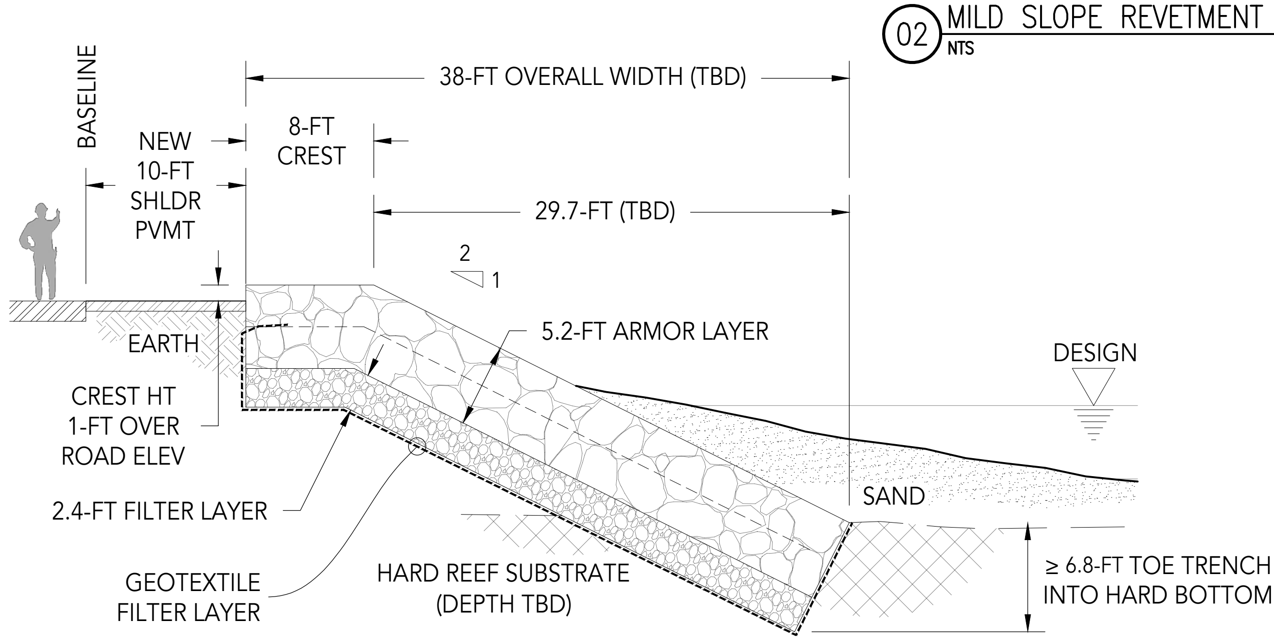
Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-031



02 MILD SLOPE REVETMENT SECTION AT STATION 27+00

NTS



ALTERNATE TOE DETAIL FOR HARD BOTTOM LOCATIONS

STONE SIZE GRADATION			
-- BY WEIGHT (LBF) --			
ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	2,135	W_{15}	36
W_{50}	2,846	W_{50}	285
W_{max}	3,558	W_{100}	1,139

STONE SIZE GRADATION			
-- NOMINAL DIAMETER (FT) --			
ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.37	d_{15}	0.61
d_{50}	2.61	d_{50}	1.21
d_{max}	2.81	d_{100}	1.92

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 6.2 ft, for this location.

Sheet Name

Kaoio Pt. To Kalaeoio Station 27+00 (Zone B) Mild Slope Revetment Section - Conceptual

Project Name

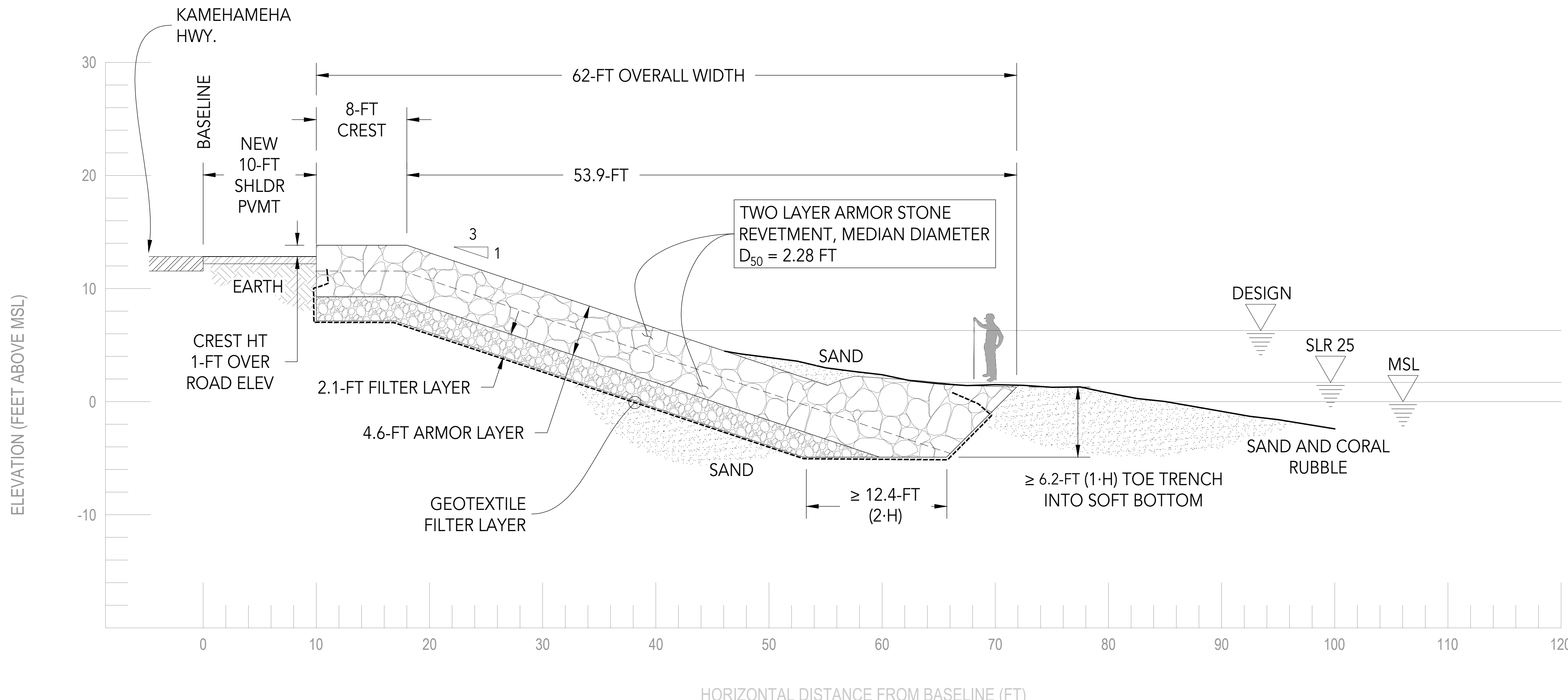
KKPH Kamehameha Highway Shore Protection

Project No. 25853

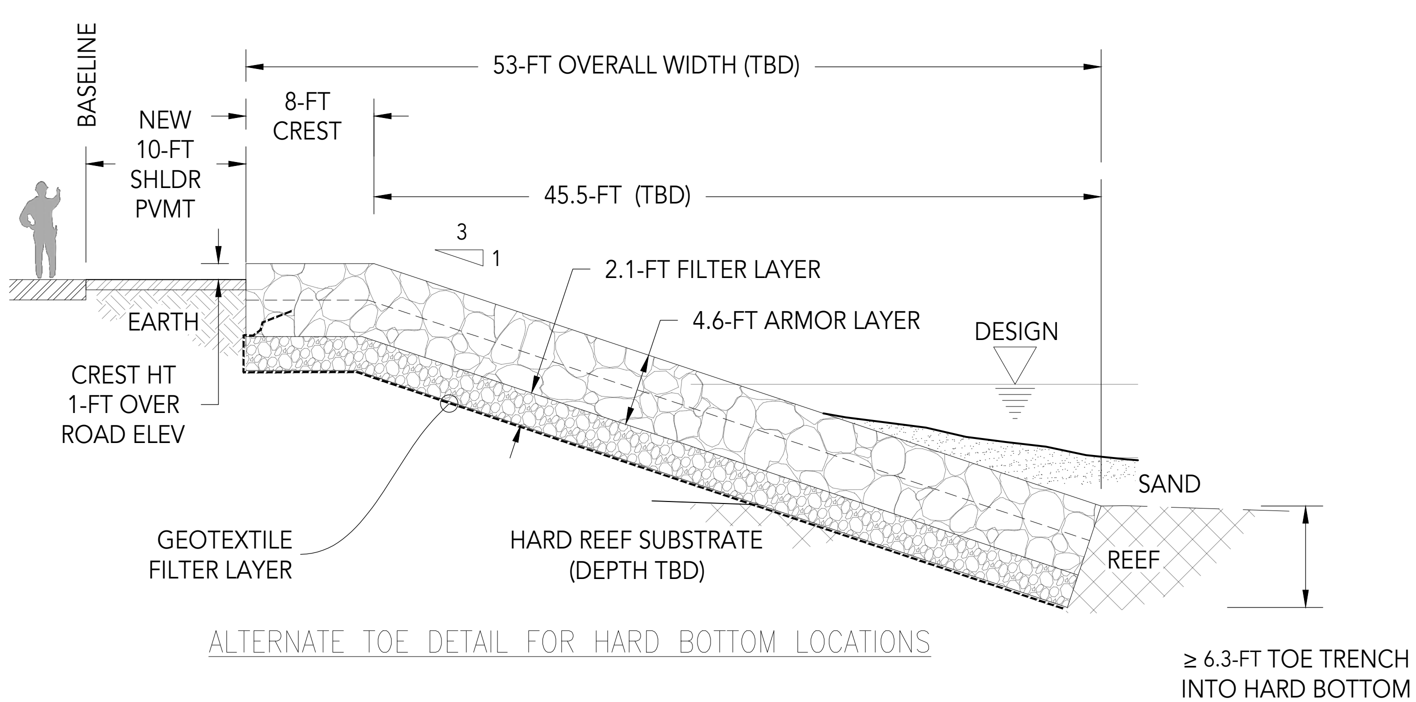
Date 21 Mar 2022

Scale 1" = 1' - 0"

Sheet C-032



02 LOW SLOPE REVETMENT SECTION AT STATION 27+00
NTS



ALTERNATE TOE DETAIL FOR HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
W_{min}	1,423	W_{15}	24
W_{50}	1,898	W_{50}	190
W_{max}	2,372	W_{100}	759

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
d_{min}	2.07	d_{15}	0.53
d_{50}	2.28	d_{50}	1.06
d_{max}	2.46	d_{100}	1.68

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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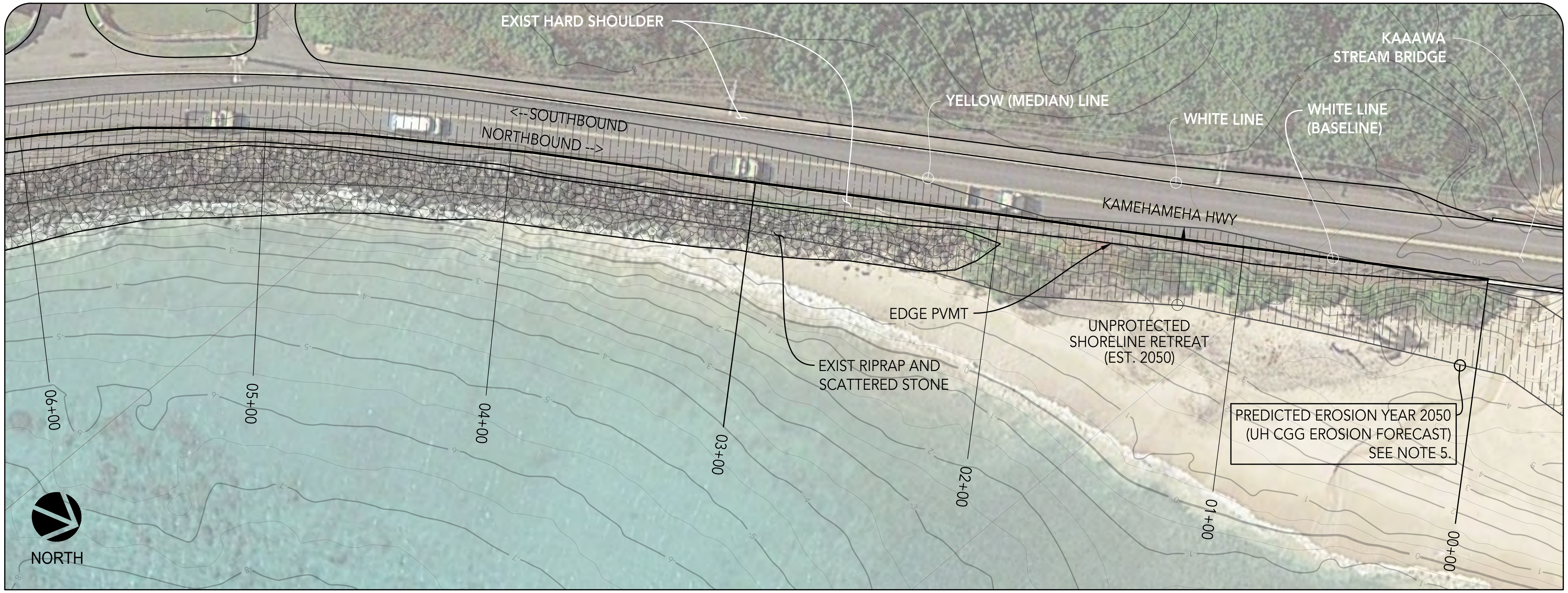
NOTES:

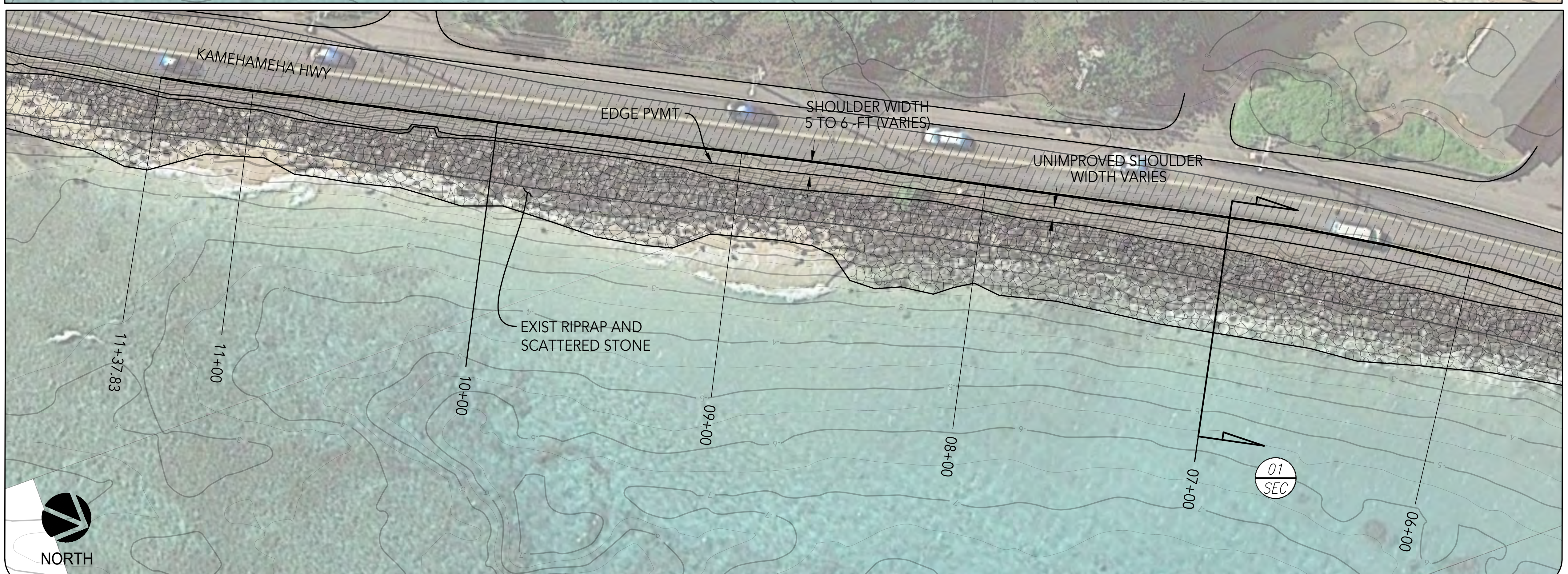
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 6.2 ft, for this location.

Sheet Name
Kaoio Pt. To Kalaeoio Station 27+00 (Zone B) Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-033





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NOTES:

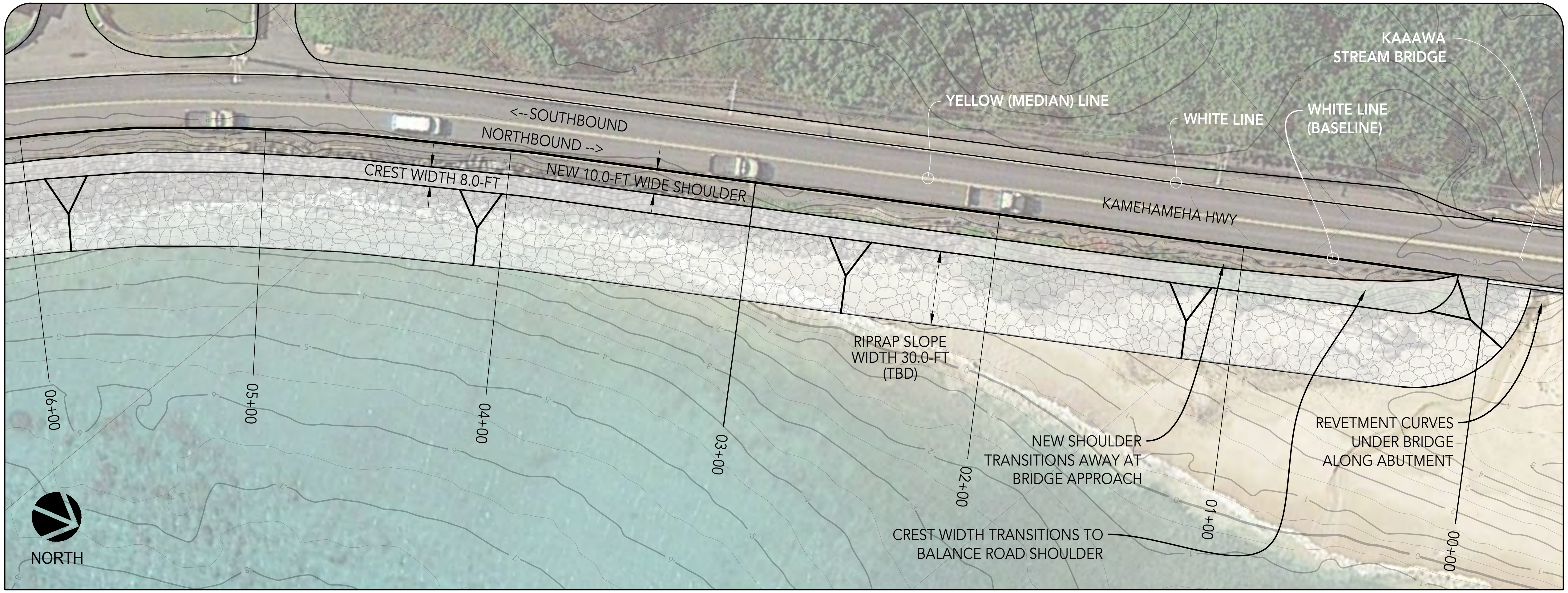
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict near uniform erosion of this reach up to and beyond the existing road shoulder location by 2050 if left unprotected. The length of this threatened stretch is approximately 1,140 ft.

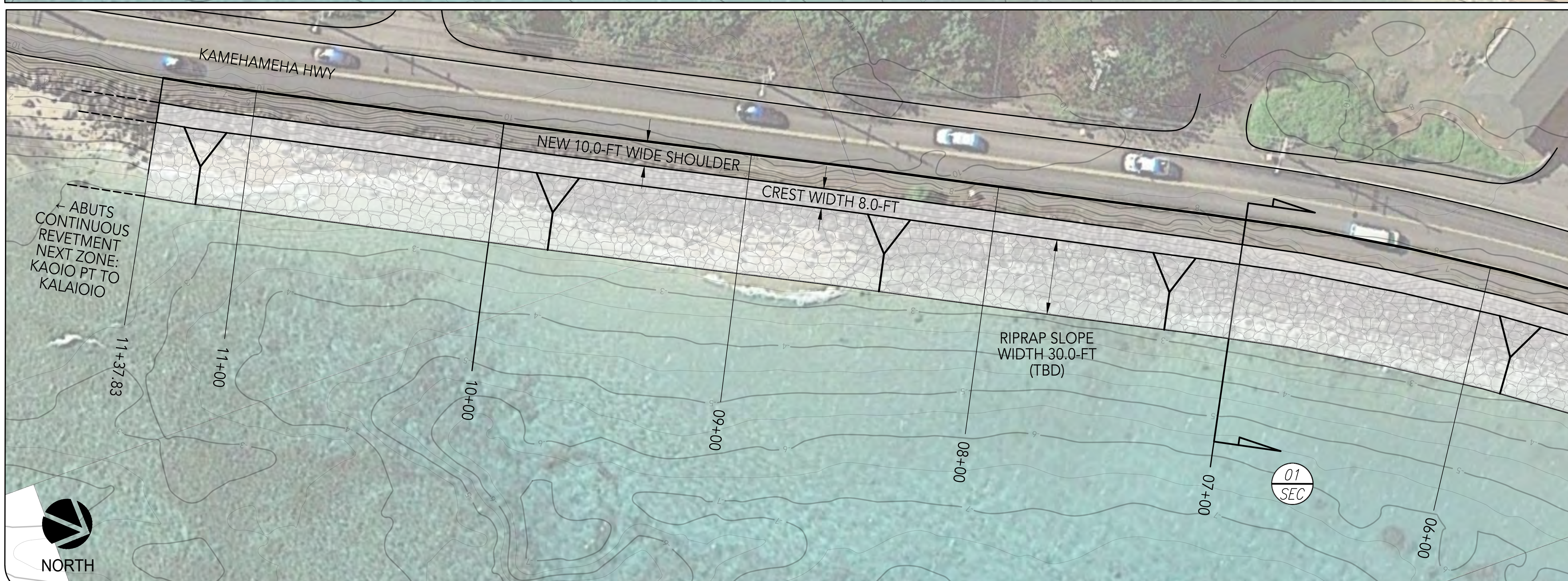
Sheet Name
Kalaeoio To Kaaawa Stream Existing Condition Plan

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-034
Date 17 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

Mon Mar 21 15:11:37 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***





SE
Sea Engineering, Inc.
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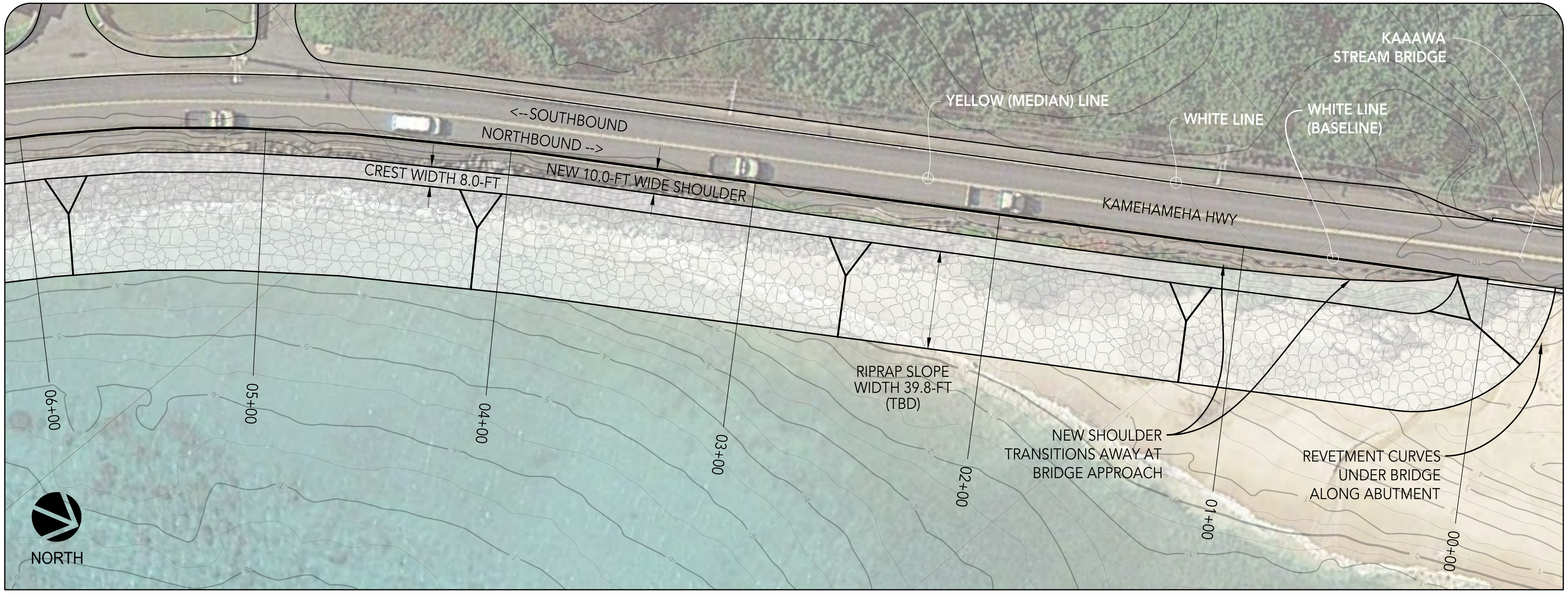
NOTES:

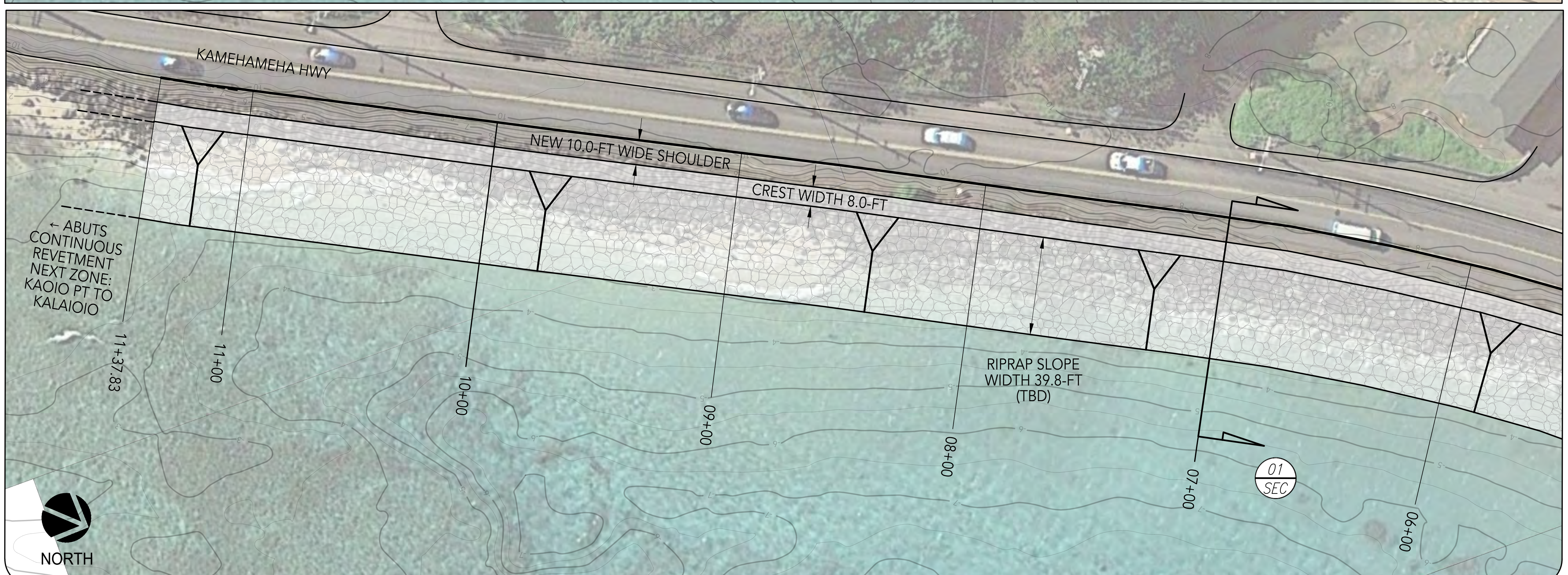
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Kalaeoio To Kaaawa Stream High Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-035
Date	17 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	





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FAX 808.259.8143

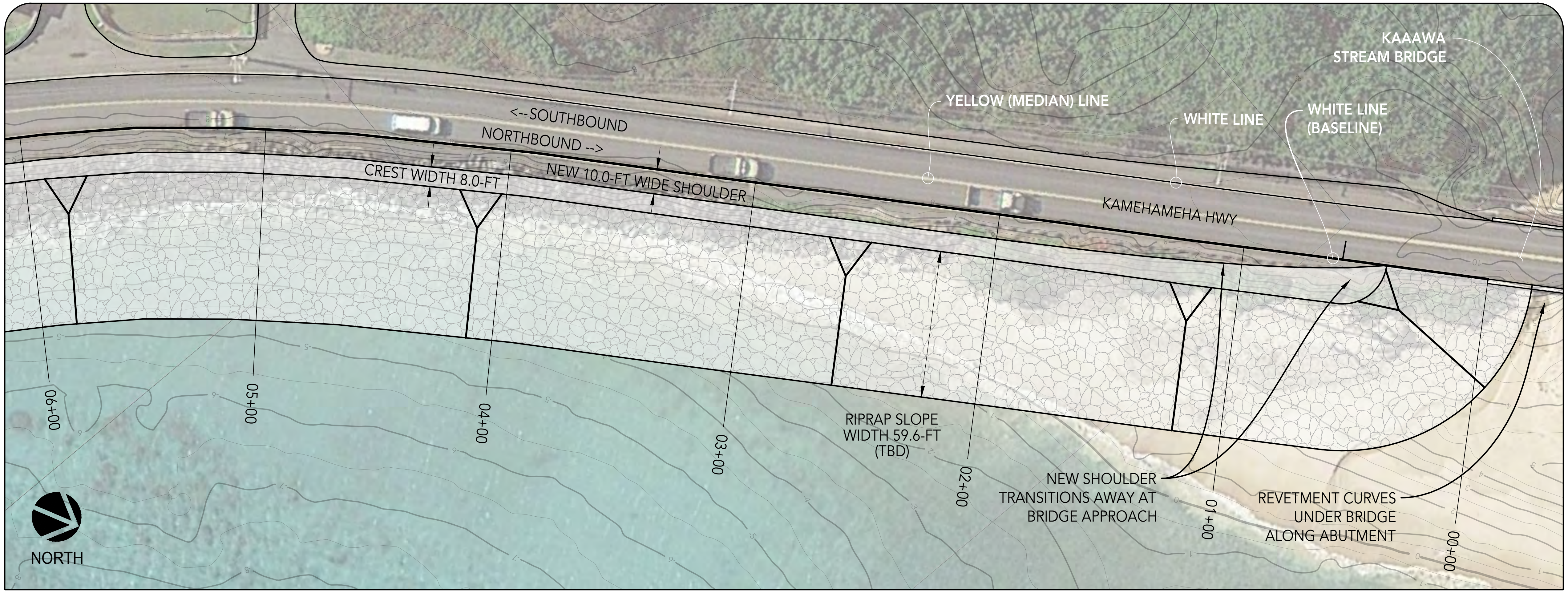
NOTES:

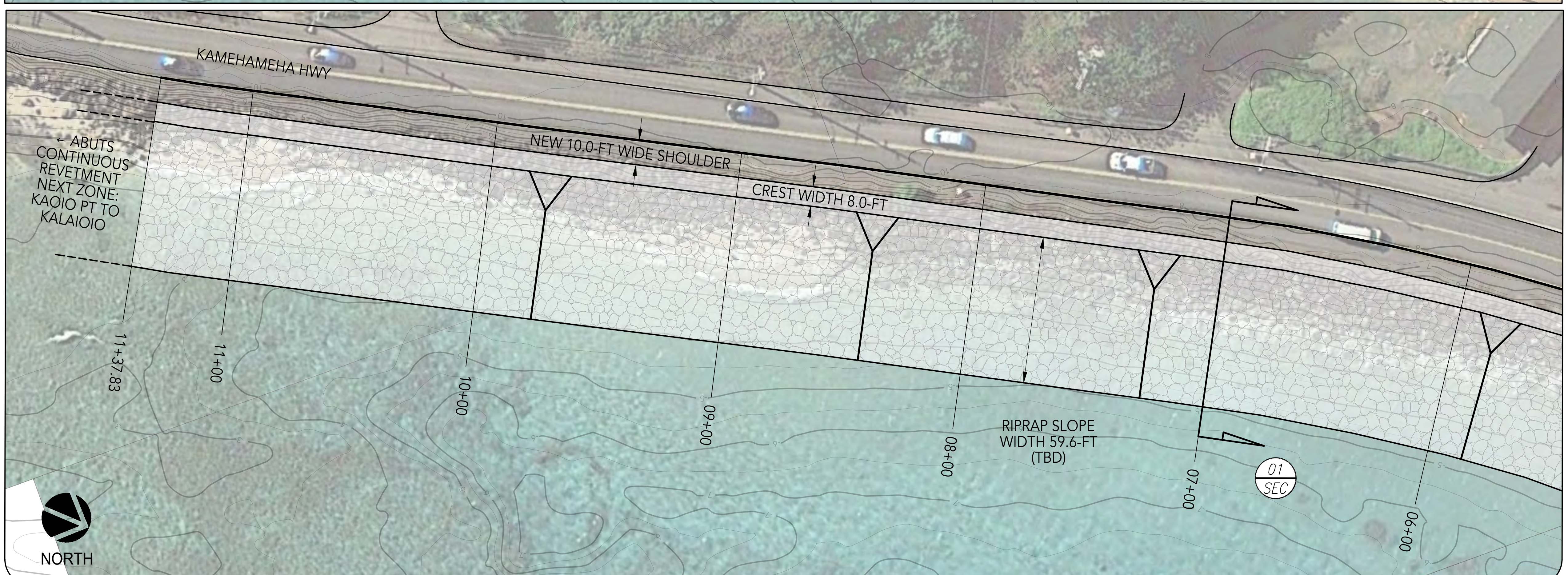
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Kalaeoio To Kaaawa Stream Mild Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-036
Date 17 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





Sea Engineering, Inc.
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PH 808.259.7966
FAX 808.259.8143

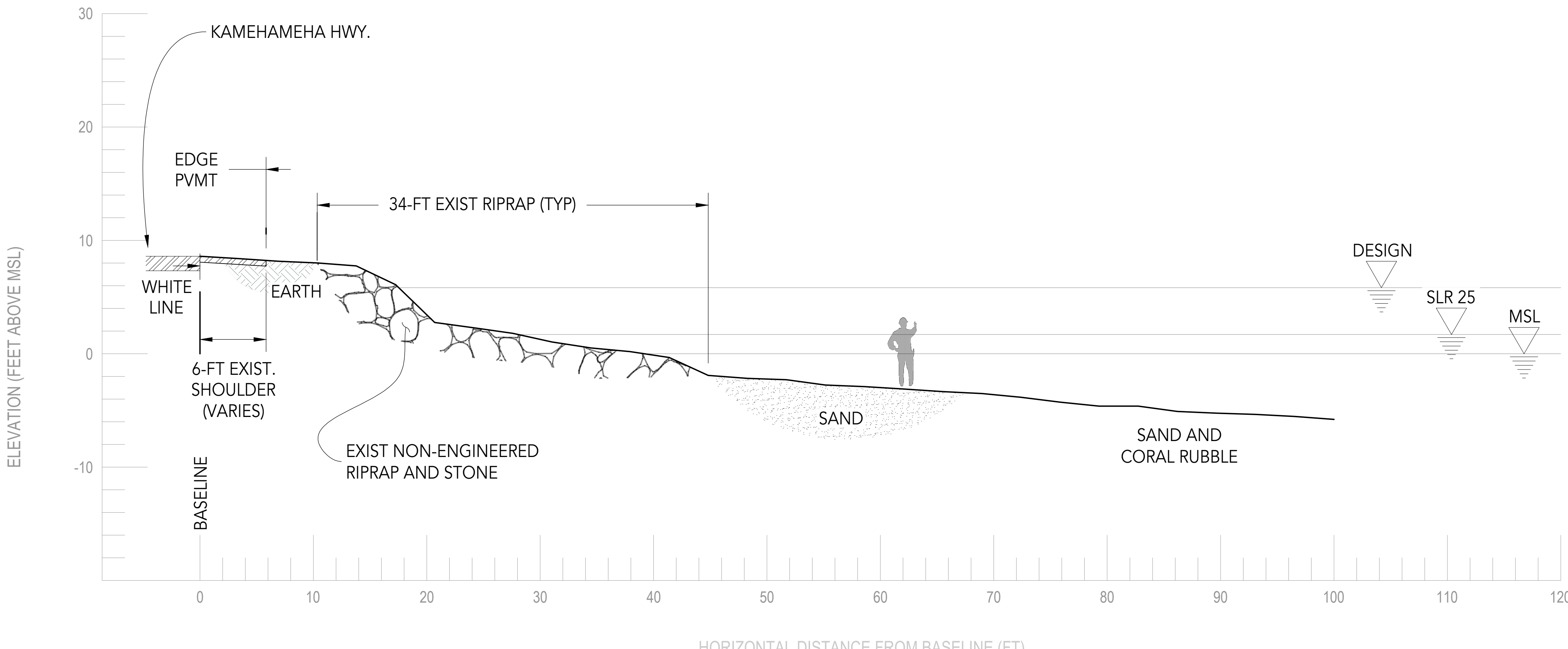
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Kalaeoio To Kaaawa Stream Low Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-037
Date	17 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	



01 EXISTING (2013) CROSS SECTION AT STATION 07+00

NTS

Sea Engineering, Inc.
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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 5.83 ft MSL

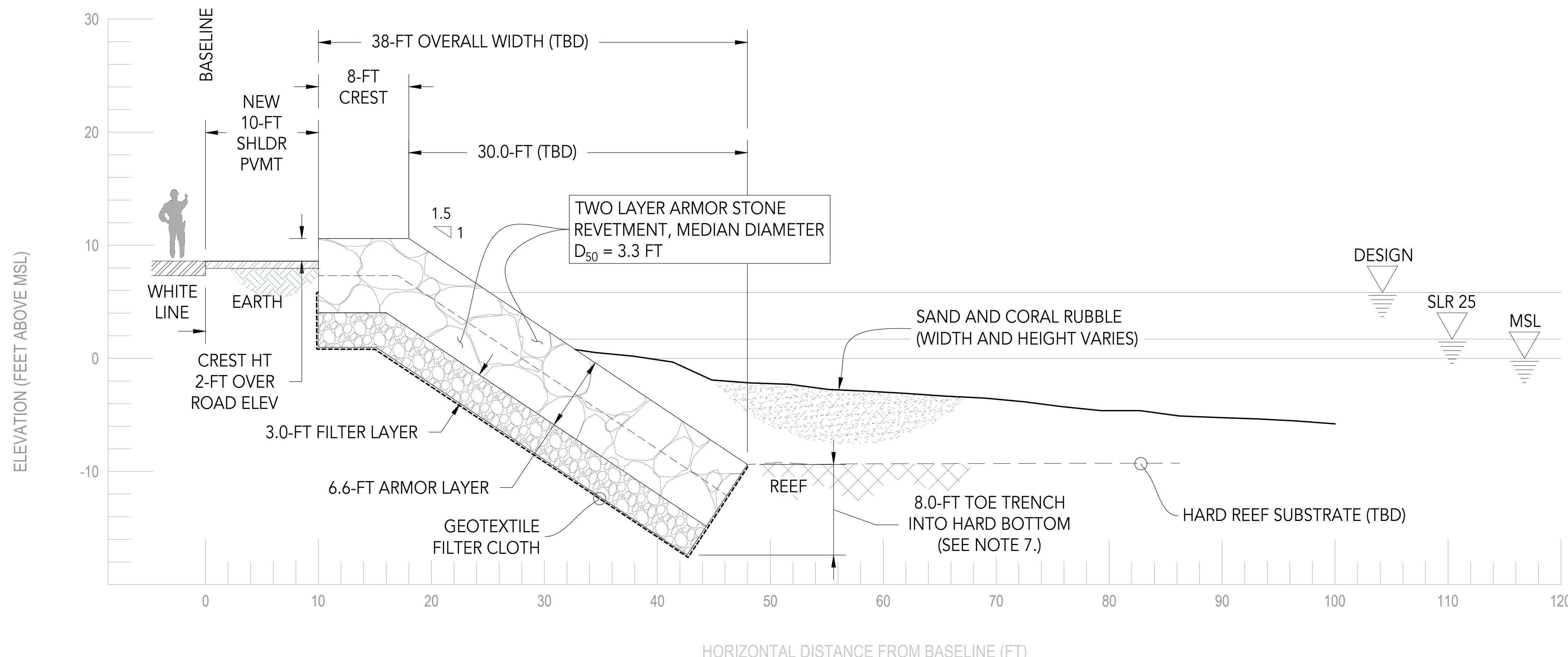
Sheet Name

Kalaeoio to Kaaawa Stream: Station 07+00 Existing Condition Section (Typical)

Project Name

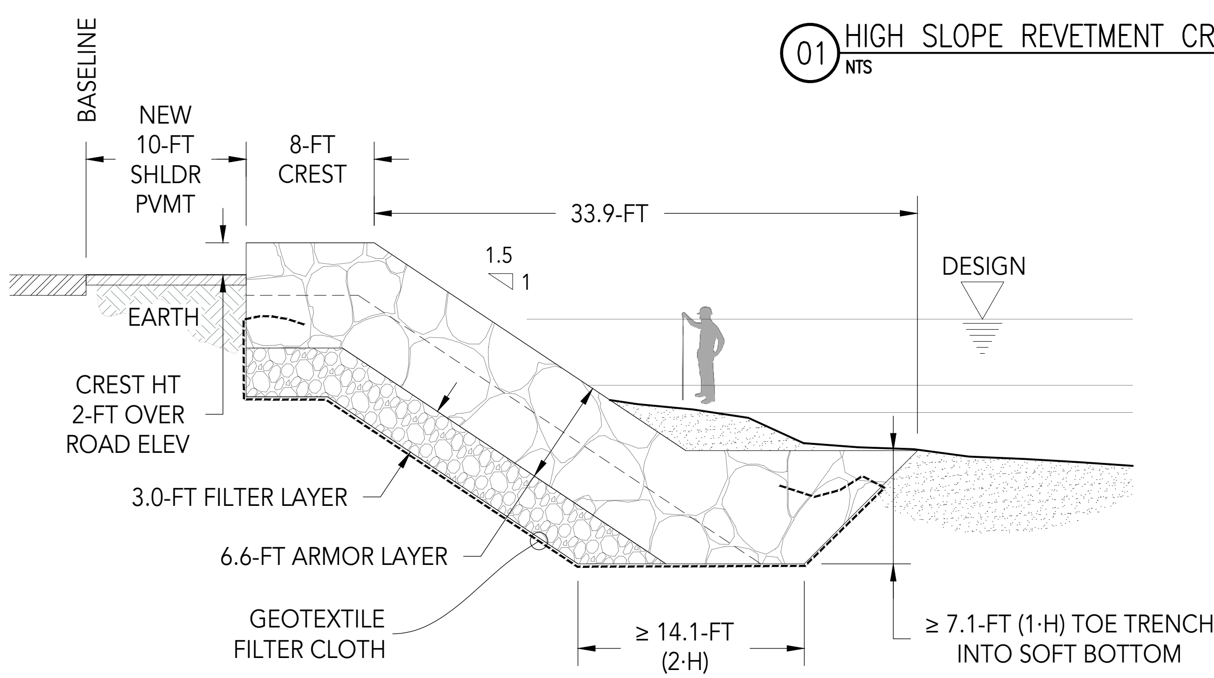
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-038
Date 17 Mar 2022	
Scale 1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 07+00

NTS



ALTERNATE TOE DETAIL FOR NON-HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	4,254	W_{15}	71
W_{50}	5,672	W_{50}	567
W_{max}	7,090	W_{100}	2,269

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.98	d_{15}	0.76
d_{50}	3.28	d_{50}	1.52
d_{max}	3.54	d_{100}	2.42

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

Sea Engineering, Inc.
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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 7.1 ft, for this location.

Sheet Name

Kalaeoio to Kaaawa Stream: Station 07+00 High Slope Revetment Section - Conceptual

Project Name

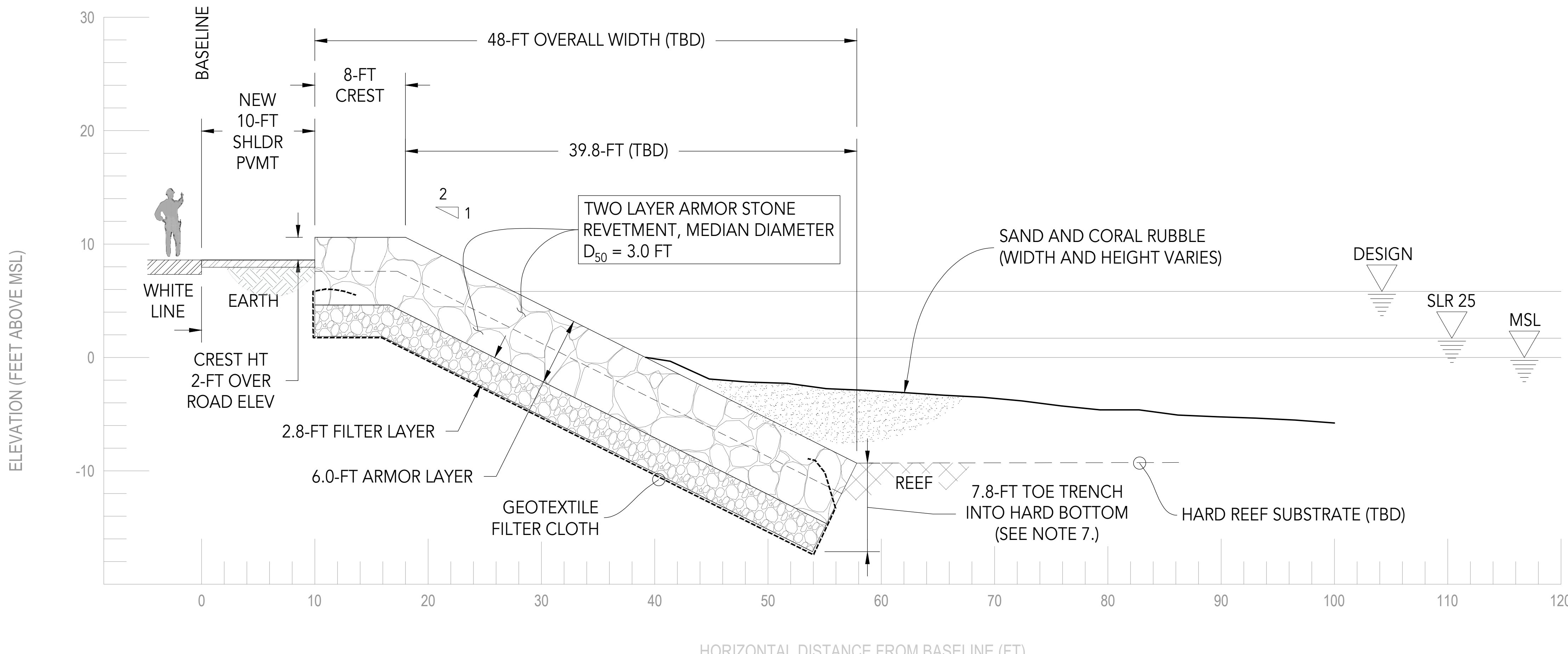
KKPH Kamehameha Highway Shore Protection

Project No. 25853

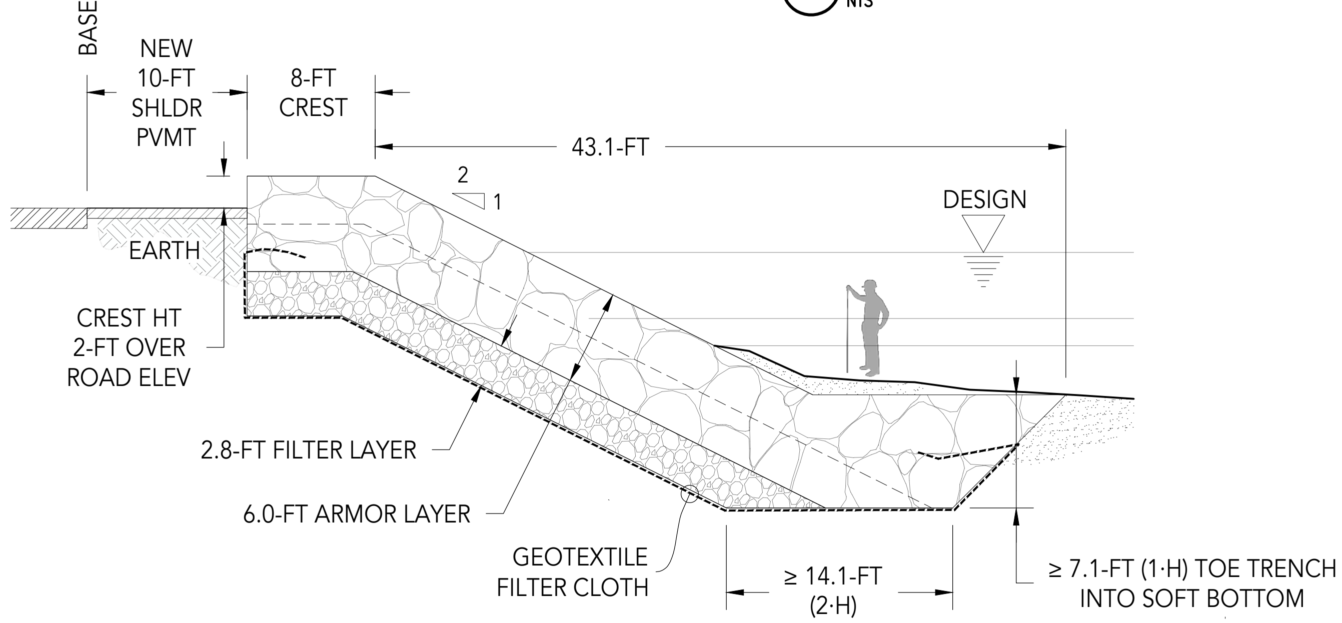
Date 17 Mar 2022

Scale 1" = 1' - 0"

Sheet C-039



(01) MILD SLOPE REVETMENT CROSS SECTION AT STATION 07+00
NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION -- BY WEIGHT (LBF) --			
ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	3,190	W_{15}	53
W_{50}	4,254	W_{50}	425
W_{max}	5,317	W_{100}	1,702

STONE SIZE GRADATION -- NOMINAL DIAMETER (FT) --			
ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.71	d_{15}	0.69
d_{50}	2.98	d_{50}	1.39
d_{max}	3.22	d_{100}	2.20

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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FAX 808.259.8143

NOTES:

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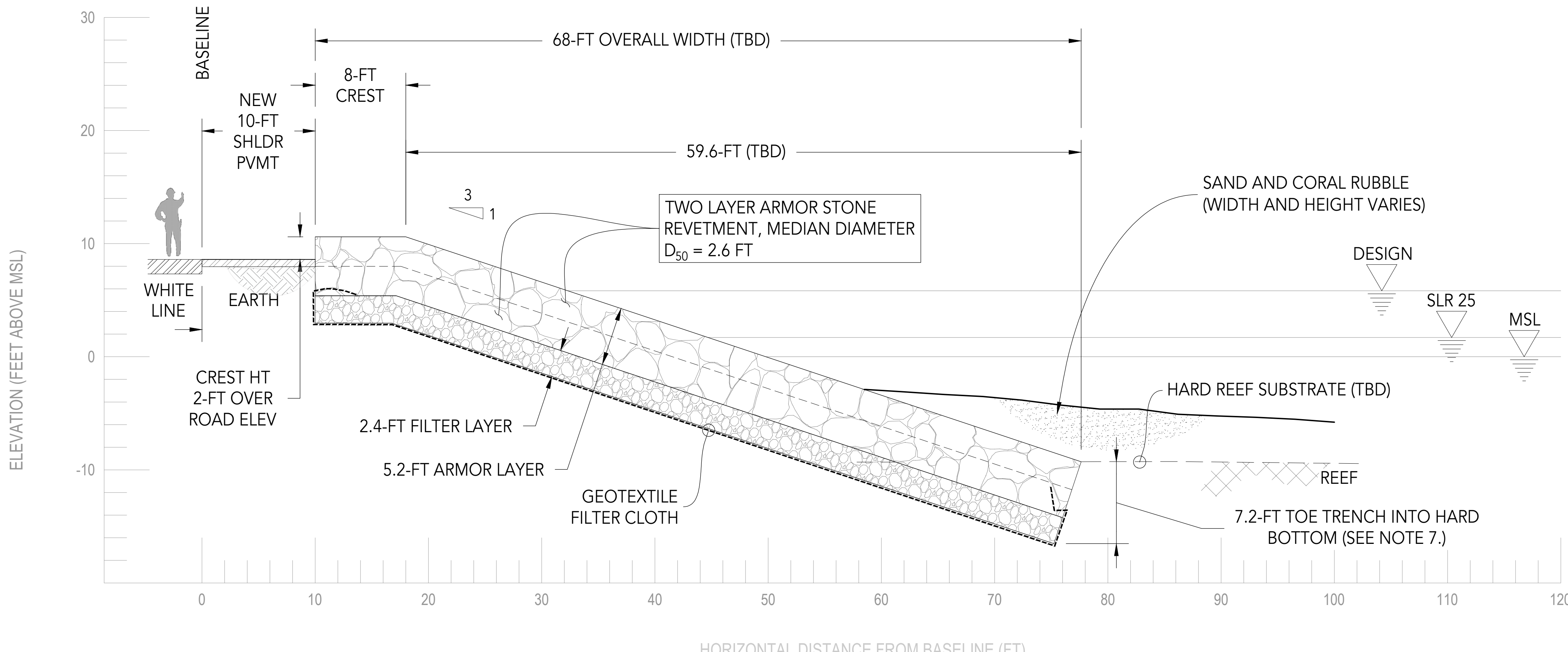
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 7.1 ft, for this location.

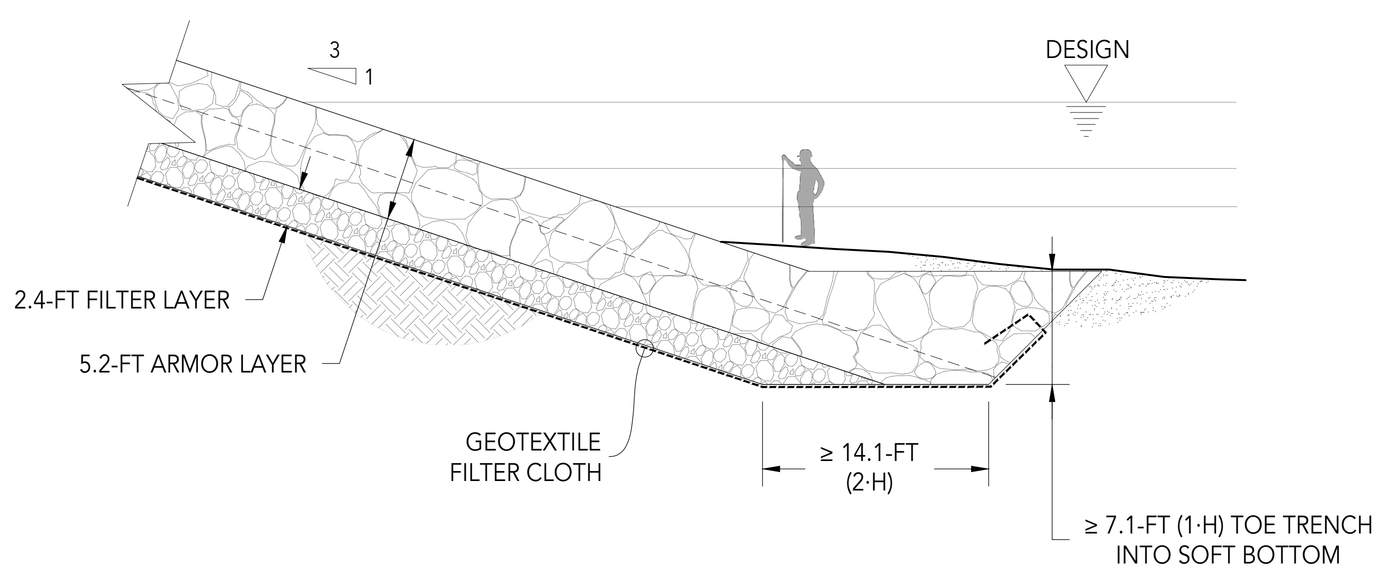
Sheet Name
Kalaeoio to Kaaawa Stream: Station 07+00 Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 17 Mar 2022
Scale 1" = 1' - 0"
Sheet C-040



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 07+00
NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
W_{min}	2,127	W_{15}	35
W_{50}	2,836	W_{50}	284
W_{max}	3,545	W_{100}	1,134

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
d_{min}	2.37	d_{15}	0.61
d_{50}	2.61	d_{50}	1.21
d_{max}	2.81	d_{100}	1.92

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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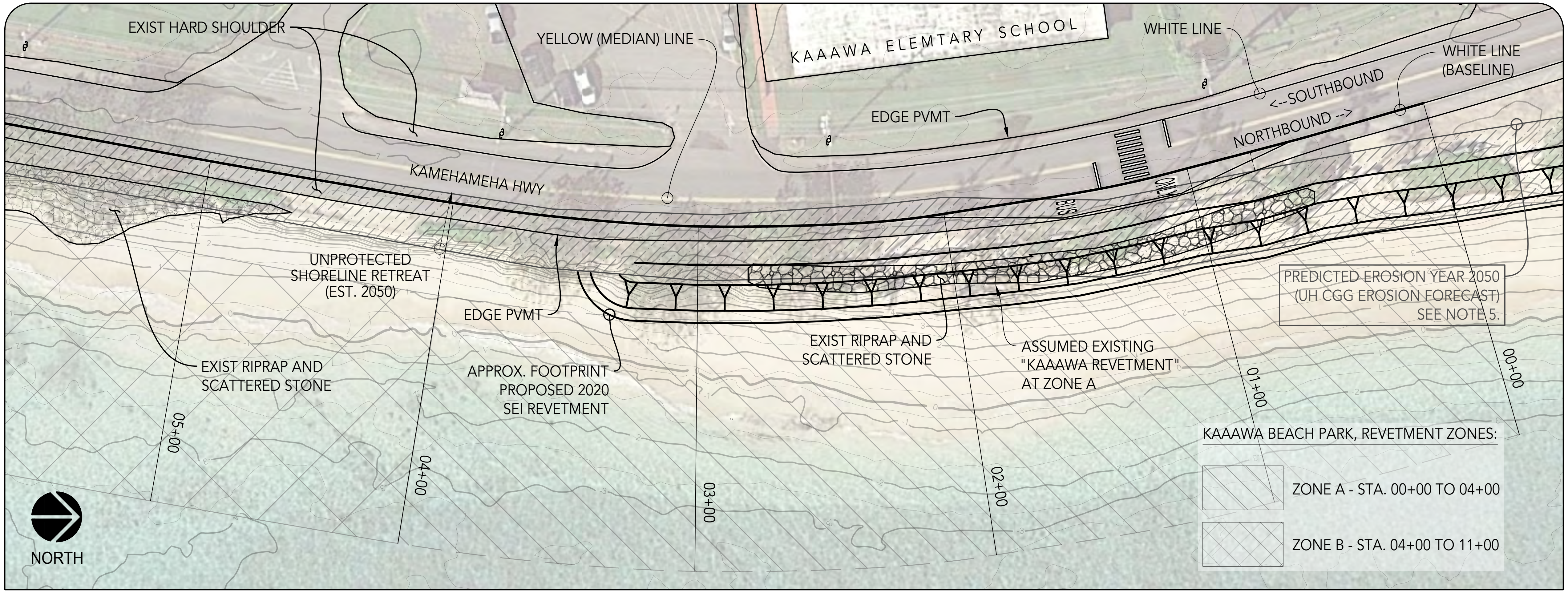
NOTES:

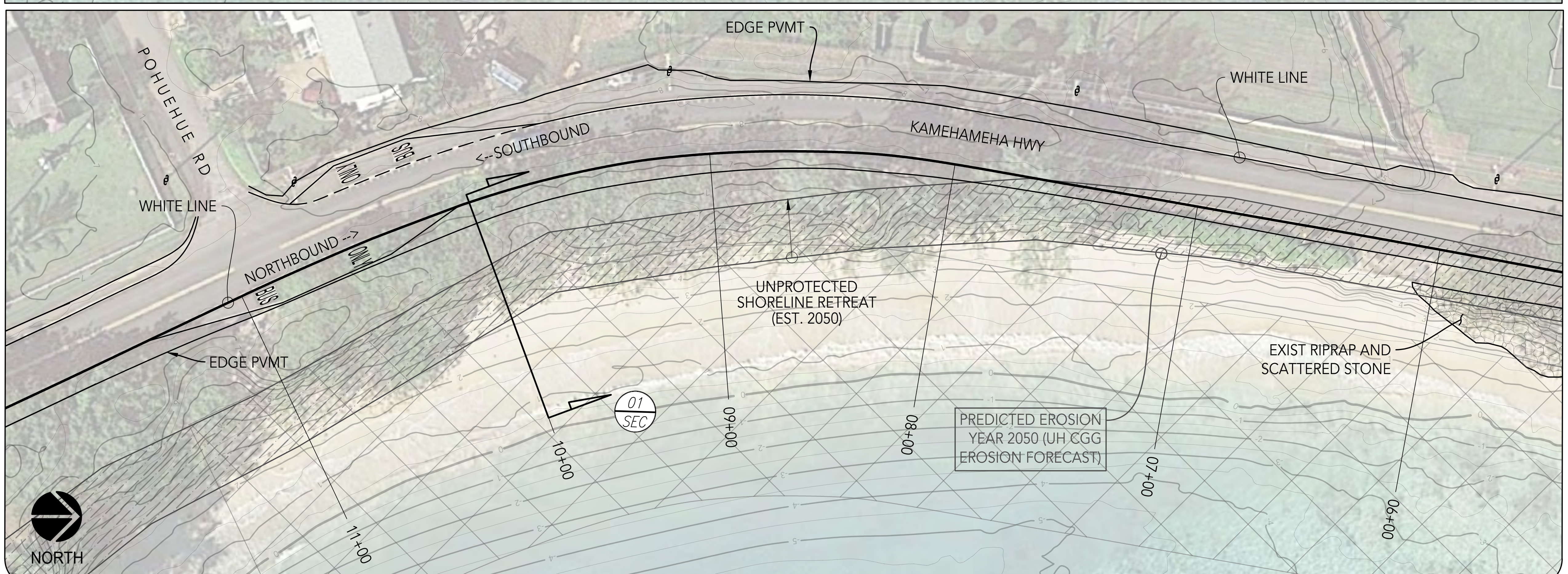
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 7.1 ft, for this location.

Sheet Name
Kalaeoio to Kaaawa Stream: Station 07+00 Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 17 Mar 2022
Scale 1" = 1' - 0"
Sheet C-041





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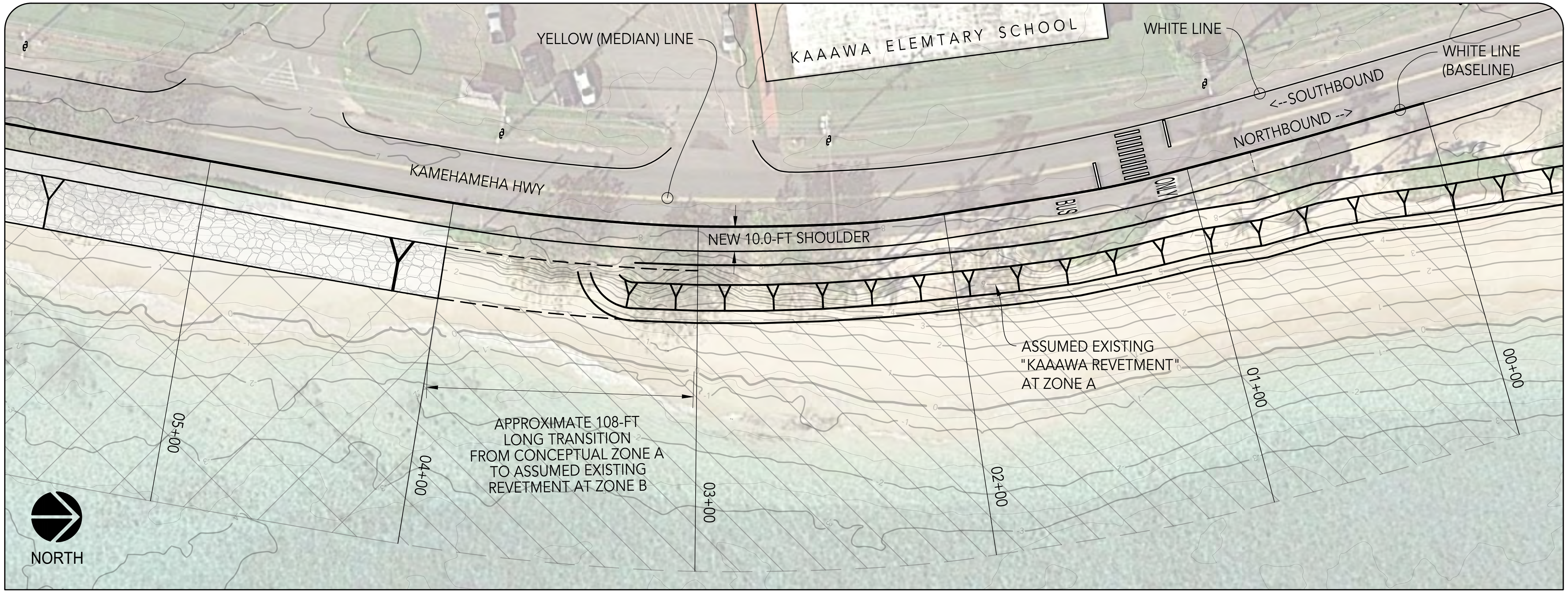
NOTES:

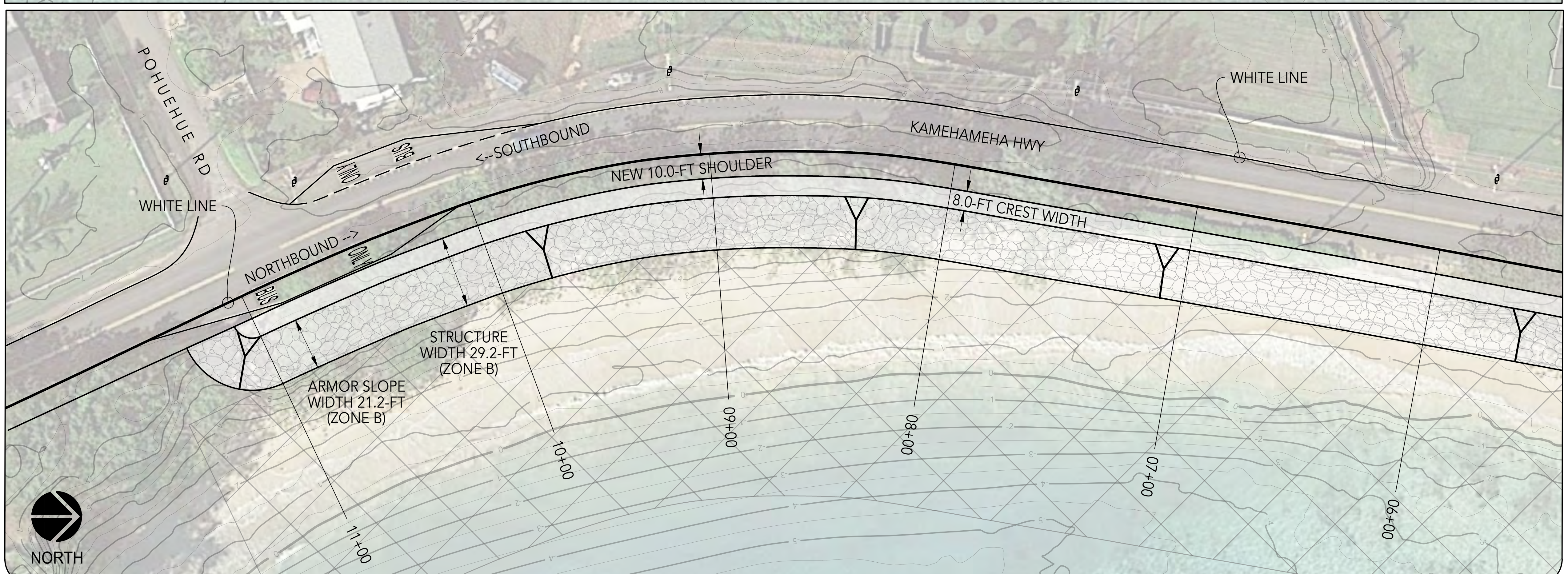
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_ erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. Revetment reach north end terminates at the point where the predicted erosion threat (dashed hatched linework) diverges seaward from the road shoulder as shown. The south end terminates fronting the intersection of Pohuehue Rd, where the shoreline begins to widen.

Sheet Name
Kaaawa Stream to Kaaawa Beach Park Existing Condition Plan

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-042
Date 17 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. Revetment Zones for this reach:

Zone A - Station 00+00 - 04+00

Zone B - Station 04+00 - 11+00

Sheet Name

Kaaawa Stream to Kaaawa Beach Park High Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-043
Date 17 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

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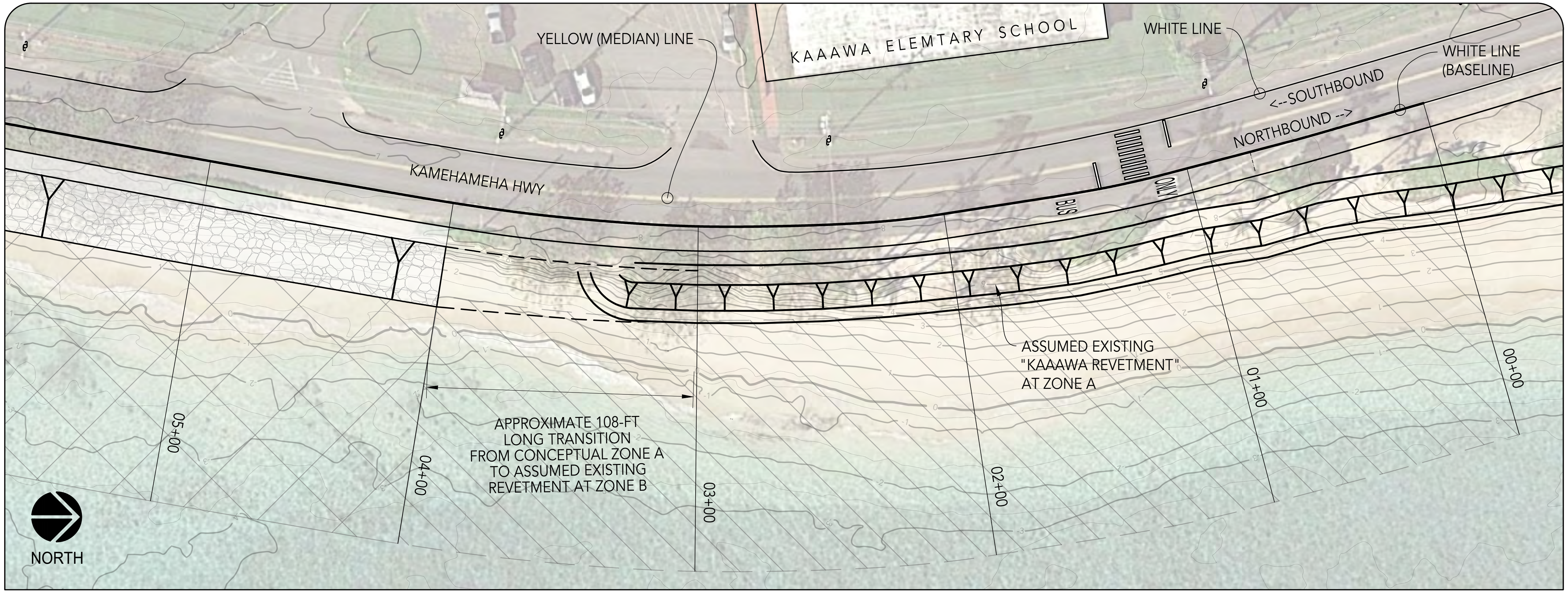

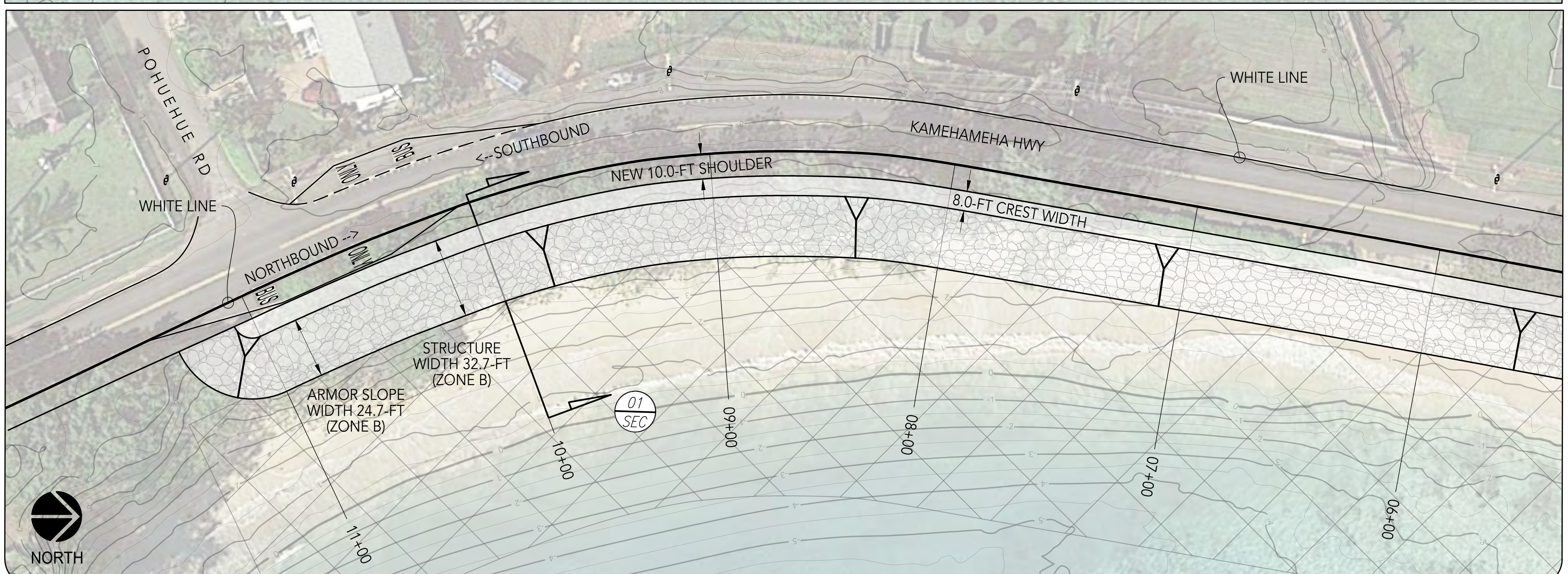

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_ erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. Revetment Zones for this reach:

Zone A - Station 00+00 - 04+00

Zone B - Station 04+00 - 11+00

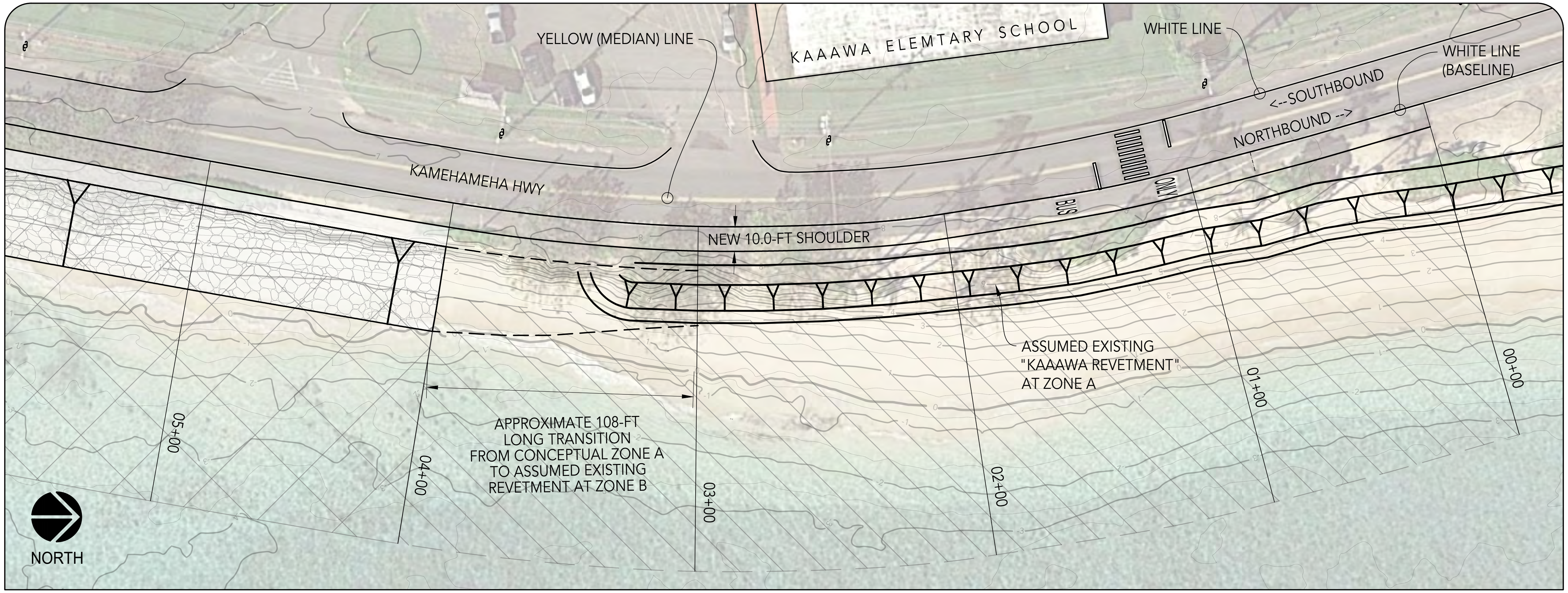
Sheet Name

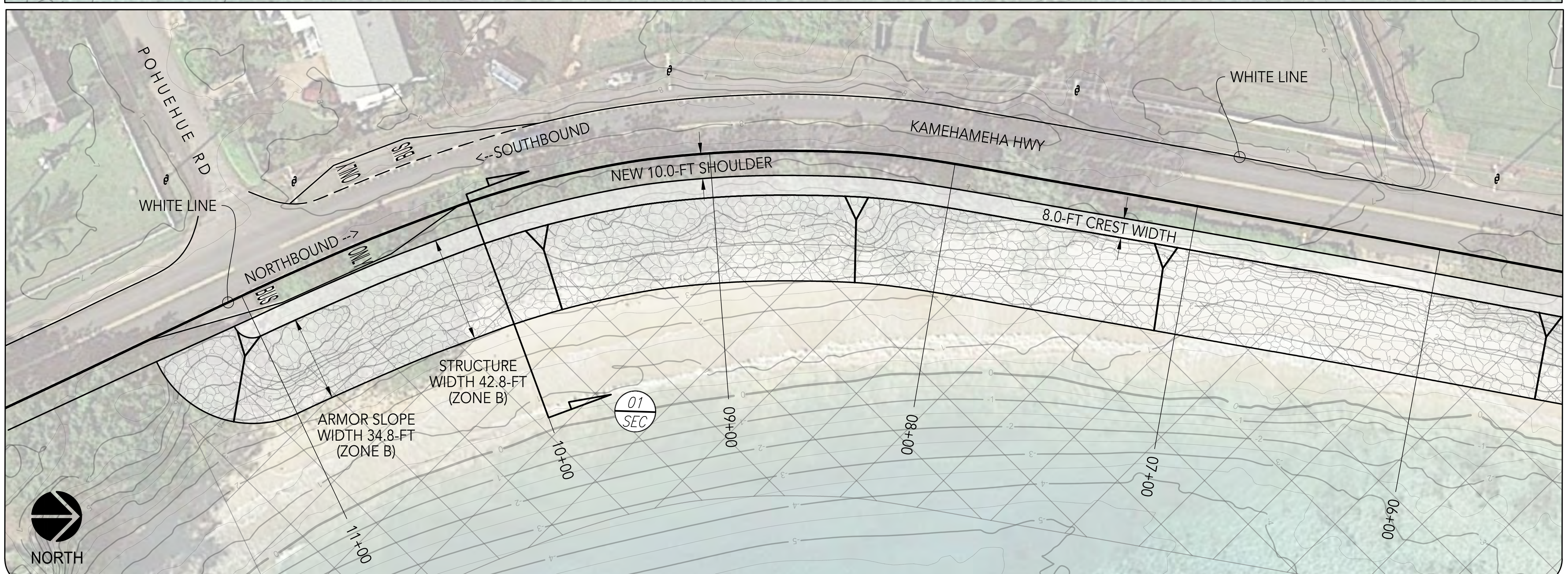
Kaaawa Stream to Kaaawa Beach Park Mild Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-044
Date 17 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_ erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. Revetment Zones for this reach:

Zone A - Station 00+00 - 04+00

Zone B - Station 04+00 - 11+00

Sheet Name

Kaaawa Stream to Kaaawa Beach Park Low Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-045
Date 17 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

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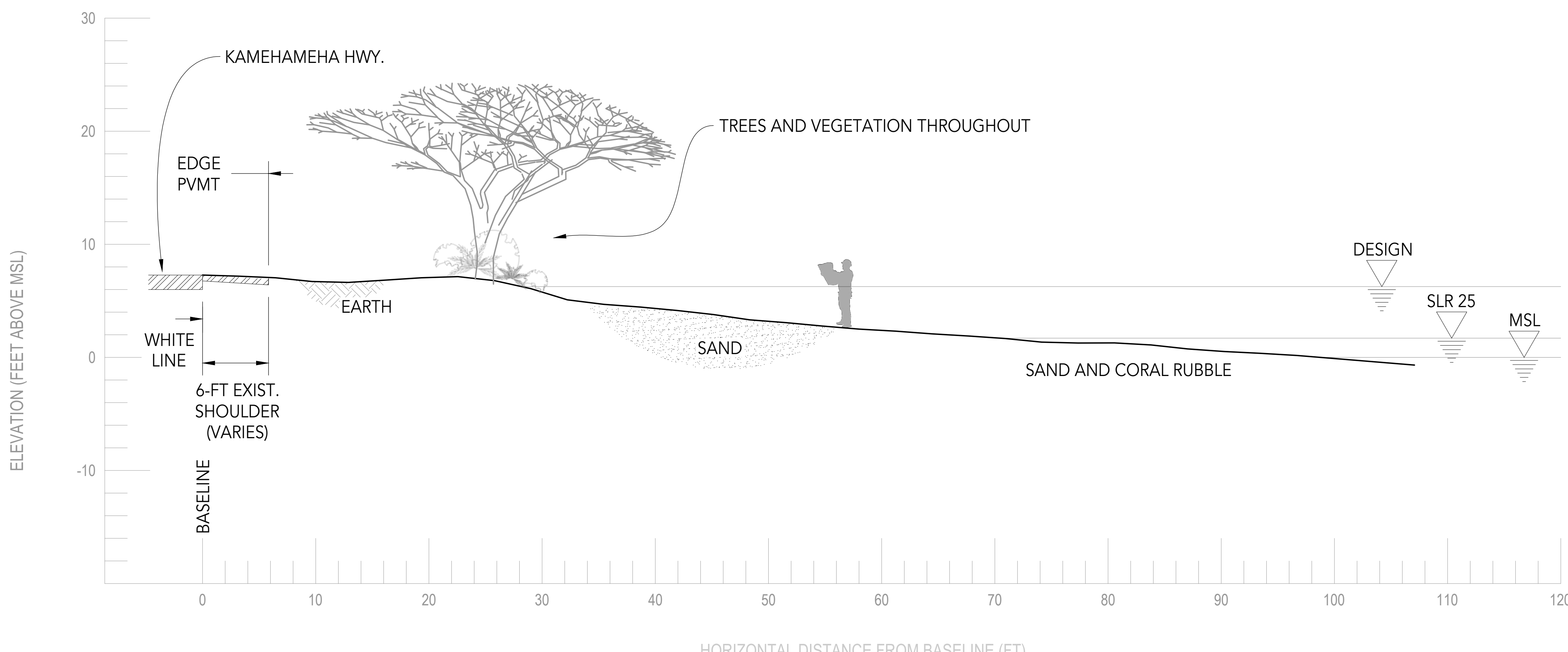

01 EXISTING (2013) CROSS SECTION AT STATION 10+00
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

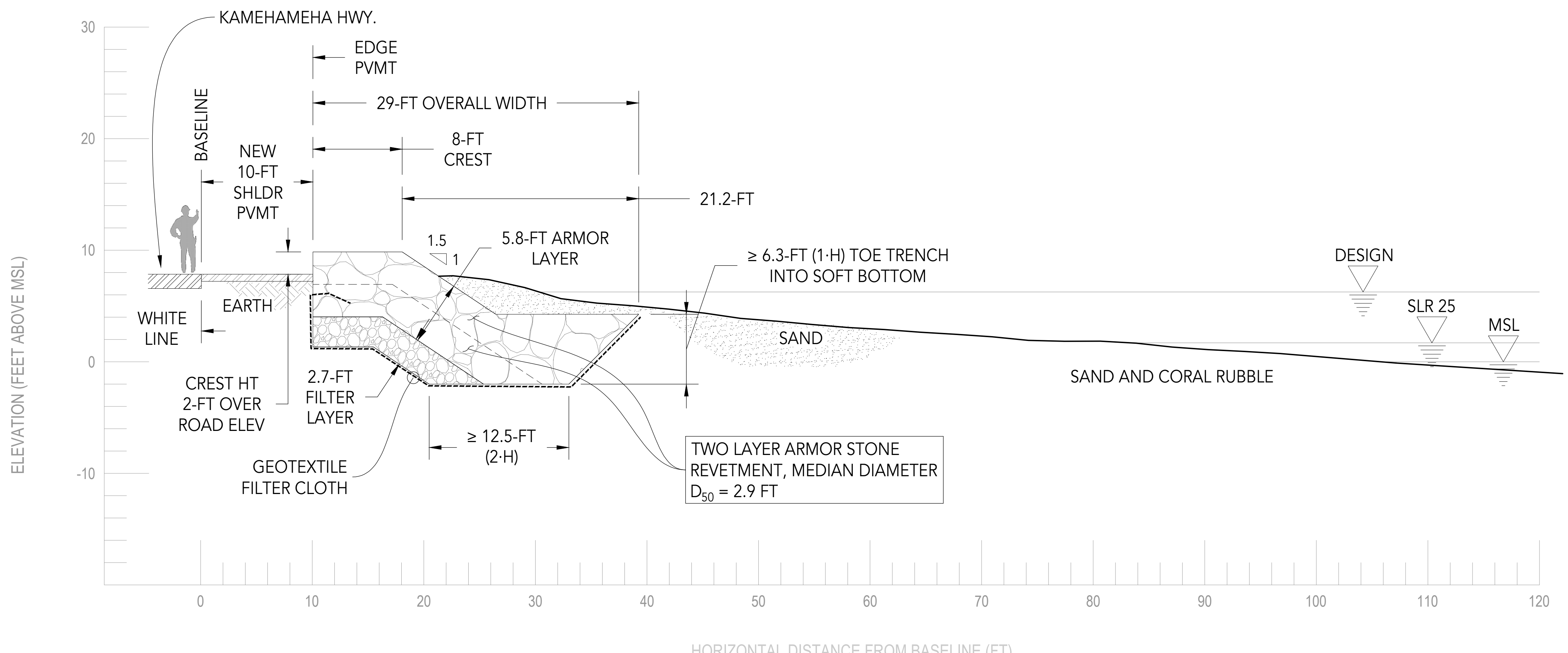
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 6.26 ft MSL

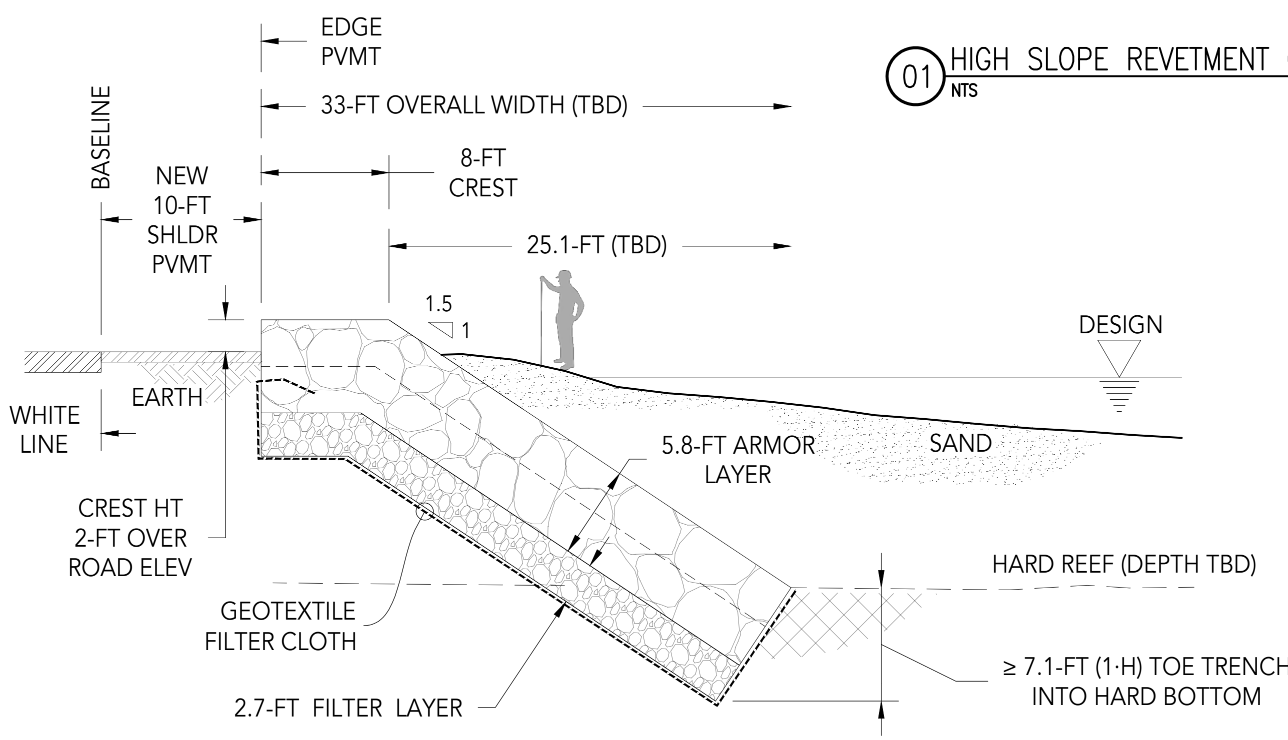
Sheet Name
Kaaawa Beach Park Station 10+00 (Zone B) Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-046
Date 17 Mar 2022	
Scale 1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 10+00
NTS



ALTERNATE TOE DETAIL FOR HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	2,958	W_{15}	49
W_{50}	3,944	W_{50}	394
W_{max}	4,930	W_{100}	1,578

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.64	d_{15}	0.68
d_{50}	2.91	d_{50}	1.35
d_{max}	3.14	d_{100}	2.14

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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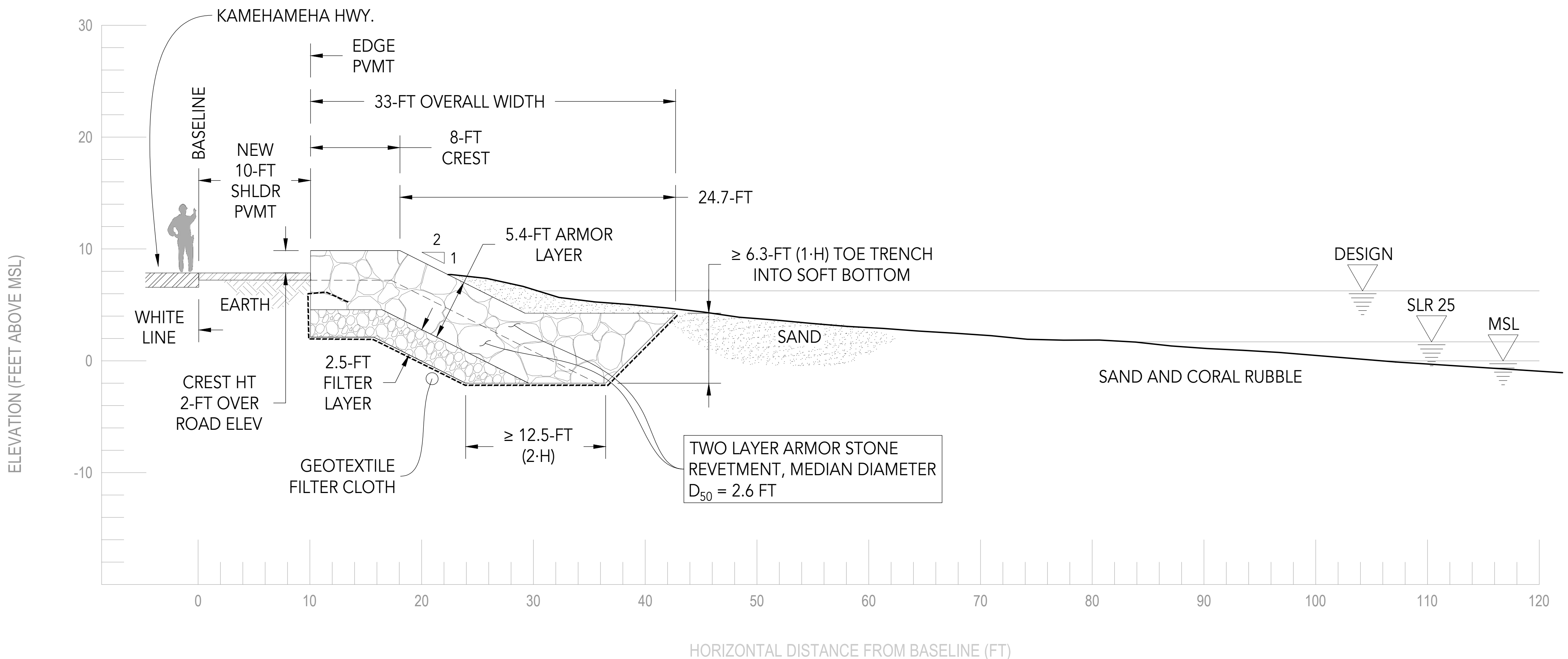
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 6.3 ft, for this location.

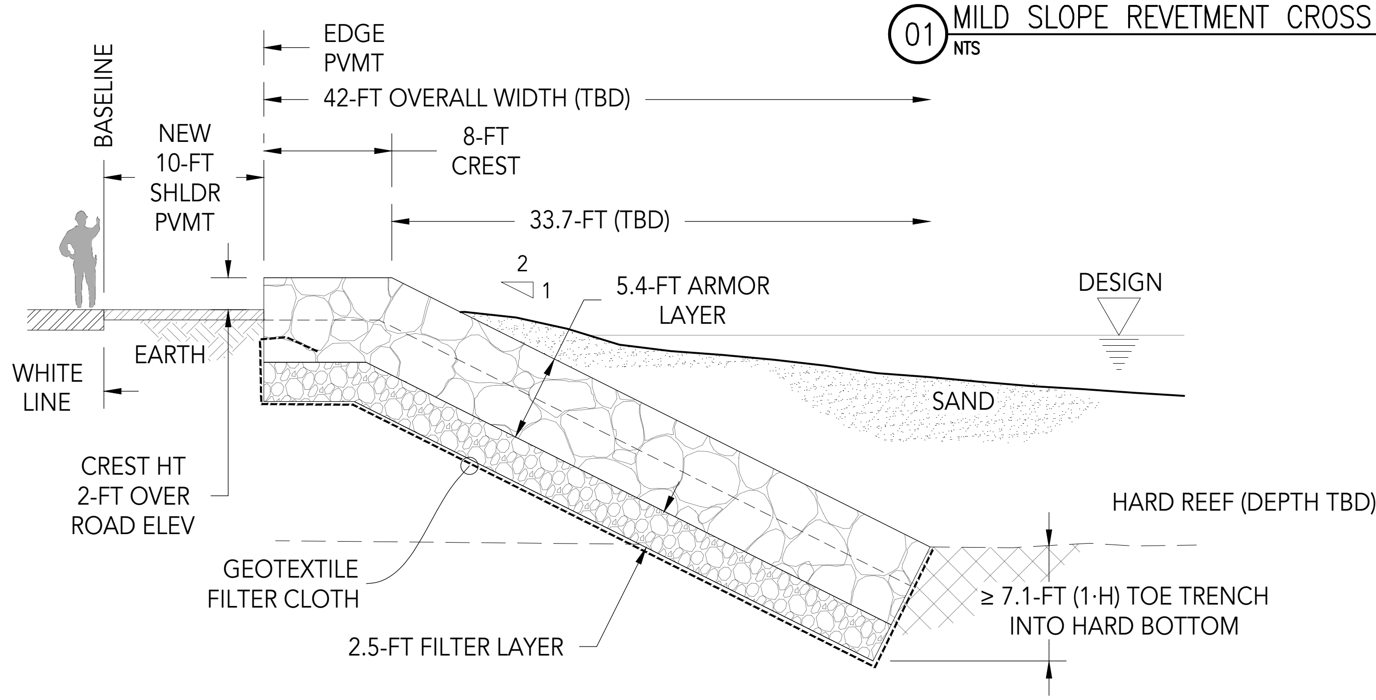
Sheet Name
Kaaawa Beach Park Station 10+00 (Zone B) High Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	17 Mar 2022	C-047
Scale	1" = 1' - 0"	



01 MILD SLOPE REVETMENT CROSS SECTION AT STATION 10+00
NTS



ALTERNATE TOE DETAIL FOR HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	2,218	W_{15}	37
W_{50}	2,958	W_{50}	296
W_{max}	3,697	W_{100}	1,183

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.40	d_{15}	0.61
d_{50}	2.64	d_{50}	1.23
d_{max}	2.85	d_{100}	1.95

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 6.3 ft, for this location.

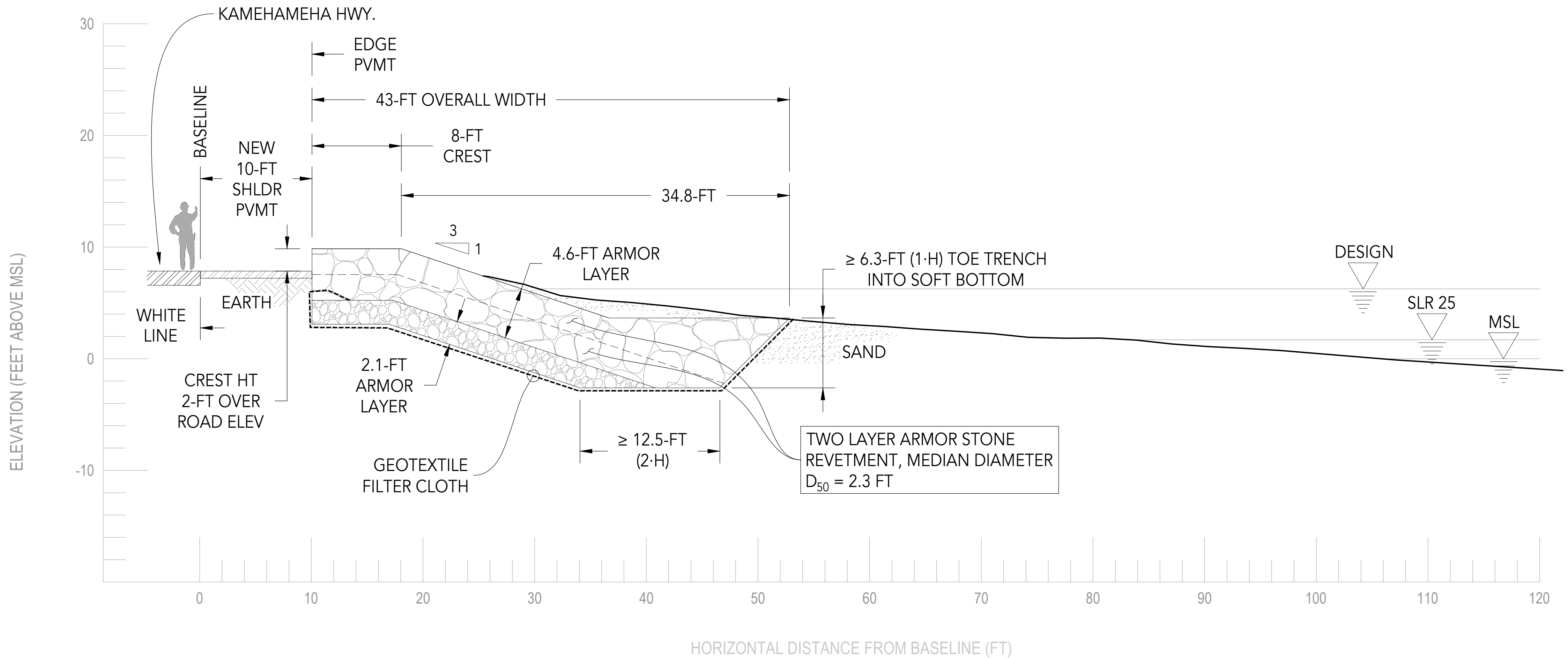
Sheet Name

Kaaawa Beach Park Station 10+00 (Zone B) Mild Slope Revetment Section - Conceptual

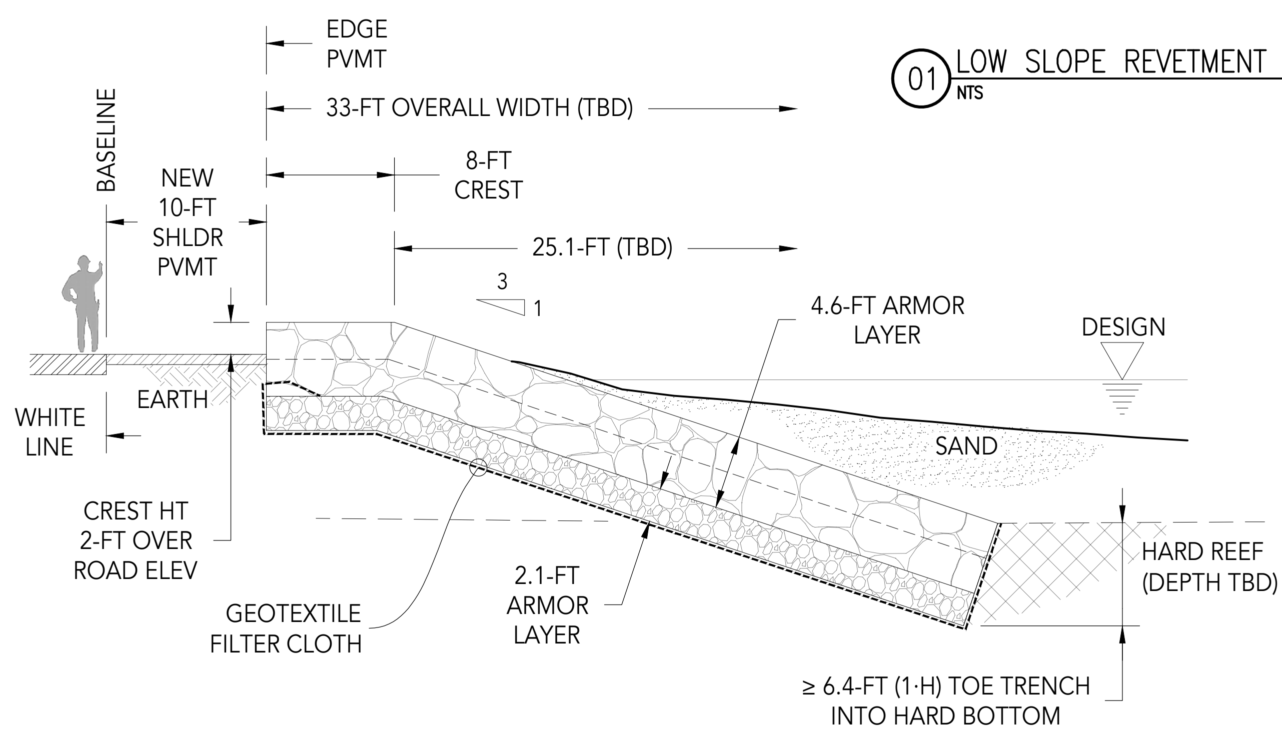
Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 17 Mar 2022
Scale 1" = 1' - 0"
Sheet C-048



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 10+00
NTS



ALTERNATE TOE DETAIL FOR HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	1,479	W_{15}	25
W_{50}	1,972	W_{50}	197
W_{max}	2,465	W_{100}	789

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.10	d_{15}	0.54
d_{50}	2.31	d_{50}	1.07
d_{max}	2.49	d_{100}	1.70

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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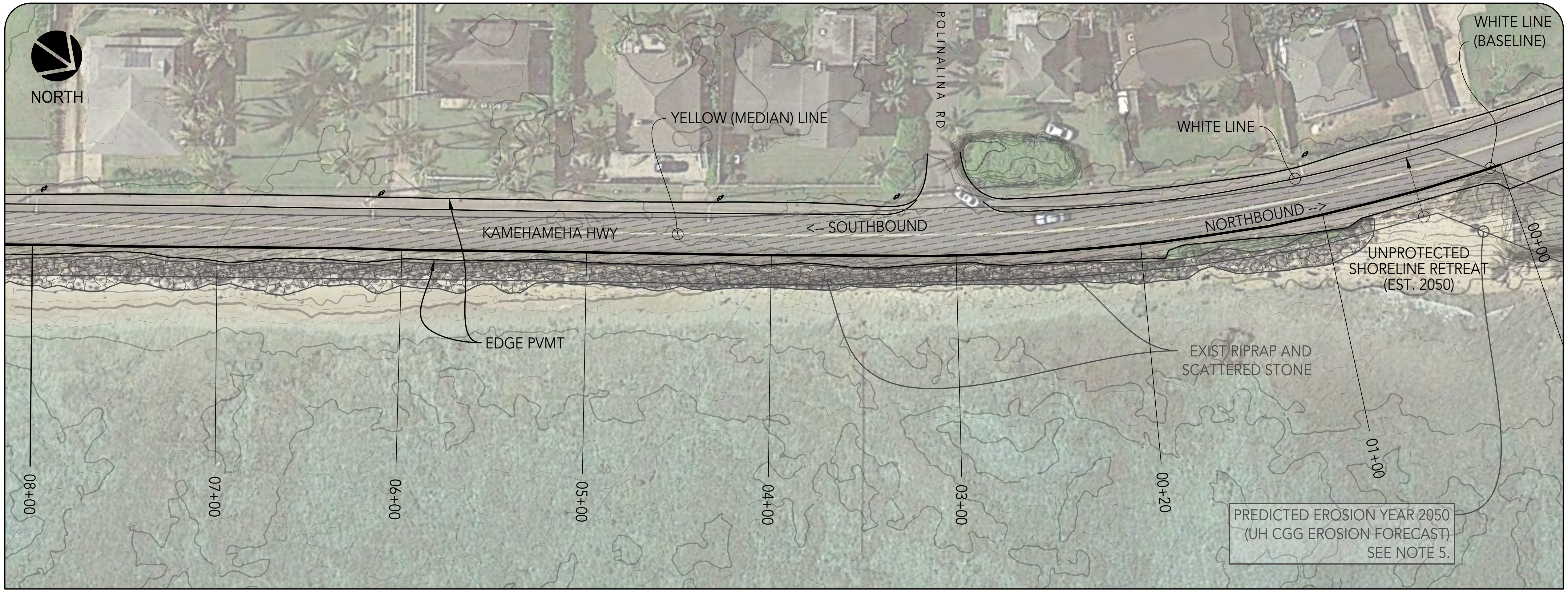
NOTES:

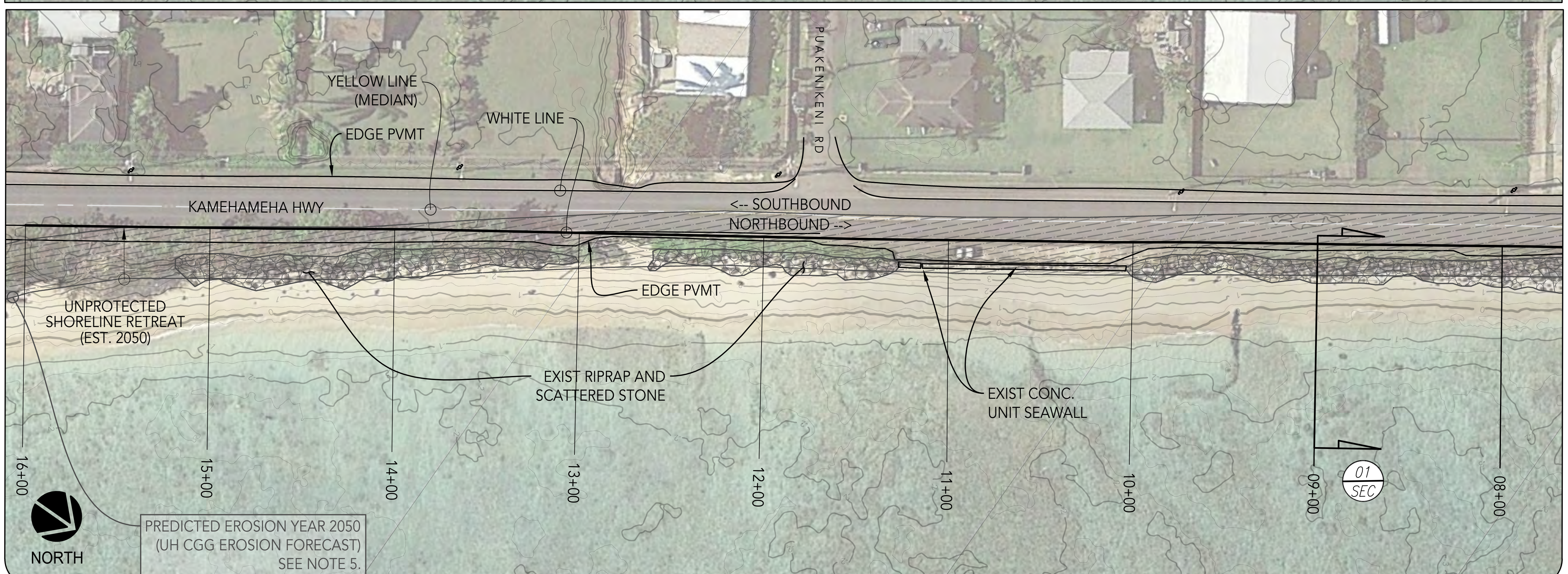
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 6.3 ft, for this location.

Sheet Name
Kaaawa Beach Park Station 10+00 (Zone B) Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-049
Date 17 Mar 2022	
Scale 1" = 1' - 0"	





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_ erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict complete erosion of this reach up to and beyond the existing road shoulder location. The revetment repair reach will therefore extend fully between the private shoreline residences from the north to the south.

Sheet Name

Kaaawa Vicinity of Puakenikeni Road Existing Condition Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-050
Date 17 Mar 2022	
Scale $\frac{3}{16}$" = 1' - 0"	

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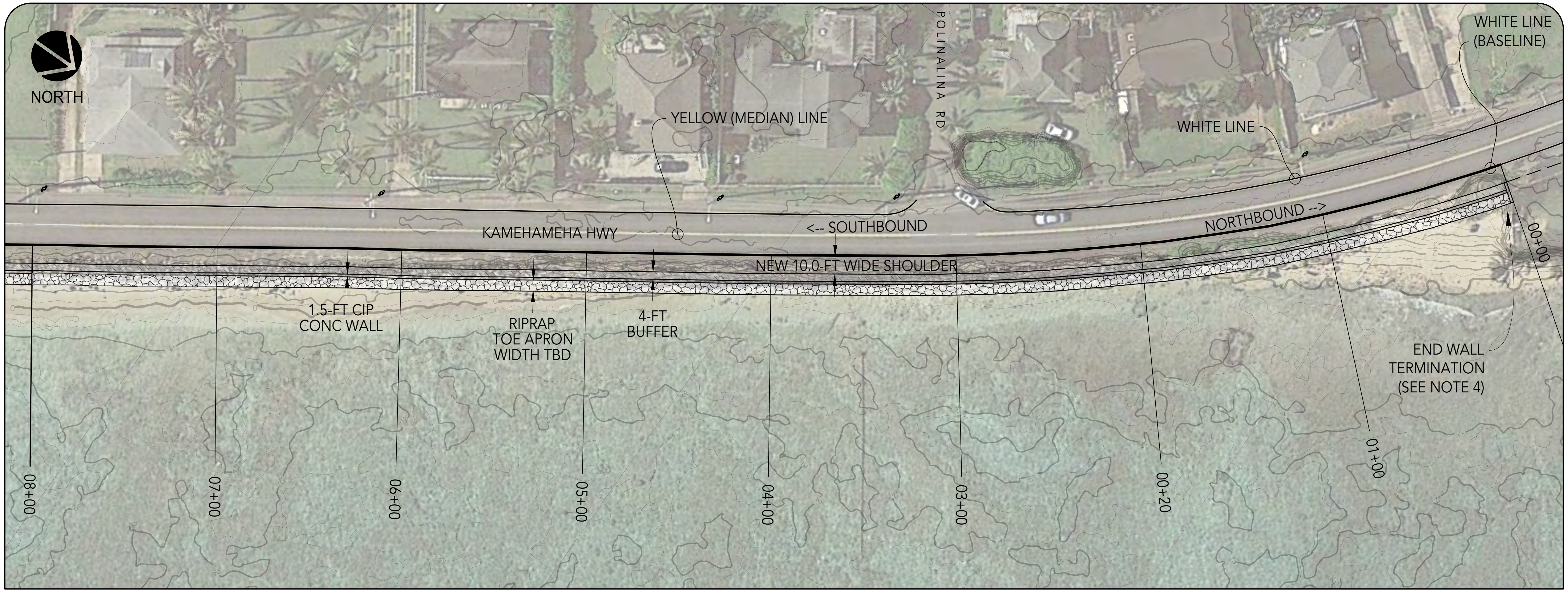

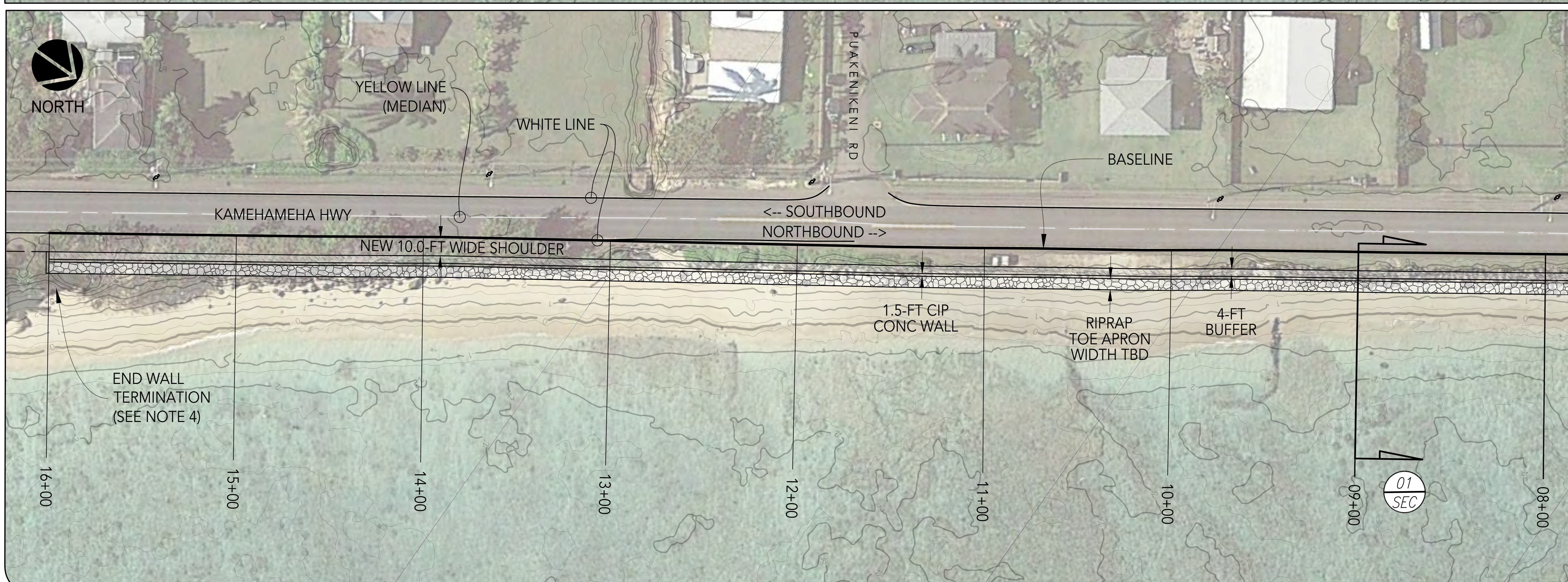

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Top of wall elevation to follow approximately 2-ft above existing road deck shoulder elevation.
4. Wall and toe apron terminate with a lateral end wall to stabilize toe apron armor stone and prevent flanking erosion.
5. Wall to tie into culvert or bridge wing walls where present.

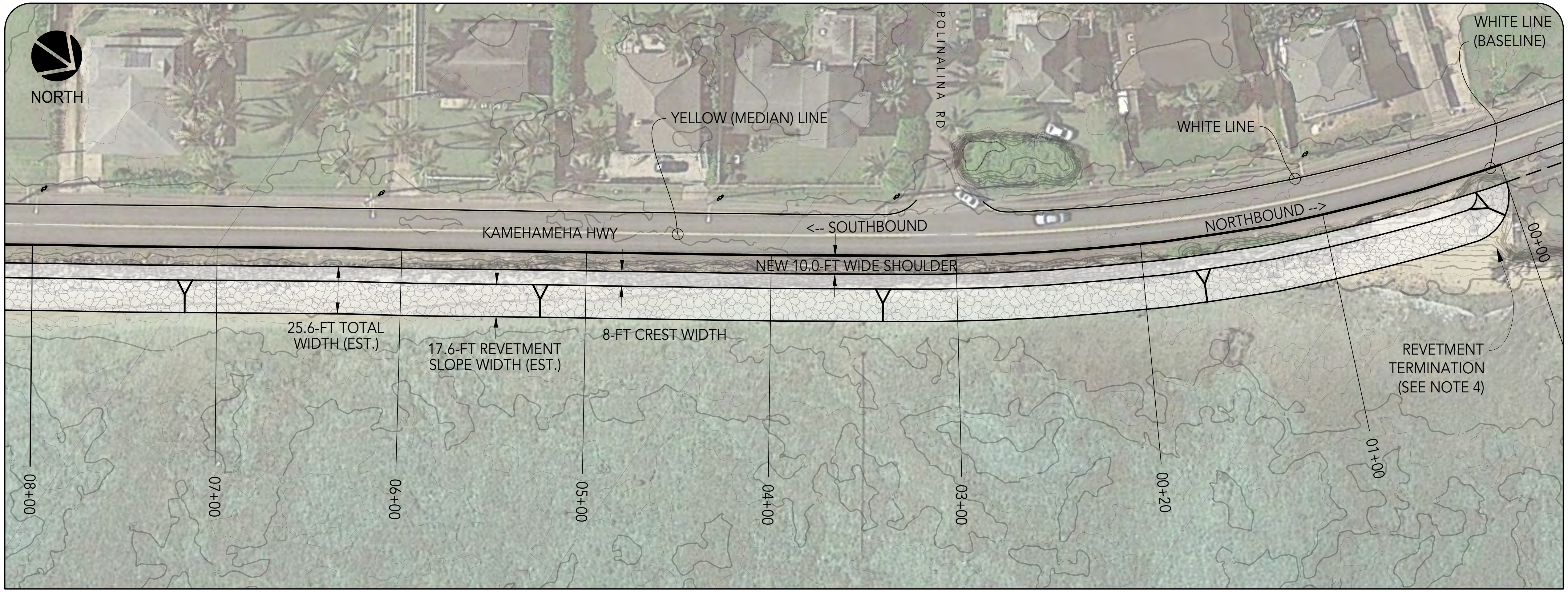
Sheet Name

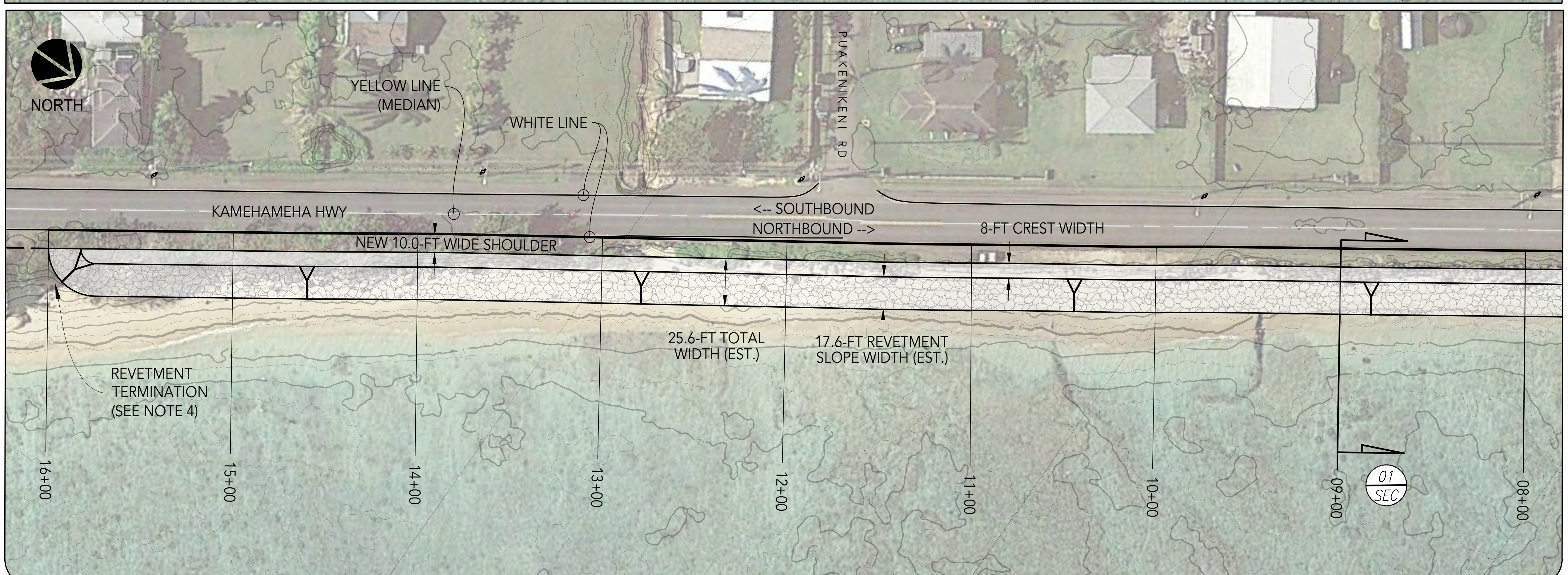
Kaaawa Vicinity of Puakenikeni Road Armored Seawall Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	17 Mar 2022	C-051
Scale	$\frac{3}{16}$" = 1' - 0"	





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NOTES:

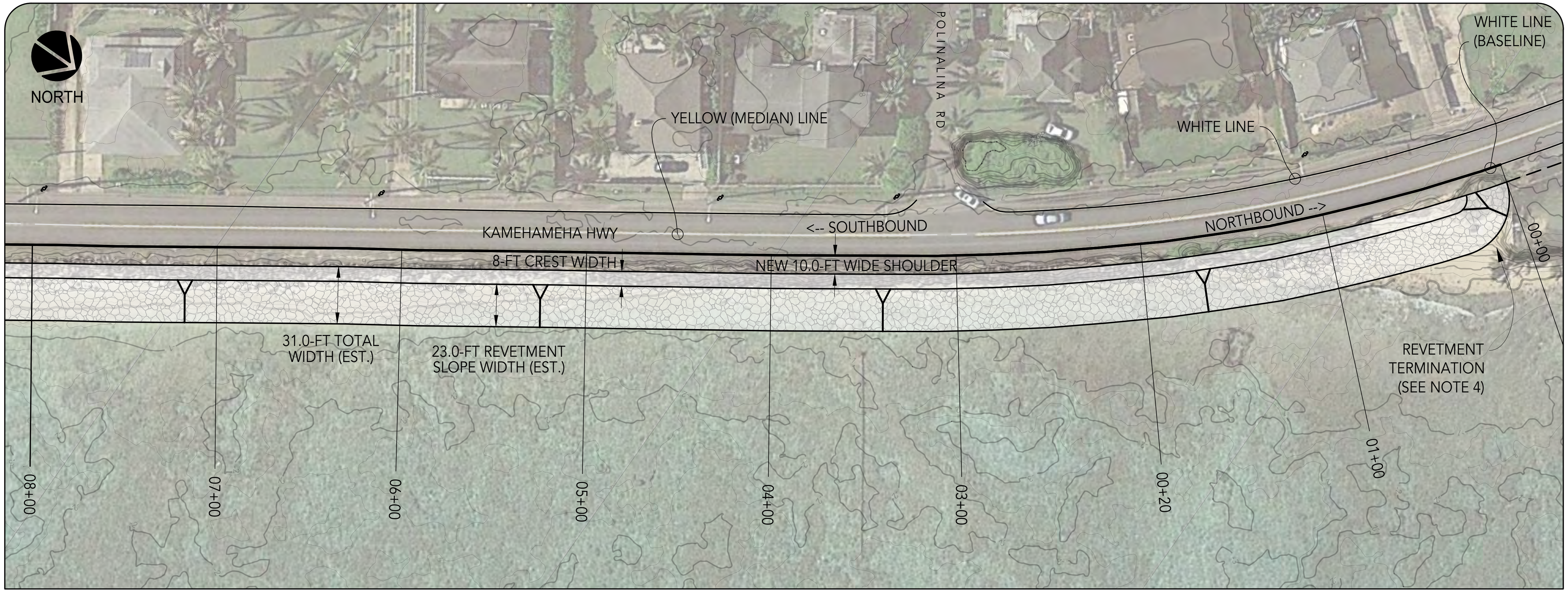
1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.

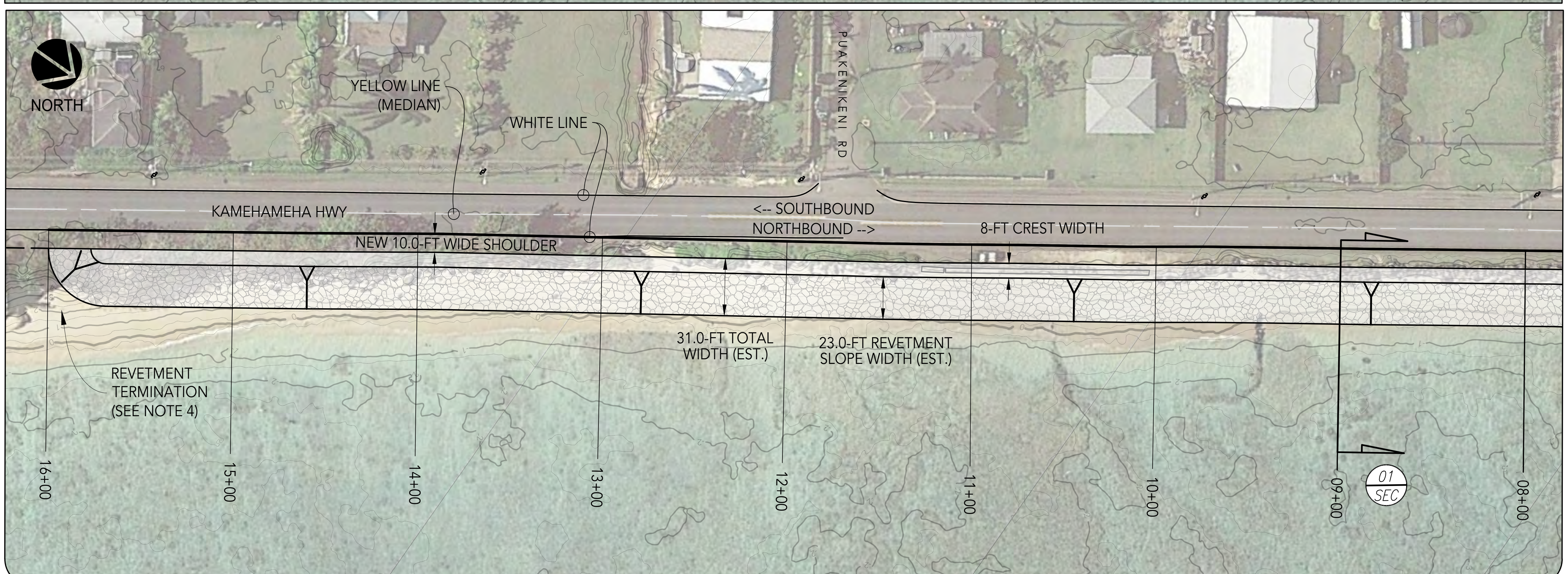
Sheet Name
Kaaawa Vicinity of Puakenikeni Road High Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 17 Mar 2022
Scale $\frac{3}{16}$" = 1' - 0"
Sheet C-052

Mon Mar 21 15:27:38 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***





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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.

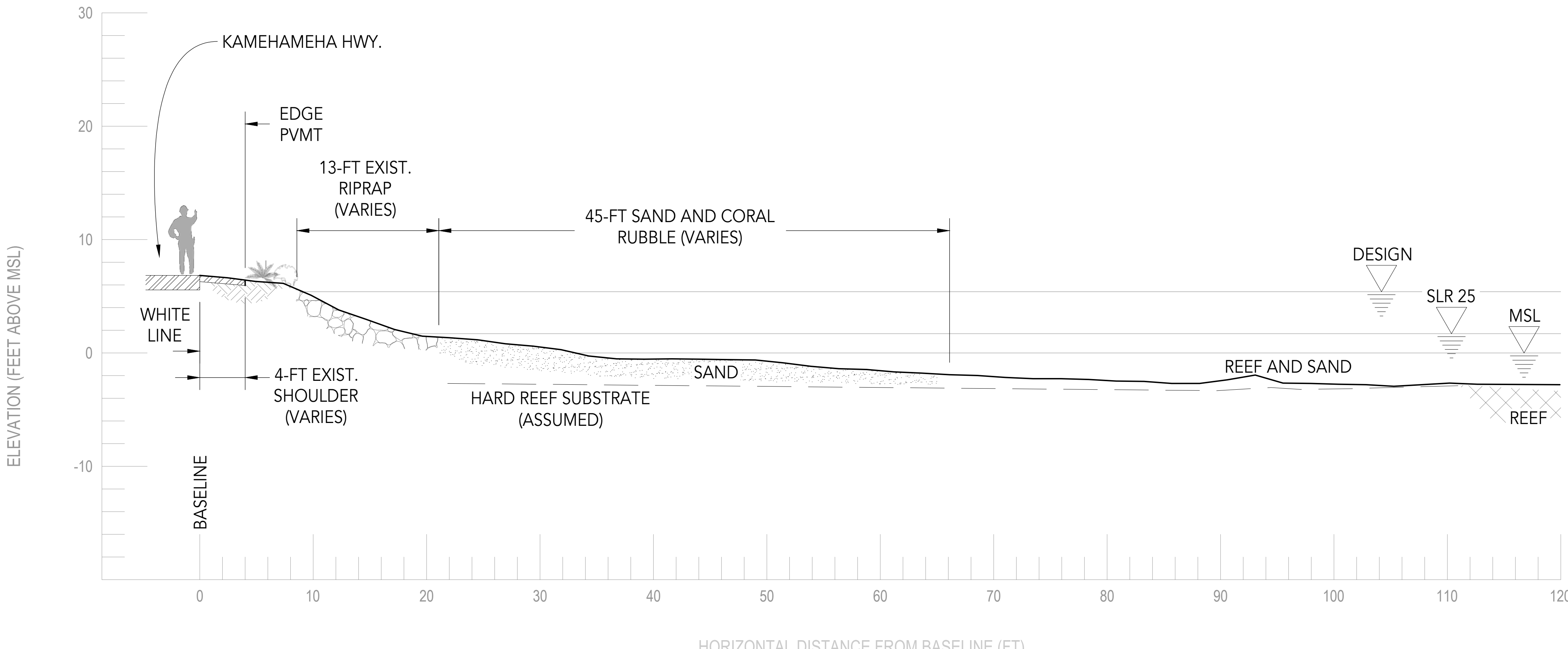
Sheet Name

Kaawa Vicinity of Puakenikeni Road Mild Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	17 Mar 2022	C-053
Scale	$\frac{3}{16}$" = 1' - 0"	



01 EXISTING (2013) CROSS SECTION AT STATION 09+00
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 5.40 ft MSL

Sheet Name
Kaaawa Puakenikeni Station 09+00 Existing Condition Section (Typical)

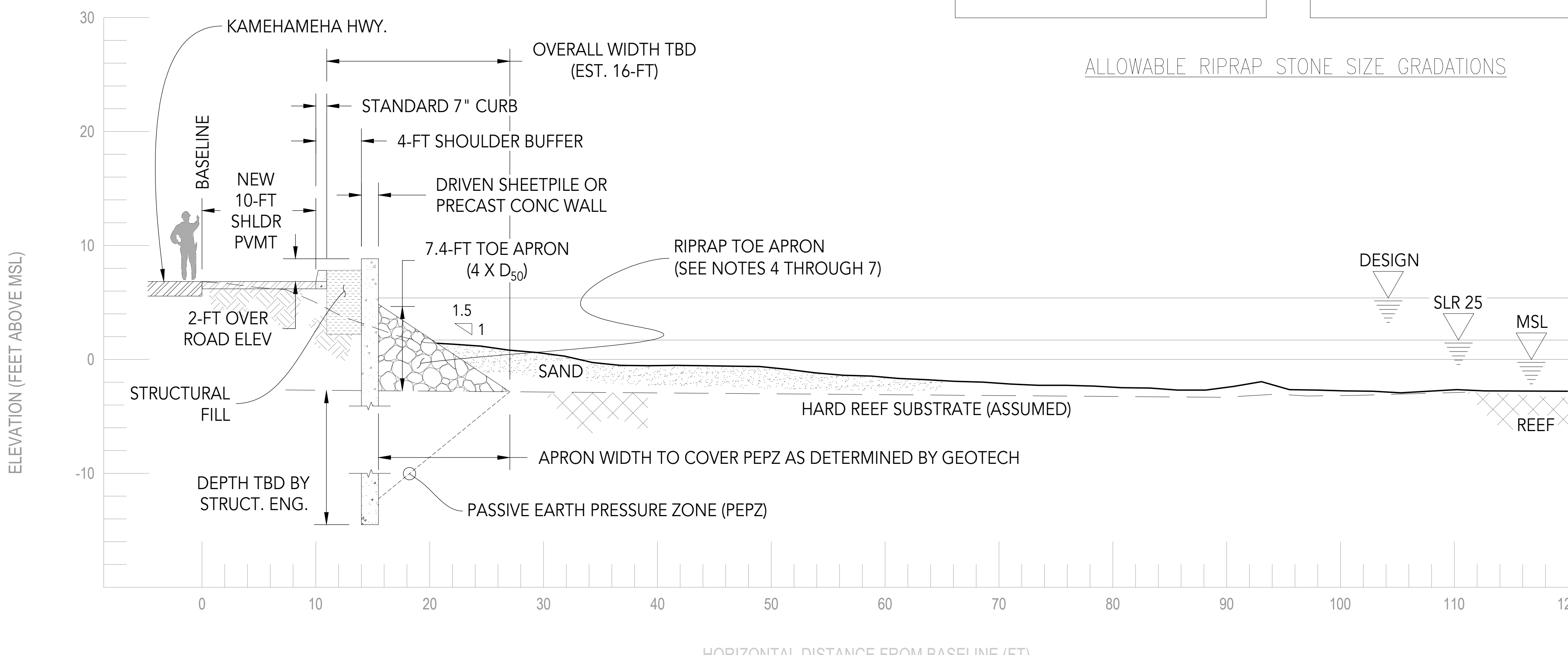
Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-054
Date 17 Mar 2022	
Scale 1" = 1' - 0"	

STONE SIZE GRADATION -- BY WEIGHT (LBF) --	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
W_{15}	129	13
W_{50}	1,036	104
W_{100}	4,142	414

STONE SIZE GRADATION -- NOMINAL DIAMETER (FT) --	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
d_{15}	0.93	0.43
d_{50}	1.86	0.87
d_{100}	2.96	1.37

ALLOWABLE RIPRAP STONE SIZE GRADATIONS



01 ARMORED SEAWALL CROSS SECTION AT STATION 09+00
NTS

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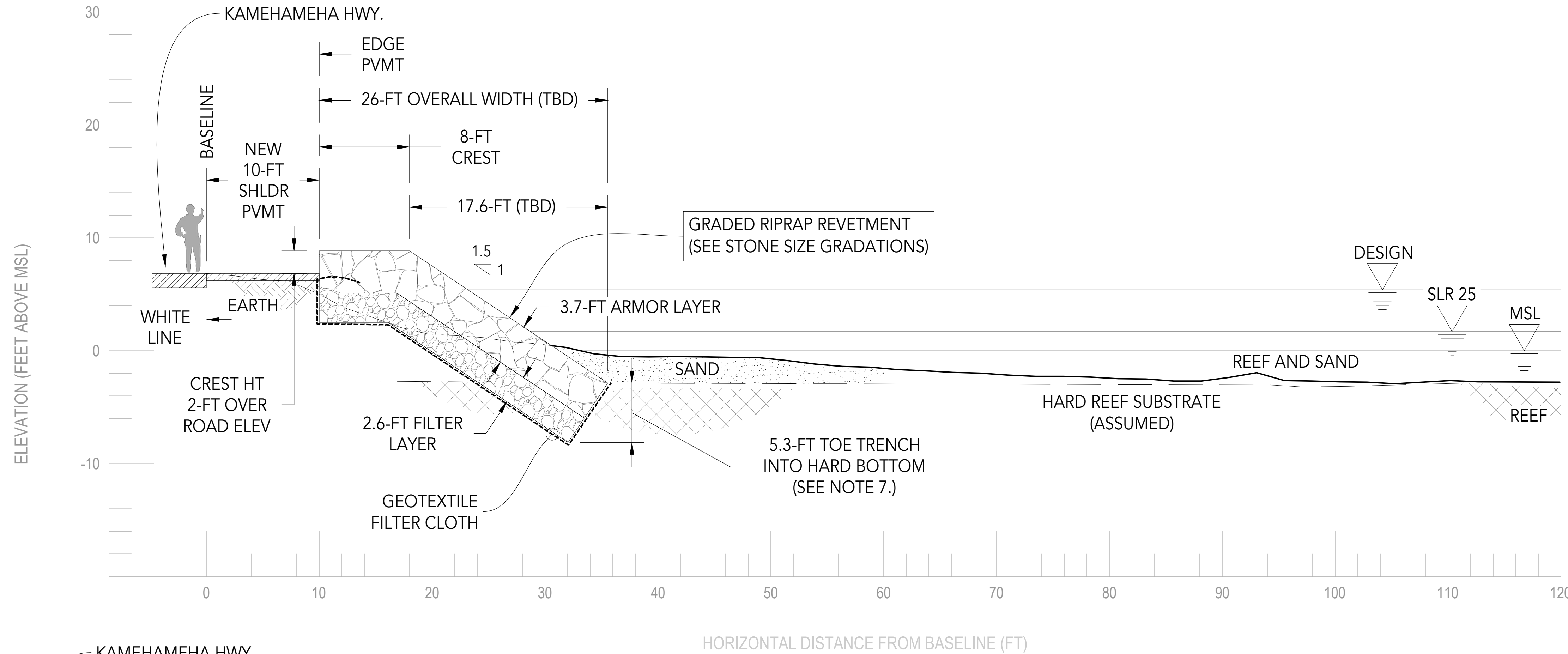
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Top of wall elevation to follow approximately 2-ft above existing road elevation.
3. Wall to tie into bridge or culvert wing walls where present.
4. Passive earth pressure zone (PEPZ) and wall depth to be determined by geotechnical and structural engineers as appropriate.
5. Toe apron riprap properties are provided in the stone size gradation tables above. Max toe apron thickness is $4 \cdot d_{50}$, or 7.4 ft.
6. Excavate sand/sediment to expose hard substrate at approx. -3 ft MSL for preparation of riprap apron base, and re-bury to original grade upon completion.
7. Place riprap toe apron on hard bottom over geotextile or filter stone layer.

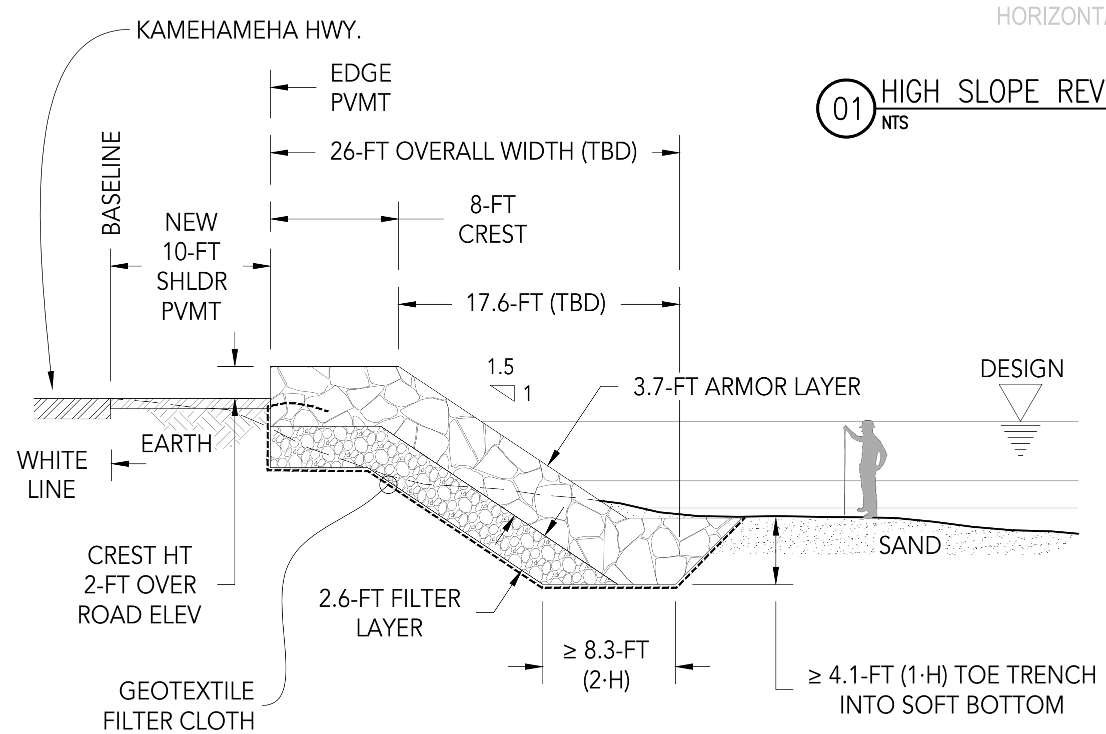
Sheet Name
Kaaawa Puakenikeni Station 09+00 Armored Seawall Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	17 Mar 2022	C-055
Scale	1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 09+00
NTS



ALTERNATE TOE DETAIL FOR NON–HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	129	13
W_{50}	1,036	104
W_{100}	4,142	414

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.93	0.43
d_{50}	1.86	0.87
d_{100}	2.96	1.37

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

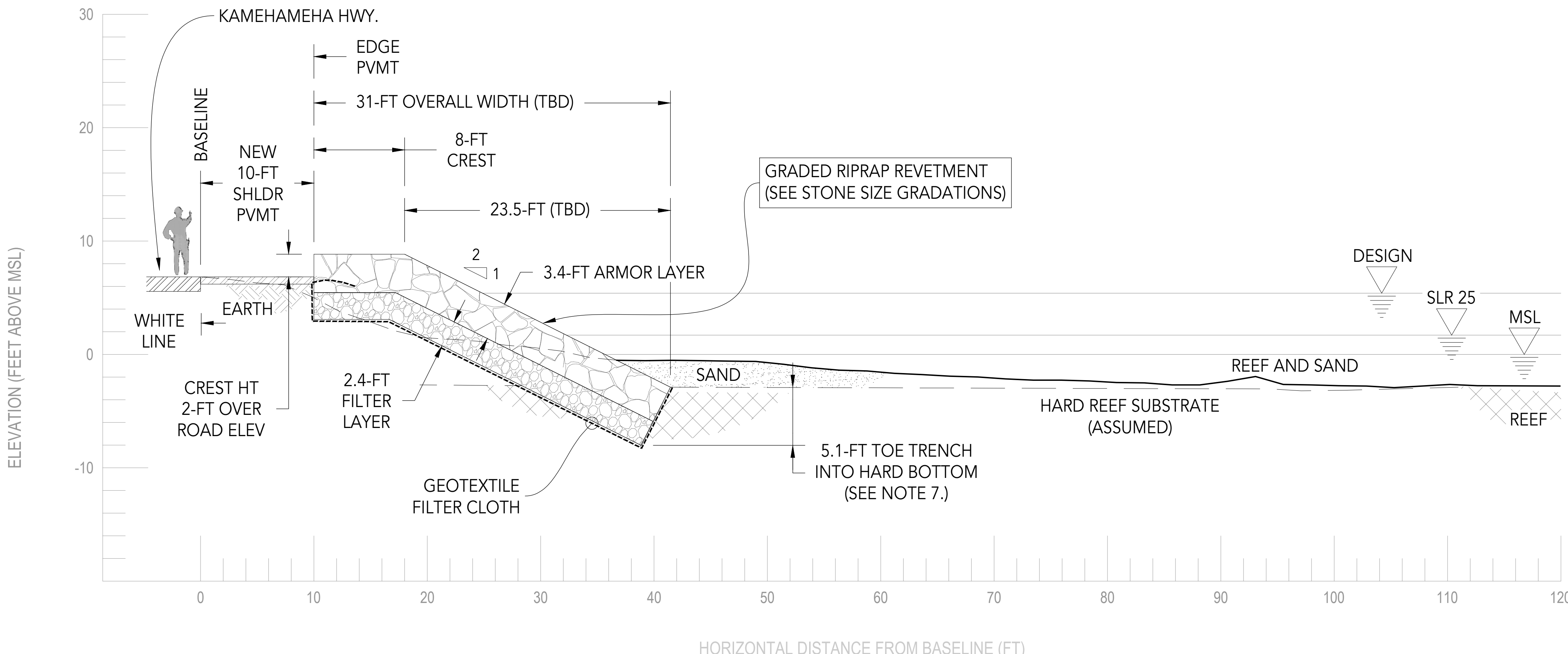
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.14 ft, for this location.

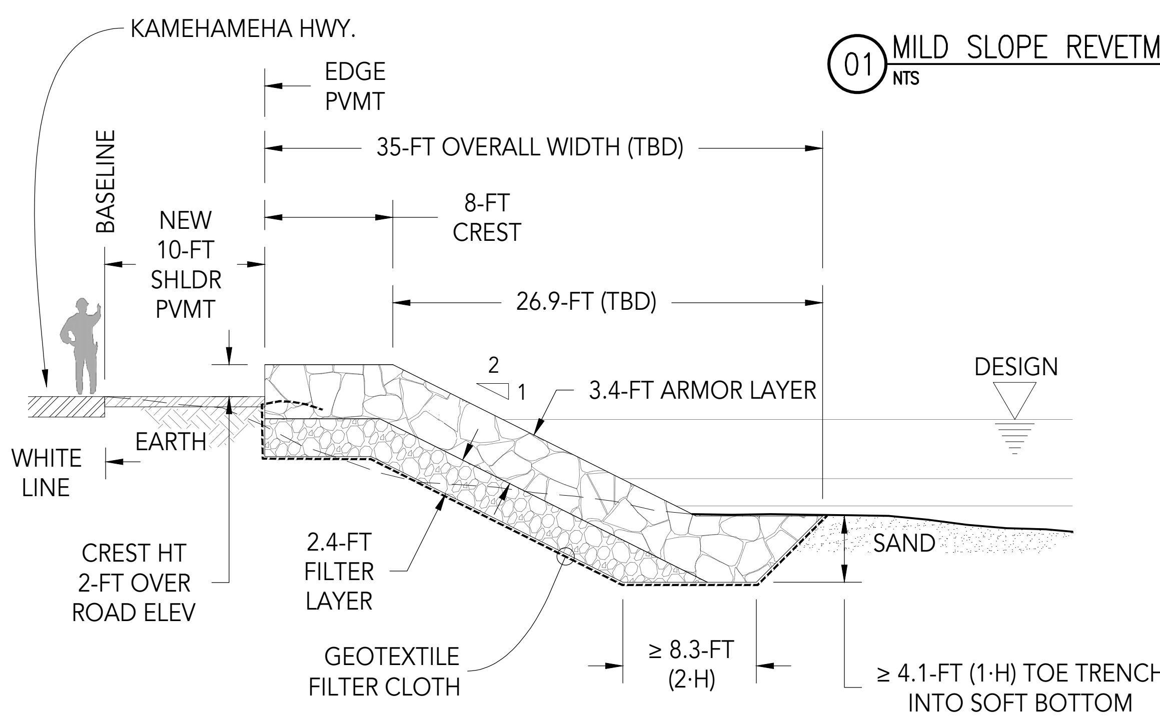
Sheet Name
Kaaawa Puakenikeni Station 09+00 High Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	17 Mar 2022	C-056
Scale	1" = 1' - 0"	



01 MILD SLOPE REVETMENT CROSS SECTION AT STATION 09+00
NTS



ALTERNATE TOE DETAIL FOR NON-HARD BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	97	10
W_{50}	777	78
W_{100}	3,107	311

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.85	0.39
d_{50}	1.69	0.79
d_{100}	2.69	1.25

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

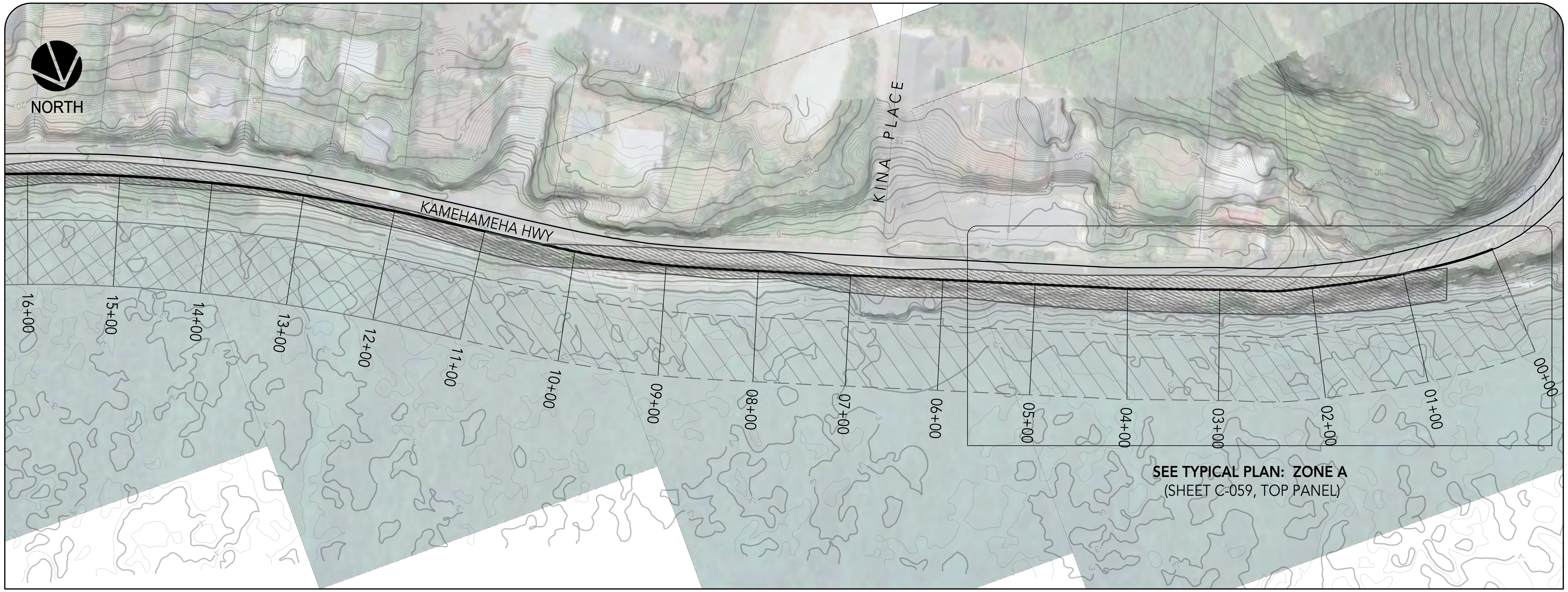
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.14 ft, for this location.

Sheet Name
Kaaawa Puakenikeni Station 09+00 Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 17 Mar 2022
Scale 1" = 1' - 0"
Sheet C-057



Sea Engineering, Inc.
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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_ erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict complete erosion of this reach up to and beyond the existing road shoulder location along the entire reach of this repair area. The length of this threatened stretch is approximately 2,900 ft.

Sheet Name

Kaaawa Vicinity of Crouching Lion Existing Condition Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-058
Date	18 Mar 2022	
Scale	$\frac{3}{16}$" = 1' - 0"	

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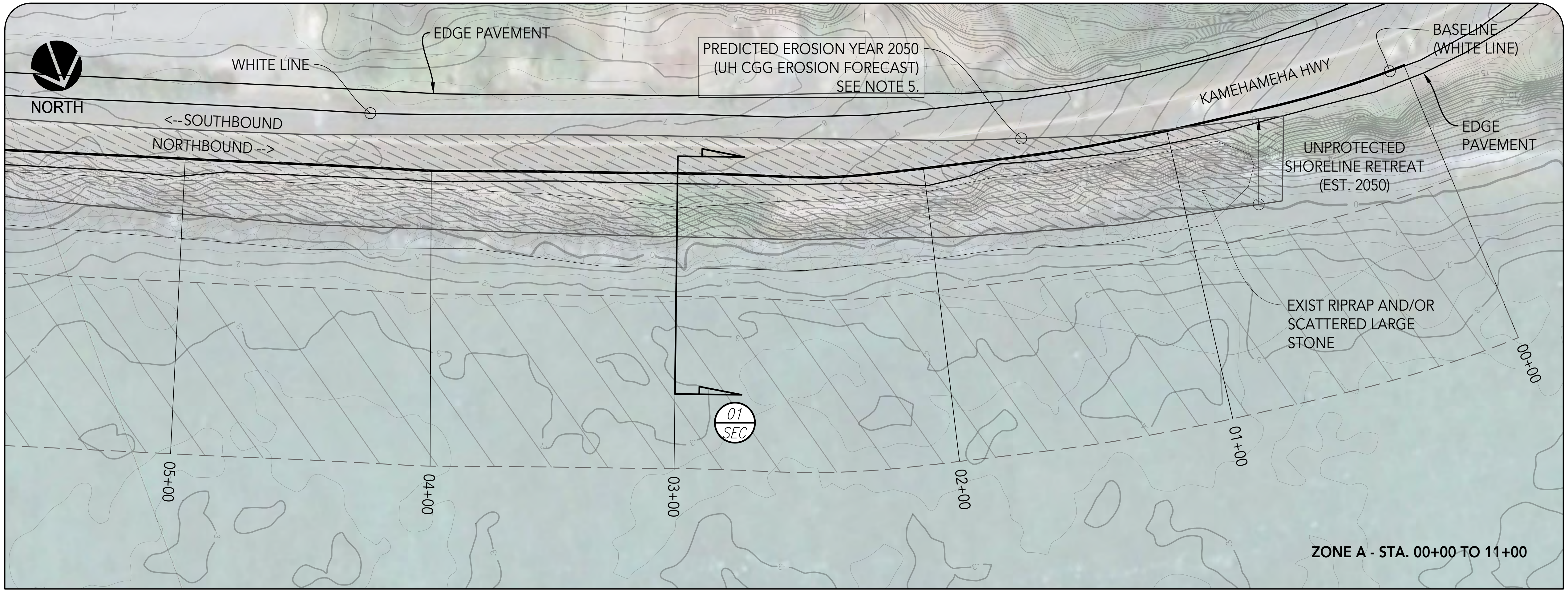

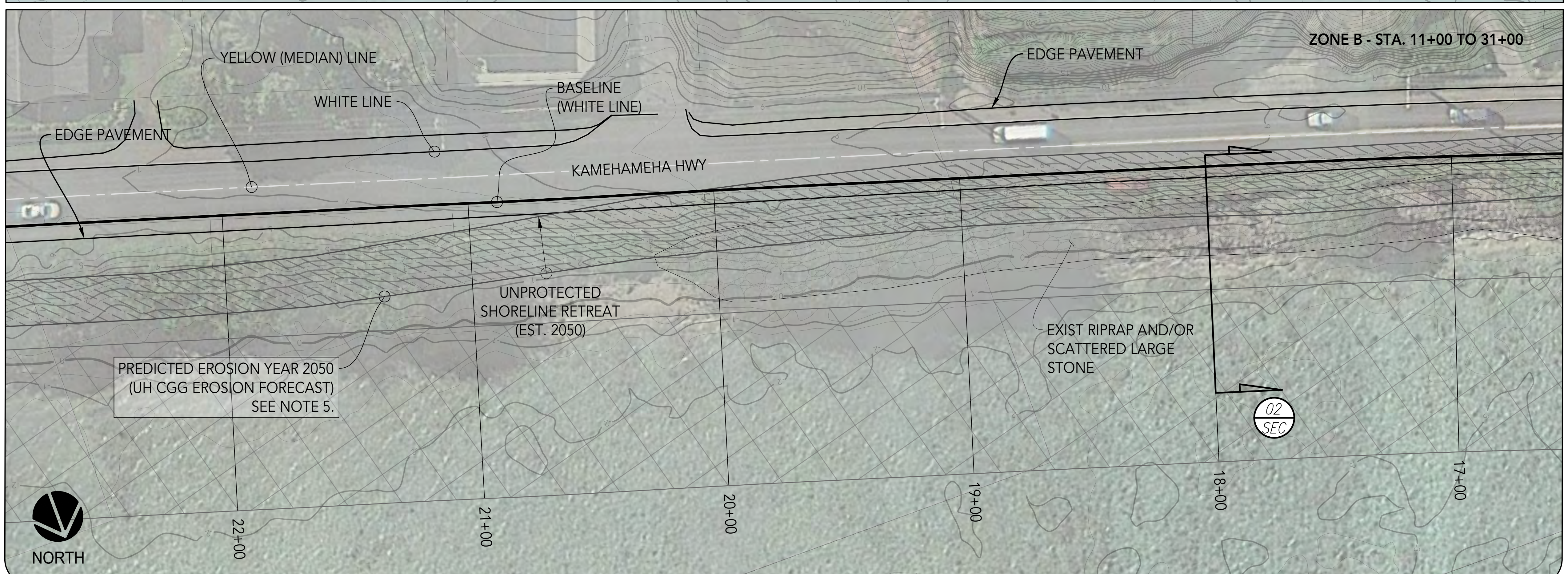

SE
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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_ erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict complete erosion of this reach up to and beyond the existing road shoulder location. The revetment repair reach will therefore extend fully between the private shoreline residences from the north to the south.

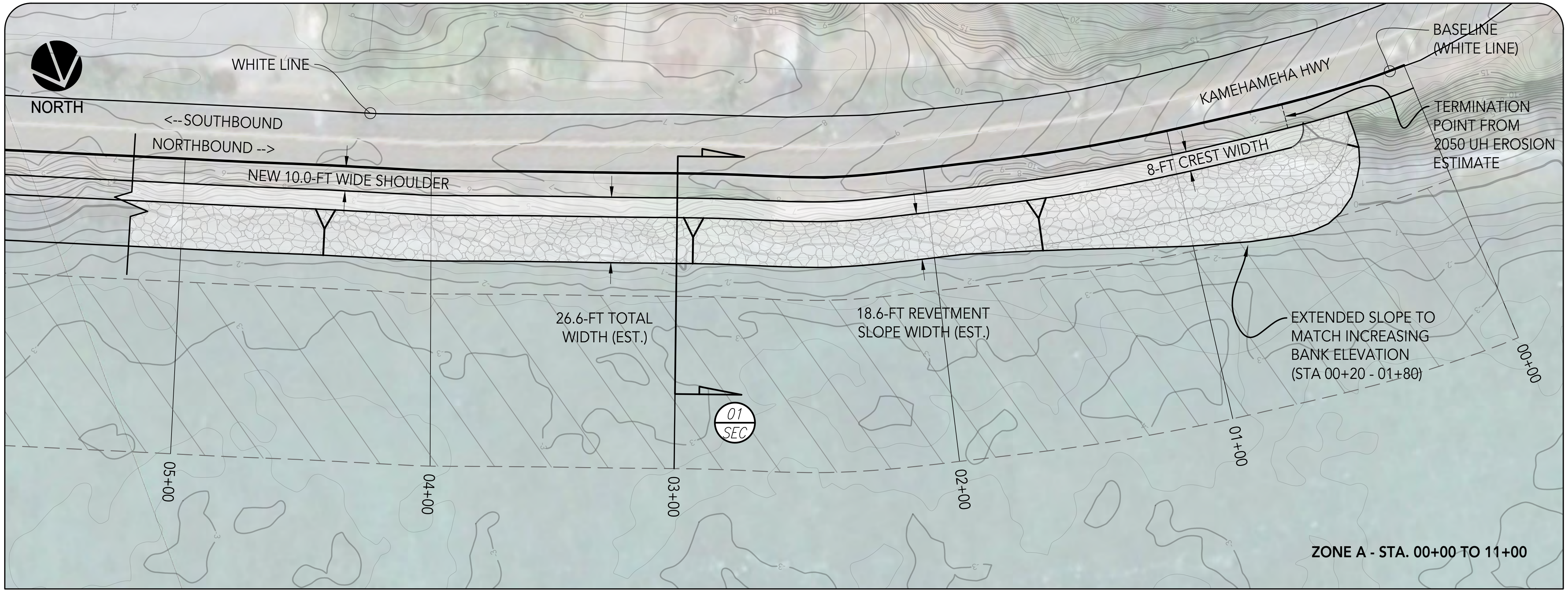
Sheet Name

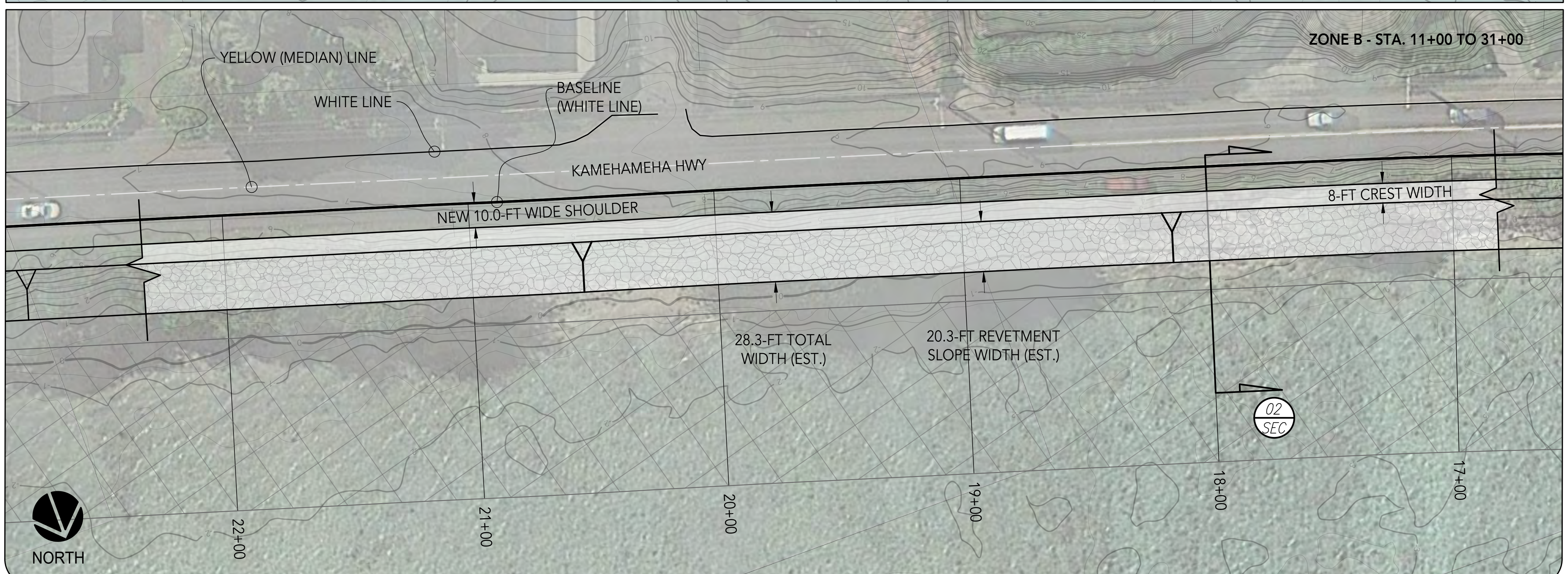
Crouching Lion Sta. 03+00 and 18+00 Existing Condition Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-059
Date 18 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





SE
Sea Engineering, Inc.
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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope as shown to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

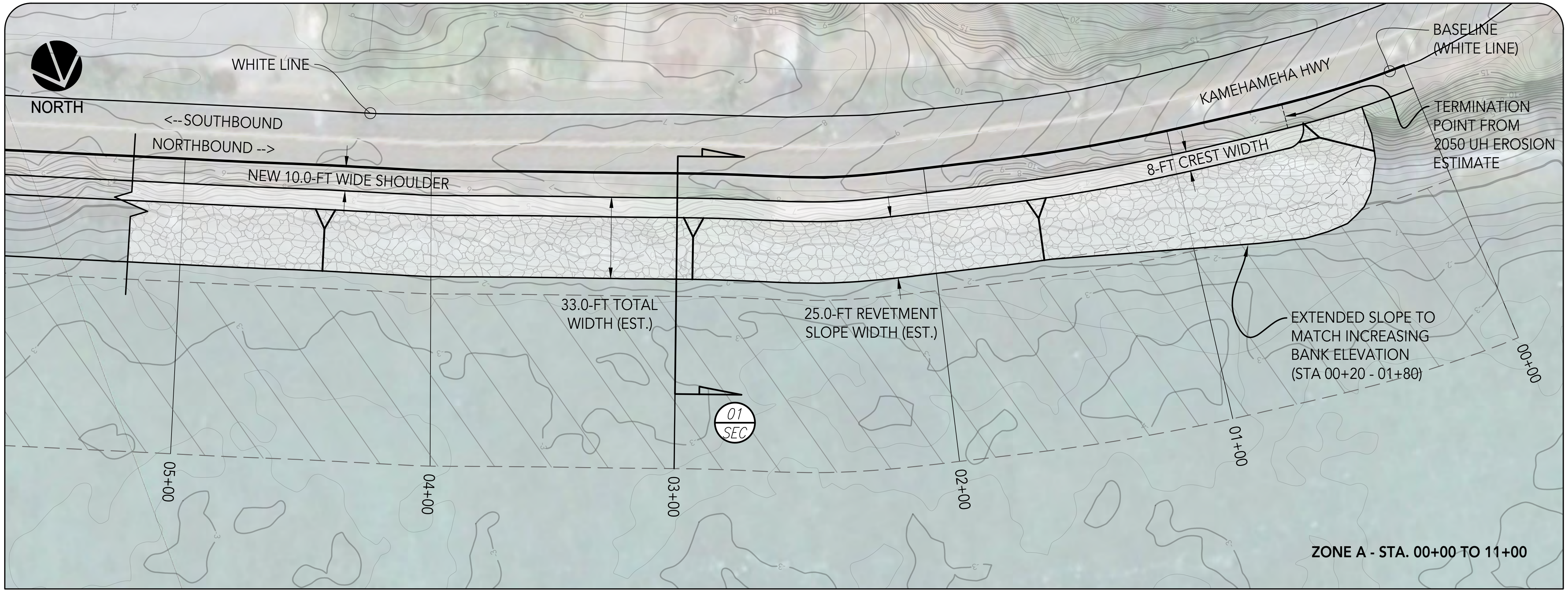
Sheet Name

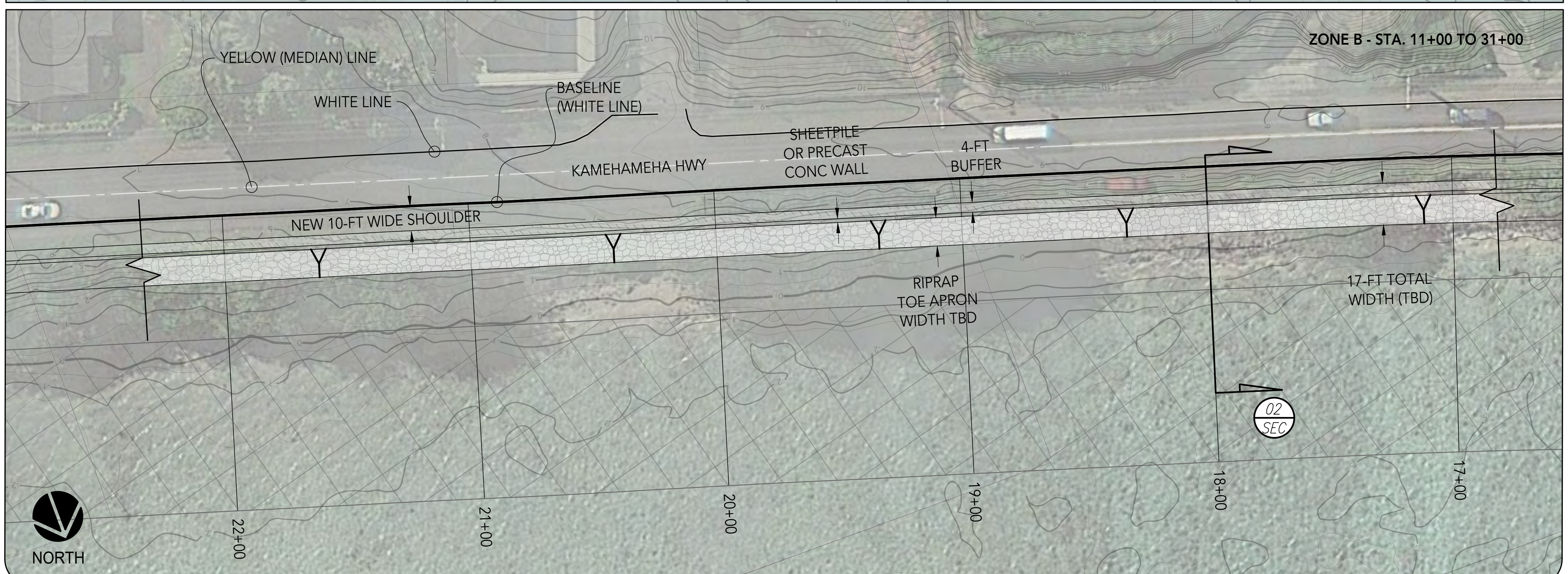
Crouching Lion Sta. 03+00 and 18+00 High Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-060
Date 18 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	





Sea Engineering, Inc.
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FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope as shown to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Crouching Lion Sta. 03+00 and 18+00 Mild Slope Revetment & Armored Seawall Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-061
Date 18 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

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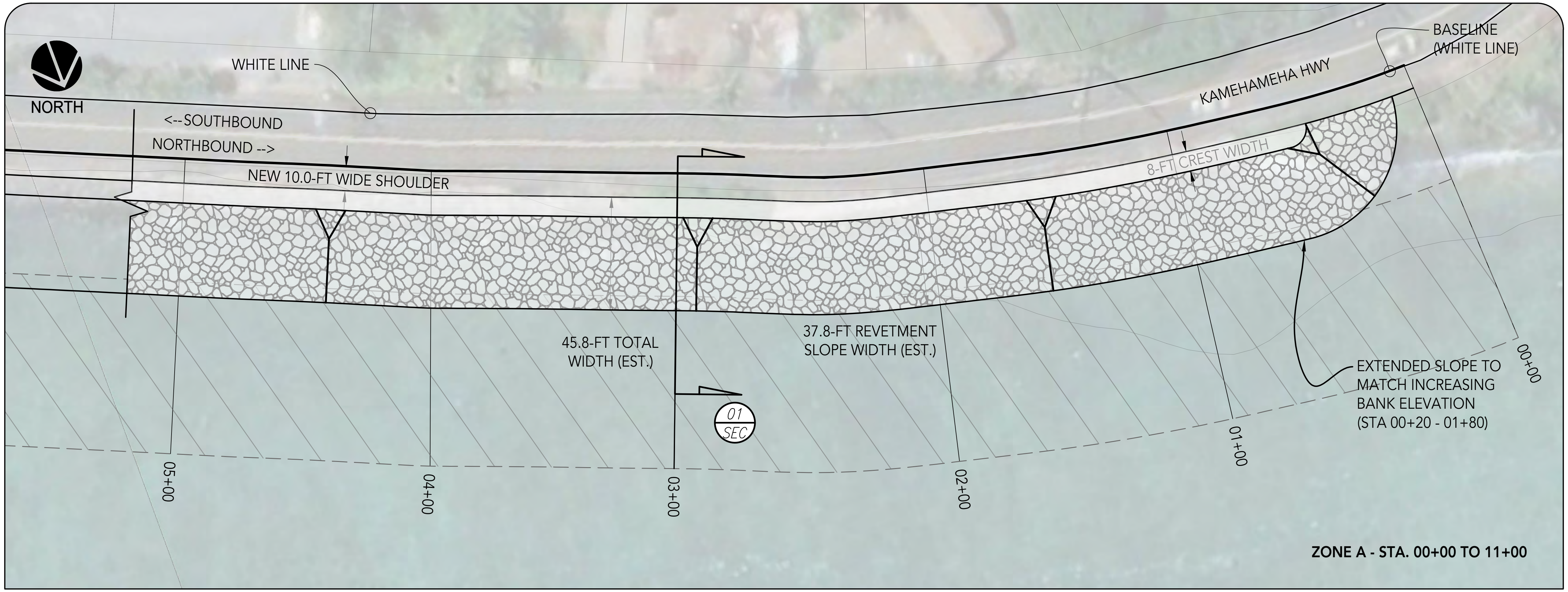

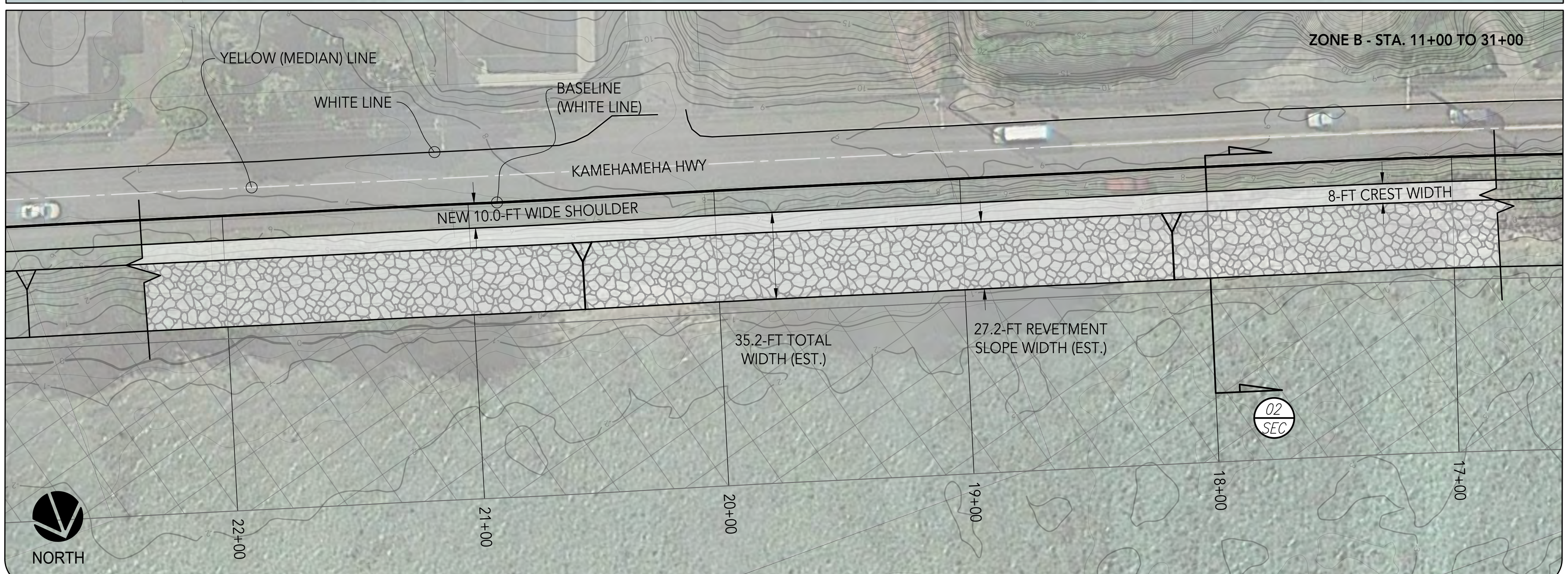

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PH 808.259.7966
FAX 808.259.8143

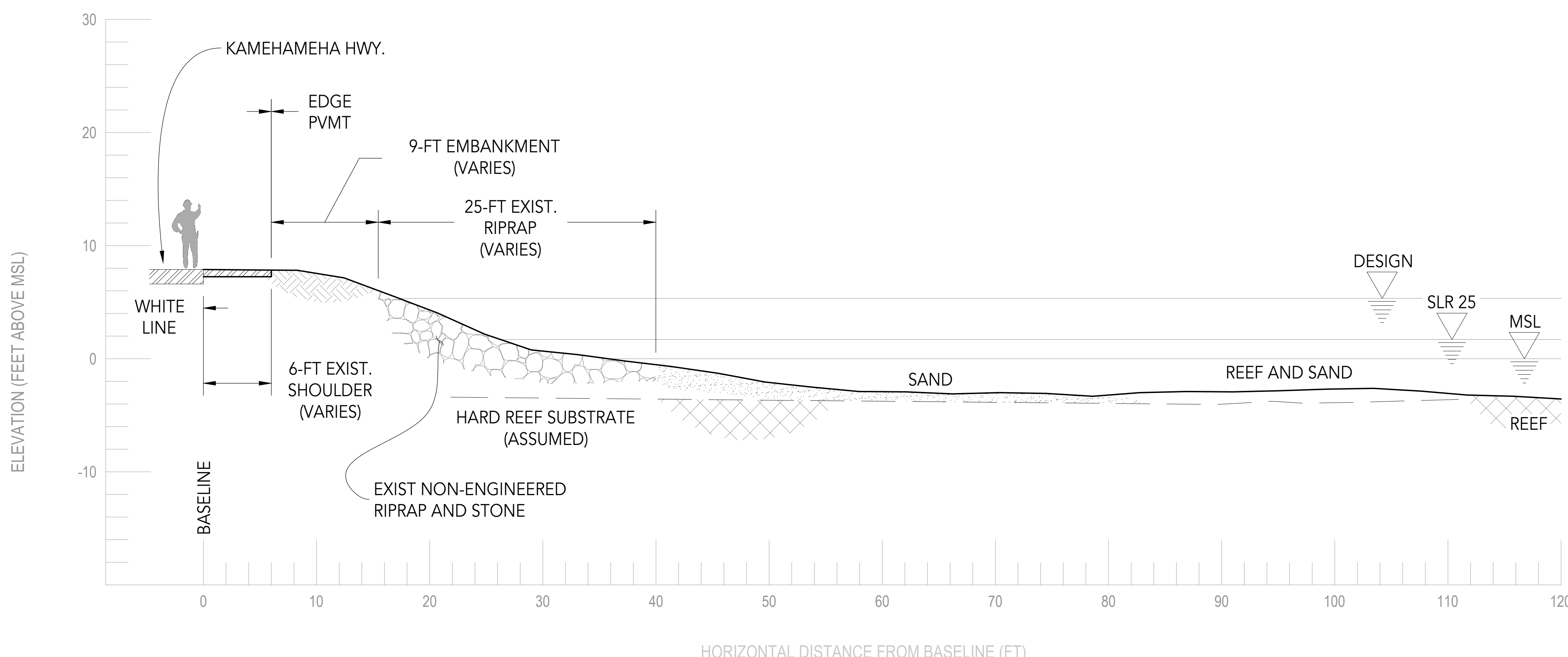
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road deck shoulder elevation.
4. Revetment ends to terminate by turning back into slope as shown to prevent flanking erosion.
5. Revetment to tie into culvert or bridge wing walls where present.
6. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study.
7. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.

Sheet Name
Crouching Lion Sta. 03+00 Low Slope Sta. 18+00 Mild Slope Revetments - Plan Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-062	
Date 18 Mar 2022		
Scale $\frac{1}{4}$" = 1' - 0"		



01 EXISTING (2013) CROSS SECTION AT STATION 03+00
NTS

Sea Engineering, Inc.
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PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 5.34 ft MSL

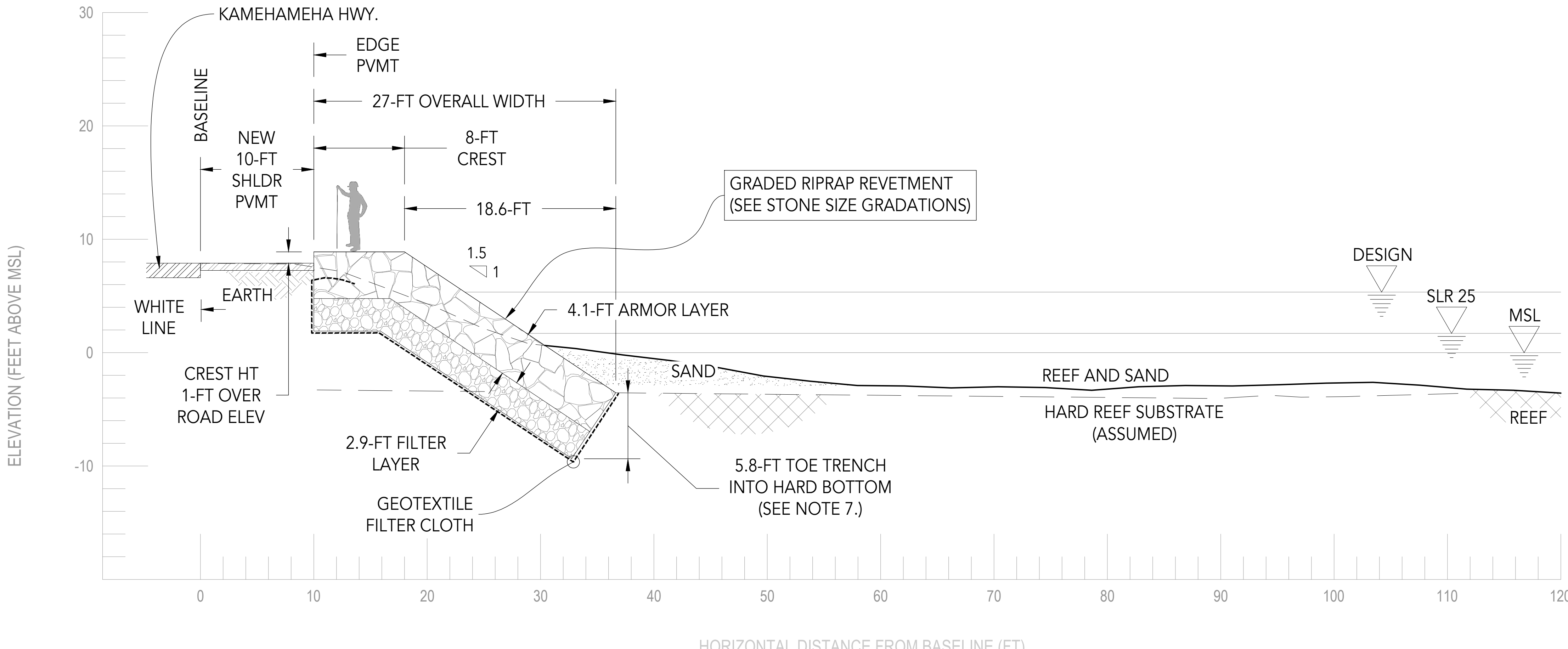
Sheet Name

Crouching Lion Station 03+00 (Zone A) Existing Condition Section (Typical)

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-063
Date	18 Mar 2022	
Scale	1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 03+00
NTS

STONE SIZE GRADATION -- BY WEIGHT (LBF) --	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
W_{15}	174	17
W_{50}	1,394	139
W_{100}	5,577	558

STONE SIZE GRADATION -- NOMINAL DIAMETER (FT) --	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
d_{15}	1.03	0.48
d_{50}	2.06	0.96
d_{100}	3.27	1.52

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

SE
Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

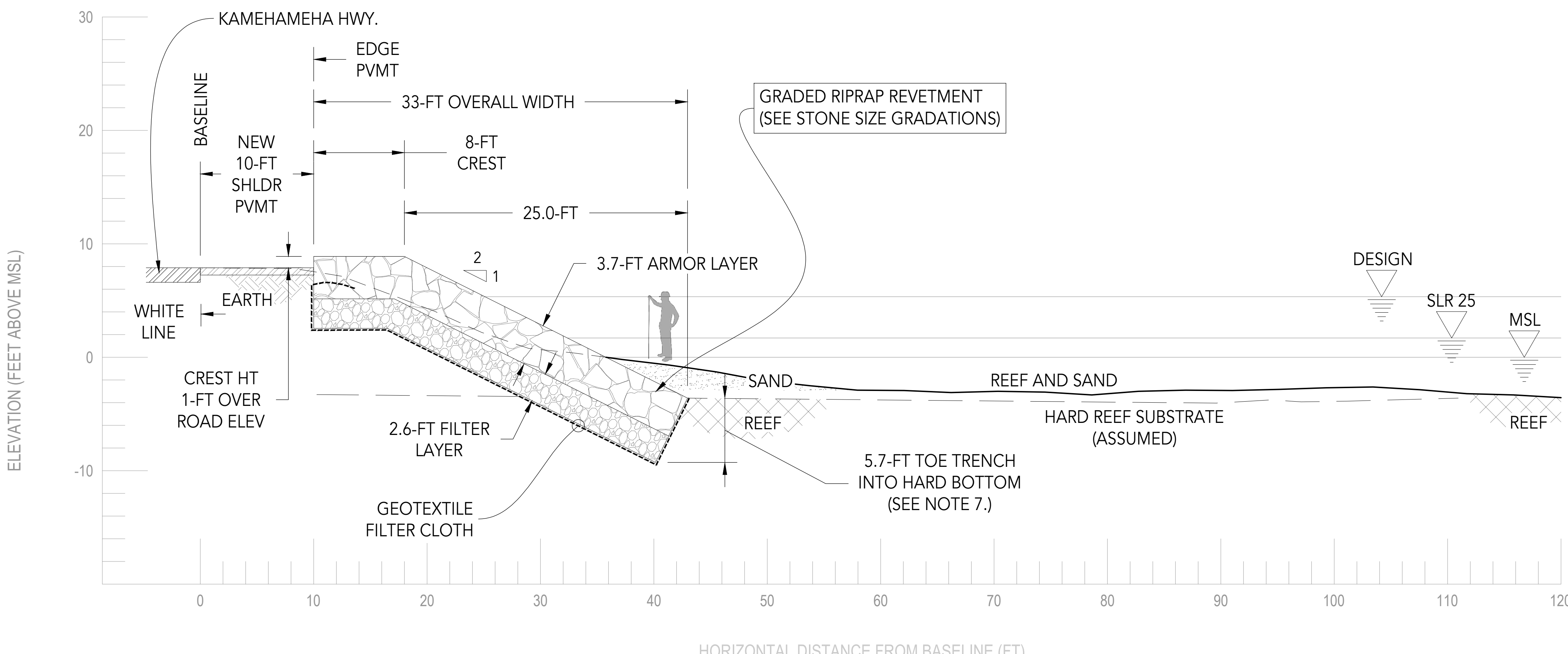
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.6 ft, for this location.

Sheet Name
Crouching Lion Station 03+00 (Zone A) High Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-064



01 MILD SLOPE REVETMENT CROSS SECTION AT STATION 03+00
NTS

STONE SIZE GRADATION		
-- BY WEIGHT (LBF) --		
	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
W_{15}	131	13
W_{50}	1,046	105
W_{100}	4,183	418

STONE SIZE GRADATION		
-- NOMINAL DIAMETER (FT) --		
	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
d_{15}	0.93	0.43
d_{50}	1.87	0.87
d_{100}	2.97	1.38

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

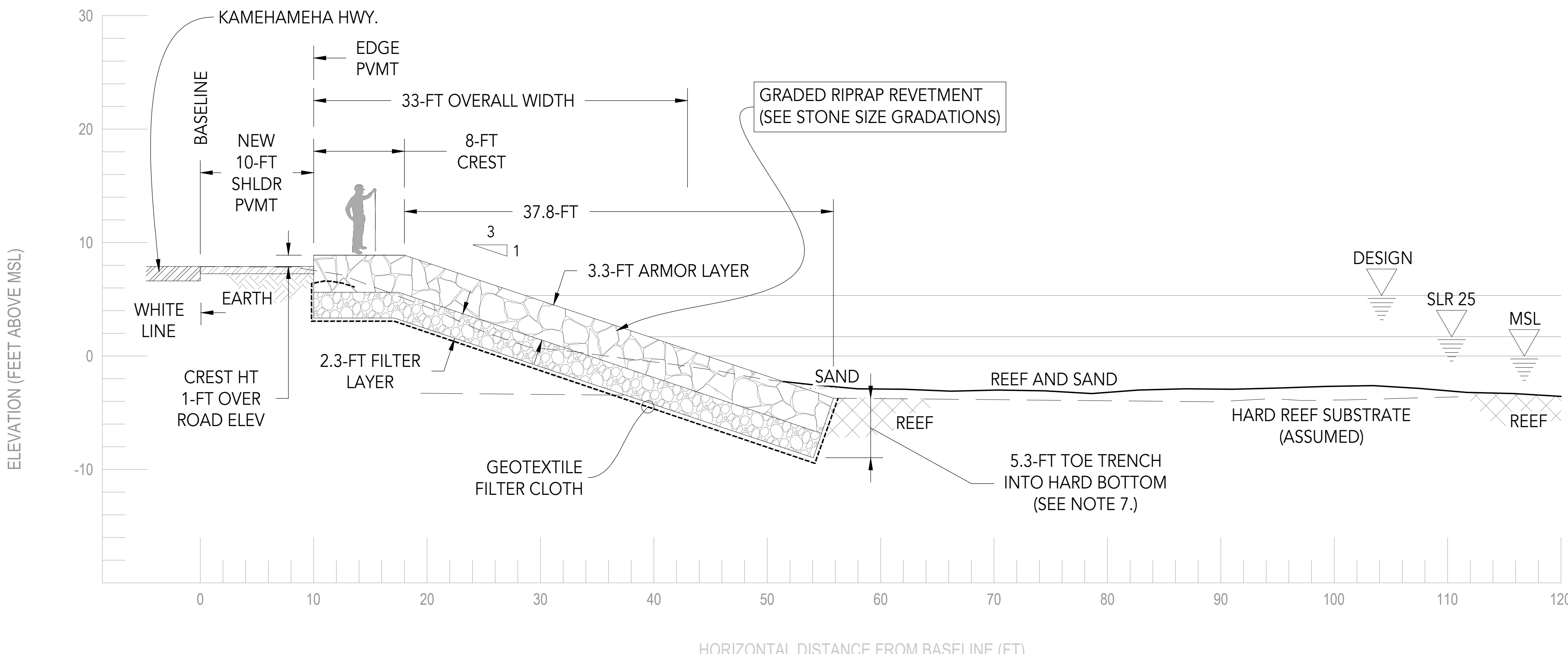
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.6 ft, for this location.

Sheet Name
Crouching Lion Station 03+00 (Zone A) Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-065



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 03+00
NTS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	87	9
W_{50}	697	70
W_{100}	2,789	279

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.82	0.38
d_{50}	1.63	0.76
d_{100}	2.59	1.20

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

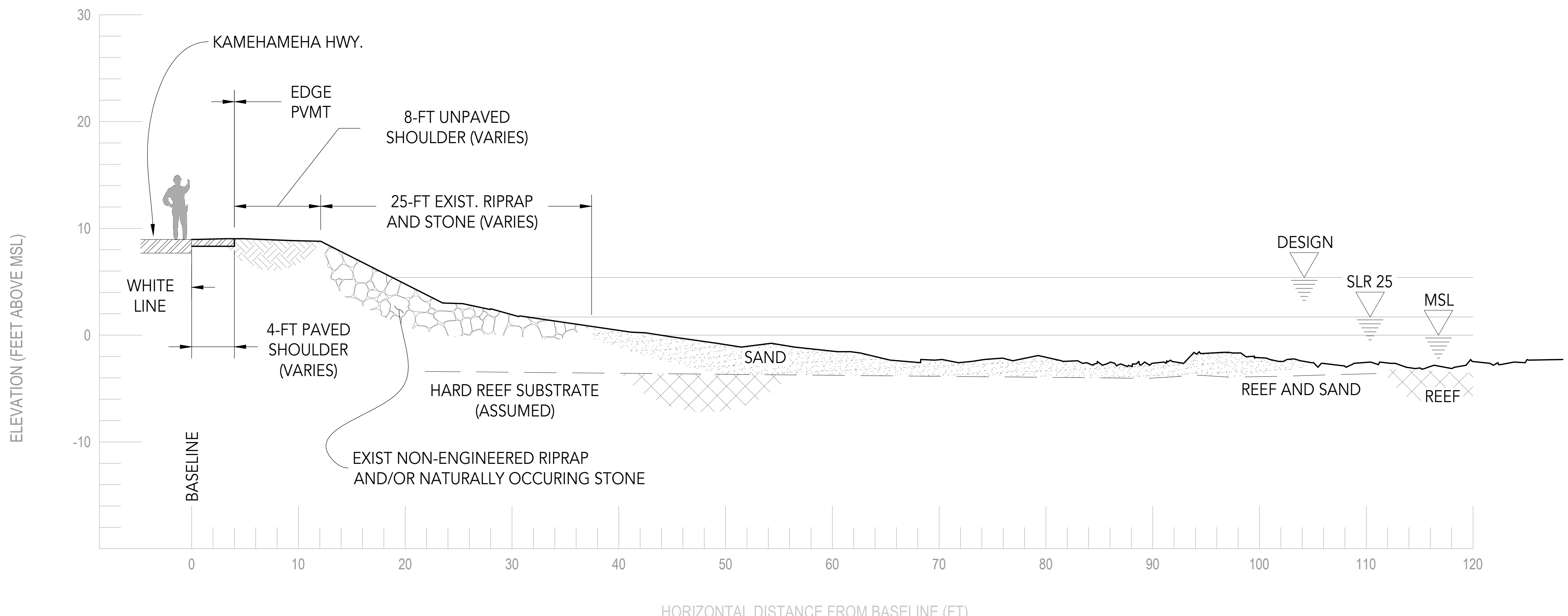
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.6 ft, for this location.

Sheet Name
Crouching Lion Station 03+00 (Zone A) Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-066



02 EXISTING (2013) CROSS SECTION AT STATION 18+00
NTS

Sea Engineering, Inc.
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PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

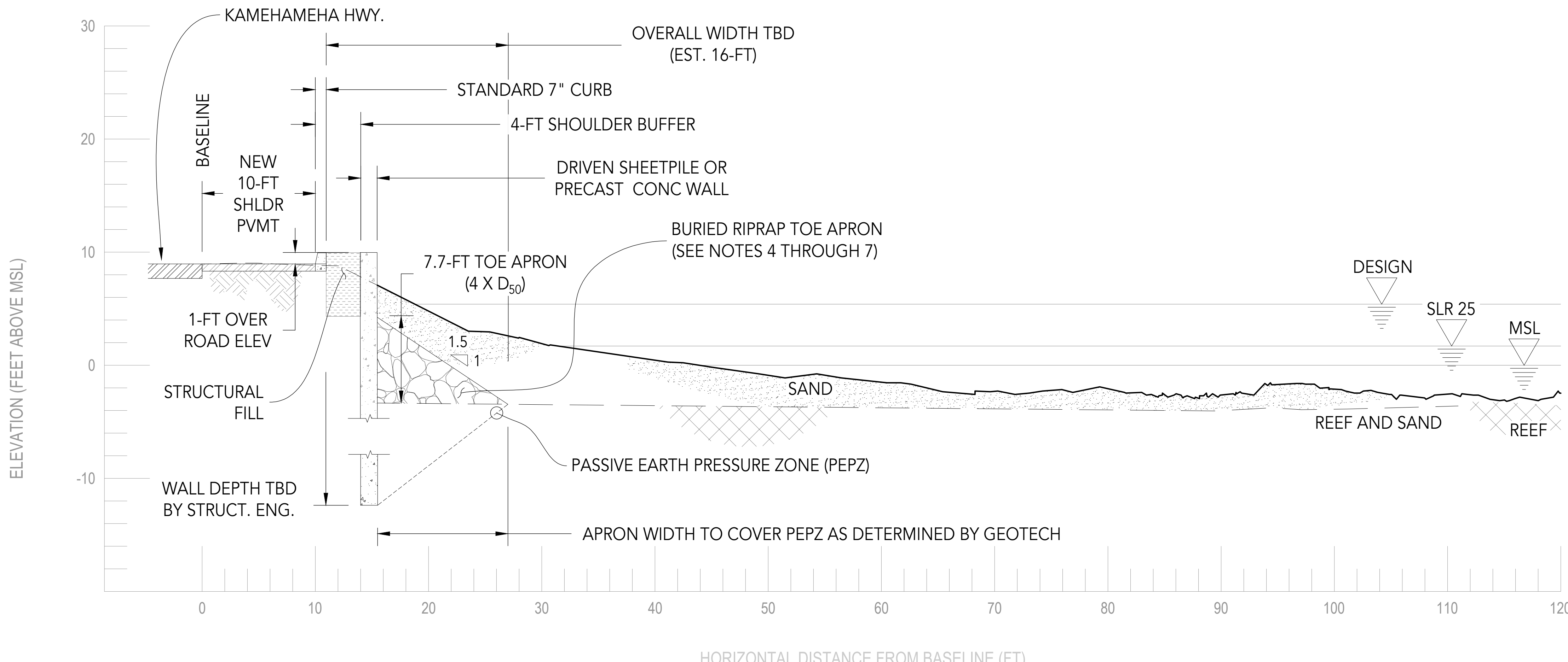
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 5.40 ft MSL

Sheet Name
Crouching Lion Station 18+00 (Zone B) Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-067
Date 18 Mar 2022	
Scale 1" = 1' - 0"	



02 ARMORED SEAWALL CROSS SECTION AT STATION 18+00
NTS

STONE SIZE GRADATION		
-- BY WEIGHT (LBF) --		
	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
W_{15}	144	14
W_{50}	1,149	115
W_{100}	4,595	459

STONE SIZE GRADATION		
-- NOMINAL DIAMETER (FT) --		
	ARMOR LAYER	FILTER LAYER
GRAD	AVG	AVG
d_{15}	0.96	0.45
d_{50}	1.93	0.90
d_{100}	3.06	1.42

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

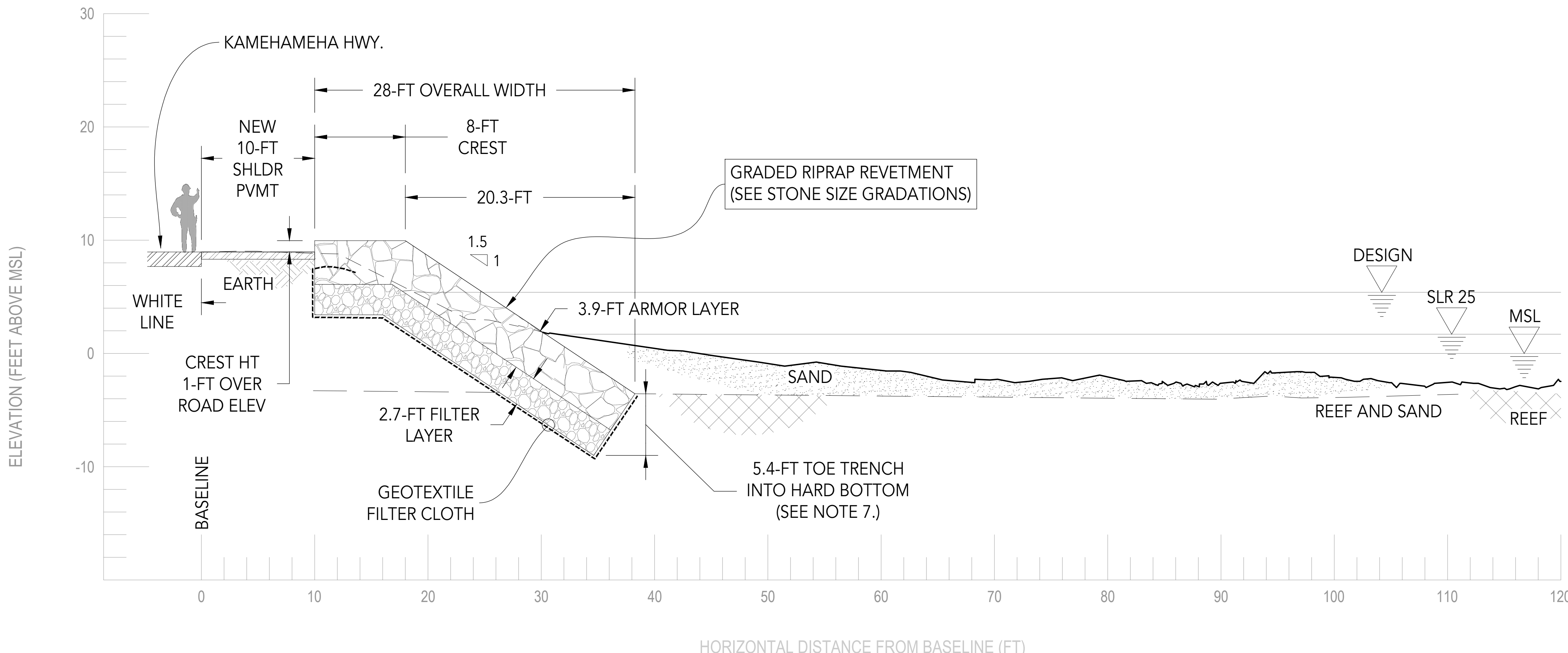
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Top of wall elevation to follow approximately 1-ft above existing road elevation.
4. Passive earth pressure zone (PEPZ) and wall depth to be determined by geotechnical and structural engineers as appropriate.
5. Toe apron riprap properties are provided in the stone size gradation tables above. Max toe apron thickness is 4·d_{50}, or 7.7 ft.
6. Excavate sand/sediment to expose hard substrate at approx. -3 ft MSL for preparation of riprap apron base, and re-bury to original grade upon completion.
7. Place riprap toe apron on hard bottom over geotextile or filter stone layer.

Sheet Name
Crouching Lion Station 18+00 (Zone B) Armored Seawall Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-068
Date	18 Mar 2022	
Scale	1" = 1' - 0"	



02 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 18+00
NTS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	144	14
W_{50}	1,149	115
W_{100}	4,595	459

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.96	0.45
d_{50}	1.93	0.90
d_{100}	3.06	1.42

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

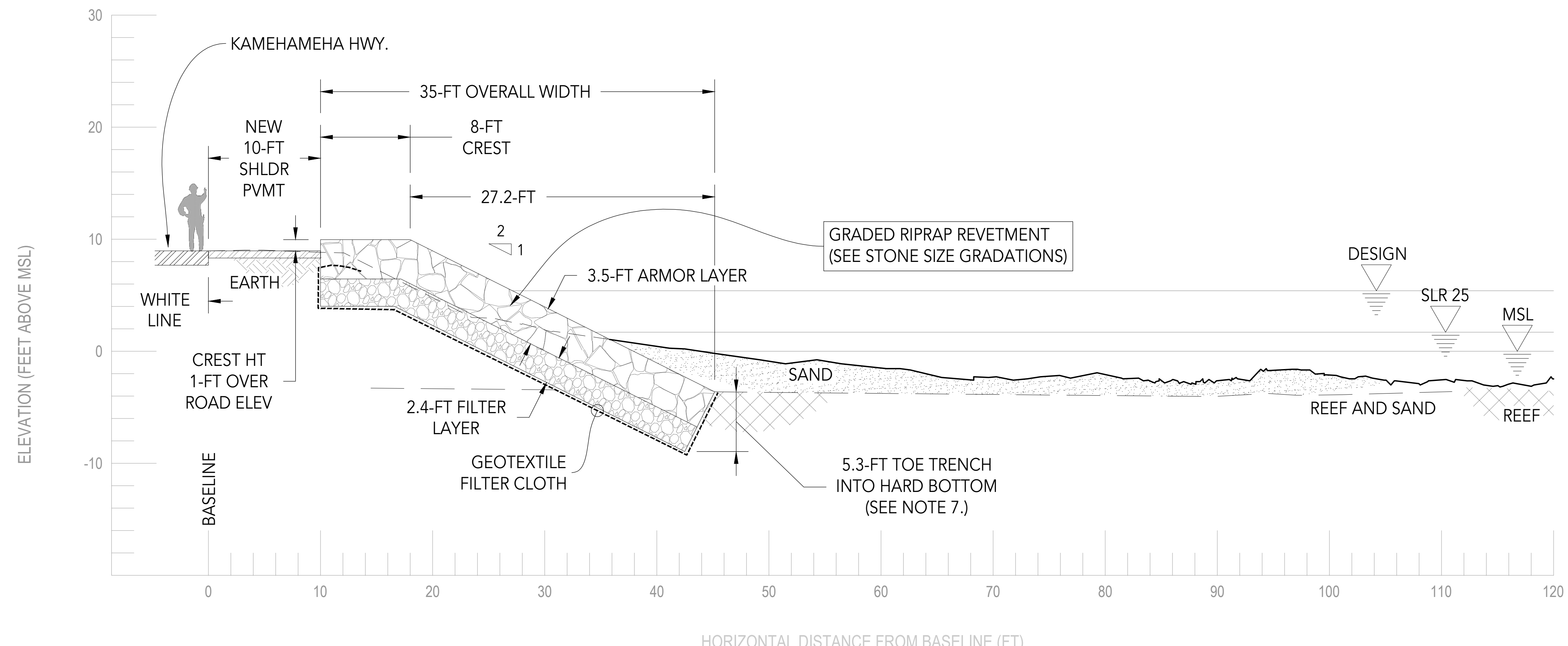
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.3 ft, for this location.

Sheet Name
Crouching Lion Station 18+00 (Zone B) High Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-069



02 MILD SLOPE REVETMENT CROSS SECTION AT STATION 18+00
NTS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	144	14
W_{50}	1,149	115
W_{100}	4,595	459

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.96	0.45
d_{50}	1.93	0.90
d_{100}	3.06	1.42

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
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PH 808.259.7966
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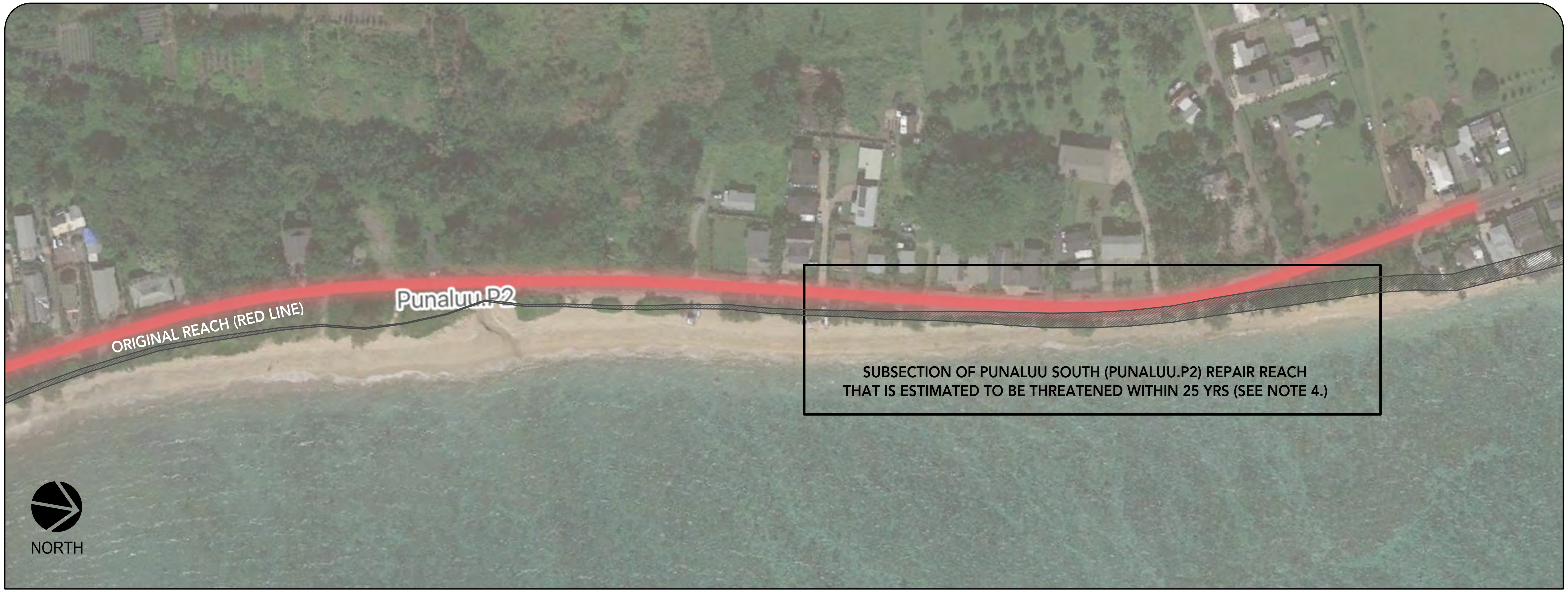
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 1-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.3 ft, for this location.

Sheet Name
Crouching Lion Station 18+00 (Zone B) Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-070



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NOTES:

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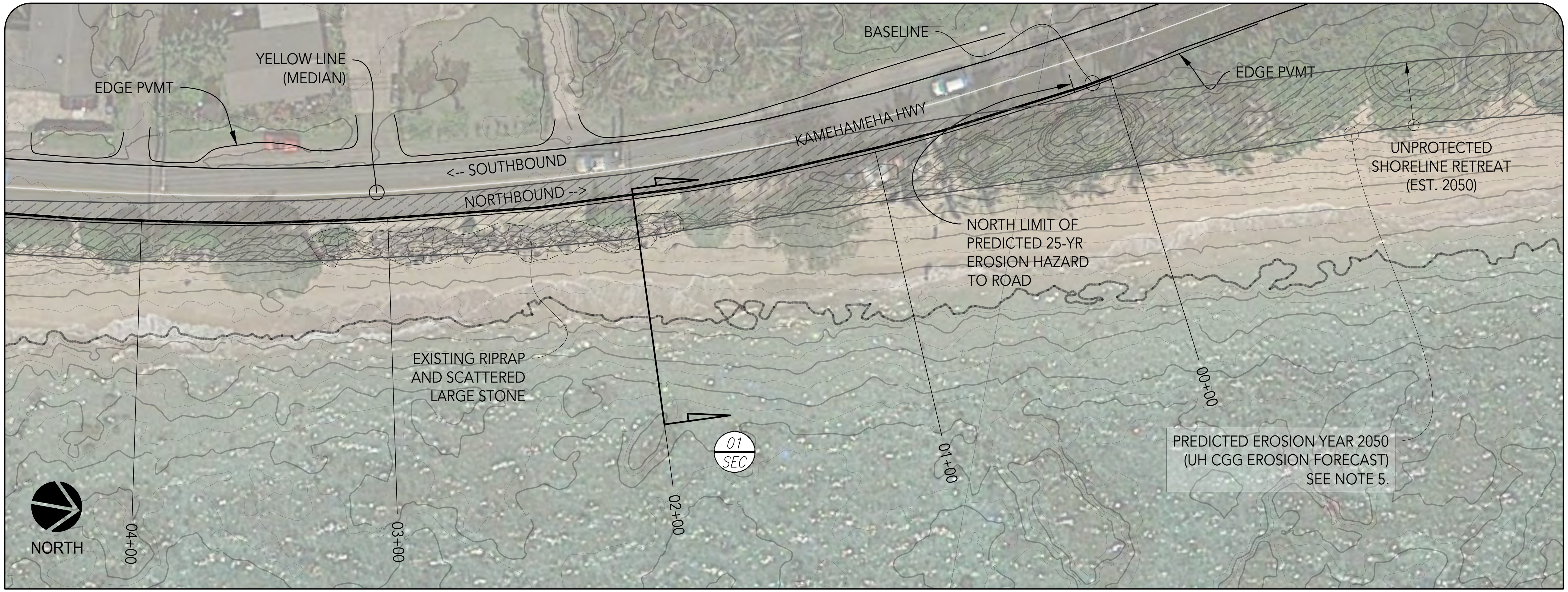
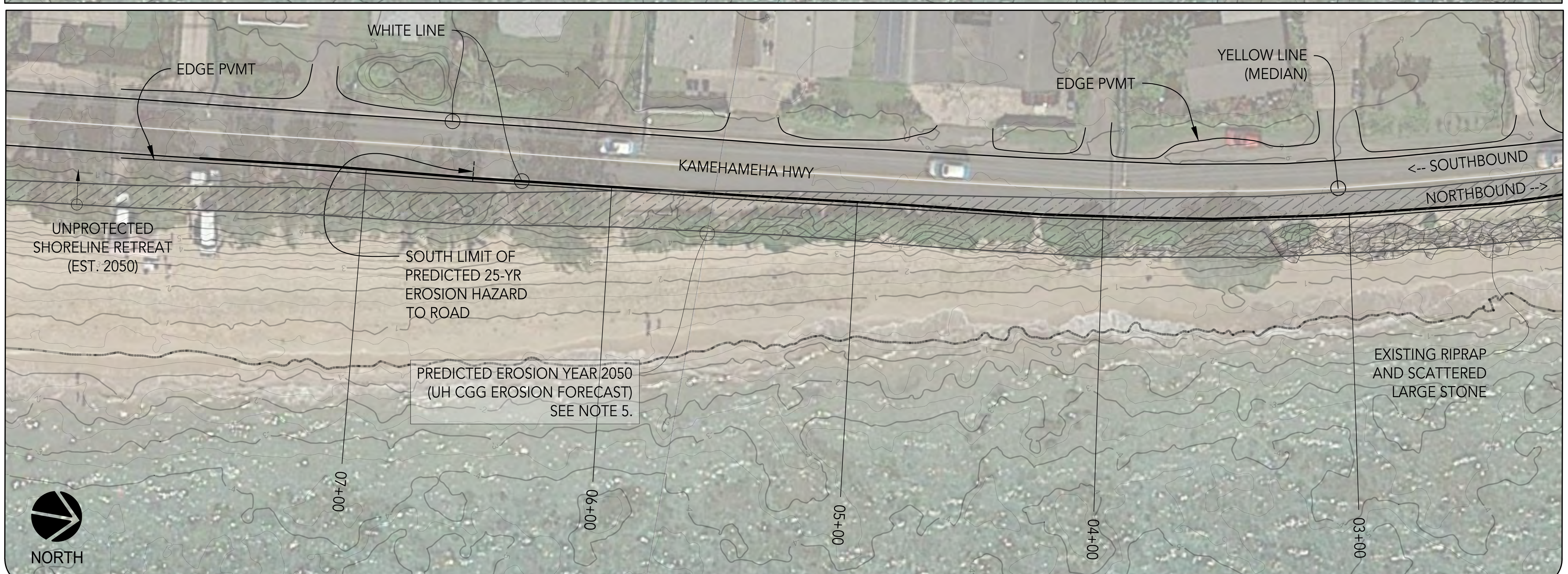
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_erosion_polygons_2050.shp"
4. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing road shoulder location. The length of this threatened stretch is approximately 650 ft, and is focused on the northern end of the Punaluu South reach as shown here.

Sheet Name: **Punaluu South (Haleaha Road) Reach Overview Plan**

Project Name: **KKPH Kamehameha Highway Shore Protection**

Project No. 25853	Sheet C-071
Date 18 Mar 2022	
Scale $\frac{1}{16}$" = 1' - 0"	





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NOTES:

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing road shoulder location. The length of this threatened stretch is approximately 650 ft, and is focused on the northern end of the Punaluu South reach (P2) as shown here.

Sheet Name

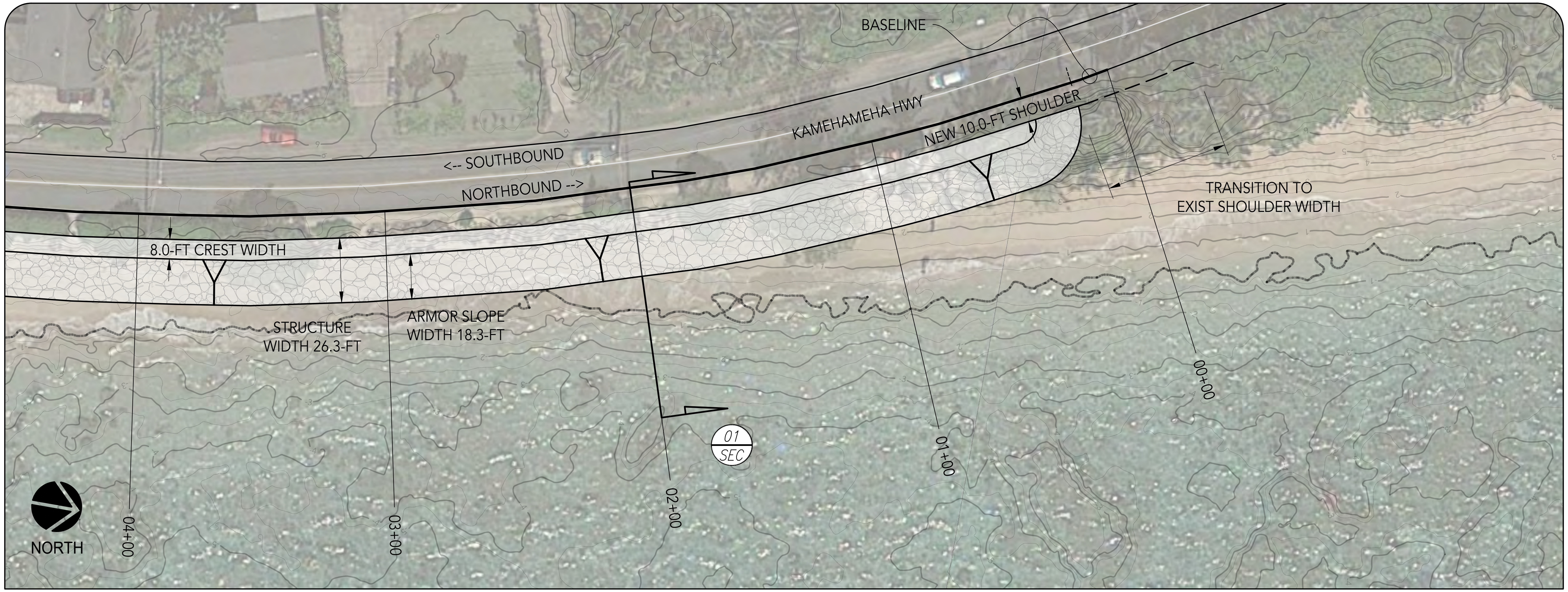
Punaluu South (Haleaha Road) Existing Condition Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-072
Date	18 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	

Mon Mar 21 16:02:22 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***



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NOTES:

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing makai road shoulder location. The length of this threatened stretch is approximately 650 ft, and is focused on the northern end of the Punaluu South repair reach (P2) as shown here.

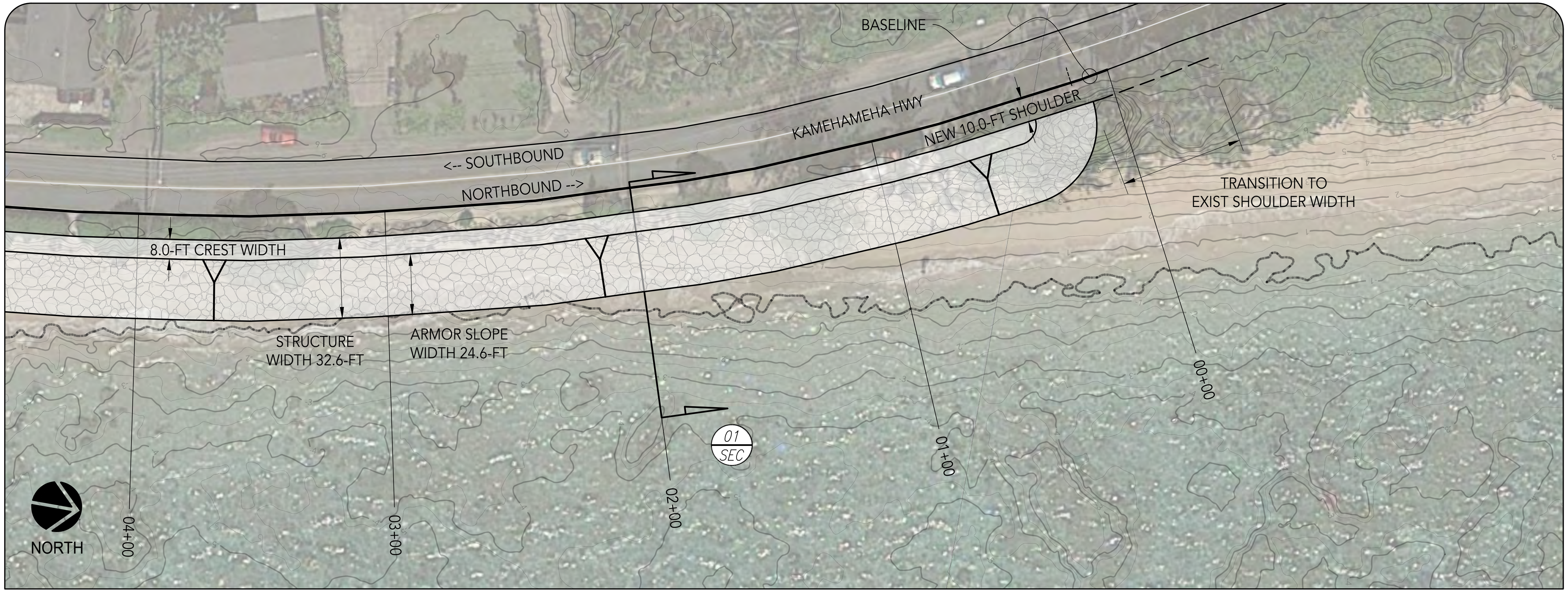
Sheet Name

Punaluu South (Haleaha Road) High Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-073
Date 18 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	



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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing makai road shoulder location. The length of this threatened stretch is approximately 650 ft, and is focused on the northern end of the Punaluu South repair reach (P2) as shown here.

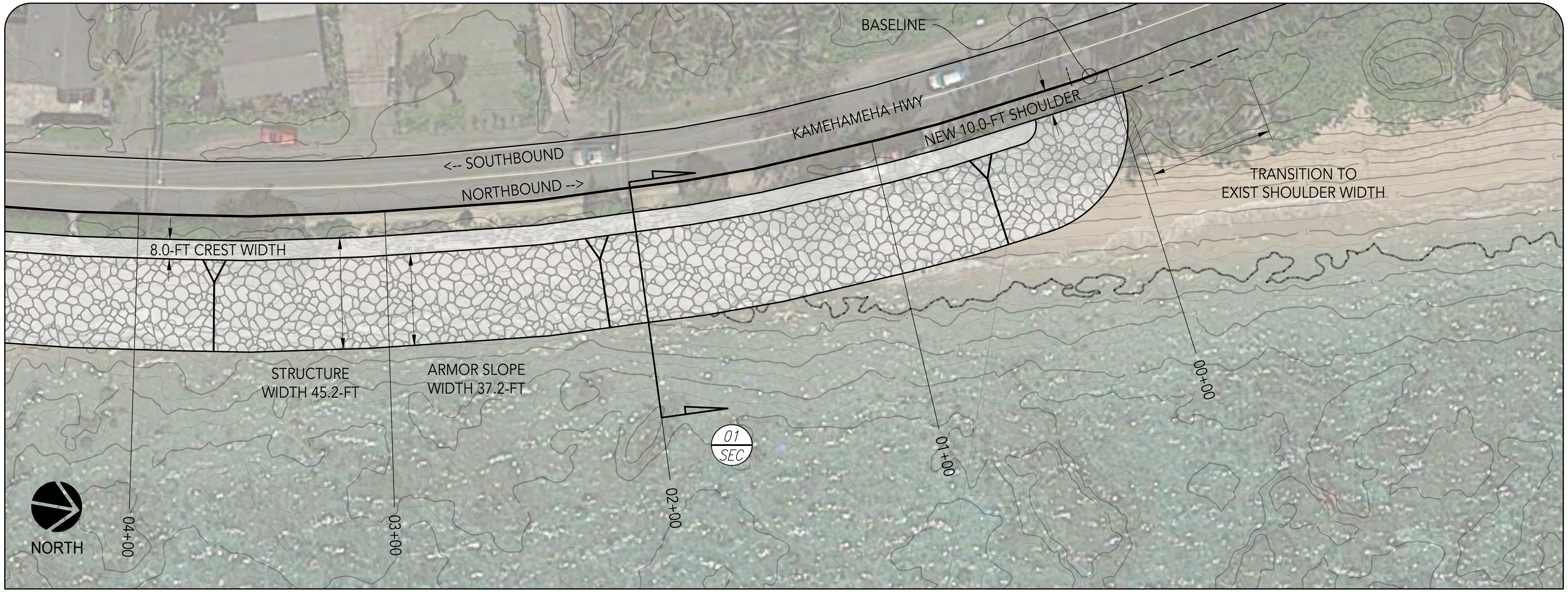
Sheet Name

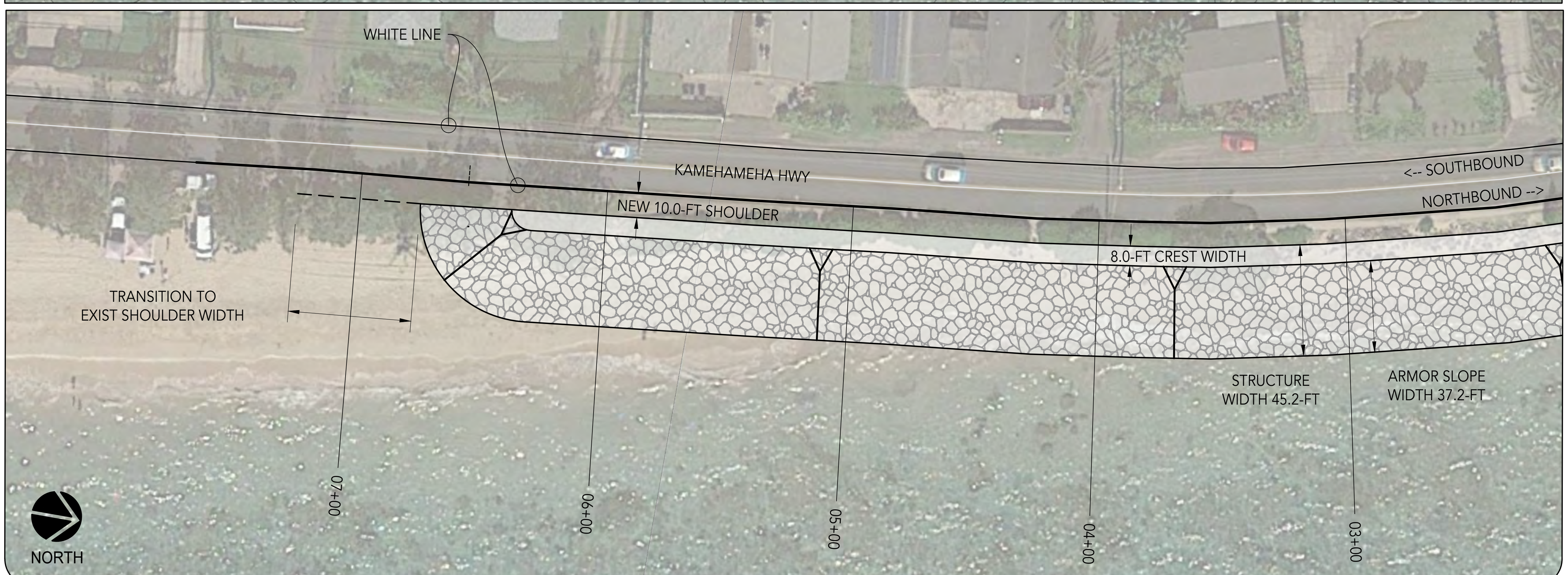
Punaluu South (Haleaha Road) Mild Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet
Date	18 Mar 2022	C-074
Scale	$\frac{1}{4}$" = 1' - 0"	





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NOTES:

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing makai road shoulder location. The length of this threatened stretch is approximately 650 ft, and is focused on the northern end of the Punaluu South repair reach (P2) as shown here.

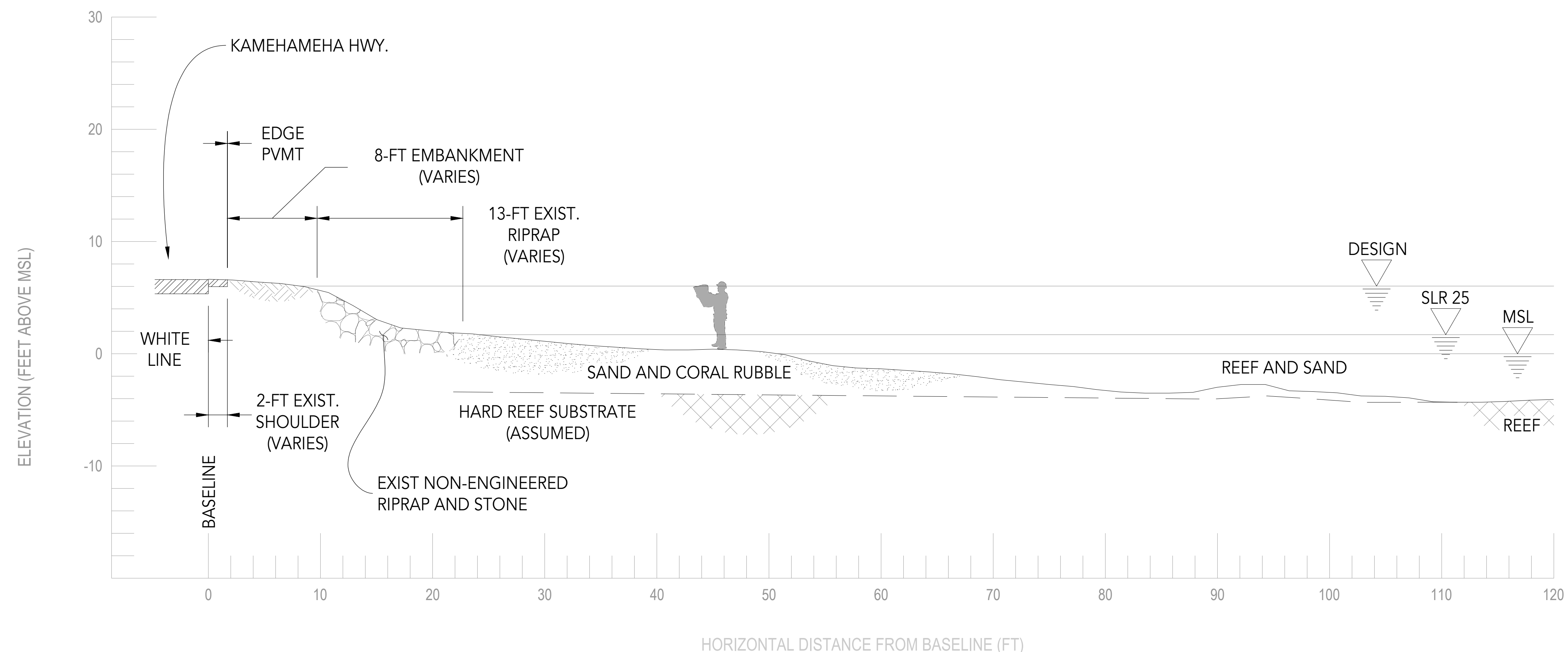
Sheet Name

Punaluu South (Haleaha Road) Low Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-075
Date 18 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	



01 EXISTING (2013) CROSS SECTION AT STATION 02+00
NTS

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NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

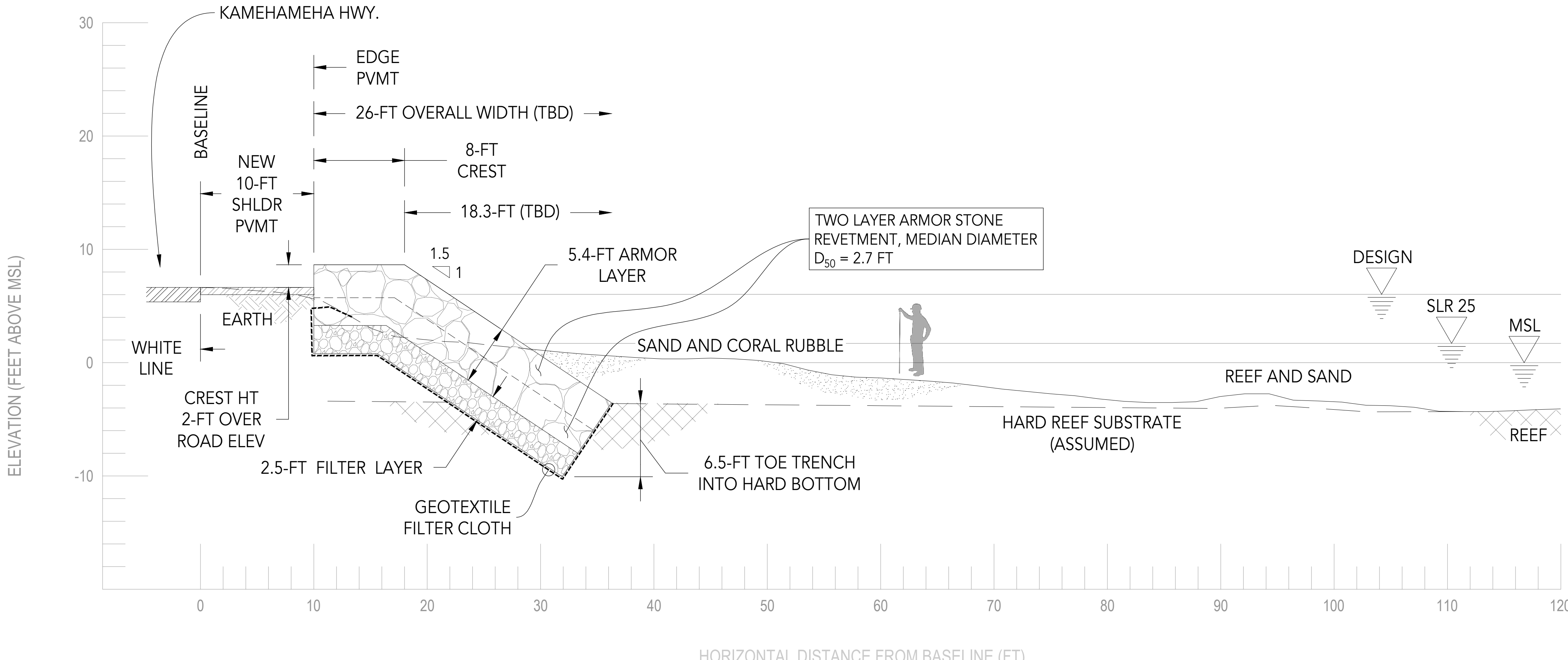
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 6.03 ft MSL

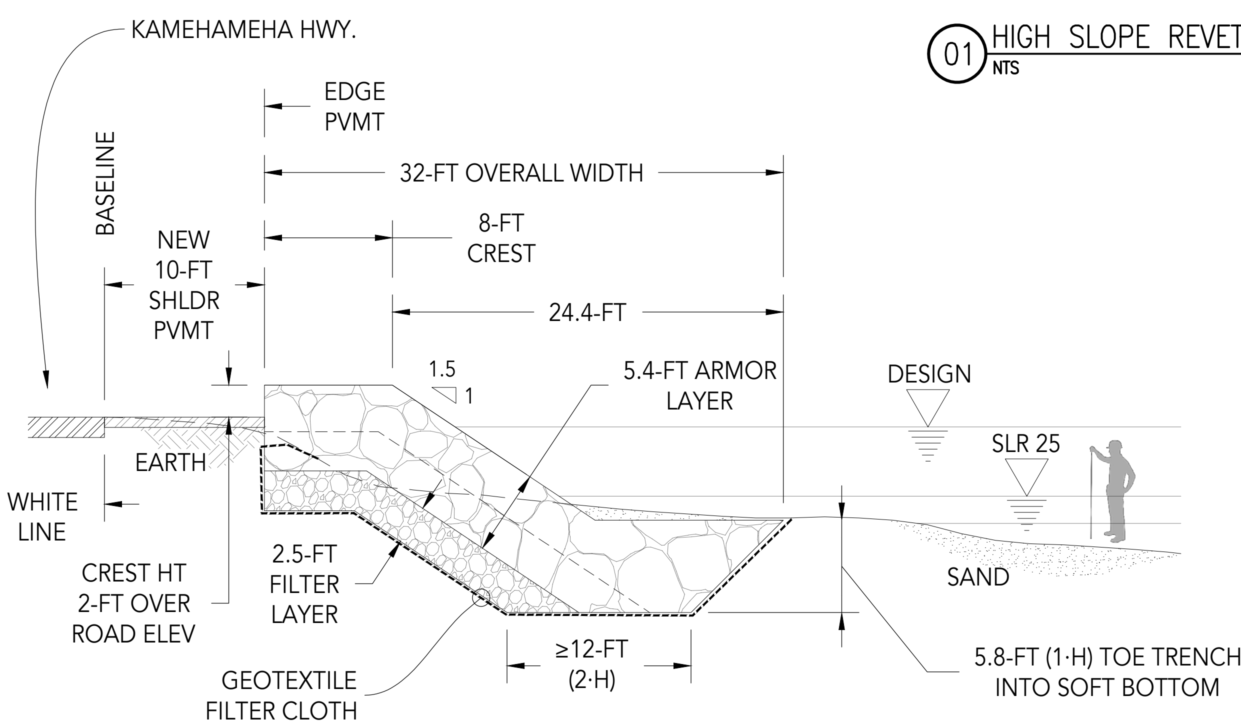
Sheet Name
Punaluu South (P2) Station 02+00 Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-076



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 02+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
W_{min}	2,310	W_{15}	38
W_{50}	3,079	W_{50}	308
W_{max}	3,849	W_{100}	1,232

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER		FILTER LAYER	
GRAD	AVG	GRAD	AVG
d_{min}	2.43	d_{15}	0.62
d_{50}	2.68	d_{50}	1.24
d_{max}	2.89	d_{100}	1.97

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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NOTES:

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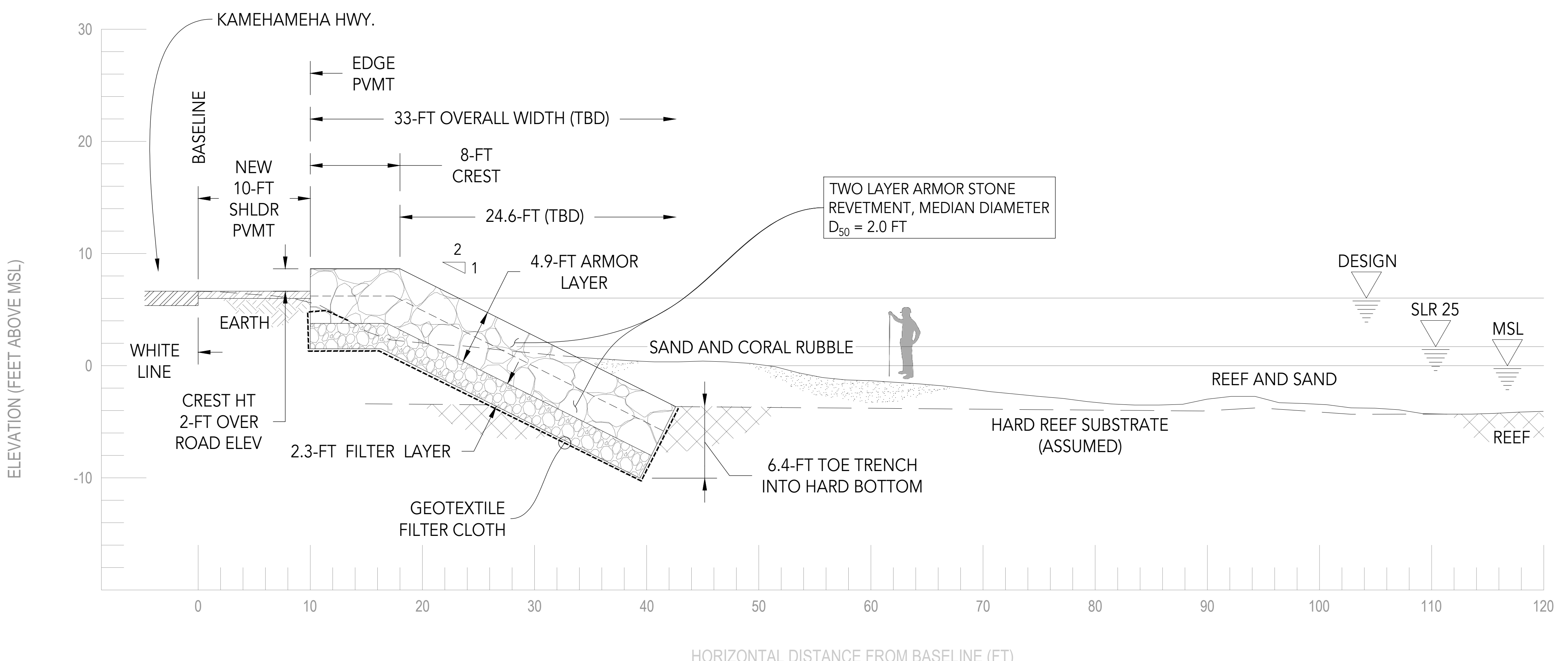
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 5.77 ft, for this location.

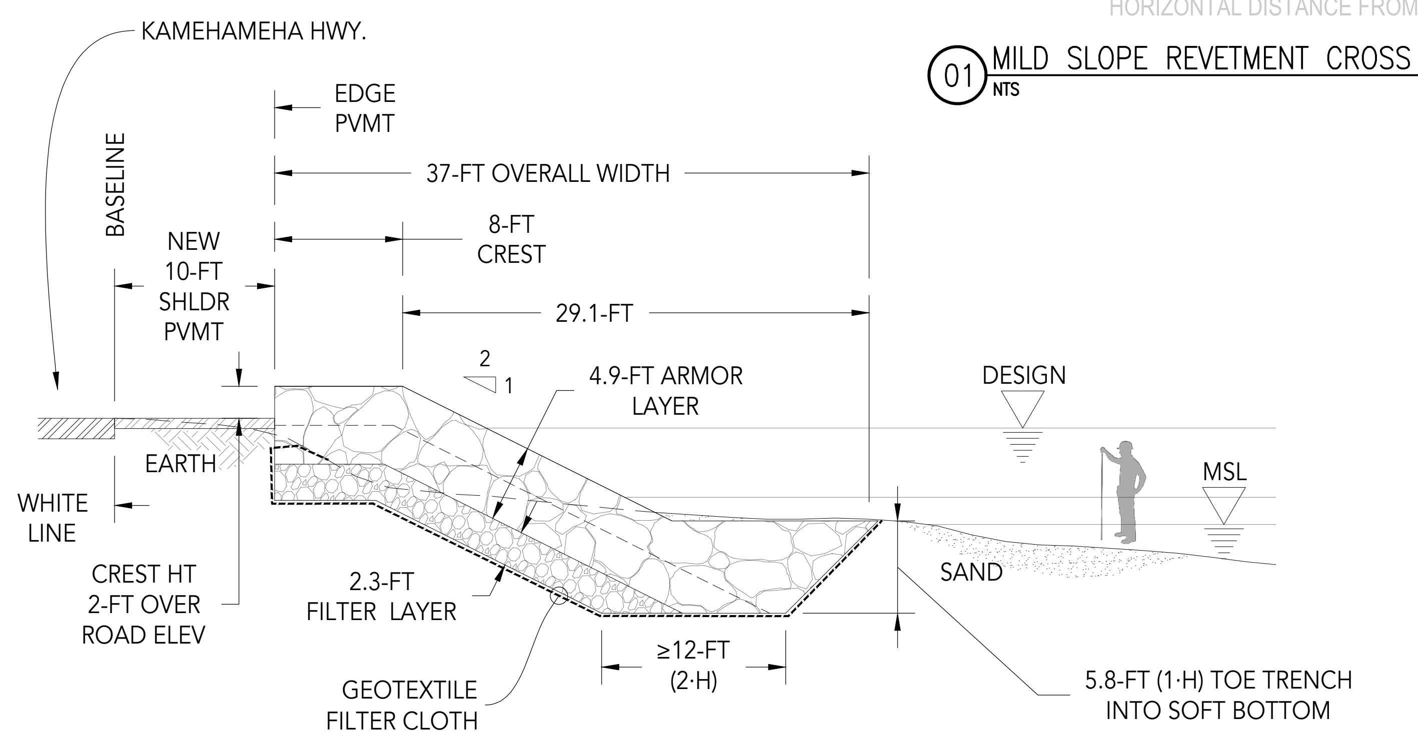
Sheet Name
Punaluu South (P2) Station 02+00 High Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-077



01 MILD SLOPE REVETMENT CROSS SECTION AT STATION 02+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
W_{min}	1,732	W_{15}	29
W_{50}	2,310	W_{50}	231
W_{max}	2,887	W_{100}	924

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
d_{min}	2.21	d_{15}	0.57
d_{50}	2.43	d_{50}	1.13
d_{max}	2.62	d_{100}	1.79

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

SE
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NOTES:

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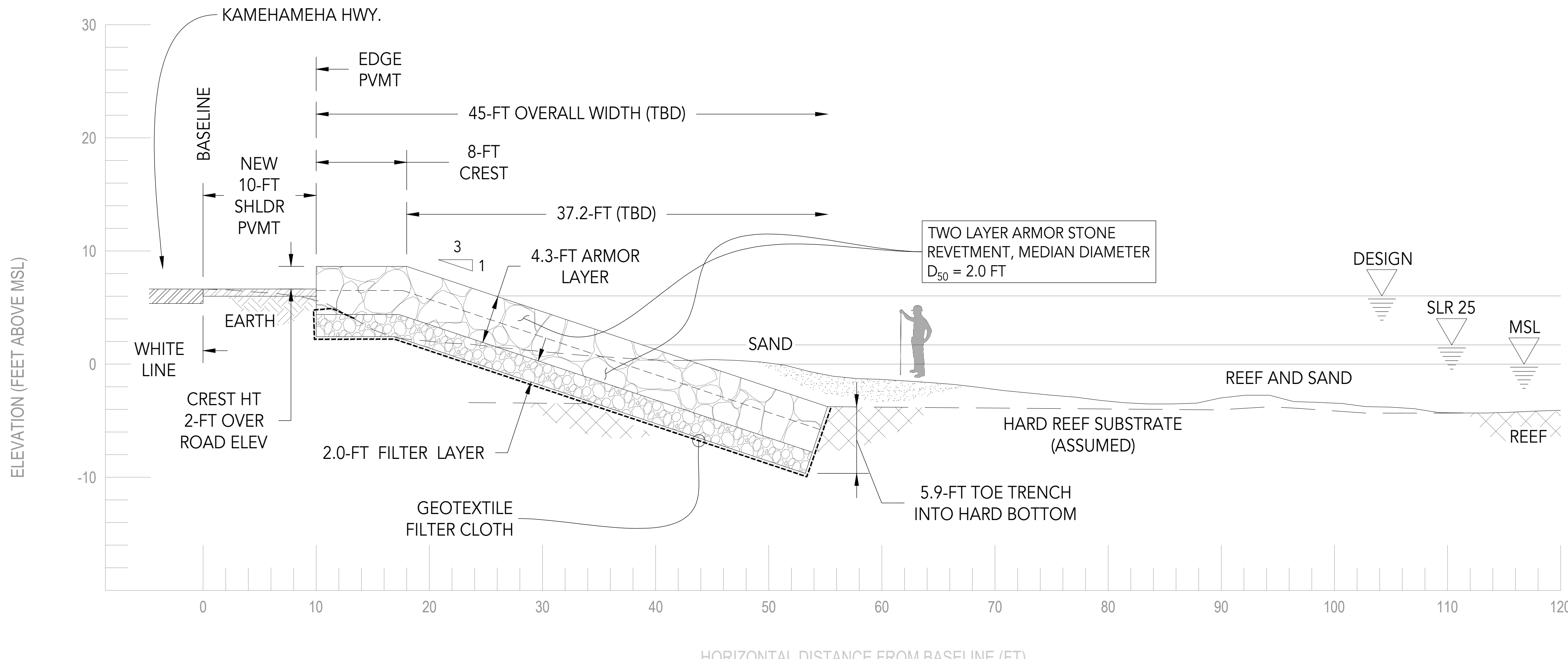
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 5.77 ft, for this location.

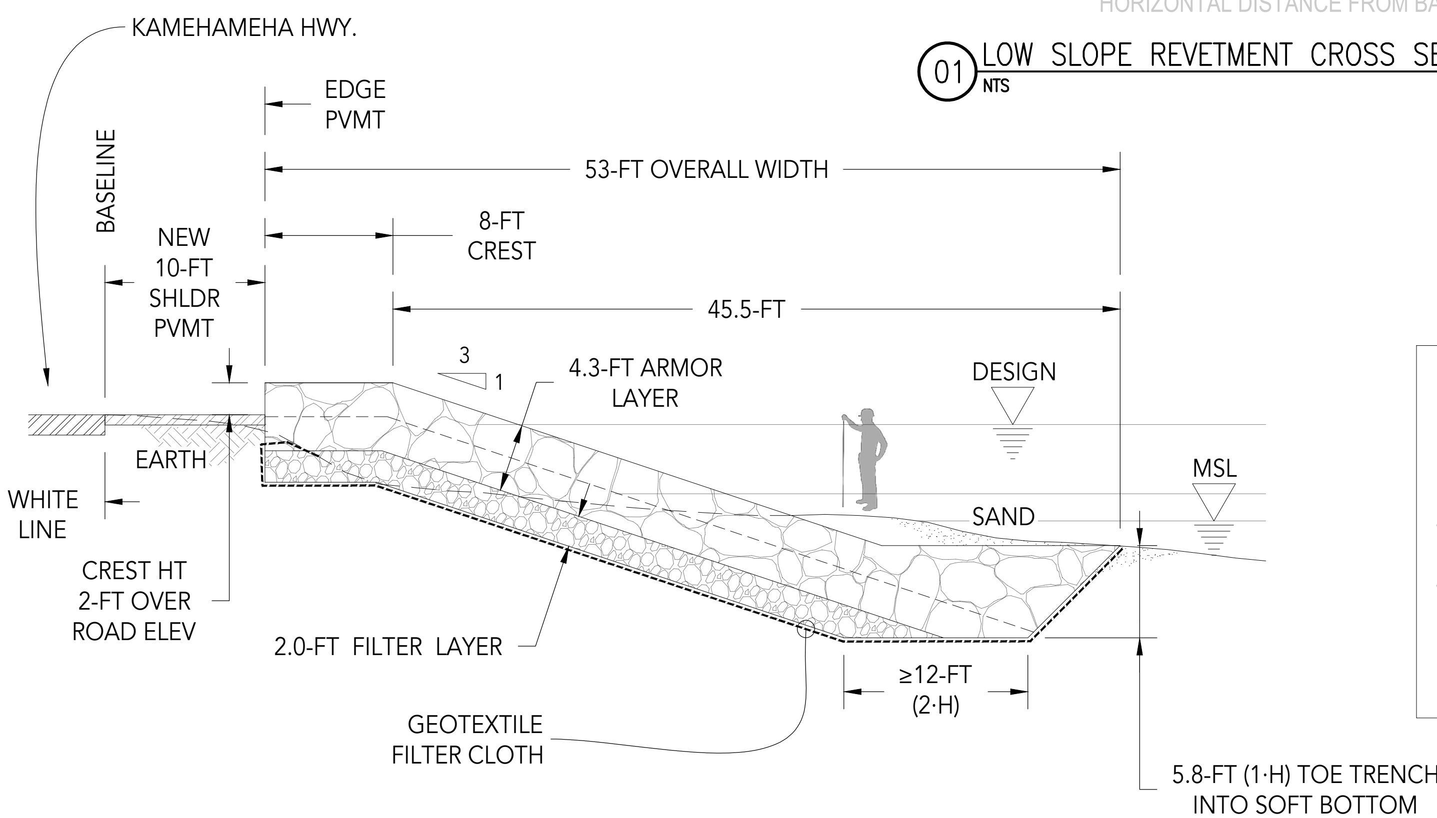
Sheet Name
Punaluu South (P2) Station 02+00 Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-078



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 02+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
W_{min}	1,155	W_{15}	19
W_{50}	1,540	W_{50}	154
W_{max}	1,925	W_{100}	616

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

ARMOR LAYER GRAD	ARMOR LAYER AVG	FILTER LAYER GRAD	FILTER LAYER AVG
d_{min}	1.93	d_{15}	0.49
d_{50}	2.13	d_{50}	0.99
d_{max}	2.29	d_{100}	1.57

ARMOR LAYER ALLOWABLE STONE SIZE RANGES

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NOTES:

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5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 5.77 ft, for this location.

Sheet Name
Punaluu South (P2) Station 02+00 Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 18 Mar 2022
Scale 1" = 1' - 0"
Sheet C-079

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NOTES:

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3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing road shoulder location. The length of this threatened stretch is approximately 300 ft.

Sheet Name
Punaluu North (P1) (Kaluanui) Existing Condition Plan

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-080
Date	21 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	

Mon Mar 21 16:06:40 2022, 1:1, CONFIDENTIAL - CONCEPTUAL ONLY, *** NOT FOR CONSTRUCTION ***

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
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Sheet Name
Punaluu North (P1) (Kaluanui) High Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-081	
Date 21 Mar 2022		
Scale $\frac{1}{4}$" = 1' - 0"		

SE
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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict partial erosion of this reach up to and beyond the existing road shoulder location. The length of this threatened stretch is approximately 300 ft.

Sheet Name

Punaluu North (P1) (Kaluanui) Mild Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-082
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
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Sheet Name

Punaluu North (P1) (Kaluanui) Low Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-083
Date 21 Mar 2022	
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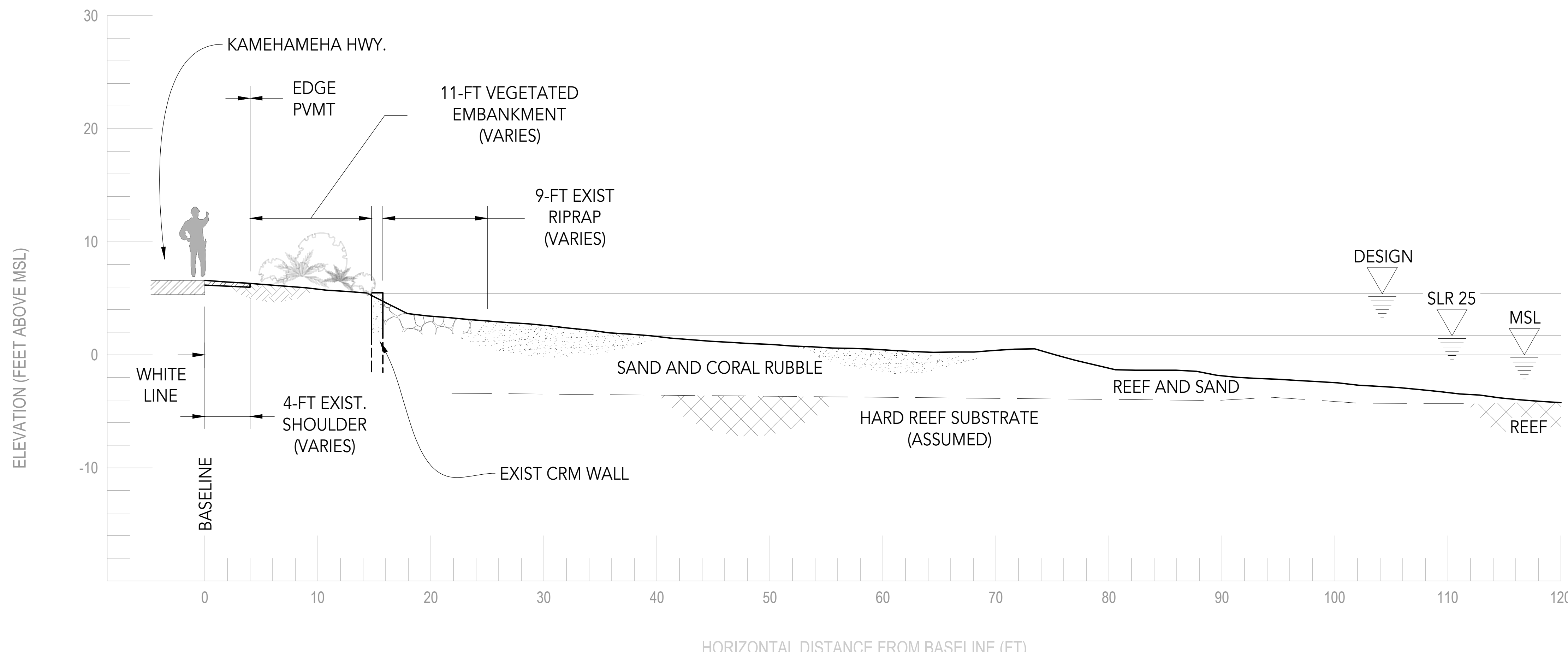

01 EXISTING (2013) CROSS SECTION AT STATION 01+00
NTS

Sea Engineering, Inc.
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PH 808.259.7966
FAX 808.259.8143

NOTES:

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2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

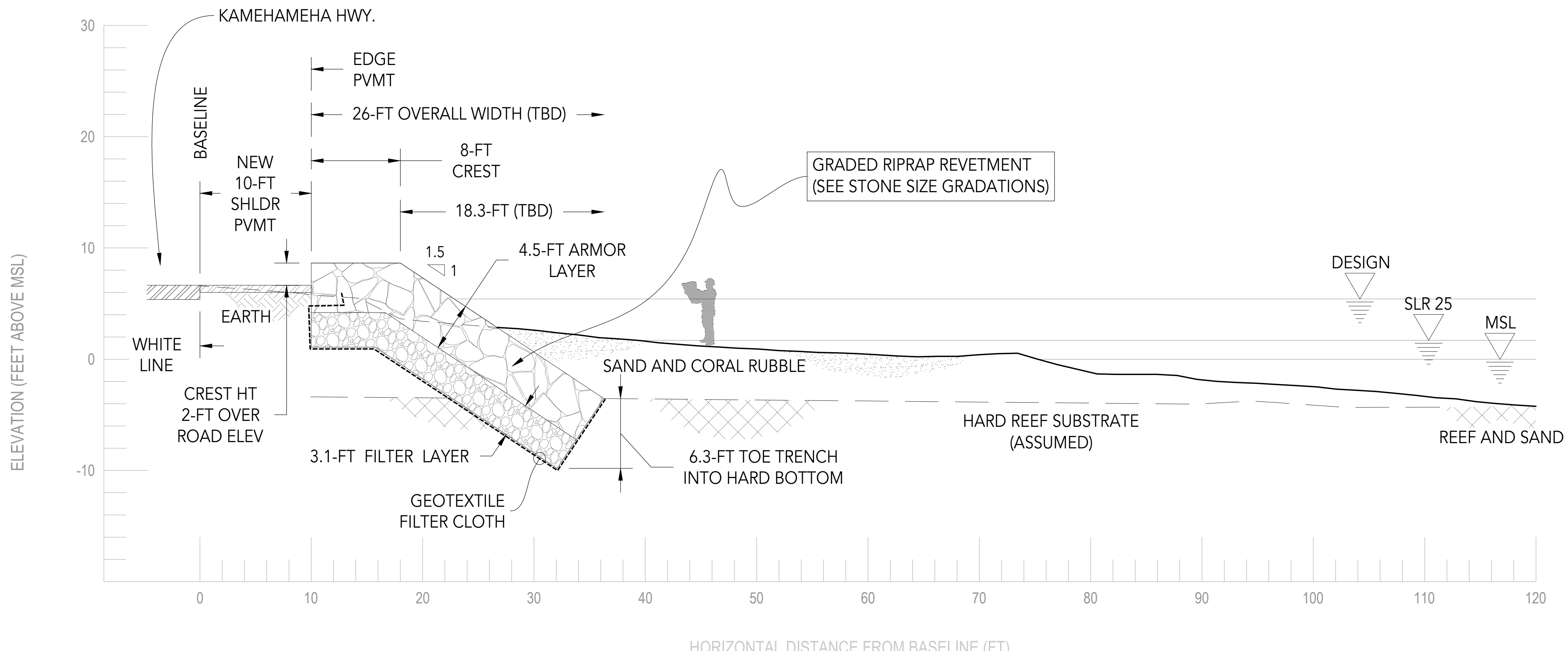
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 5.41 ft MSL

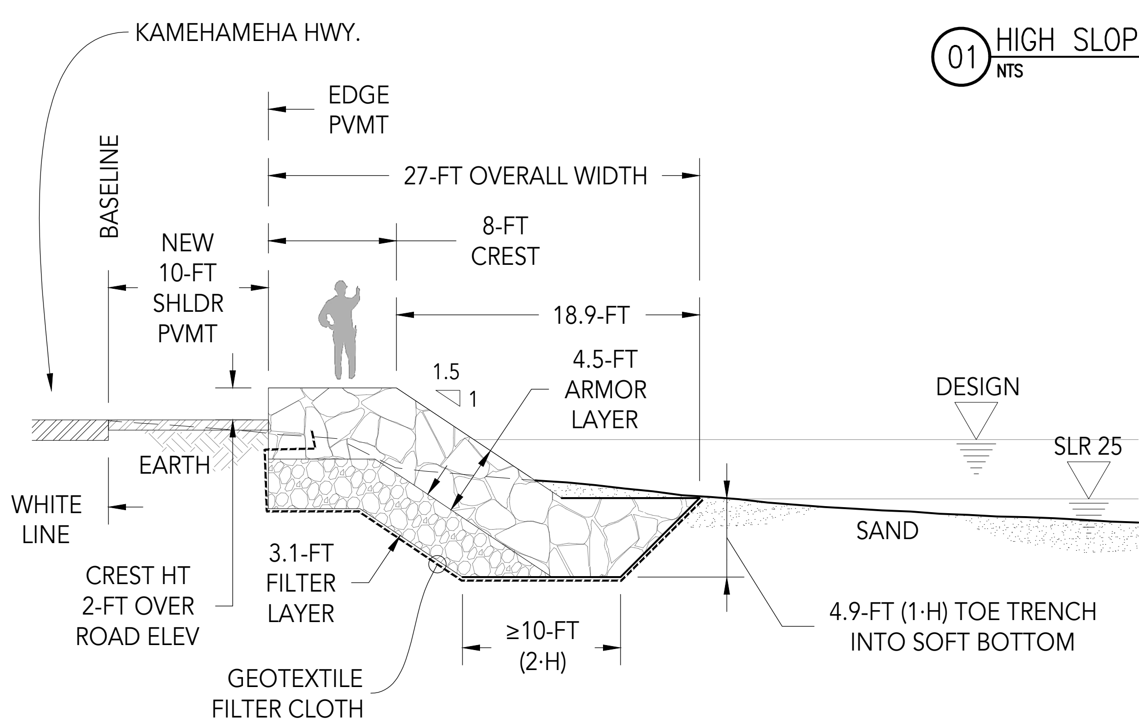
Sheet Name
Punaluu North (P1) Station 01+00 Existing Condition Section (Typical)

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-084
Date 21 Mar 2022	
Scale 1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 01+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	220	22
W_{50}	1,761	176
W_{100}	7,044	704

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	1.11	0.52
d_{50}	2.22	1.03
d_{100}	3.53	1.64

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

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FAX 808.259.8143

NOTES:

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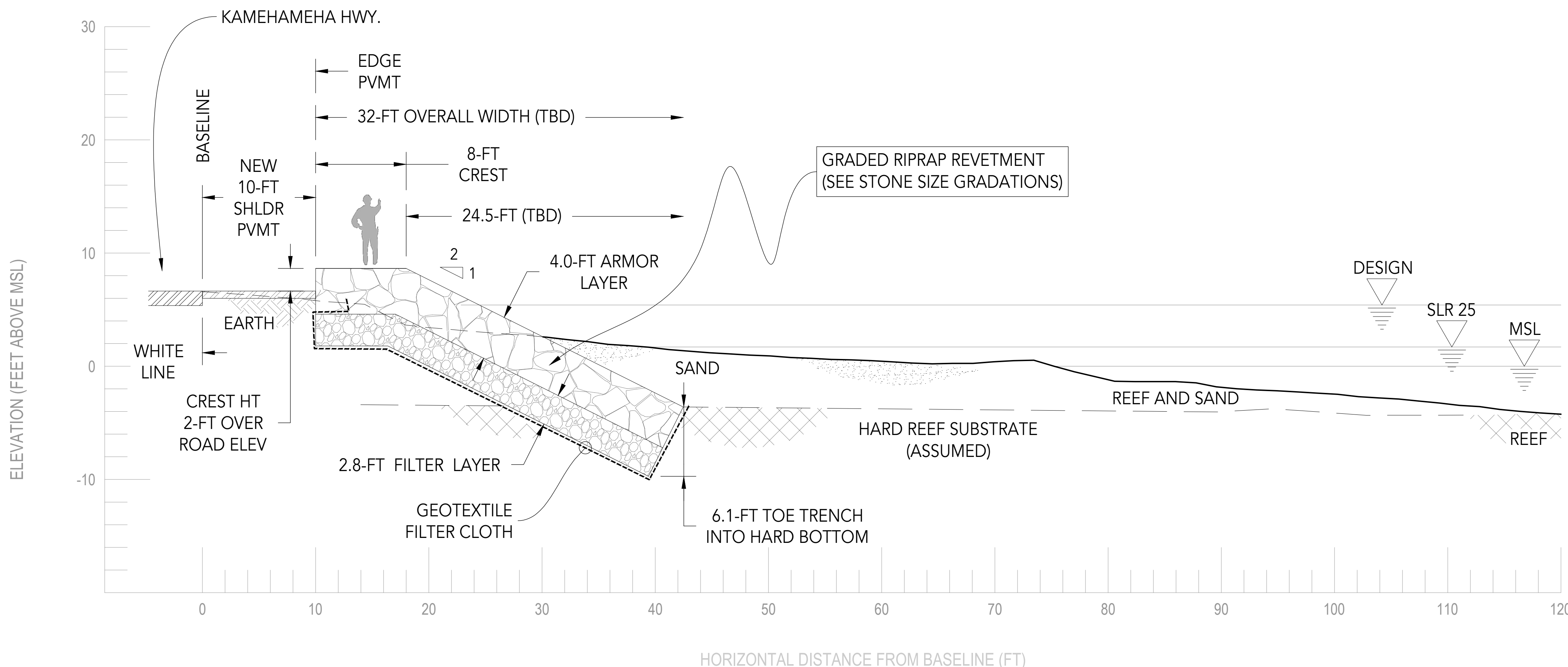
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.94 ft, for this location.

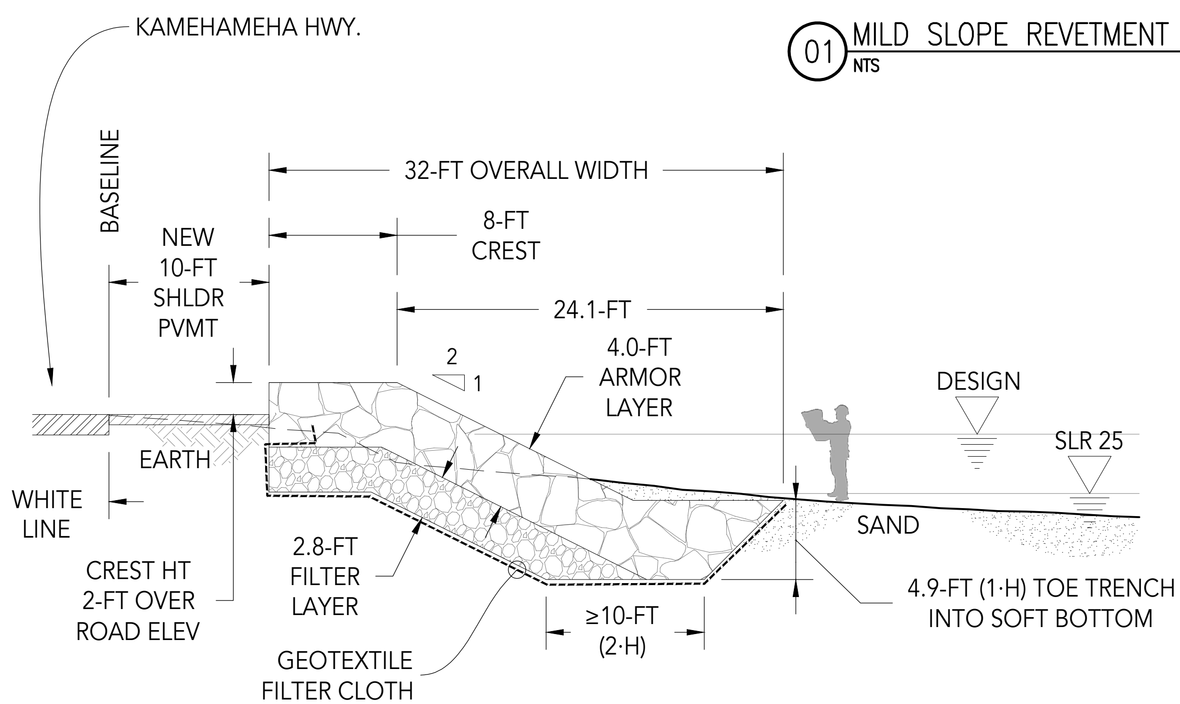
Sheet Name
Punaluu North (P1) Station 01+00 High Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-085



01 MILD SLOPE REVETMENT CROSS SECTION AT STATION 01+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	165	17
W_{50}	1,321	132
W_{100}	5,283	528

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	1.01	0.47
d_{50}	2.02	0.94
d_{100}	3.21	1.49

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

SE
Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

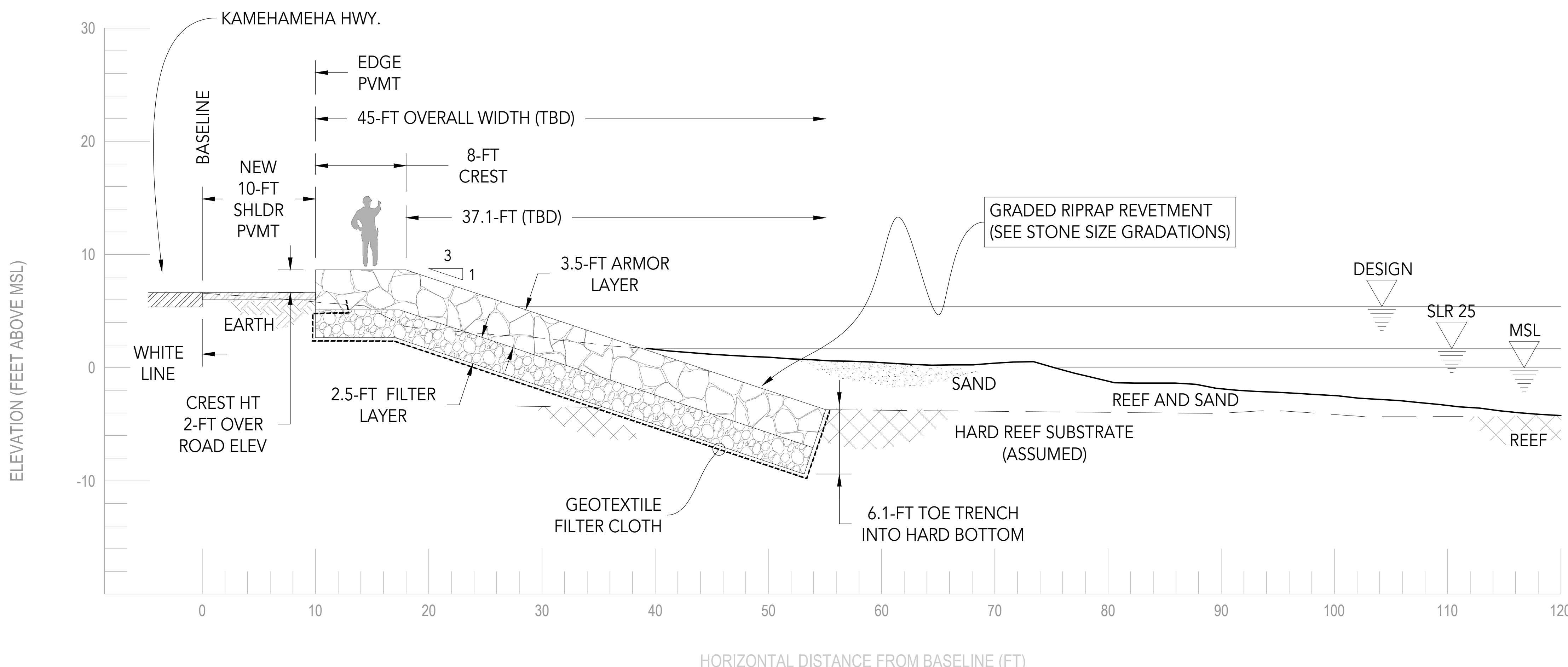
NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Revetment crest elevation to follow approximately 2-ft above existing road elevation.
4. Revetment ends to terminate by turning back into slope to prevent flanking erosion.
5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.94 ft, for this location.

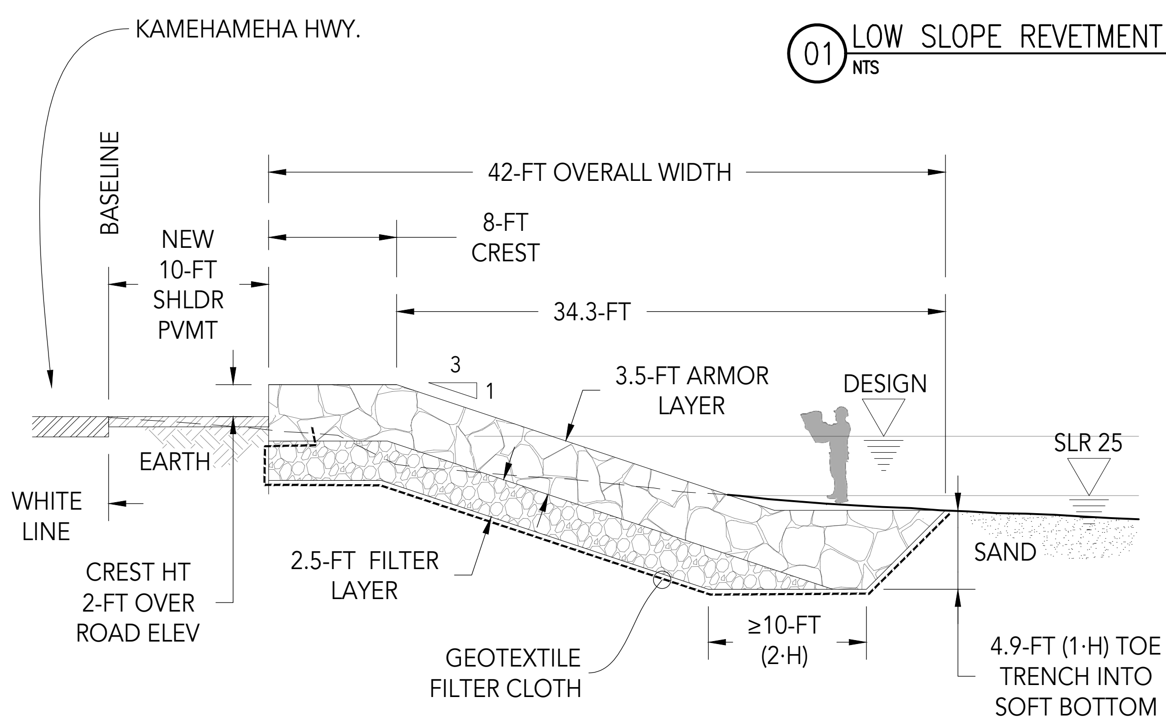
Sheet Name
Punaluu North (P1) Station 01+00 Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-086
Date	21 Mar 2022	
Scale	1" = 1' - 0"	



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 01+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	110	11
W_{50}	881	88
W_{100}	3,522	352

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.88	0.41
d_{50}	1.77	0.82
d_{100}	2.80	1.30

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
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PH 808.259.7966
FAX 808.259.8143

NOTES:

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8. Design wave height, H = 4.94 ft, for this location.

Sheet Name
Punaluu North (P1) Station 01+00 Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-087

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Predicted shoreline erosion for 2050 (approximately 28 years from today) taken from the University of Hawaii, Coastal Geology Group (UH CGG) erosion hazard study for Oahu. Estimated retreat shown in this drawing from GIS layer in shapefile "Oahu_erosion_polygons_2050.shp"
4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict complete erosion of this reach up to and beyond the existing road shoulder location along nearly the entire reach of this repair area. The length of this threatened stretch is approximately 2,400 ft, from 00+00 to 24+00.

Sheet Name

Hauula Existing Condition Overview Plan

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-088
Date 21 Mar 2022	
Scale $\frac{3}{32}$" = 1' - 0"	

SE

Sea Engineering, Inc.

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WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

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2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict near uniform erosion of this reach up to and beyond the existing road shoulder location by 2050 if left unprotected. The length of this threatened stretch is approximately 2,400 ft.

Sheet Name

Hauula
Vicinity of Sta. 13+00
Existing Condition
Typical Plan (2013)

Project Name

KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-089
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

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5. UH Erosion estimates predict near uniform erosion of this reach up to and beyond the existing road shoulder location by 2050 if left unprotected. The length of this threatened stretch is approximately 2,400 ft.

Sheet Name

Hauula Vicinity of Sta. 13+00 Existing Condition Typical Plan (2021)

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet: C-090
Date	21 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	

Sea Engineering, Inc.
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FAX 808.259.8143

NOTES:

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict near uniform erosion of this reach up to and beyond the existing road shoulder location by 2050 if left unprotected. The length of this threatened stretch is approximately 2,400 ft., from Sta. 00+00 to 24+00.

Sheet Name
Hauula Vicinity of Sta. 13+00 High Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-091
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

Sea Engineering, Inc.
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FAX 808.259.8143

NOTES:

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict near uniform erosion of this reach up to and beyond the existing road shoulder location by 2050 if left unprotected. The length of this threatened stretch is approximately 2,400 ft., from Sta. 00+00 to 24+00.

Sheet Name
Hauula Vicinity of Sta. 13+00 Mild Slope Revetment Plan - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-092
Date 21 Mar 2022	
Scale $\frac{1}{4}$" = 1' - 0"	

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

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4. Project Baseline follows the makai (oceanside) white "fog line" lane marking along Kamehameha Hwy. as shown.
5. UH Erosion estimates predict near uniform erosion of this reach up to and beyond the existing road shoulder location by 2050 if left unprotected. The length of this threatened stretch is approximately 2,400 ft., from Sta. 00+00 to 24+00.

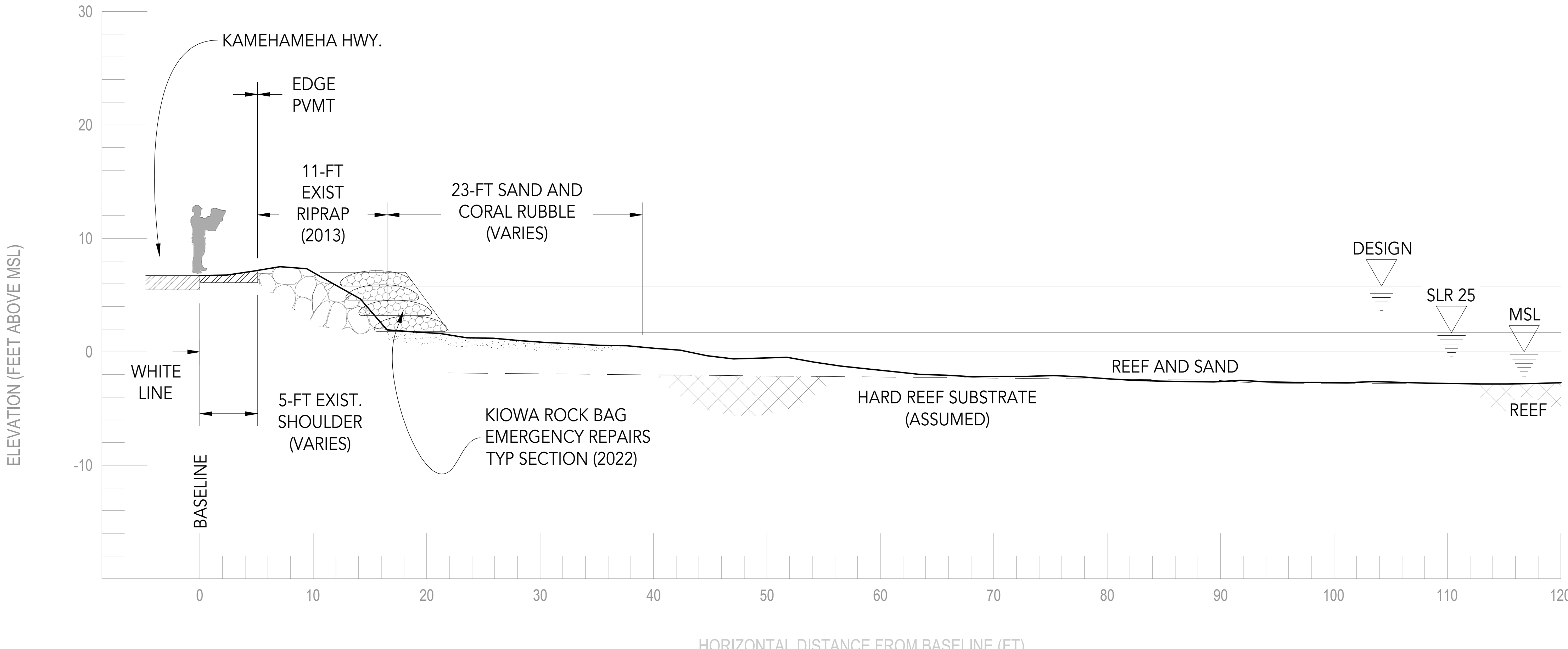
Sheet Name

Hauula Vicinity of Sta. 13+00 Low Slope Revetment Plan - Conceptual

Project Name

KKPH Kamehameha Highway Shore Protection

Project No.	25853	Sheet C-093
Date	21 Mar 2022	
Scale	$\frac{1}{4}$" = 1' - 0"	



01 EXISTING (2013) CROSS SECTION AT STATION 13+00
NTS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

1. Topographic and bathymetric contours based on 2013 USACE LiDAR survey.
2. Contour interval is half-foot, all elevations given in feet above mean sea level (MSL).
3. Water Levels:

MSL = Mean Sea Level

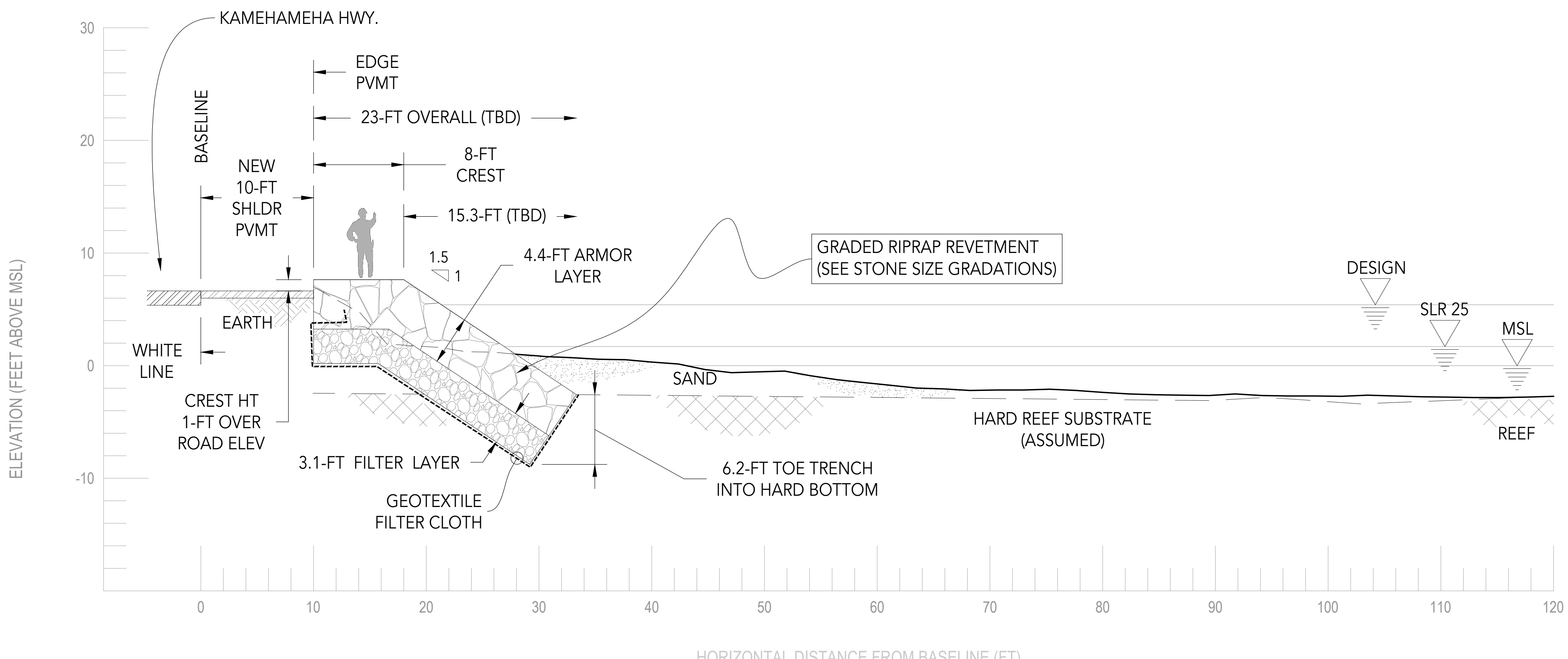
SLR25 = Estimated Sea Level Rise in 25 Years, 1.7 ft MSL

Design = Design Water Level, including storm surge, SLR and astronomical tide, 5.80 ft MSL

Sheet Name
Hauula Station 13+00 Existing Condition Section (Typical)

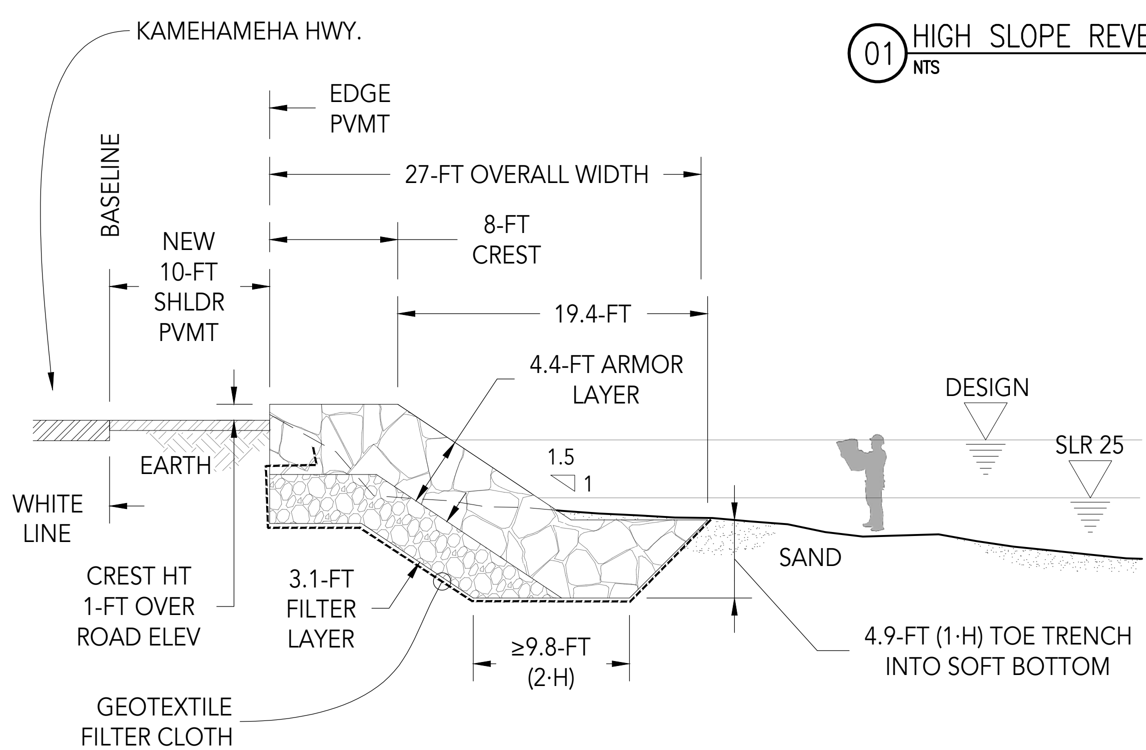
Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853	Sheet C-094
Date 21 Mar 2022	
Scale 1" = 1' - 0"	



01 HIGH SLOPE REVETMENT CROSS SECTION AT STATION 13+00

NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	212	21
W_{50}	1,696	170
W_{100}	6,784	678

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	1.10	0.51
d_{50}	2.20	1.01
d_{100}	3.49	1.61

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

SE
Sea Engineering, Inc.
MAKAI RESEARCH PIER
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PH 808.259.7966
FAX 808.259.8143

NOTES:

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5. Revetment to tie into bridge or culvert wing walls where present.
6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.88 ft, for this location.

Sheet Name

Hauula Station 13+00 High Slope Revetment Section - Conceptual

Project Name

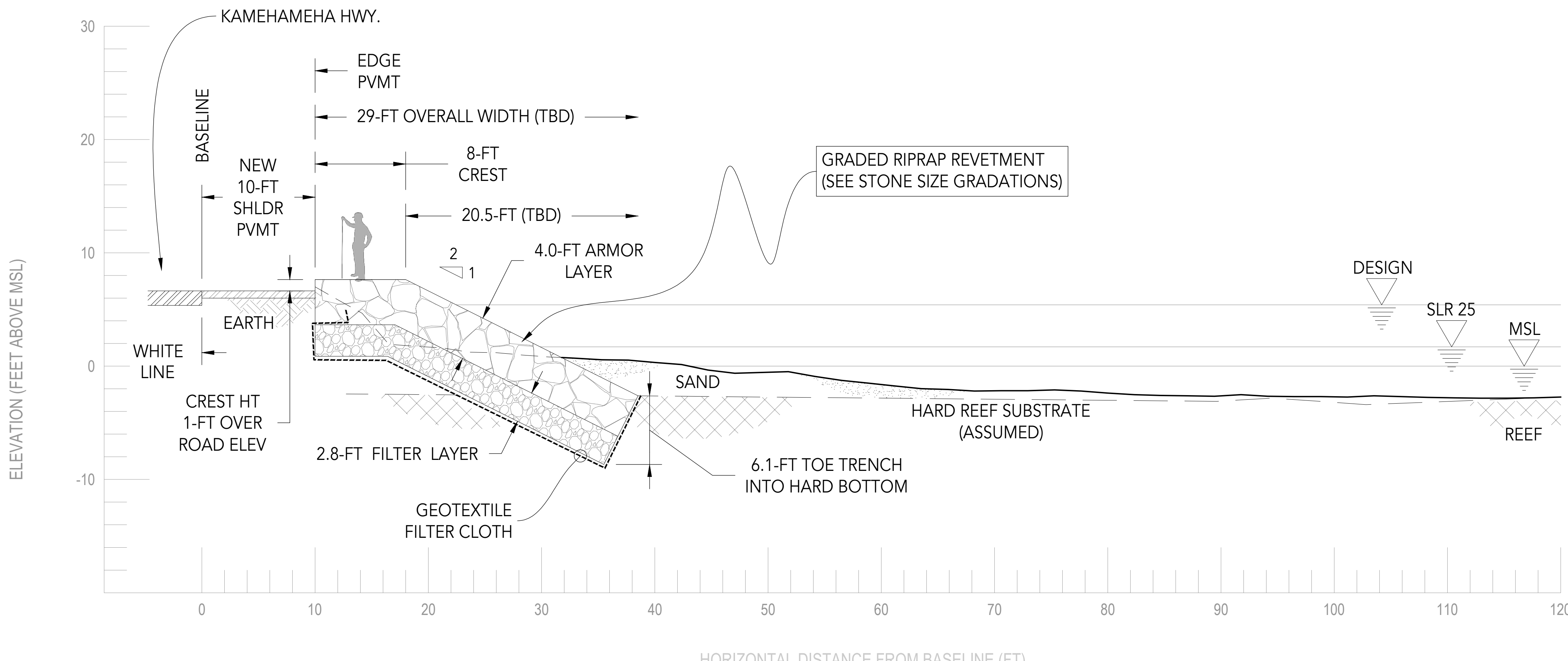
KKPH Kamehameha Highway Shore Protection

Project No. 25853

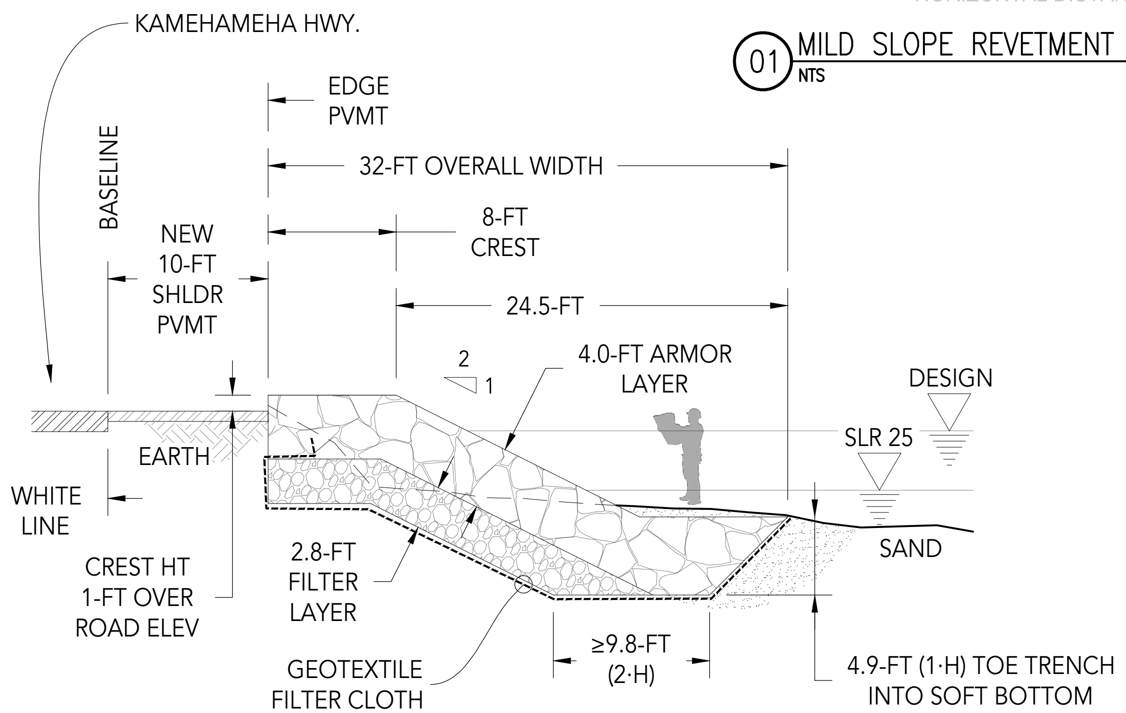
Date 21 Mar 2022

Scale 1" = 1' - 0"

Sheet C-095



01 MILD SLOPE REVETMENT CROSS SECTION AT STATION 13+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	159	16
W_{50}	1,272	127
W_{100}	5,088	509

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	1.00	0.46
d_{50}	2.00	0.93
d_{100}	3.17	1.47

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
FAX 808.259.8143

NOTES:

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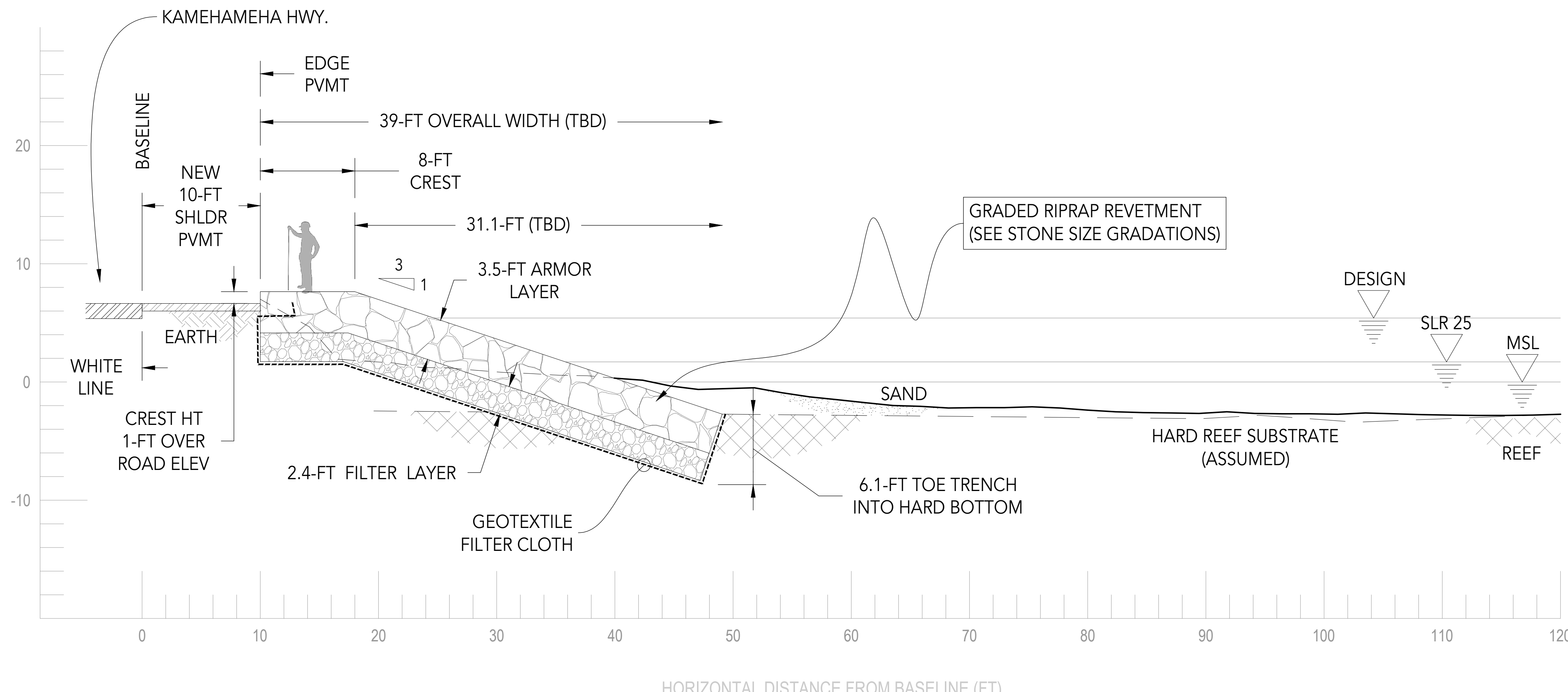
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.88 ft, for this location.

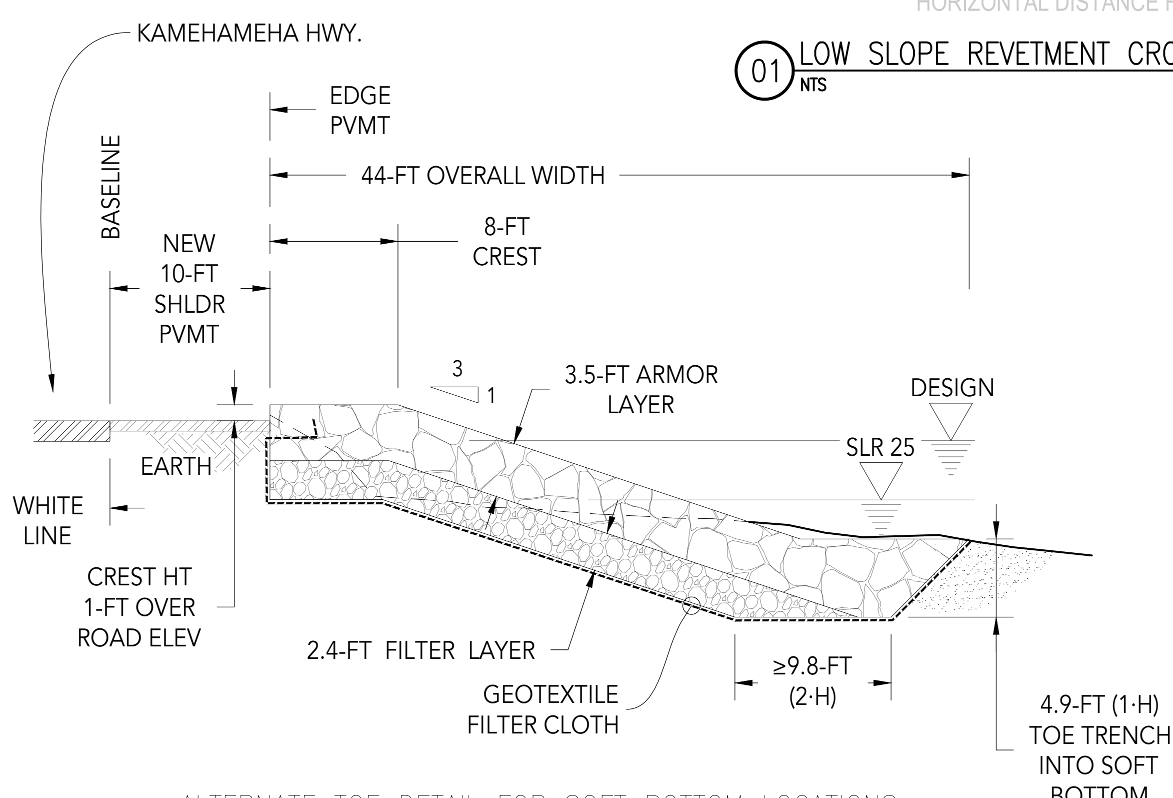
Sheet Name
Hauula Station 13+00 Mild Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 21 Mar 2022
Scale 1" = 1' - 0"
Sheet C-096



01 LOW SLOPE REVETMENT CROSS SECTION AT STATION 13+00
NTS



ALTERNATE TOE DETAIL FOR SOFT BOTTOM LOCATIONS

STONE SIZE GRADATION

-- BY WEIGHT (LBF) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
W_{15}	106	11
W_{50}	848	85
W_{100}	3,392	339

STONE SIZE GRADATION

-- NOMINAL DIAMETER (FT) --

GRAD	ARMOR LAYER AVG	FILTER LAYER AVG
d_{15}	0.87	0.40
d_{50}	1.74	0.81
d_{100}	2.77	1.28

ALLOWABLE RIPRAP STONE SIZE GRADATIONS

Sea Engineering, Inc.
MAKAI RESEARCH PIER
WAIMANALO, HI 96795
PH 808.259.7966
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NOTES:

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6. Revetment riprap properties are provided in the stone size gradation tables this sheet.
7. If hard bottom not present or unsuitable for toe trench, alternative toe design is required.
8. Design wave height, H = 4.88 ft, for this location.

Sheet Name
Hauula Station 13+00 Low Slope Revetment Section - Conceptual

Project Name
KKPH Kamehameha Highway Shore Protection

Project No. 25853
Date 11 Aug 2022
Scale 1" = 1' - 0"
Sheet C-097

Appendix B:
Marine Assessment

MARINE ENVIRONMENTAL RESEARCH CONSULTING, LLC

WINDWARD SHORE PROTECTION
BASELINE MARINE ASSESSMENT

PREPARED FOR:
Sea Engineering, Inc.
41-305 Kalanianaole Hwy
Makai Research Pier
Waimanalo, HI 96795

PREPARED BY:
Marine Research Consultants, Inc.
46-312C Haiku Rd
Kaneohe, HI 96744
808-779-4009

July 14, 2023

I. INTRODUCTION AND PURPOSE

Kamehameha Highway (Hwy) extends from Kaneohe near the east end of the island of Oahu along the northeast (windward) coast to the north shore town of Haleiwa. It is the only highway connecting the coastal communities of Kaneohe, Kahaluʻu, Kaʻaʻawa, Punaluʻu, Hauʻula, and La‘ie, and is a primary access for police, fire, and emergency medical vehicles. The State Department of Transportation-Highways Division (DOT-H) records the Annual Average Daily Traffic count as 13,000 vehicles. Many portions of the highway follow the coastline within feet of the waterline, and only a few feet above it. Coastal erosion and shoreline recession are an increasing threat to the highway.

Nine sectors of Kamehameha Hwy in Kualoa, Kaaawa, Punaluu, and Hauula have been identified to be in critical need of erosion mitigation and/or installation of roadside shore protection structures (Figure 1). These sectors range from 264 feet (ft) to 4,752 ft in length and comprise the majority of Kamehameha Highway that is immediately adjacent to the coastline. These nine sectors comprise the survey areas for the Windward Shore Protection Baseline Marine Assessment.

The purpose of this document is to provide the results of a rapid ecological assessment (REA) of two aspects of the marine ecosystem fronting the affected areas of Kamehameha Highway: marine water chemistry and marine biotic community structure. As the two southern most survey areas are adjacent and similar in physical structure and environmental influences, the marine environment offshore of these areas was surveyed as a single sector. For the purposes of the marine baseline assessment, these eight sectors were designated “A” through “H” from North to South (Figure 1).

Water chemistry was assessed by collecting a set of samples along 13 transects (T1 – T13) extending from the shoreline to points offshore deemed to be the limit of influence from material emission at the shoreline. (Figure 1). The physical composition and biotic community structure of marine habitats were also documented within each of the eight survey sectors A through H. One primary focus of the assessment of biotic communities was to fully describe coral reef assemblages. As coral communities are both long-lived and attached to the bottom, they serve as the best indicators of the time-integrated forces that affect nearshore reef areas. Evaluation of the existing condition of water chemistry and marine communities provides an insight into the physical and chemical factors that influence the marine setting. Understanding the existing physical, chemical, and biological conditions of the marine environment provides a basis for predicting potential effects that might occur as a result of the proposed shoreline erosion mitigation.

II. METHODS

A. Water Chemistry

All fieldwork for the water chemistry assessment was conducted by Dr. Steven Dollar and Ms. Andrea Millan on May 24, 2023. Water chemistry was investigated along 13 transects located in each of the 8 sectors identified as shoreline mitigation sites. Representative images of the shoreline at the origin of the transects are shown in Figure 2. A single transect was surveyed in sectors less than 1,500 ft in length while two transects were surveyed in sectors greater than 1,500 ft in length (Figure 1, Table 1). Each transect originated at the shoreline and extended perpendicular to the shoreline for a distance of either 10 or 20 m offshore. Water samples were collected by swimmers at 5 or 6 locations along each transect at distances of approximately 0.1, 1, 3, 5, 10, and 15 or 20 m from the shoreline. Such a sampling scheme was designed to span the distance from shore that could potentially experience impacts from shoreline mitigation work. Sampling was concentrated close to the shoreline as this area receives the most terrestrial input, and hence is most important with respect to identifying the effects of shoreline modification. At sites where water depth was less than 2 m only surface samples (within 20 centimeters [cm] of the surface) were collected. At sites where water depth was greater than 2 m, surface and near bottom samples were collected.

Water quality constituents that were evaluated included all specific criteria designated for open coastal waters in Chapter 11 54, Section 06 (b) (Open Coastal waters) of the State of Hawaii Department of Health (DOH) Water Quality Standards. These criteria include: total nitrogen (TN), nitrate + nitrite nitrogen (NO_3^-+ NO_2^-, hereafter referred to as NO_3^-), ammonium nitrogen (NH_4^+), total phosphorus (TP), Chlorophyll a (Chl a), turbidity, temperature, pH, and salinity. In addition, dissolved silica (Si) and orthophosphate phosphorus (PO_4^{3-}) were reported as these constituents are sensitive indicators of biological activity and the degree of groundwater mixing.

EPA and Standard Methods (SM) methods that were employed for the Monitoring Program, as well as resolution / detection limits, are listed in the Code of Federal Regulations (CRF) Title 40, Chapter 1, Part 136, and are shown in Table 2. In situ field measurements included water temperature, dissolved oxygen, and salinity, which were acquired using an RBR Concerto data logger with sensors for pressure (depth), conductivity (salinity), temperature, and dissolved oxygen calibrated to factory specifications.

Laboratory analyses were conducted by Marine Consulting and Analytical Resources LLC (MCAR) (Lab number HI 00928). Analyses for Si, NH_4^+, PO_4^{3-}, and NO_3^- were performed with a Seal Analytical AutoAnalyzer 3 HR (AA3HR) using standard methods for seawater analysis. TN and TP were analyzed in a similar fashion following digestion. Salinity was determined using a Mettler Toledo Seven Excellence Multi-parameter meter with an InLab 731-ISM conductivity probe.

Chl *a* was measured by filtering 150 ml through a GFF/F glass-fiber filters; pigments on filters were extracted in 90% acetone in the dark at -20 °C for 24 hours. Fluorescence of the extract was measured with a Turner Designs Trilogy Fluorometer model 7200-000 equipped with an extracted chlorophyll non-acidification module. Salinity was determined using a Mettler Toledo Seven Excellence Multi-parameter meter with an InLab 731-ISM conductivity probe, calibrated to a Hach Instruments traceable salinity standard of 35.00 parts per thousand (‰ or ppt), 53.0 mS/cm, with a readability of 0.01 ppt. Turbidity was determined using a Hanna Instruments Model #HI88703 Turbidimeter and reported in nephelometric turbidity units (NTU) (precision of 0.01 NTU). Measurements of pH were acquired with a Thermo Scientific Orion Star meter with a Thermo Scientific 8107UWMMD electrode.

B. Marine Biotic Community Structure

The biotic survey at Sector F was conducted during Phase 1 of the project on January 12, 2021 (Dollar 2021). The biotic surveys at all other sectors were conducted on May 2 and May 26, 2023, by Dr. Steven Dollar, Ms. Andrea Millan, and Ms. Stacy Peltier (Table 1). The physical and biotic composition of the survey area was assessed by divers using snorkel and working from shore. Dive surveys were conducted by swimming in a zigzag pattern from the shoreline to approximately 75 m offshore throughout the area that fronted each of the eight survey areas A through H (Figure 1). During these underwater investigations, notes on species composition were recorded and numerous digital photographs were collected to document the existing conditions of the area.

The first attempt to survey Sectors B and C on May 2, 2023, was not successful owing to highly turbid conditions resulting in zero visibility underwater. On May 24, 2023, turbid conditions persisted at Sector B but had improved enough at Sector C to complete the biotic survey at this site (Table 1).

Table 1. Length and biotic survey information for 8 survey sectors as well as latitude and longitude of 13 transects within all survey sectors.

SECTOR	LENGTH (ft)	BIOTIC SURVEY?	WATER TRANSECT	LATITUDE	LONGITUDE
A	2,650	YES	T-1	21º 36.422'	-157º 54.289'
			T-2	21º 36.297'	-157º 54.074'
B	370	NO	T-3	21º 36.751'	-157º 53.744'
C	3,000	YES	T-4	21º 35.112'	-157º 53.244'
			T-5	21º 34.944'	-157º 53.216'
D	2,904	YES	T-6	21º 33.571'	-157º 51.748'
			T-7	21º 33.464'	-157º 51.440'
E	1,584	YES	T-8	21º 33.166'	-157º 50.965'
F*	1,848	YES	T-9	21º 32.900'	-157º 50.793'
			T-10	21º 32.651'	-157º 50.706'
G	4,752	YES	T-11	21º 32.504'	-157º 50.530'
			T-12	21º 32.186'	-157º 50.423'
H	1,056	YES	T-13	21º 31.305'	-157º 50.127'

**Sector F Biotic Survey conducted during phase 1 in January 2021.*

Table 2. Water Quality Constituents, Methods, and Detection Limits/Readability for Samples Collected along 13 Transects.

Constituent	*Method*	*Detection Limit/Readability*
NH_4^+	EPA 350.1, Rev. 2.0 or SM4500-NH3 G	0.042 micrograms/liter (µg/L)
$NO_3^- + NO_2^-$	EPA 353.2, Rev. 2.0 or SM4500-NO3F	0.084 µg/L
PO_4^{3-}	EPA 365.5 or SM4500-P F	0.28 µg/L
Total P	EPA 365.1, Rev. 2.0 or SM4500-P E J	0.93 µg/L
Total N	SM 4500-N C	1.96 µg/L
Si	EPA 370.1 or SM 4500 SiO2 E	0.45 µg/L
Chlorophyll *a*	SM 10200	0.006 µg/L
pH	EPA 150.1 or SM4500H+B	0.002 pH units
Turbidity	EPA 180.1, Rev. 2.0 or SM2130 B	0.008 nephelometric turbidity units (NTU)
Temperature	SM 2550 B	0.001 degrees Celsius (°C)
Salinity	SM 2520	0.001 parts per thousand (‰)
Dissolved Oxygen	SM4500 O G	0.001% saturation (% sat)

III. RESULTS

A. Water Chemistry

1. Distribution of Chemical Constituents

Results of water chemistry analyses on samples collected along 13 transects are shown in Table 3 and Table 4. Dissolved nutrient concentrations are shown in micromoles (µM) in Table 3 and milligrams (mg) per liter (L) in Table 4. Figure 3 – Figure 6 show plots of concentrations of dissolved nutrients as functions of distance from shore. Also shown in Figure 3 – Figure 6 are plots of salinity as functions of distance from shore. Figure 7 shows plots of turbidity, Chl *a*, and pH as functions of distance from shore.

Plots of dissolved Si show a consistent pattern with highest values nearest the shoreline and progressive decrease with distance seaward. Plots of salinity show a near perfect mirror image with lowest values nearest the shoreline with increases moving seaward (Figure 3). The steepest gradients occurred on Transect 5, located at Site C in south Punaluu and Transect 10 located at Site F in Kaaawa. The only location that did not show any gradient of decreasing Si and increasing salinity was Transect 3 at Site B in north Punaluu (Figure 1, Figure 3).

The horizontal gradients of Si and salinity likely represent input of groundwater or surface water to the ocean near the shoreline. Both Transects 5 and 10 were located at the junctures where streams were flowing to the ocean (Figure 2). Hence, the samples collected near the shoreline with anomalously elevated Si and low salinity represented a mixing zone between stream water and ocean water.

At sampling transects with no stream water input at the shoreline, gradients of Si and salinity were smaller but still distinct. Low salinity groundwater, which typically contains high concentrations of Si, percolates to the ocean at the shoreline, resulting in a nearshore zone of mixing. In many areas of the Hawaiian Islands, such groundwater percolation results in steep horizontal gradients of increasing salinity and decreasing nutrients with increasing distance from shore. The gradients in the nearshore zone off the Kamehameha Hwy mitigation sites showing only groundwater input (such as T-4 and T-12) are comparatively small relative to sites where streams enter the ocean (such as T-5 and T-10).

Dissolved nitrate+nitrite nitrogen (NO_3^-) displays a different pattern than that displayed by Si. Nearshore samples from the sites where streams are present (T-5 and T-10) do not show the peak values of NO_3^- similar to Si. Rather, the highest value at the shoreline occurred at Transect 13 at Site H off Kualoa Ranch (Figure

3 and Table 3). The elevated nearshore values indicate relatively higher groundwater input at the shoreline in this area relative to other sites.

Orthophosphate phosphorus (PO_4^{-3}) is also generally elevated in groundwater and stream water relative to ocean water. In the data set collected off the Kamehameha Hwy mitigation sites, the pattern of decreasing concentration of PO_4^{-3} with respect to distance from the shoreline is nearly identical to the pattern of Si. As with Si, stream water entering the ocean at the locations of Transects 5 and 10 contains relatively high concentrations of PO_4^{-3}, which is reflected in steep gradients within 5 m of the shoreline (Figure 4). All the other transects show smaller yet distinct gradients of decreasing concentration with distance from shore suggesting some groundwater flux. Horizontal gradients of TN (Figure 5) and TP (Figure 6) are similar to the patterns of NO_3^- and PO_4^{-3}, respectively.

Horizontal gradients of ammonium nitrogen (NH_4^+) show patterns completely different than any of the nutrients discussed above. Concentrations near the shoreline at Transects 5 and 10 where stream water mixed with ocean water did not display steep gradients. In addition, the concentrations of NH_4^+ were low on Transect 13 where groundwater NO_3^- was elevated. In contrast, the concentrations of NH_4^+ on Transect 2, in Sector A located off Hauula, were nearly an order of magnitude higher than at other shoreline sites (Table 3, Figure 4). The cause of the anomalous concentrations is not apparent, although NH_4^+ is often associated with organic degradation.

Organic nitrogen TON was generally constant across the length of transects, with exception of Transect 13, where all other species of inorganic nitrogen (NO_3^- and TN) were also elevated (Figure 5). Plots of organic phosphorus (TOP) revealed slightly lower concentrations at the shoreline with overall consistent values across the remainder of the transects (Figure 6).

Values of turbidity were generally consistent along the length of each transect with slightly elevated levels at the shoreline. However, values of turbidity differed between transects ranging from <1 NTU at Transect 1 to approximately 6 NTU at Transect 3. The single exception was Transect 7 at Site D off Crouching Lion. The values of turbidity at this site peaked at 29.6 NTU at the shoreline and remained greater than 6 NTU across the entire transect (Table 3, Figure 7). Chl *a* displayed a similar pattern as turbidity, although in addition to Transect 7, anomalously high values were also seen on Transect 4 (Table 3, Figure 7).

Plots of horizontal gradients of pH showed slightly lower values at the most shoreward samples, with little variation across the remainder of the transects (Figure 7). Temperature showed no gradient of consistent change across the transects (Table 3). Dissolved oxygen values at all transects were greater than

100% saturation (Table 3). The super-saturated condition is likely a result of high photosynthetic production of oxygen by the abundant algal communities that were present at most of the sites. As all the survey sites were shallow in depth (<2 m) there was only a small water column to which oxygen was added by photosynthetic activity, thus concentrating the additional dissolved oxygen. The lowest values of oxygen saturation occurred at Transect 3 (102-113 % saturation) where the substrate of the offshore region consisted primarily of sand with little algal cover.

2. Compliance with DOH Criteria

State of Hawaii Department of Health Water Quality Standards (HDOH-WQS) that apply to the areas offshore of Kamehameha Hwy are listed as "open coastal water" in HRS Chapter §11-54-6(b). Two sets of standards are listed depending on whether an area receives more than 3 million gallons per day (mgd) of freshwater input per shoreline mile ("wet standards"), or less than 3 mgd of freshwater input per shoreline mile ("dry"). As the area contains numerous streams that flow to the ocean, as well as groundwater discharge, wet criteria are probably the most valid applicable criteria.

The HDOH-WQS are also separated into three standards: geometric means, "not to exceed more than 10% of the time," and "not to exceed more than 2% of the time." As these classifications require multiple samplings, they cannot be used for a strict evaluation of whether waters at the sampling site were within compliance standards. However, these values provide a guideline to evaluate the overall status of sampled waters in terms of the relation with State standards.

Values that exceed State WQS are highlighted in Table 3 and Table 4. Three of the dissolved nutrient constituents (NO_3, NH_4^+, and TN) exceeded State of Hawaii water quality standards criteria for wet conditions in 13, 6, and 2 of the samples, respectively (N=78). All samples exceeding state standards were collected within 5 m of the shoreline, indicating that beyond this distance any influence of nutrient input at the shoreline was diluted to background levels. Values of TP complied with State standards in all 78 samples collected along all 13 transects. All nutrient samples collected at transects T4, T5, T9, T11, and T12 were within State standards. These transects were not adjacent to or immediately down current from stream inputs to the marine environment.

Measured values of turbidity did not exceed the 10% criterion on Transects 1, 2, 8, 9, 10 and 11. On Transects 3 and 7 all values of turbidity exceeded the 10% criterion. The variation in turbidity between transects is likely a result of proximity to stream discharge and variable wave action between transects.

B. *Coral Reef Community Structure*

1. Physical Structure

Photographs of the shoreline taken at the origin of the water chemistry transects show the geophysical structure of the interface between the highway and the ocean (Figure 2). The composition of the interfaces varies along the regions of Kamehameha Hwy where shoreline mitigation procedures are planned. Some portions of the shoreline along the highway are comprised of steep eroded soil and rock escarpments that terminate in sand beaches (such as at T-1 and T-10 in Figure 2). Other sections adjacent to the highway consist of constructed shorelines made of boulders that extend to the waterline (such as at T-6 and T-11 in Figure 2). In areas where the shoreline consists of sandy beaches, the sand extends through the intertidal zone and abruptly transitions into a mixed sand and rubble zone (Figure 8). The sand and rubble zone extends seaward for the entire offshore range of the study area and beyond. In general, the amount of sand decreases while the amount of solid rock bottom increases with distance shore.

The entire sand/rubble/rock zone within the study area is shallow in depth, never deeper than approximately 2 m. Within the survey region the offshore area beyond the sandy intertidal zone consists of a relatively homogeneous environment with little distinct zonation in physical structure.

2. Biotic Community Structure

a) Algae

The biotic composition of the reef community fronting the Kamehameha Hwy survey sectors can generally be considered an algal dominated system. Most of the sand and rubble/rock surfaces were covered with a variety of turf and macroalgae (Table 5, Figure 9). The most common macroalgae species/species groups were *Halimeda discoidea*, *Halimeda opuntia*, *Padina sanctae-crucis*, crustose coralline algae, and cyanobacteria (Figure 10, Figure 11). These five macroalgae were detected within all seven biotic survey sectors. Also prevalent was the invasive alien red alga *Acanthophora specifera*, which was detected in 6 of the 7 sectors (Figure 10A). In the 50 years since its unintended introduction from Guam, *A. specifera* has become one of the most successful and abundant algae on Hawaiian reef flats. Other common species were *Dictyosphaeria cavernosa*, *Neomeris* spp., *Dictyota sandvicensis, Padina australis, Turbinaria ornata, Asparagopsis taxiformis*, *Galaxaura rugosa*, and *Lyngbya majuscula.* All of these species were detected at 5 or 6 of the 7 biotic survey sectors (Table 5).

Lyngbya majuscula was the dominant biotic species within Sector C. This filamentous cyanobacterium (blue-green alga) was growing on the sandy bottom as well as on hard substrates such as rocks, boulders, and the limestone fossil reef where it was often in contact with stony corals (Figure 11). *Lyngbya majuscula* is known as the "stinging seaweed" owing to a toxin within the algae that may cause skin irritation as well as swollen eyes, irritation of the nose and throat, headache, fatigue, and fever upon contact (Stinging Seaweed Disease, 2022).

b) Coral

Reef building corals were present throughout the rubble and rock zones, although colonies were generally isolated with no true accreting reef structure. Over the entire survey area, thirteen species of stoney corals were documented, and it was estimated that corals accounted for approximately 1% of bottom cover (Table 6). Representative images of corals found during the Windward Shore Protection survey are shown in Figure 12 – Figure 14. The most common corals observed during the biotic surveys were species typically found on shallow reef flats such as *Porites evermanni*, *Porites lobata*, *Porites compressa*, *Pocillopora meandrina*, *Pocillopora damicornis*, and *Montipora capitata* (Table 6). These six species were observed at 6 or 7 of the sectors where biotic surveys were conducted. *Montipora patula*, *Cyphastrea ocellina*, and *Psammacora stellata* were detected at 4 or 5 sites, while *Montipora flabellata*, *Palythoa tuberculosa*, *Pavona varians*, *Pocillopora grandis*, and *Pocillopora ligulata* were detected at fewer than 4 sectors.

Most of the isolated coral colonies were small (<20 cm) although some large colonies of *Montipora* spp. and *Porites* spp. were observed. Some of the larger circular colonies of *Porites* present on the reef flat form "microatolls" with truncated flat upper surfaces, likely as a response to reaching the upper limit of growth in the shallow water column (Figure 15A and B). While coral occurrence was generally sparse, there were several areas at the outer limits of some of the sectors where mixed assemblages of several species occurred in a small area (Figure 15C). These often occurred in zones of rugosity such as hard ledges and larger boulders. In general, corals throughout all sectors were healthy and signs of paling, bleaching, or disease were extremely rare (Figure 15D).

In terms of comparison between survey areas, the greatest number of species were detected within Sector A (12 species) followed by Sectors C and F (each with 10 species) (Table 6). Sectors D, E, and G had between 7 and 9 species while Sector H was comprised of 3 species of coral. While some of the variation in species diversity can be attributed to the size of the survey area, the variation can also be attributed to differences in habitat. The physical characteristics of Sector H include uniformly shallow (<0.5 m at the time of the survey), warm water. These conditions do not favor growth of some species of Hawaiian corals that prefer slightly deeper, cooler waters.

c) Non-Coral Macroinvertebrates

In general, non-coral macro-invertebrates were conspicuously sparse on the reef flat (Table 7). The most common of the non-coral invertebrates and the only one detected at more than three sites was the rock boring sea urchin (*Echinometra matheai*), which bores into the limestone surface of the reef (Figure 16A). Three other species of urchins (*Echinothrix diadema*, *Heterocentrotus mammilatus*, and *Tripneustes gratilla*) were identified but only at a single site (Sector F). Five species of sea cucumbers were observed with typically two species or less at each sector (Figure 16B and C). The single exception was Sector G, which included all five species of sea cucumbers. The only other non-coral invertebrate that could be considered common were zoanthids interspersed in sand beds and occasionally mixed with macroalgae at Sector H (Figure 16D).

d) Fish

Reef fish were relatively uncommon on the reef flat, and the fish that were observed were generally small (less than 20 cm). When considering all 7 sectors, 44 species of fish were detected (Table 8). The most common and conspicuous groups were the surgeonfish, wrasses, and damselfishes, which were comprised of 7, 5, and 8 species, respectively (Figure 17A). The convict tang *Acanthurus triostegus* was ubiquitous throughout the survey area and was observed within all 7 sectors (Figure 17B). Other commonly observed fish were the saddle wrasse *Thalassoma duperrey* and the Hawaiian damselfish *Dascyllus albisella* (Figure 17C). The largest school of fish observed during the survey was a school of goatfish (*Mulloidichthys flavovittata* and *M. vanicolensis*) transiting across the shallow reef at Sector A (Figure 17D). The relative paucity of fish and the small size of individuals is likely a response to heavy fishing pressure in the area.

When comparing sectors, Sector D was comprised of the greatest number of species of fish (24), followed by Sector A (20), and Sector E (14) (Table 8). Sectors F, G, and H, which were the southernmost areas, included the least number of species (9, 8, and 6, respectively). These southern sectors are comprised of shallow, uniform areas with less structure for fish to shelter in than the more northerly sectors.

Green sea turtles (*Chelonia mydas*) are commonly found within the nearshore areas of the northeast coast of Oahu. However, no turtles were observed during the present survey, although they undoubtedly occur on the reef flat offshore of Kamehameha Highway. No marine mammals or other federally protected species were observed during any of the Kamehameha Baseline Marine Assessment surveys.

IV. DISCUSSION AND CONCLUSIONS

The purpose of this assessment is to assemble information to make valid evaluations of the potential for impact to the marine environment from the proposed shoreline erosion mitigation fronting Kamehameha Highway in Kualoa, Kaaawa, Punaluu, and Hauula on the northeast shoreline of Oahu, Hawaii. Shoreline mitigation protection is intended to prevent future erosion damage and avoid recurring efforts at temporary emergency protection measures. The information collected in this study provides a baseline data set that describes the physical, chemical, and biotic composition of the area, as well as the processes driving such structure. Such information can be used to address any concerns that might be raised regarding effects to the marine environment that might arise during the planning process for the shoreline mitigation.

Results of this baseline study reveal that the composition of the nearshore area consists of a homogeneous shallow sand and rubble/rock reef flat. The predominant biotic composition of the area is a varied assemblage of macroalgae and turf algae. The most common macroalgae species/species groups were *Halimeda* spp., *Padina sanctae-crucis*, crustose coralline algae, and cyanobacteria. The dominant alga in several sectors was the alien invasive species *Acanthophora specifera*, while the dominant biota within Sector C was the cyanobacterium, *Lyngbya majuscula*, the “stinging seaweed.”

Beyond the nearshore zone, corals are present. While the number of coral species was relatively high, coral cover was low with no accreting reef structure. Most colonies occurring as small isolated individuals, although there were some flat-topped microatolls that exceeded one meter in diameter. The low density and small size of corals is most likely in response to shallow water depth which restricts upward growth. The predominant bottom cover of sand, and exposure to wave-generated energy which resuspends sand also limit coral settlement and growth. In total, Fish community structure was noticeably depauperate, likely in response to high fishing pressure.

Owing to persistent turbulent conditions resulting in nearly zero visibility at the site, an in situ marine biotic survey was not conducted at Sector B. The elevated turbidity is likely a response to a combination of stream input of sediment that covers the bottom and exposure to sediment resuspending wave forces. Based on these conditions it is likely that the biotic communities at Sector B are less abundant than at other survey sectors.

Results of analyses of water chemistry indicate a component of stream water entering the ocean at two locations (Transects 5 and 10), and higher groundwater entering the ocean near the shoreline on Transect 13. Within 5 meters of the shoreline, both the stream water and groundwater inputs are rapidly mixed to background coastal oceanic values through wind, wave and current action. The magnitude of effect from such terrestrial input is so low that it does not result in elevation above State of Hawaii DOH water quality standards beyond 5 m of the shoreline. The only constituent with values above DOH limits along the entire length of survey transects is turbidity. Elevated values of turbidity are a result of wave resuspension of naturally occurring bottom sediments.

In summary, it is not likely that the proposed action to stabilize shoreline erosion adjacent to Kamehameha Highway would have any negative effect to existing biotic communities. Best Management Practices (BMPs) will be implemented to restrict or eliminate any transfer of terrigenous material to the marine environment. The nearshore sand and rubble zones extends seaward to a distance that is likely beyond the limit of influence of any shoreline activities. As the area is essentially an open coastline subjected to wind, waves, and tides, normal currents flush the area on a regular basis, preventing the buildup of any input of materials from land. In addition, biota inhabiting the area appear to be pre-adapted to resuspension of sediment as sand is a major component of the nearshore habitat. Perhaps most importantly, the ongoing erosion of the shoreline is likely causing some input of terrigenous material to the nearshore ocean. The proposed mitigation is intended to halt such erosion along with any associated detrimental effects. Thus, the proposed project has the potential to eliminate any such impacts, and may provide long-term improvement to both water quality and marine biota resources.

Table 3. Water chemistry measurements from samples collected for the Windward Shore Protection project on May 2 20, 2023. Nutrient concentrations are shown in micromoles (µM). Also shown are the State of Hawaii, Department of Health(DOH) "not to exceed more than 10% of the time" and "not to exceed more than 2% of the time" water quality standards (WQS) for open coastal waters under "wet" conditions. For sampling locations, see Figure 1.

TRANSECT (SECTOR)	DFS (m)	PO_4^{3-} (µM)	NO_3^- (µM)	NH_4^+ (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	pH (rel)	Salinity (ppt)	Chl-a (µg/l)	TURB (ntu)	Temp (ºC)	DO %sat
T-1 (A)	0.1	0.12	1.08	0.40	22.84	0.20	6.20	0.32	7.68	8.178	33.25	0.35	0.70	26.46	125.31
	1	0.09	0.31	0.08	8.49	0.23	6.71	0.32	7.09	8.228	33.66	0.30	0.37	26.45	123.46
	3	0.07	0.10	0.04	4.70	0.23	6.38	0.30	6.53	8.245	34.09	0.30	0.46	26.22	132.65
	5	0.06	0.07	0.06	2.12	0.24	6.28	0.30	6.41	8.245	34.55	0.19	0.41	25.95	133.33
	10S	0.06	0.05	0.05	1.16	0.23	6.69	0.29	6.80	8.249	34.62	0.19	0.36	25.91	132.83
	10D	0.07	0.07	0.04	1.30	0.24	5.68	0.31	5.79	8.240	34.58	0.17	0.38	25.91	134.51
T-2 (A)	0.1	0.10	2.36	7.81	40.55	0.21	4.60	0.31	14.77	8.313	30.07	0.99	0.81	27.44	138.87
	1	0.06	1.29	4.73	27.89	0.22	4.51	0.28	10.53	8.344	31.03	1.30	1.55	27.49	149.42
	3	0.08	0.55	1.63	13.41	0.20	5.79	0.28	7.96	8.392	32.50	1.12	1.03	27.33	156.29
	10	0.06	0.09	0.03	1.84	0.23	6.69	0.29	6.81	8.329	34.54	0.20	0.49	26.58	151.54
	15	0.08	0.06	0.01	1.40	0.22	6.37	0.29	6.44	8.273	34.62	0.43	0.95	26.13	134.96
	20	0.07	0.08	0.03	1.38	0.23	6.33	0.31	6.45	8.267	34.49	0.26	0.45	26.04	134.09
T-3 (B)	0.1	0.12	0.33	1.48	7.75	0.23	5.80	0.35	7.62	8.118	34.02	1.98	5.70	27.14	102.38
	1	0.12	0.27	1.17	7.60	0.17	5.29	0.29	6.72	8.130	34.03	2.48	5.04	27.07	102.53
	3	0.12	0.32	0.96	7.49	0.19	5.56	0.31	6.84	8.125	33.99	2.38	6.88	26.99	103.16
	5	0.11	0.19	0.49	8.24	0.16	5.85	0.27	6.53	8.143	33.86	2.06	5.28	26.87	104.09
	10S	0.11	0.09	0.10	8.63	0.18	6.77	0.29	6.96	8.153	33.68	1.36	5.37	26.39	113.71
	10D	0.11	0.10	0.08	8.56	0.21	5.99	0.32	6.18	8.162	33.64	1.23	5.29	26.55	108.73
T-4 (C)	0.1	0.19	0.26	0.07	18.40	0.15	5.40	0.34	5.72	8.238	33.23	5.76	4.81	27.35	111.19
	1	0.14	0.36	0.07	14.40	0.20	5.47	0.34	5.90	8.255	33.57	3.48	3.30	26.89	126.59
	3	0.13	0.44	0.10	11.95	0.18	5.62	0.31	6.16	8.272	33.73	0.43	3.39	26.86	124.27
	5	0.11	0.47	0.06	9.36	0.20	5.44	0.31	5.97	8.290	33.91	0.45	1.25	26.54	132.14
	10S	0.09	0.30	0.07	5.82	0.21	5.70	0.30	6.06	8.312	34.20	0.34	0.67	26.47	136.20
	10D	0.09	0.22	0.09	4.94	0.21	5.86	0.30	6.18	8.321	34.27	0.31	0.50	26.46	139.31
T-5 (C)	0.1	0.74	0.62	0.22	236.21	0.12	7.81	0.86	8.64	8.093	18.46	2.19	7.49	26.98	106.08
	1	0.27	0.37	0.21	177.31	0.25	10.73	0.52	11.31	8.225	20.79	0.53	5.00	26.95	107.06
	3	0.19	0.25	0.09	171.26	0.22	6.88	0.41	7.22	8.242	20.97	0.25	3.36	26.94	109.32
	5	0.17	0.24	0.10	172.21	0.26	6.88	0.43	7.22	8.238	23.82	0.20	2.67	26.83	124.96
	10S	0.17	0.24	0.13	136.33	0.25	6.70	0.41	7.07	8.269	31.61	0.23	2.05	26.78	123.27
	10D	0.09	0.01	0.17	37.85	0.27	7.09	0.36	7.27	8.333	34.08	0.26	1.70	26.25	150.64
T-6 (D)	0.1	0.08	3.20	0.45	6.75	0.24	9.61	0.32	13.27	8.496	34.05	1.25	3.67	28.92	135.37
	1	0.07	1.09	0.17	5.31	0.26	8.33	0.32	9.59	8.520	34.12	1.23	4.58	28.67	145.31
	3	0.05	0.99	0.24	4.72	0.28	9.15	0.33	10.38	8.512	34.08	1.55	5.73	28.57	149.59
	5	0.06	0.26	0.15	4.68	0.26	7.24	0.31	7.65	8.427	34.19	0.20	2.49	28.10	154.53
	10S	0.06	0.04	0.13	2.56	0.26	7.19	0.32	7.36	8.377	34.44	0.19	1.15	27.46	159.74
	15D	0.06	0.05	0.14	2.52	0.29	7.73	0.35	7.92	8.376	34.52	0.24	0.55	27.39	159.14
T-7 (D)	0.1	0.21	6.43	bdl	97.32	0.31	9.34	0.52	15.77	8.243	28.58	6.48	29.60	29.60	124.00
	1	0.14	3.70	bdl	64.70	0.28	8.01	0.43	11.71	8.359	30.20	4.60	23.80	29.71	136.06
	3	0.09	1.92	0.03	40.06	0.24	7.71	0.33	9.66	8.499	31.15	0.82	7.72	29.69	142.13
	5	0.05	0.37	0.05	26.26	0.27	9.06	0.33	9.48	8.631	31.97	1.11	6.77	29.57	161.84
	10	0.04	0.07	0.16	17.60	0.30	9.43	0.34	9.66	8.685	32.69	1.35	6.49	29.54	192.57
	20	0.04	0.02	0.18	16.69	0.30	9.27	0.34	9.48	8.710	32.75	1.95	10.80	29.35	208.12
DOH WQS (wet)		NTE 10%	1.00	0.61	na	na	na	1.29	17.85	*	**	0.90	1.25	***	****
		NTE 2%	1.78	1.07	na	na	na	1.93	25.00			1.75	2.00		

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary by more than one degree C. from ambient conditions.
***pH shall not deviate more than 0.5 units from a value of 8.1.
**** DO should not be less than 75% saturation.
Peach shaded values exceed the NTE more than 10% of the time DOH WQS for "wet" conditions; blue shaded values exceed the NTE more than 2% of the time.

DFS = distance from shore
S = surface
D = deep

Table 3 (continued). Water chemistry measurements from samples collected for the Windward Shore Protection project on May 2 20, 2023. Nutrient concentrations are shown in micromoles (**µ**M). Also shown are the State of Hawaii, Department of Health(DOH) “not to exceed more than 10% of the time” and “not to exceed more than 2% of the time” water quality standards (WQS) for open coastal waters under “wet” conditions. For sampling locations, see Figure 1.

TRANSECT (SECTOR)	DFS (m)	PO_4^{3-} (µM)	NO_3^- (µM)	NH_4^+ (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	pH (rel)	Salinity (ppt)	Chl-a (µg/l)	TURB (ntu)	Temp (ºC)	DO %sat
T-8 (E)	0.1	0.14	9.10	0.02	45.24	0.23	7.76	0.37	16.88	8.369	31.67	1.93	1.73	29.16	166.05
	1	0.05	3.63	0.08	23.08	0.27	6.32	0.33	10.03	8.387	31.82	0.53	0.79	29.36	162.80
	3	0.07	1.07	0.12	10.79	0.23	6.61	0.31	7.81	8.360	32.96	0.25	0.47	29.16	161.06
	5	0.06	1.02	0.13	9.67	0.31	20.46	0.37	21.61	8.348	33.84	0.50	0.91	28.96	156.67
	10	0.05	0.49	0.11	5.97	0.26	7.35	0.32	7.95	8.339	33.98	0.21	1.19	28.70	153.14
	20	0.05	0.31	0.10	4.88	0.26	7.14	0.32	7.55	8.337	34.33	0.31	0.79	28.58	156.51
T-9 (F)	0.1	0.11	0.64	0.19	5.93	0.23	6.47	0.34	7.30	8.252	34.36	0.35	0.64	28.49	116.26
	1	0.06	0.25	0.16	2.74	0.26	7.24	0.32	7.64	8.274	34.44	0.15	1.27	27.60	133.65
	3	0.04	0.11	0.29	1.68	0.27	6.21	0.32	6.62	8.288	34.58	0.16	1.32	27.20	139.27
	5	0.06	0.07	0.16	1.36	0.23	5.74	0.29	5.97	8.288	34.69	0.18	0.44	27.01	139.07
	10S	0.06	0.05	0.11	1.28	0.20	5.44	0.26	5.61	8.273	34.66	0.18	0.37	26.80	131.29
	10d	0.07	0.08	0.09	1.29	0.20	5.23	0.26	5.40	8.271	34.66	0.13	0.23	26.81	131.26
T-10 (F)	0.1	0.58	10.93	1.07	311.79	0.06	6.68	0.63	18.67	8.038	17.88	0.68	1.99	26.89	101.93
	1	0.24	2.67	0.19	98.65	0.15	4.97	0.38	7.83	8.237	29.51	0.30	1.37	27.55	111.87
	3	0.21	2.40	0.17	90.21	0.14	4.37	0.35	6.94	8.256	29.90	0.38	1.15	27.60	129.09
	5	0.17	1.39	0.18	57.72	0.17	5.90	0.34	7.48	8.259	31.63	0.32	0.81	27.86	125.22
	10S	0.11	0.92	0.18	42.44	0.24	5.75	0.35	6.85	8.260	32.44	0.25	1.00	27.80	125.99
	10d	0.12	0.31	0.17	15.55	0.24	6.90	0.36	7.38	8.246	33.84	0.32	0.74	27.09	130.42
T-11 (G)	0.1	0.06	0.29	0.22	4.72	0.23	7.57	0.30	8.08	8.472	34.30	0.32	1.26	28.95	184.33
	1	0.06	0.18	0.15	4.44	0.21	6.70	0.27	7.03	8.479	34.30	0.26	0.66	28.79	131.96
	3	0.05	0.15	0.16	3.87	0.23	7.20	0.28	7.51	8.477	34.37	0.26	0.77	28.64	138.79
	5	0.03	0.12	0.19	1.60	0.27	7.86	0.30	8.16	8.374	34.55	0.33	0.82	28.02	138.23
	10	0.05	0.07	0.18	1.39	0.22	6.78	0.26	7.04	8.358	34.62	0.30	0.65	27.47	137.16
	20	0.05	0.09	0.17	1.13	0.21	6.67	0.26	6.93	8.336	34.66	0.19	1.07	27.28	132.32
T-12 (G)	0.1	0.08	0.10	0.18	5.03	0.25	8.18	0.33	8.45	8.297	34.55	0.95	3.47	27.35	106.34
	1	0.09	0.12	0.28	4.88	0.26	6.39	0.35	6.79	8.301	34.55	0.55	2.06	27.28	115.48
	3	0.09	0.08	0.17	4.63	0.28	7.06	0.36	7.32	8.298	34.51	0.71	1.03	27.23	117.15
	5	0.08	0.09	0.17	3.43	0.25	6.31	0.33	6.57	8.293	34.58	0.36	1.34	26.99	120.79
	10S	0.06	0.09	0.17	3.61	0.29	7.18	0.36	7.44	8.297	34.55	0.38	1.28	27.26	116.25
	10D	0.07	bdl	0.24	2.36	0.29	7.52	0.35	7.76	8.285	34.58	0.29	1.75	27.26	116.26
T-13 (H)	0.1	0.06	21.09	1.15	36.68	0.32	19.95	0.37	42.19	8.607	31.19	2.52	1.33	30.83	181.97
	1	0.05	14.16	0.18	28.31	0.27	16.67	0.32	31.01	8.667	31.59	0.92	1.52	30.84	187.02
	3	0.03	4.08	0.30	14.00	0.26	9.69	0.29	14.07	8.706	32.36	0.68	2.58	30.78	204.30
	5	0.06	0.67	0.16	6.79	0.23	9.90	0.29	10.73	8.701	33.04	0.66	1.94	30.55	211.56
	10	0.04	0.21	0.16	4.69	0.21	7.27	0.25	7.64	8.663	33.71	0.41	1.88	29.99	210.54
	20	0.05	0.12	0.25	3.99	0.18	7.16	0.24	7.53	8.619	34.09	1.02	1.81	29.68	205.99
DOH WQS (wet)		NTE 10%	1.00	0.61	na	na	na	1.29	17.85	*	**	0.90	1.25	***	****
		NTE 2%	1.78	1.07	na	na	na	1.93	25.00			1.75	2.00		

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary by more than one degree C. from ambient conditions.
***pH shall not deviate more than 0.5 units from a value of 8.1.
**** DO should not be less than 75% saturation.
Peach shaded values exceed the NTE more than 10% of the time DOH WQS for "wet" conditions; blue shaded values exceed the NTE more than 2% of the time.

DFS = distance from shore
S = surface
D = deep

Table 4. Water chemistry measurements from samples collected for the Windward Shore Protection project on May 2 20, 2023. Nutrient concentrations are shown in micrograms per liter (µg/L). Also shown are the State of Hawaii, Department of Health (DOH) “not to exceed more than 10% of the time” and “not to exceed more than 2% of the time” water quality standards (WQS) for open coastal waters under “wet” conditions. For sampling locations, see Figure 1.

TRANSECT (SECTOR)	DFS (m)	PO_4^{3-} (µg/L)	NO_3^- (µg/L)	NH_4^+ (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	pH (rel)	Salinity (ppt)	Chl-a (µg/l)	TURB (ntu)	Temp (ºC)	DO %sat
T-1 (A)	0.1	3.72	15.06	5.57	639.65	6.30	86.82	10.02	107.45	8.178	33.25	0.35	0.70	26.46	125.31
	1	2.91	4.34	1.09	237.84	6.98	93.87	9.90	99.30	8.228	33.66	0.30	0.37	26.45	123.46
	3	2.23	1.45	0.59	131.59	7.07	89.36	9.30	91.39	8.245	34.09	0.30	0.46	26.22	132.65
	5	1.98	0.92	0.85	59.24	7.35	87.98	9.33	89.75	8.245	34.55	0.19	0.41	25.95	133.33
	10S	1.98	0.76	0.76	32.43	7.00	93.63	8.98	95.14	8.249	34.62	0.19	0.36	25.91	132.83
	10D	2.08	0.96	0.56	36.36	7.46	79.58	9.54	81.10	8.240	34.58	0.17	0.38	25.91	134.51
T-2 (A)	0.1	3.10	33.00	109.40	1135.38	6.55	64.43	9.65	206.82	8.313	30.07	0.99	0.81	27.44	138.87
	1	1.86	18.09	66.26	780.96	6.80	63.13	8.66	147.48	8.344	31.03	1.30	1.55	27.49	149.42
	3	2.57	7.65	22.75	375.44	6.25	81.10	8.83	111.50	8.392	32.50	1.12	1.03	27.33	156.29
	10	1.92	1.27	0.41	51.60	7.21	93.61	9.13	95.28	8.329	34.54	0.20	0.49	26.58	151.54
	15	2.33	0.83	0.10	39.20	6.75	89.17	9.07	90.10	8.273	34.62	0.43	0.95	26.13	134.96
	20	2.26	1.17	0.48	38.71	7.20	88.64	9.46	90.29	8.267	34.49	0.26	0.45	26.04	134.09
T-3 (B)	0.1	3.75	4.64	20.78	216.88	7.08	81.21	10.83	106.62	8.118	34.02	1.98	5.70	27.14	102.38
	1	3.63	3.83	16.31	212.78	5.41	73.99	9.03	94.14	8.130	34.03	2.48	5.04	27.07	102.53
	3	3.72	4.43	13.48	209.61	6.01	77.85	9.73	95.76	8.125	33.99	2.38	6.88	26.99	103.16
	5	3.44	2.64	6.86	230.58	4.84	81.97	8.28	91.46	8.143	33.86	2.06	5.28	26.87	104.09
	10S	3.50	1.21	1.41	241.77	5.51	94.75	9.02	97.37	8.153	33.68	1.36	5.37	26.39	113.71
	10D	3.50	1.39	1.15	239.81	6.40	83.91	9.90	86.45	8.162	33.64	1.23	5.29	26.55	108.73
T-4 (C)	0.1	5.77	3.59	0.99	515.16	4.72	75.56	10.49	80.14	8.238	33.23	5.76	4.81	27.35	111.19
	1	4.31	5.03	0.95	403.07	6.18	76.59	10.48	82.57	8.255	33.57	3.48	3.30	26.89	126.59
	3	4.09	6.09	1.37	334.60	5.60	78.71	9.70	86.17	8.272	33.73	0.43	3.39	26.86	124.27
	5	3.44	6.60	0.83	261.98	6.10	76.21	9.54	83.64	8.290	33.91	0.45	1.25	26.54	132.14
	10S	2.79	4.15	0.91	162.88	6.38	79.82	9.17	84.88	8.312	34.20	0.34	0.67	26.47	136.20
	10D	2.79	3.08	1.27	138.31	6.46	82.11	9.25	86.46	8.321	34.27	0.31	0.50	26.46	139.31
T-5 (C)	0.1	22.79	8.62	3.08	6613.85	3.74	109.30	26.52	121.00	8.093	18.46	2.19	7.49	26.98	106.08
	1	8.39	5.22	2.91	4964.72	7.81	150.26	16.20	158.38	8.225	20.79	0.53	5.00	26.95	107.06
	3	5.75	3.50	1.32	4795.19	6.91	96.31	12.66	101.12	8.242	20.97	0.25	3.36	26.94	109.32
	5	5.29	3.38	1.39	4821.89	8.11	96.33	13.40	101.09	8.238	23.82	0.20	2.67	26.83	124.96
	10S	5.23	3.35	1.83	3817.17	7.60	93.84	12.83	99.02	8.269	31.61	0.23	2.05	26.78	123.27
	10D	2.75	0.12	2.34	1059.81	8.52	99.26	11.27	101.72	8.333	34.08	0.26	1.70	26.25	150.64
T-6 (D)	0.1	2.54	44.86	6.29	189.08	7.52	134.61	10.06	185.75	8.496	34.05	1.25	3.67	28.92	135.37
	1	2.02	15.28	2.35	148.57	8.01	116.67	10.02	134.30	8.520	34.12	1.23	4.58	28.67	145.31
	3	1.58	13.88	3.29	132.08	8.55	128.08	10.13	145.25	8.512	34.08	1.55	5.73	28.57	149.59
	5	1.74	3.61	2.11	131.15	8.02	101.41	9.76	107.13	8.427	34.19	0.20	2.49	28.10	154.53
	10S	1.77	0.51	1.85	71.69	8.15	100.61	9.92	102.97	8.377	34.44	0.19	1.15	27.46	159.74
	15D	1.71	0.76	1.95	70.66	9.10	108.16	10.81	110.87	8.376	34.52	0.24	0.55	27.39	159.14
T-7 (D)	0.1	6.63	90.00	bdl	2724.93	9.50	130.76	16.14	220.77	8.243	28.58	6.48	29.60	29.60	124.00
	1	4.39	51.80	bdl	1811.67	8.79	112.16	13.18	163.97	8.359	30.20	4.60	23.80	29.71	136.06
	3	2.83	26.90	0.42	1121.78	7.51	107.94	10.34	135.25	8.499	31.15	0.82	7.72	29.69	142.13
	5	1.69	5.25	0.70	735.37	8.46	126.80	10.15	132.75	8.631	31.97	1.11	6.77	29.57	161.84
	10	1.17	0.96	2.23	492.77	9.24	132.00	10.41	135.18	8.685	32.69	1.35	6.49	29.54	192.57
	20	1.25	0.34	2.56	467.44	9.24	129.83	10.49	132.73	8.710	32.75	1.95	10.80	29.35	208.12
DOH WQS (wet)		NTE 10%	14.00	8.50	na	na	na	40.00	250.00	*	**	0.90	1.25	***	****
		NTE 2%	25.00	15.00	na	na	na	60.00	350.00			1.75	2.00		

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary by more than one degree C. from ambient conditions.
***pH shall not deviate more than 0.5 units from a value of 8.1.
**** DO should not be less than 75% saturation.
Peach shaded values exceed the NTE more than 10% of the time DOH WQS for "wet" conditions; blue shaded values exceed the NTE more than 2% of the time.

DFS = distance from shore
S = surface
D = deep

Table 4 (continued). Water chemistry measurements from samples collected for the Windward Shore Protection project on May 2 20, 2023. Nutrient concentrations are shown in micrograms per liter (µg/L). Also shown are the State of Hawaii, Department of Health (DOH) “not to exceed more than 10% of the time” and “not to exceed more than 2% of the time” water quality standards (WQS) for open coastal waters under “wet” conditions. For sampling locations, see Figure 1.

TRANSECT (SECTOR)	DFS (m)	PO_4^{3-} (µg/L)	NO_3^- (µg/L)	NH_4^+ (µg/L)	Si (µg/L)	TOP (µg/L)	TON (µg/L)	TP (µg/L)	TN (µg/L)	pH (rel)	Salinity (ppt)	Chl-a (µg/l)	TURB (ntu)	Temp (ºC)	DO %sat
T-8 (E)	0.1	4.40	127.38	0.25	1266.69	7.16	108.70	11.56	236.33	8.369	31.67	1.93	1.73	29.16	166.05
	1	1.67	50.80	1.09	646.15	8.43	88.49	10.10	140.38	8.387	31.82	0.53	0.79	29.36	162.80
	3	2.23	15.04	1.64	302.05	7.28	92.60	9.51	109.28	8.360	32.96	0.25	0.47	29.16	161.06
	5	1.83	14.22	1.83	270.71	9.66	286.50	11.49	302.55	8.348	33.84	0.50	0.91	28.96	156.67
	10	1.64	6.84	1.54	167.19	8.18	102.90	9.82	111.27	8.339	33.98	0.21	1.19	28.70	153.14
	20	1.64	4.31	1.37	136.67	8.19	99.96	9.83	105.64	8.337	34.33	0.31	0.79	28.58	156.51
T-9 (F)	0.1	3.38	8.96	2.67	166.10	7.28	90.52	10.66	102.16	8.252	34.36	0.35	0.64	28.49	116.26
	1	1.80	3.45	2.17	76.82	8.14	101.33	9.94	106.95	8.274	34.44	0.15	1.27	27.60	133.65
	3	1.27	1.57	4.12	46.96	8.50	86.99	9.77	92.68	8.288	34.58	0.16	1.32	27.20	139.27
	5	1.71	0.99	2.23	37.95	7.15	80.31	8.85	83.52	8.288	34.69	0.18	0.44	27.01	139.07
	10S	1.92	0.75	1.51	35.82	6.29	76.21	8.21	78.47	8.273	34.66	0.18	0.37	26.80	131.29
	10d	2.05	1.14	1.32	35.98	6.09	73.19	8.14	75.64	8.271	34.66	0.13	0.23	26.81	131.26
T-10 (F)	0.1	17.93	152.99	14.91	8730.20	1.72	93.52	19.65	261.42	8.038	17.88	0.68	1.99	26.89	101.93
	1	7.39	37.42	2.63	2762.11	4.51	69.55	11.90	109.61	8.237	29.51	0.30	1.37	27.55	111.87
	3	6.39	33.64	2.41	2525.80	4.47	61.15	10.85	97.19	8.256	29.90	0.38	1.15	27.60	129.09
	5	5.31	19.51	2.52	1616.03	5.23	82.65	10.54	104.68	8.259	31.63	0.32	0.81	27.86	125.22
	10S	3.52	12.88	2.53	1188.34	7.37	80.43	10.88	95.84	8.260	32.44	0.25	1.00	27.80	125.99
	10d	3.81	4.37	2.39	435.34	7.37	96.62	11.19	103.38	8.246	33.84	0.32	0.74	27.09	130.42
T-11 (G)	0.1	1.92	4.10	3.12	132.19	7.24	105.95	9.16	113.18	8.472	34.30	0.32	1.26	28.95	184.33
	1	1.92	2.47	2.13	124.43	6.42	93.82	8.34	98.42	8.479	34.30	0.26	0.66	28.79	131.96
	3	1.58	2.10	2.24	108.49	7.20	100.83	8.78	105.17	8.477	34.37	0.26	0.77	28.64	138.79
	5	0.96	1.62	2.60	44.88	8.36	109.97	9.32	114.20	8.374	34.55	0.33	0.82	28.02	138.23
	10	1.43	1.02	2.51	39.04	6.71	94.97	8.14	98.49	8.358	34.62	0.30	0.65	27.47	137.16
	20	1.55	1.31	2.32	31.56	6.53	93.34	8.08	96.98	8.336	34.66	0.19	1.07	27.28	132.32
T-12 (G)	0.1	2.60	1.38	2.46	140.82	7.69	114.50	10.29	118.34	8.297	34.55	0.95	3.47	27.35	106.34
	1	2.85	1.64	3.86	136.50	8.12	89.51	10.97	95.02	8.301	34.55	0.55	2.06	27.28	115.48
	3	2.67	1.10	2.44	129.57	8.55	98.87	11.21	102.41	8.298	34.51	0.71	1.03	27.23	117.15
	5	2.54	1.20	2.38	95.93	7.71	88.39	10.25	91.97	8.293	34.58	0.36	1.34	26.99	120.79
	10S	1.95	1.33	2.31	101.01	9.06	100.45	11.01	104.09	8.297	34.55	0.38	1.28	27.26	116.25
	10D	2.02	bdl	3.35	66.07	8.95	105.23	10.96	108.60	8.285	34.58	0.29	1.75	27.26	116.26
T-13 (H)	0.1	1.76	295.29	16.11	1027.16	9.80	279.28	11.57	590.69	8.607	31.19	2.52	1.33	30.83	181.97
	1	1.44	198.28	2.45	792.59	8.35	233.35	9.79	434.08	8.667	31.59	0.92	1.52	30.84	187.02
	3	1.05	57.14	4.19	392.04	8.06	135.59	9.10	196.92	8.706	32.36	0.68	2.58	30.78	204.30
	5	1.98	9.43	2.21	190.01	7.02	138.55	9.01	150.19	8.701	33.04	0.66	1.94	30.55	211.56
	10	1.12	2.97	2.18	131.32	6.51	101.84	7.62	106.99	8.663	33.71	0.41	1.88	29.99	210.54
	20	1.64	1.64	3.47	111.71	5.64	100.27	7.29	105.38	8.619	34.09	1.02	1.81	29.68	205.99
DOH WQS (wet)	NTE 10%		14.00	8.50	na	na	na	40.00	250.00	*	**	0.90	1.25	***	****
	NTE 2%		25.00	15.00	na	na	na	60.00	350.00			1.75	2.00		

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary by more than one degree C. from ambient conditions.
***pH shall not deviate more than 0.5 units from a value of 8.1.
**** DO should not be less than 75% saturation.
Peach shaded values exceed the NTE more than 10% of the time DOH WQS for "wet" conditions; blue shaded values exceed the NTE more than 2% of the time.

DFS = distance from shore
S = surface
D = deep

Table 5. Species of Algae Detected within Each Sector and Number of Sectors in which each Species was Present

DIVISION	SPECIES	SECTOR							# OF SITES
		A	C	D	E	F	G	H	
CHLOROPHYTA	*Avrainvillea amadelpha*	-	-	-	-	-	-	C	1
	Caulerpa webbiana	-	-	R	-	-	-	-	1
	Cladophora sp.	-	-	R	-	-	R	-	2
	Codium arabicum	-	R	-	-	-	-	-	1
	Codium edule	-	R	-	-	-	R	-	2
	Dictyosphaeria cavernosa	C	C	C	C	-	A	R	6
	Dictyosphaeria versluysii	R	A	-	-	-	A	R	4
	Halimeda discoidea	A	C	A	A	A	A	C	7
	Halimeda opuntia	A	C	A	A	A	A	A	7
	Microdictyon setchellianum	A	-	A	A	-	A	-	4
	Neomeris spp.	R	R	C	R	C	C	-	6
	Pseudobryopsis oahuensis	-	-	R	-	-	-	-	1
	Ulva spp.	-	-	-	-	-	R	A	2
	Ventricaria ventricosa	-	-	R	-	-	-	-	1
CYANO-BACTERIA	General	C	C	C	C	C	C	C	7
	Hormothamnion enteromorphioides	R	R	-	R	-	-	-	3
	Leptolyngbya crosbyana	R	-	-	R	-	R	-	3
	Lyngbya majuscula	C	A	A	C	R	-	C	6
	Symploca hydnoides	-	-	-	R	-	-	-	1
OCHROPHYTA	*Dictyota acutiloba*	R	-	C	C	-	-	A	4
	Dictyota ciliolata	-	-	C	C	-	-	-	2
	Dictyota sandvicensis	R	R	A	-	-	R	C	5
	Padina australis	-	R	C	C	-	C	A	5
	Padina sanctae-crucis	A	R	A	A	C	A	A	7
	Sphacelaria spp.	A	-	-	C	-	R	-	3
	Turbinaria ornata	C	R	R	-	-	R	R	5
RHODOPHYTA	*Acanthophora pacifica*	-	-	R	-	-	-	-	1
	Acanthophora spicifera	A	-	A	C	A	C	A	6
	Amansia glomerata	-	-	-	-	-	C	-	1
	Amphiroa beauvoisii	-	-	-	-	-	R	-	1
	Asparagopsis taxiformis	C	R	-	-	C	R	C	5
	Crustose Coralline Algae	C	C	C	C	C	C	C	7
	Galaxaura rugosa	R	R	R	R	-	C	-	5
	Gracilaria salicornia	-	-	A	-	C	-	A	3
	Laurencia spp.	C	-	C	C	-	-	R	4
	Liagora ceranoides	R	C	-	R	-	R	-	4
	Wrangelia elegantissima	R	-	R	-	-	C	C	4
TOTAL NUMBEROF SPECIES OBSERVED		22	18	24	20	10	24	19	37

Notes: R = Rare, C = Common, A = Abundant

Table 6. Species of Coral Detected within Each Sector and Number of Sectors in which each Species was Present

SPECIES	SECTOR							# OF SITES
	A	C	D	E	F	G	H	
Cyphastrea ocellina	R	R	-	-	R	R	-	4
Montipora capitata	C	R	C	R	C	-	R	6
Montipora flabellata	R	-	R	-	-	-	-	2
Montipora patula	C	R	C	R	C	-	-	5
*Palythoa tuberculosa**	-	R	-	-	R	-	-	2
Pavona varians	-	-	R	-	-	-	-	1
Pocillopora damicornis	R	C	R	R	R	C	-	6
Pocillopora grandis	R	-	-	-	-	-	-	1
Pocillopora ligulata	R	-	-	-	-	-	-	1
Pocillopora meandrina	C	R	R	C	C	C	-	6
Porites compressa	R	R	R	C	R	C	-	6
Porites evermanni	R	R	R	R	C	R	R	7
Porites lobata	C	C	C	C	C	C	R	7
Psammocora stellata	R	R	-	-	R	R	-	4
TOTAL # OF SPECIES OBSERVED	12	10	9	7	10	7	3	14

Notes: *R* = Rare, *C* = Common, *A* = Abundant
**Palythoa tuberculosa* is a zoanthid, not a true stony coral.

Table 7. Species of Invertebrates Detected within Each Sector and Number of Sectors in which each Species was Present

	SPECIES	COMMON NAME	SECTOR							# OF SITES
			A	C	D	E	F	G	H	
SEA CUCUMBERS	*Actinopyga obesa*	Plump Sea Cucumber	R	-	-	-	R	R	-	3
	Actinopyga varians	White-Spotted Sea Cucumber	-	R	R	-	-	R	-	3
	Holothuria atra	Black Sea Cucumber	-	-	R	R	-	C	-	3
	Holothuria whitmaei	Teated Sea Cucumber	-	-	-	-	-	R	-	1
	Holothuria cinerascens	Ashy Sea Cucumber	-	-	-	-	-	R	C	2
SEA URCHINS	*Echinometra mathaei*	Pale Rock-Boring Sea Urchin	C	R	C	-	C	C	-	5
	Echinothrix diadema	Blue-Black Urchin	-	-	-	-	R	-	-	1
	Heterocentrotus mamillatus	Slate Pencil Urchin	-	-	-	-	R	-	-	1
	Tripneustes gratilla	Pebble Collector Urchin	-	-	-	-	R	-	-	1
OTHER	Porifera (phylum)	Sponge	-	-	-	-	R	-	-	1
	Gastropod (class)	Snails	-	-	-	-	-	-	R	1
	Zoantharia (order)	Zoanthids	-	R	R	-	R	-	C	4
TOTAL NUMBER OF SPECIES OBSERVED			2	3	4	1	7	6	3	12

Notes: R = Rare, C = Common, A = Abundant

Table 8. Species of Fish Detected within Each Sector and Number of Sectors in which each Species was Present

SECTOR:	A	B	D	E	F	G	H	#of sites
Aulostomidae (Trumpetfishes)								
Aulostomus chinensis	R	-	-	R	-	-	-	2
Acanthuridae (Surgeonfishes)								
Acanthurus blochii	-	-	R	-	-	-	-	1
A. dussumieri	-	-	R	-	-	-	-	1
A. nigrofuscus	-	-	-	-	C	R	-	2
A. triostegus	R	C	C	R	C	R	R	7
A. xanthopterus	-	-	C	-	-	-	-	1
Zebrasoma flavescens	-	-	-	R	-	-	-	1
Z. veliferum	R	-	-	-	-	-	-	1
Apogonidae (Cardinalfishes)								
Pristiapogon kalopterus	-	-	C	R	-	-	-	2
Balistidae (Triggerfishes)								
Rhinecanthus rectangulus	R	R	R	-	-	-	-	3
Belonidae (Needlefishes)								
Platybelone argalus platyura	C	-	-	-	-	-	-	1
Blenniidae (Blennies)								
Exallias brevis	-	-	R	-	-	-	-	1
Chaetodontidea (Butterflyfishes)								
Chaetodon auriga	R	-	R	-	-	-	-	2
C. lunula	-	-	R	R	-	R	R	4
C. milliaris	-	-	C	R	-	-	-	2
C. quadrimaculatus	R	-	-	-	-	-	-	1
C. unimaculatus	-	-	R	-	-	-	-	1
Holocentiridae (Squirrelfishes)								
Myripristis kuntee	-	-	R	-	-	-	-	1
Neoniphon sammara	R	-	-	-	-	-	-	1
Labridae (Wrasses)								
Cheilio inermis	-	-	-	-	R	-	-	1
Novaculichthys taeniourus	-	-	-	-	R	-	-	1
Pseudocheilinus octotaenia	-	-	R	-	-	-	-	1
Stethojulis balteata	R	-	R	R	C	R	-	5
Thalassoma duperrey	C	R	C	C	C	R	-	6
T. purpureum	-	-	-	-	R	-	-	1
T. quinquevittatum	-	-	-	-	-	-	R	1
Thalassoma trilobatum	-	-	-	R	-	-	-	1
Lutjanidae (Snapper)								
Lutjanus fulvus	-	-	-	-	-	R	-	1
Mullidae (Goatfishes)								
Mulloidichthys flavolineatus	C	-	-	-	-	-	-	1
M. vanicolensis	C	-	-	-	-	-	-	1
Upeneus taeniopterus	-	R	-	-	-	-	-	1
Ostraciidae (Boxfishes)								
Ostracion meleagris	-	-	R	R	R	-	-	3
Pomacentridae (Damselfishes)								
Abudefduf abdominalis	-	-	C	A	-	C	-	3
A. vaigiensis	C	-	C	A	-	-	R	4
Dascyllus albisella	C	-	A	C	C	-	R	5
Plectroglyphidodon imparipennis	-	-	R	-	-	-	-	1
Stegastes marginatus	R	-	-	-	-	-	-	1
Sphyraenidae (Barracudas)								
Sphyraena barracuda	-	-	R	-	-	-	-	1
Synodontidae (Lizardfishes)								
Synodus sp.	R	-	-	-	-	-	-	1
Tetraodontidae (Pufferfishes)								
Canthigaster amboinensis	R	R	R	-	-	R	-	4
C. jactator	R	R	C	R	-	-	-	4
Zanclidae (Moorish Idol)								
Zanclus cornutus	C	R	-	-	-	-	-	2
Eels								
Not Identified	-	-	-	-	-	-	R	1
Echidna nebulosa	R	-	R	-	-	-	-	2
TOTAL NUMBER OF SPECIES	20	7	24	14	9	8	6	44

Notes: R = Rare, C = Common, A = Abundant

V. References Cited

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Officer, C. B. 1979. Discussion of the behavior of nonconservative dissolved constituents in estuaries. Est. Coast. Mar. Sci. 9:569 576.

Smith, S. V. and M. J. Atkinson 1993. Mass balance analysis of C, N, and P fluxes in coastal water bodies, including lagoons. Coastal Lagoon Processes. (Ed) B. Kjerfve, Elsevier Oceanography Series, 60. pp 123-145.

"Stinging Seaweed Disease." State of Hawaii, Department of Health, Disease Outbreak Control Division, July 19, 2022, https://health.hawaii.gov/docd/disease_listing/stinging-seaweed-disease/.

Figure 1a. Windward Shore Protection Baseline Marine Assessment survey areas. Yellow lines indicate survey areas A through C. Blue circles indicate water chemistry transects 1 through 5.

Figure 1b. Windward Shore Protection Baseline Marine Assessment survey areas. Yellow lines indicate survey areas D through H. Blue circles indicate water chemistry transects 6 through 13.

Figure 2a. Representative images of the shoreline at northerly transects, “T”; sectors are indicated by letters in parentheses.

Figure 2b. Representative images of the shoreline at southerly transects, “T”; sectors are indicated by letters in parentheses.

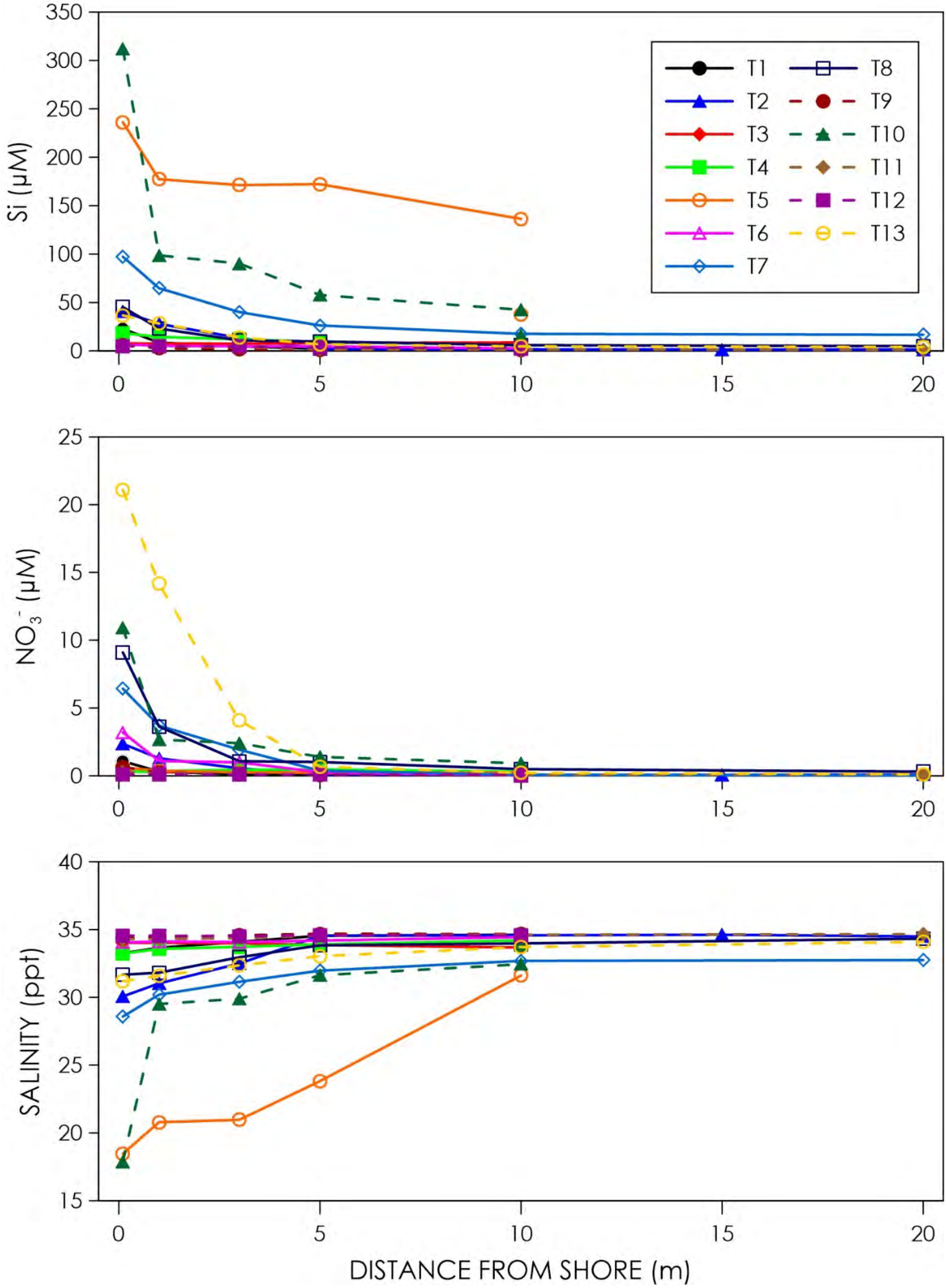


Figure 3. Plots of silica, nitrate nitrogen, and salinity for samples collected along thirteen transects extending from the shoreline to 10–20 meters (m) offshore.

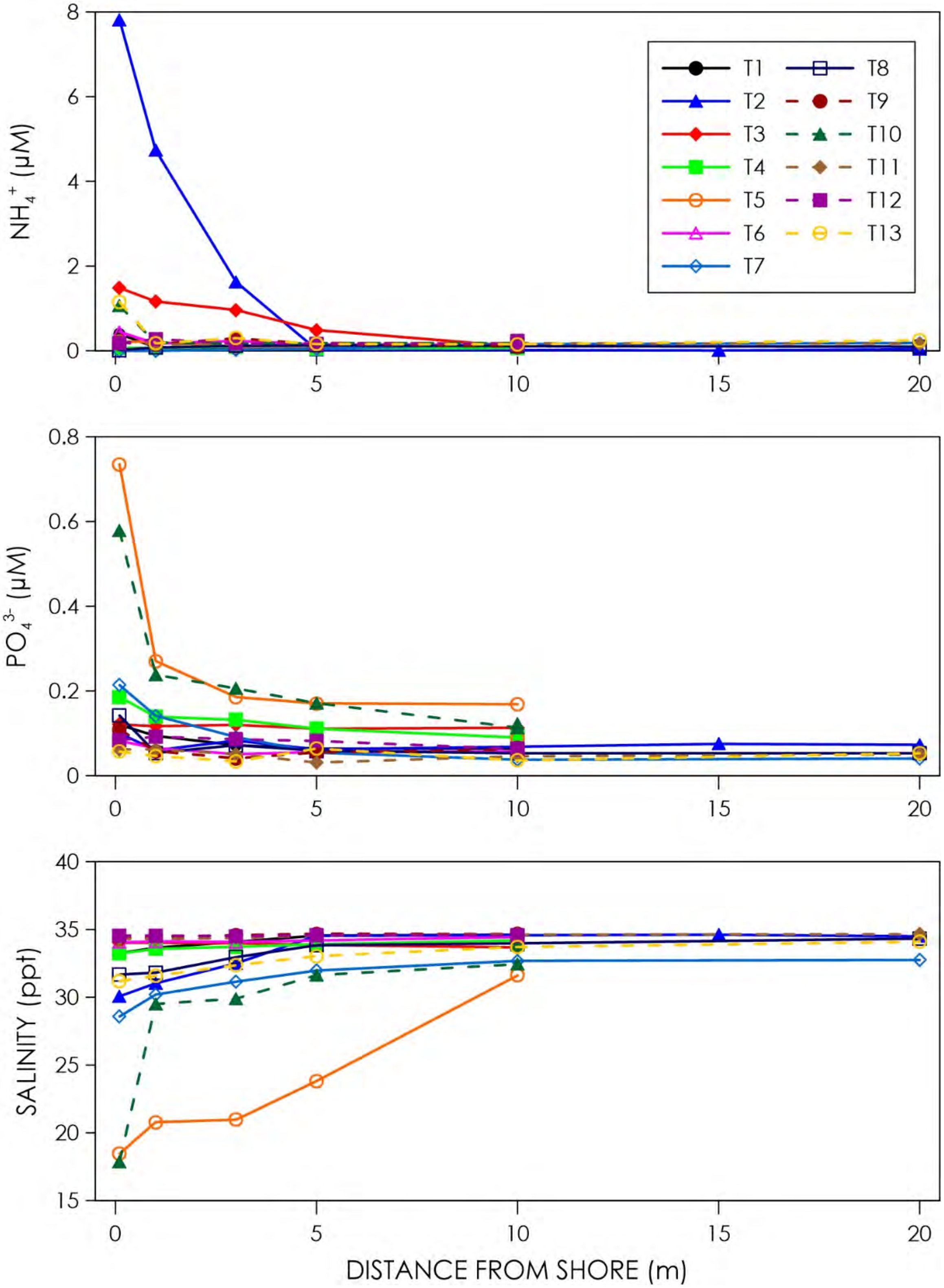


Figure 4. Plots of ammonium nitrogen, phosphate phosphorous, and salinity for samples collected along thirteen transects extending from the shoreline to 10–20 meters (m) offshore.

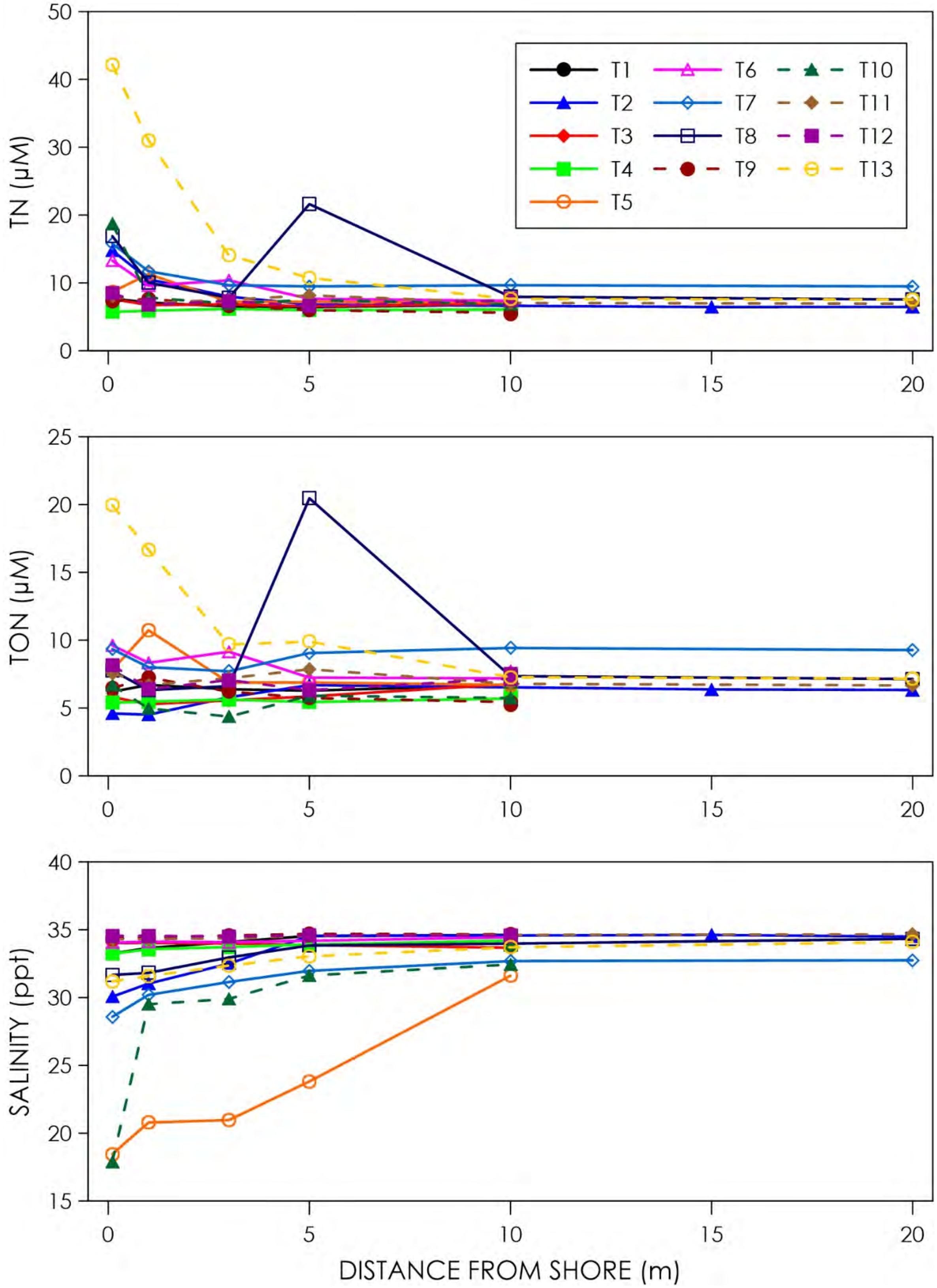


Figure 5. Plots of total nitrogen, total organic nitrogen, and salinity for samples collected along thirteen transects extending from the shoreline to 10–20 meters (m) offshore.

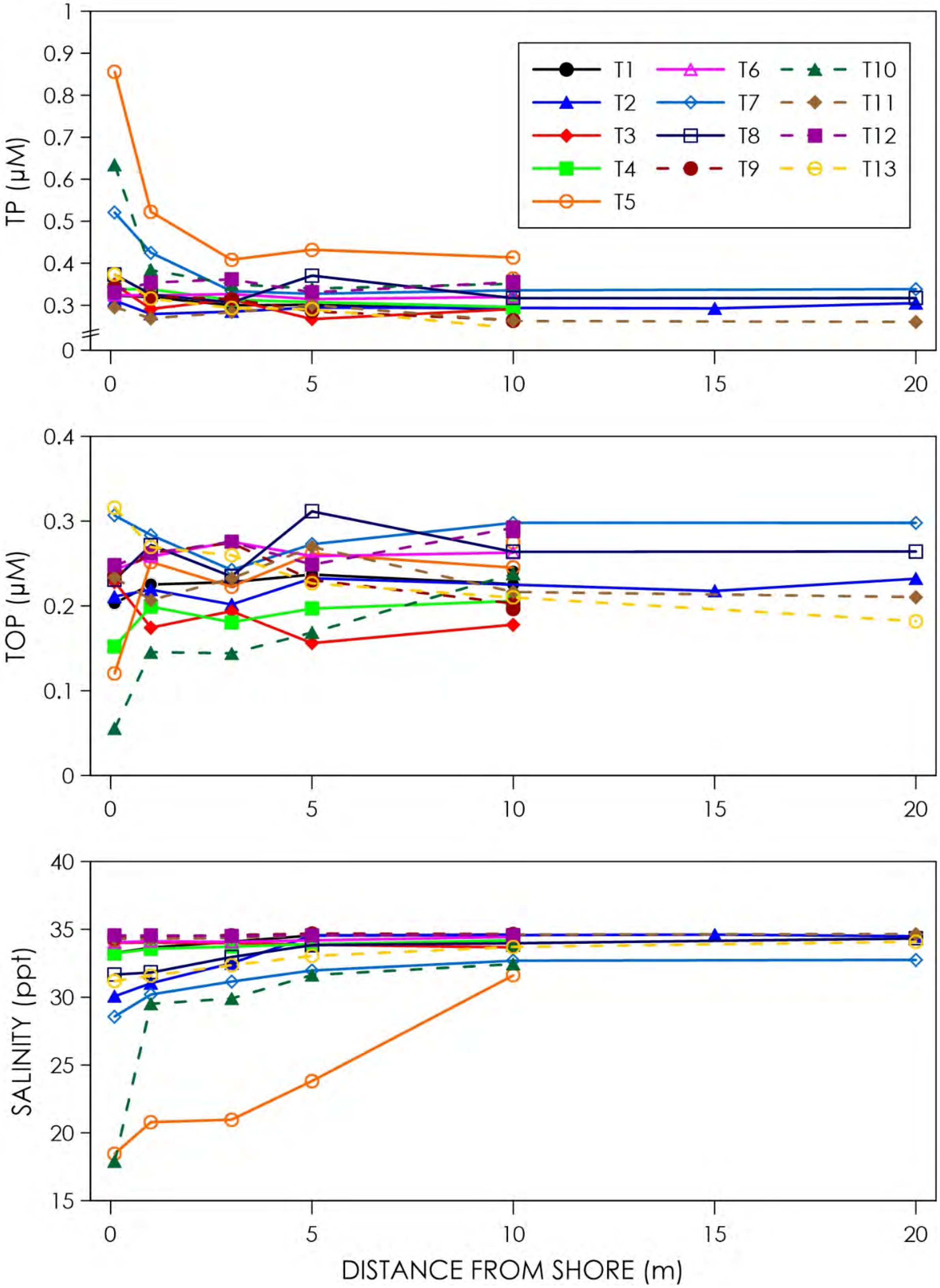


Figure 6. Plots of total phosphorous, total organic phosphorous, and salinity for samples collected along thirteen transects extending from the shoreline to 10–20 meters (m) offshore.

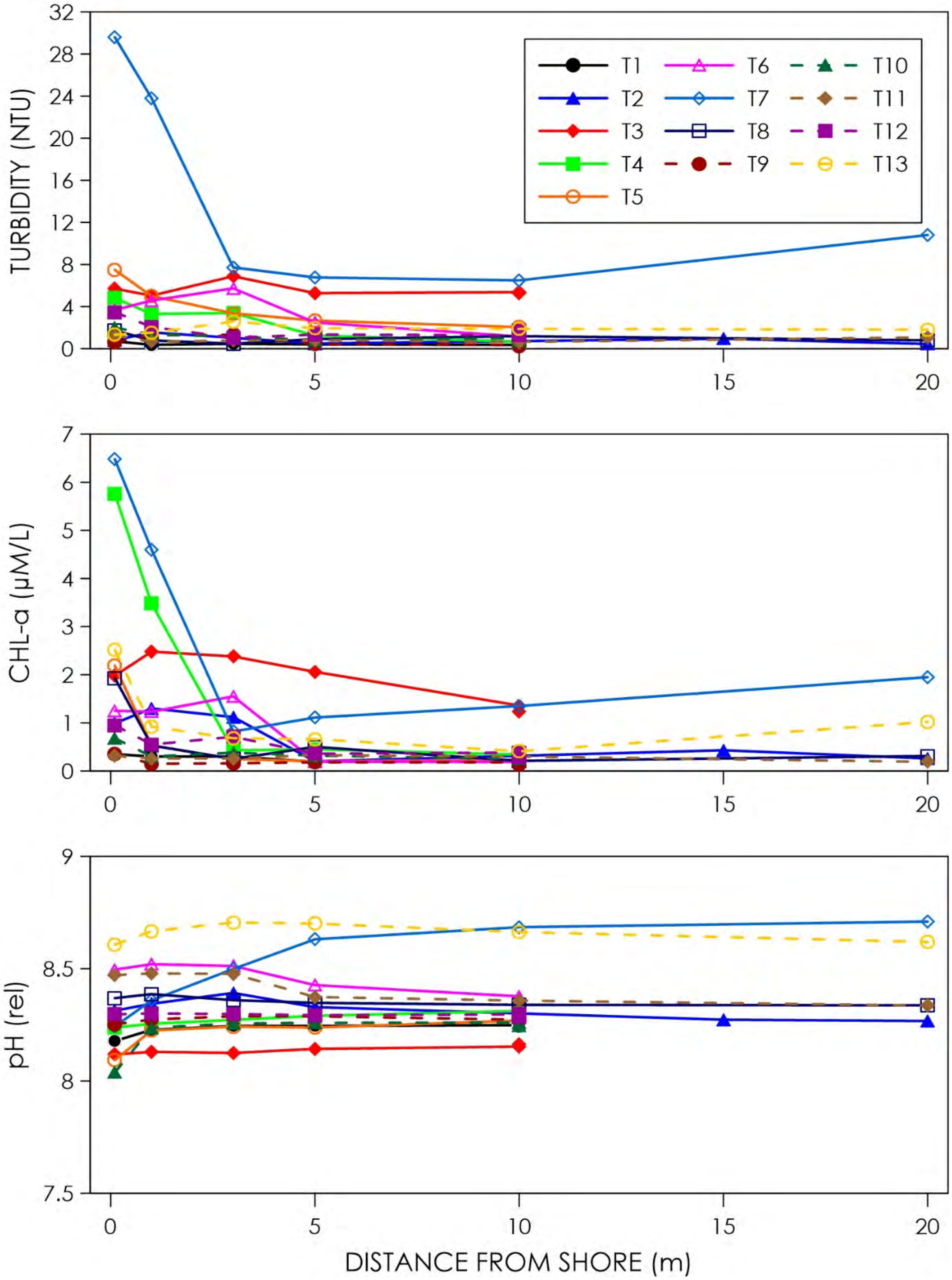
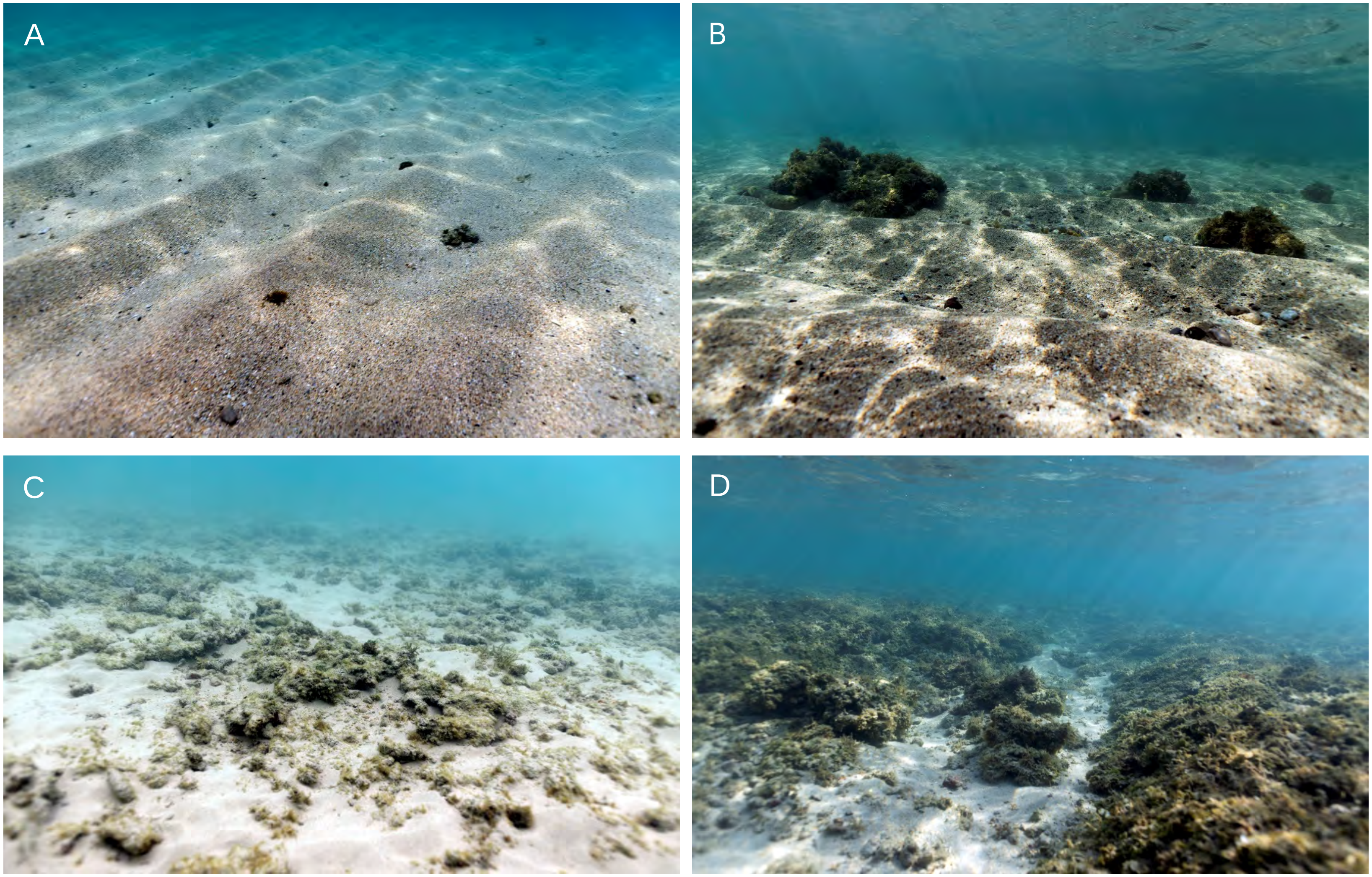
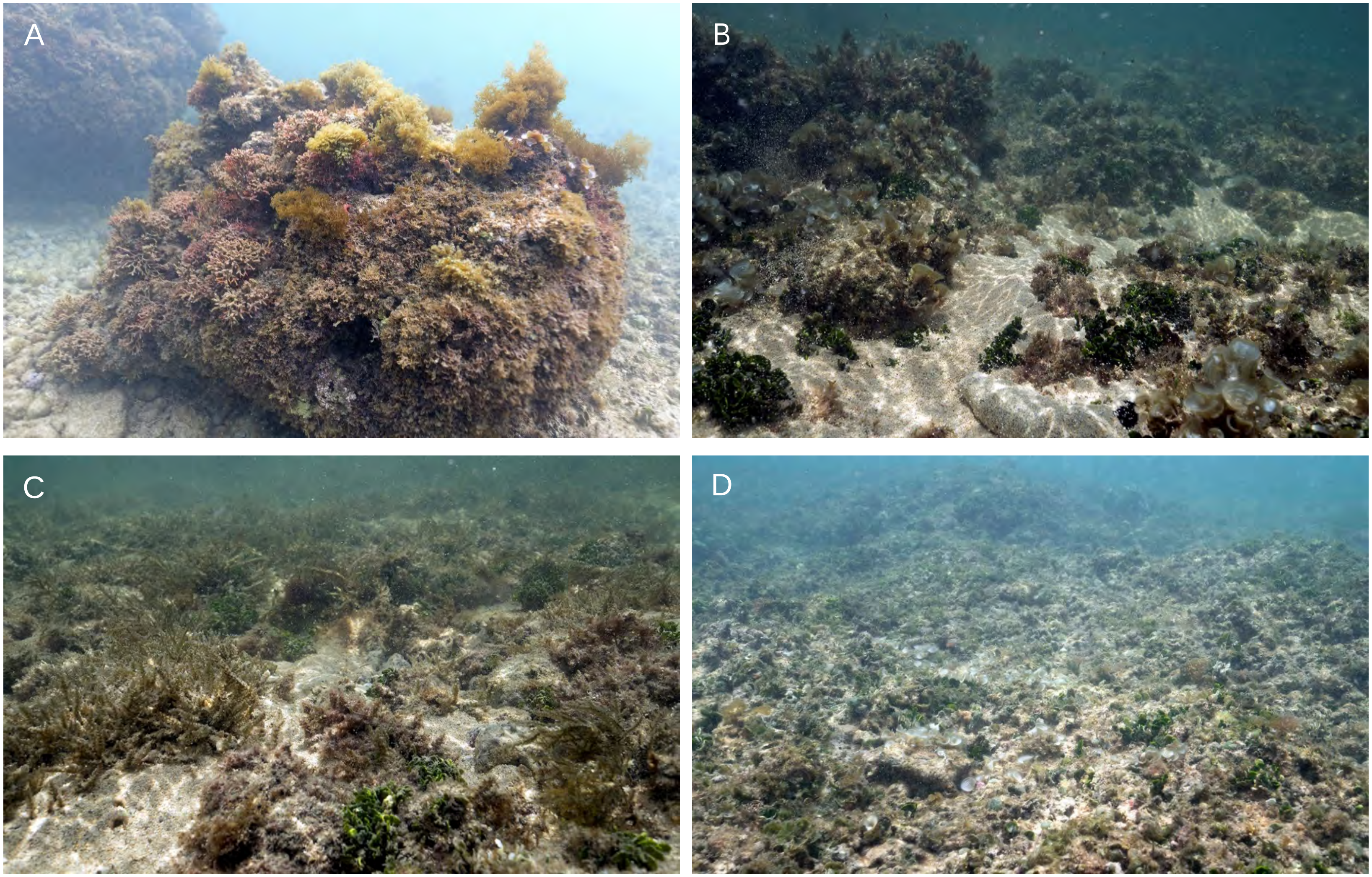


Figure 7. Plots of turbidity, chlorophyll *a*, and pH for samples collected along thirteen transects extending from the shoreline to 10–20 meters (m) offshore.



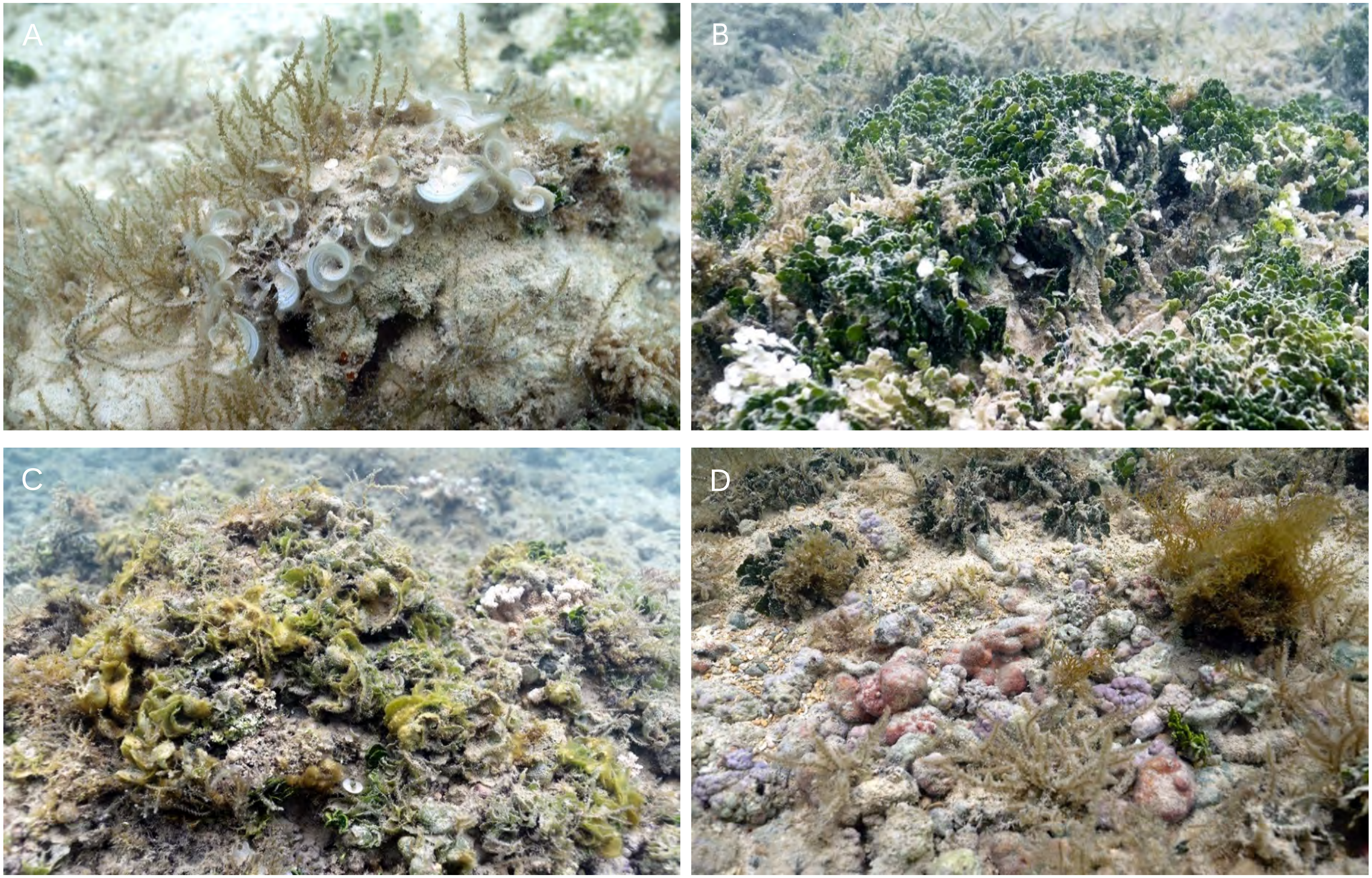
Notes: A, B, and D – Sector A; C – Sector E.

Figure 8. Representative Images of Transition from Nearshore Sand Plains to Primarily Hard Bottom Substrate



Notes: A – Boulder covered in mixed community of macroalgae including *Dictyota* spp. and *Galaxaura rugosa* at Sector D; B – Mixed macroalgal community on sand and hard substrate at Sector G; C – Mixed macroalgal community on sand and hard substrate at Sector H; and D – Mixed macroalgae community on hard bottom including *Halimeda* spp. and *Padina* spp. at Sector E.

Figure 9. Representative Images of Macroalgae

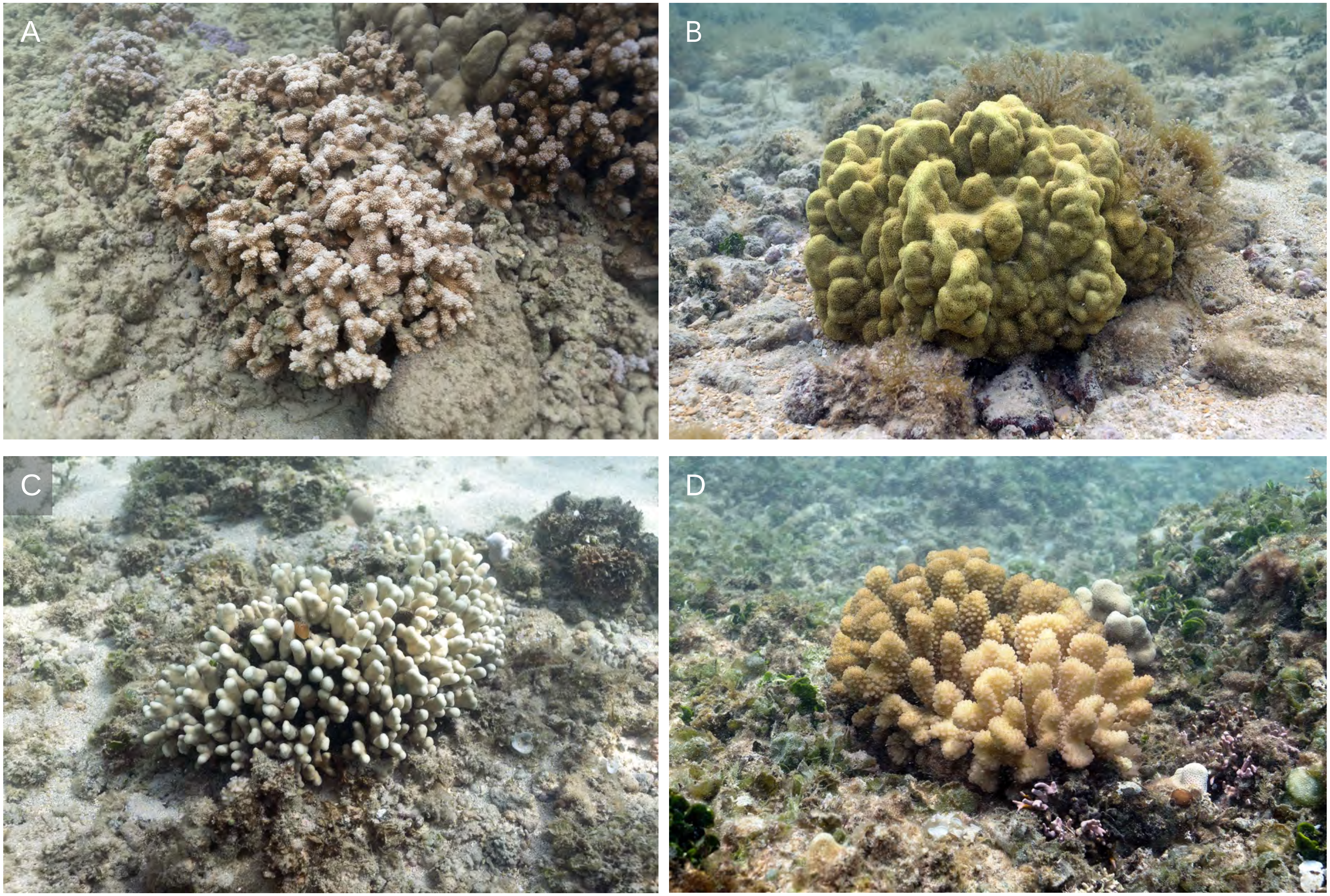


Notes: A – *Acanthophora spicifera* (brown stalks) and *Padina sanctae-crucis* (pale leaves) at Sector H; B – *Halimeda opuntia* at Sector H; C – *Microdictyon setchellianum* at Sector D; and D – Crustose coralline algae (red, purple) and *Dictyota acutiloba* (upper right) at Sector E.

Figure 10. Representative Images of Macroalgae

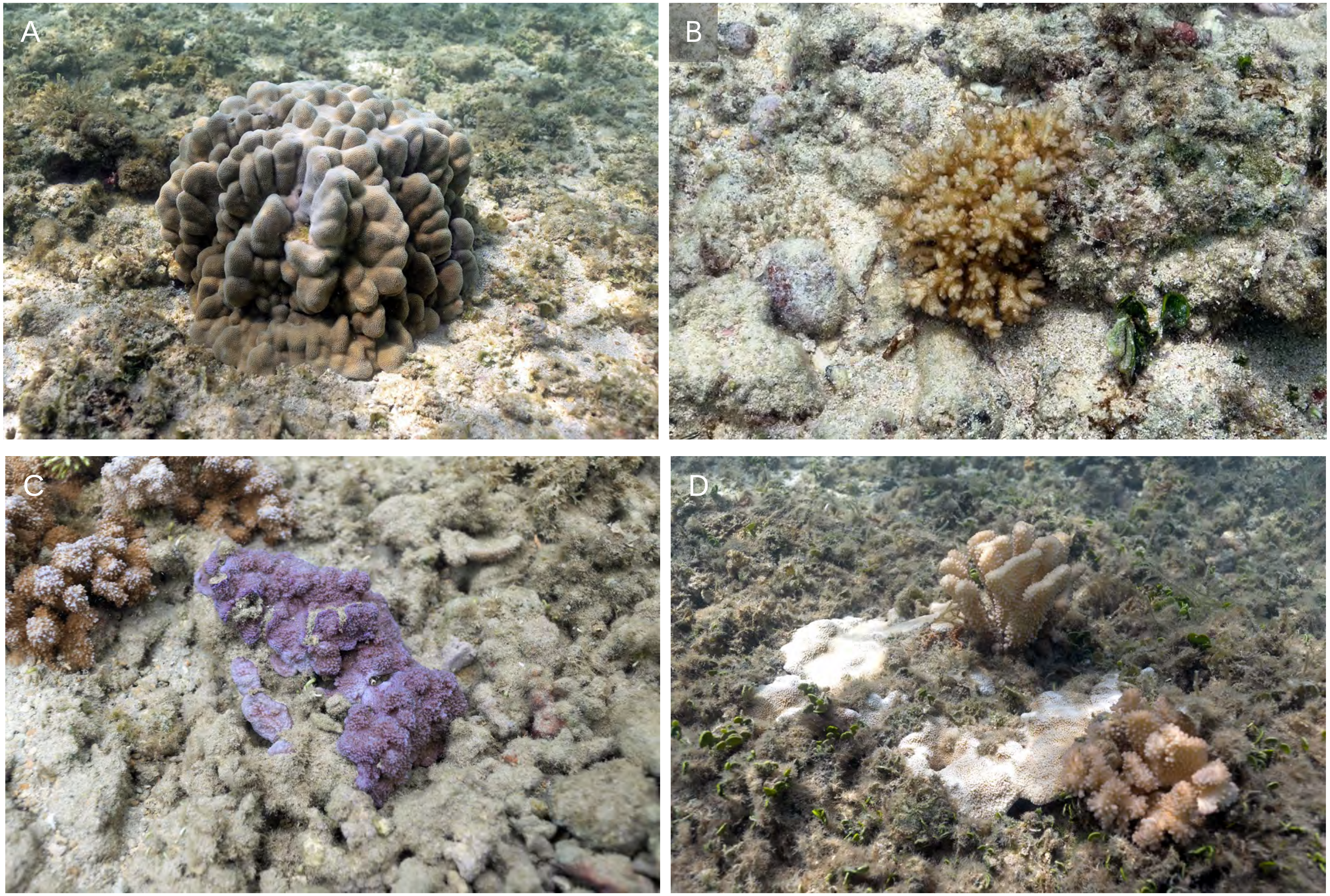
Notes: A – Populating hard substrate; B – Surrounding a *Pocillopora meandrina* colony; C – With mixed macroalgae and *Actinopyga varians*; and D – populating large boulders.

Figure 11. Representative Images of the Cyanobacteria *Lyngbya majuscula* at Sector C



Notes: A – *Montipora capitata* at Sector D; B – *Porites lobata* at Sector H; C – *Porites compressa* at Sector A; and D – *Pocillopora meandrina* at Sector G.

Figure 12. Representative Images of Coral Species



Notes: A – *Porites evermanni* at Sector A; B – *Pocillopora damicornis* at Sector G; C – *Montipora flabellata* at Sector D; and D – *Pocillopora grandis* (background), *Montipora patula* (encrusting), and *Pocillopora meandrina* (foreground) at Sector A.

Figure 13. Representative Images of Coral Species

Notes: A – *Cyphastrea ocellina* at Sector G; B – *Pocillopora ligulata* at Sector A; C – *Psammocora stellata* at Sector A; and D – *Palythoa tuberculosa* at Sector C.

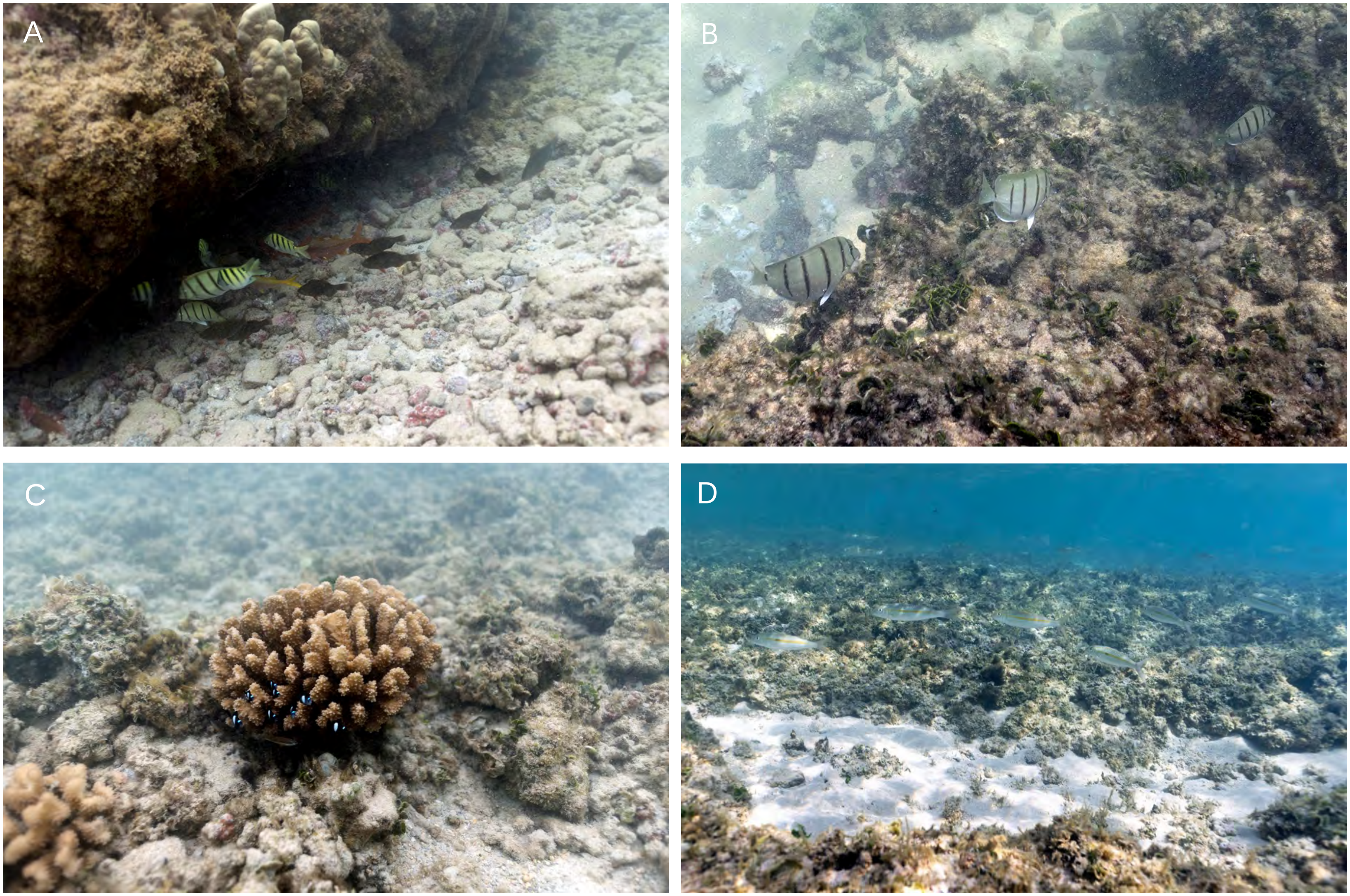
Figure 14. Representative Images of Coral Species

Notes: A and B – Truncated corals (microatolls) having reached the upper limit of growth in the water column at Sector A; C – Coral assemblage at Sector A; and D – Colony of *Porites evermanni* with discoloration indicating disease at Sector G.

Figure 15. Representative Images of Coral Species

Notes: A – *Echinometra mathaei* at Sector G; B – *Holothuria cinerascens* tentacles at Sector H; C – *Actinopyga varians* at Sector D; and D – Unidentified zoanthids at Sector H.

Figure 16. Representative Images of Non-Coral Invertebrates



Notes: A – Mixed school of surgeonfish, damselfish, goatfish, and parrotfish at Sector D; B – *Acanthurus triostegus* at Sector G; C – Juvenile *Dascyllus albisella* at Sector H; and D – School of *Mulloidichthys flavovittata* at Sector A.

Figure 17. Representative Images of Fish

Appendix C:
Archaeological Literature Review and Field Inspection Report

Archaeological Literature Review & Field Inspection Kamehameha Highway – Windward Coast Shoreline Mitigation Project Multiple Ahupua‘a, Ko‘olauloa & Ko‘olaupoko Districts, O‘ahu Island TMK: (1) 4-9, 5-1 & 5-3-various plats & parcels

Existing boulder revetment just south of Swanzy Beach Park, Ka‘a‘awa; view southeast

Prepared for
AECOM Corporation
Honolulu, Hawai‘i

Prepared by
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Trisha K. Watson, Ph.D.
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Honolulu, Hawai‘i

August 2022

Management Summary

This report was completed at the request of AECOM Corp., in support of the Hawaiʻi Department of Transportation's project to develop mitigation solutions to ocean-wave erosion and undermining of Kamehameha Highway along portions of the windward Oʻahu coastline. The project area generally extends from Hauʻula Homestead Road (Hauʻula town) to Kualoa Point. Because the project area consists of nine (9) sections extending several miles from Hauʻula to Kualoa, it has been divided into three Sheets (designated Sheets 1–3) for reporting and analytical purposes. The project area traverses coastal portions of the following 13 ahupuaʻa (in order from north to south):

Sheet 1 (see Figure 3)
- Section 1 - Hauʻula, Mākao and Kapaka
- Section 2 - Kaluanui
- Section 3 - Haleʻaha, Kapano, Puheʻemiki and Waiʻono

Sheet 2 (see Figure 4)
- Section 4 – Kahana, Makaua 2, Makaua 1 and Kaʻaʻawa
- Section 5 – Kaʻaʻawa
- Section 6 – Kaʻaʻawa
- Section 7 – Kaʻaʻawa and Kualoa 2

Sheet 3 (see Figure 5)
- Section 8 – Kualoa 2 and Kualoa 1
- Section 9 – Kualoa 1

Soils data demonstrate that a high proportion of the project area sections are within or immediately adjacent to Jaucas sand. These deposits are generally the most archaeologically sensitive on Oʻahu since they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The objectives of this Archaeological Literature Review and Field Inspection (ALRFI) were to: (1) document and describe the project area's land-use history in the context of both its traditional Hawaiian character as well as its historic-period changes; (2) identify any archaeological historic properties or component features in and immediately adjacent to the project area; and (3) prove information relevant to the likelihood of encountering historically-significant cultural deposits in subsurface context during potential erosion-mitigation activities. Historic bridges are not covered under this report. This ALRFI is not an archaeological inventory survey (AIS), and it is not intended for formal review by the State Historic Preservation Division (SHPD). It may be used, however, to support the project proponent's consultation with the SHPD in compliance with applicable state and federal historic preservation and environmental laws.

As described in this report, archival research and fieldwork demonstrate several relevant findings: (1) Other than a few rock walls dating from the historic or early modern period and the ruins of an old sugar mill known as Wilikaʻai (at Kualoa), there are no above-ground archaeological sites or historic properties within, or in the immediate vicinity of, the highway ROW/project area; (2) Only one above-ground traditional Hawaiian site (a rock terrace, SIHP #

50-80-06-6850) has been documented within the 500-ft. buffer around the project area (and this site is about 500 ft. mauka of the highway); and (3) By far, the two most common archaeological site types within, or in the immediate vicinity of, the highway ROW/project area are (a) human burials in subsurface context (which include intact burials as well as a wide variety of disturbed sites with incomplete/fragmentary sets of human skeletal remains) and (b) subsurface cultural layers (i.e., intact soil-sediments [mostly Jaucas sand deposits] that are culturally-enriched with traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation), some of which also include human burials. Some of these sites with subsurface cultural layers and human burials are actively eroding into the ocean.

Based on all available evidence, including project-specific findings outlined in Section 4.2 (Survey Results), which integrated previous archaeological findings (Section 3) with soil mapping data (Section 1) and observations made during the fieldwork for this project, our recommendations are as follows: (1) Sections 1, 3, 6, 7 and 9 are highly likely to contain significant historic properties, or component features therein, in subsurface context, likely consisting of human burials and/or subsurface cultural layers. In some cases, as outlined in Section 4.2, it is expected that lateral extensions of previously-identified sites will be encountered if ground disturbance takes places along the mauka or makai edges of the highway ROW. All work in these sections should be subject to archaeological monitoring. (2) The remaining sections (2, 4, 5 and 8) have a moderate potential to contain additional significant historic properties, or component features therein, in subsurface context, including human burials and/or subsurface cultural layers. All work in these sections should be subject to archaeological monitoring. (3) An approximately 100-meter long mortared rock wall (SIHP # 50-80-06-7922) dating from the original construction of the Kamehameha Highway in the late 1920s (documented by Rieth et al. 2017) along the makai shoulder of the highway in section 4 needs to be taken into account (i.e., not altered or damaged without express written consent of the SHPD). (4) The SHPD-Archaeology Branch should be consulted on archaeological matters associated with proposed ground disturbance associated with the proposed shoreline mitigation project.

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Table

Section 1 Introduction

1.1 Project Background

This report was completed at the request of AECOM Corp., in support of the Hawaiʻi Department of Transportation's (HDOT) project to develop mitigation solutions to ocean-wave erosion and undermining of Kamehameha Highway along portions of the windward Oʻahu coastline. The project area generally extends from Hauʻula Homestead Road (Hauʻula town) to Kualoa Point. Most of the project area is within the Koʻolauloa District; a short section extends into Koʻolaupoko District (Figure 1 and Figure 2).

The client-provided project description is to:

> Develop mid-term shoreline mitigation solution(s) to address current undermining of Kamehameha Highway due to wave erosion. Nine (9) locations along the Windward Coast of Oʻahu have been identified for mitigation – located in stretches of unimproved shoreline (i.e., no development) where existing erosion measures are currently failing or non-existent. It is anticipated that mitigation solutions will consider rock revetment, vertical sheet pile, beach fill, etc. The exact treatment, or combination of treatments, at each area will be determined upon site condition and coordination with HDOT. Minor roadway realignment (horizontal and vertical) may need to be considered in the environmental evaluation, but it is not anticipated to be a viable mid-term solution (should be considered as a long term solution). Project impacts are expected to be primarily between the roadway and ocean; at worst case, project impacts are unlikely to encroach mauka of the highway right of way.

Because the project area consists of nine (9) sections of the Kamehameha Highway extending several miles from Hauʻula to Kualoa, it has been divided into three Sheets (designated Sheets 1–3) for reporting and analytical purposes (Figure 3 to Figure 5). This heuristic device is used throughout the introductory, background and results sections below.

The project area traverses the coastline of 13 ahupuaʻa (in order from north to south):

- Sheet 1 (see Figure 3)
  - Section 1 - Hauʻula, Mākao and Kapaka
  - Section 2 - Kaluanui
  - Section 3 - Haleʻaha, Kapano, Puheʻemiki and Waiʻono
- Sheet 2 (see Figure 4)
  - Section 4 – Kahana, Makaua 2, Makaua 1 and Kaʻaʻawa
  - Section 5 – Kaʻaʻawa
  - Section 6 – Kaʻaʻawa
  - Section 7 – Kaʻaʻawa and Kualoa 2
- Sheet 3 (see Figure 5)
  - Section 8 – Kualoa 2 and Kualoa 1
  - Section 9 – Kualoa 1

Figure 6 to Figure 8 depict the TMK locations for Sheets 1–3, which consist of the state-owned highway right-of-way (ROW) and immediately adjacent lands in TMK (1) 4-9, 5-1 and 5-3-various plats and parcels.

Figure 9 to Figure 11 depict the soil types for Sheets 1–3, which demonstrate that a high proportion of the project area sections are within or immediately adjacent to Jaucas sand. These deposits are generally the most archaeologically sensitive on Oʻahu since they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The objectives of this Archaeological Literature Review and Field Inspection (ALRFI) are the following: (1) documentation and description of the project area's land-use history in the context of both its traditional Hawaiian character as well as its historic-period changes; (2) identification of any archaeological historic properties or component features in and immediately adjacent to the project area; and (3) providing information relevant to the likelihood of encountering historically-significant cultural deposits in subsurface context during potential erosion-mitigation activities.

Historic bridges are not covered under this report.

This ALRFI is not an archaeological inventory survey (AIS), and it is not intended for formal review by the State Historic Preservation Division (SHPD). It may be used, however, to support the project proponent's consultation with the SHPD in compliance with applicable state and federal historic preservation and environmental laws.

As described in this report, archival research and fieldwork demonstrate several relevant findings: (1) Other than a few rock walls dating from the historic or early modern period and the ruins of an old sugar mill known as Wilikaʻai (at Kualoa), there are no above-ground archaeological sites or historic properties within, or in the immediate vicinity of, the highway ROW/project area; (2) Only one above-ground traditional Hawaiian site (a rock terrace, SIHP # 50-80-06-6850) has been documented within the 500-ft. buffer around the project area (and this site is about 500 ft. mauka of the highway); and (3) By far, the two most common archaeological site types within, or in the immediate vicinity of, the highway ROW/project area are (a) human burials in subsurface context (which include intact burials as well as a wide variety of disturbed sites with incomplete/fragmentary sets of human skeletal remains) and (b) subsurface cultural layers (i.e., intact soil-sediments [mostly Jaucas sand deposits] that are culturally-enriched with traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation), some of which also include human burials. Some of these sites with subsurface cultural layers and human burials are actively eroding into the ocean.

Figure 1. Portion of 2017 U.S. Geological Survey (USGS) topographic map (Kahana and Hauula quadrangles) showing project area as nine (9) sections (base map source: USGS online at http://ngmdb.usgs.gov/topoview)

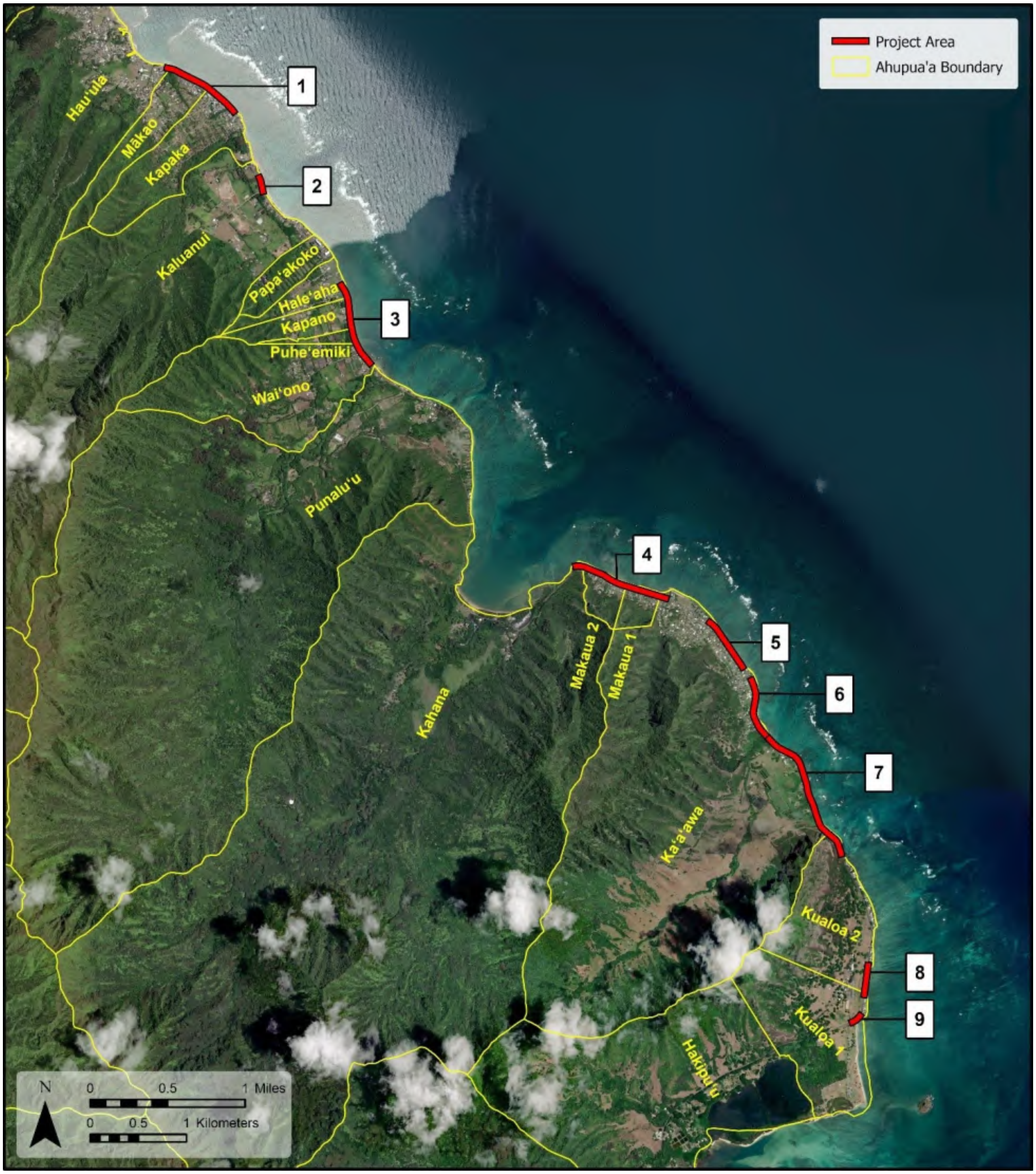

Figure 2. Aerial photograph showing location of project area (nine [9] sections) and the various ahupuaʻa (base image source: ESRI's ArcMap 2.2)

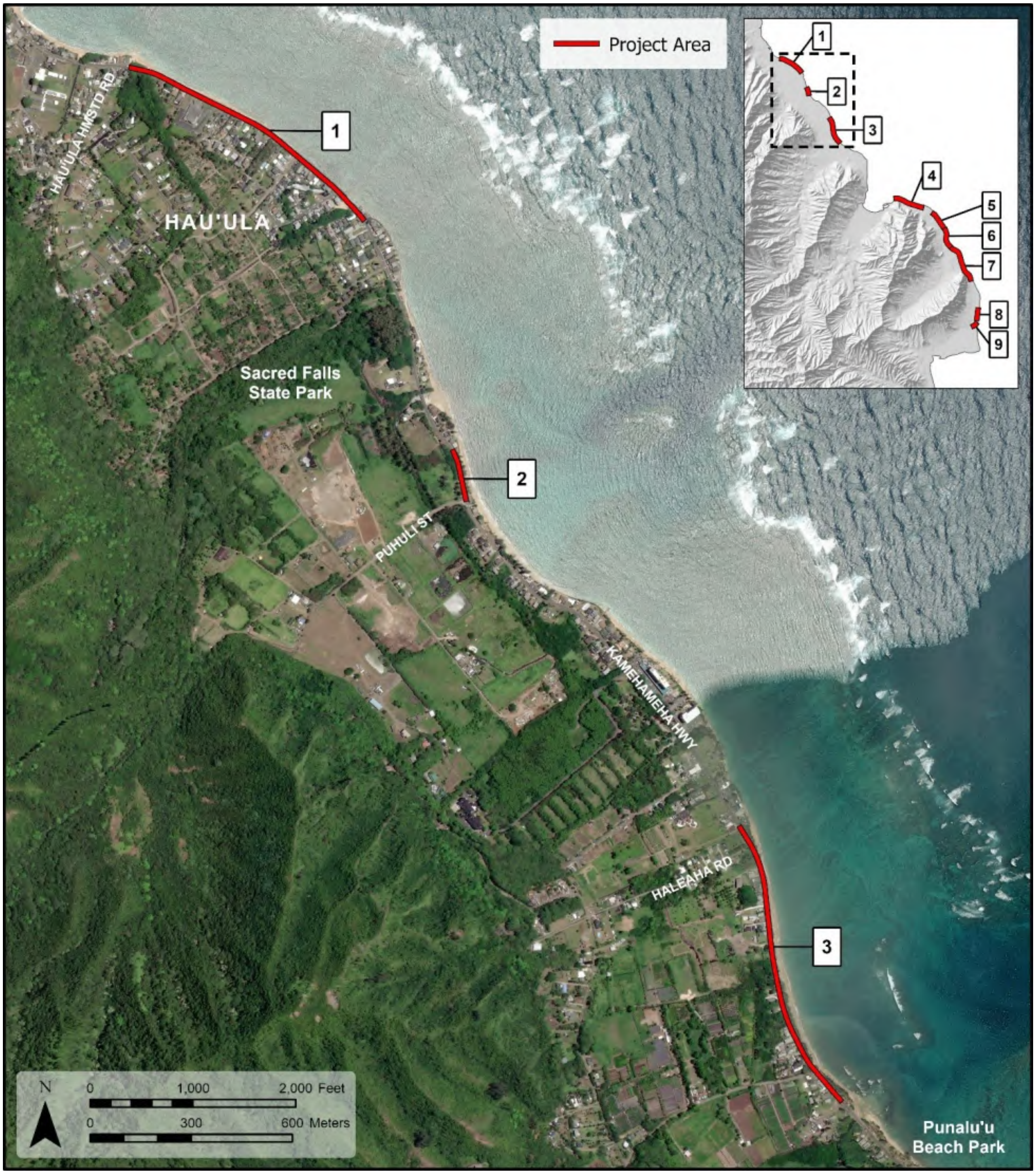

Figure 3. Aerial photograph showing location of Sheet 1 (sections 1–3) and selected roads, place names, and other landmarks (base image source: ESRI's ArcMap 2.2)

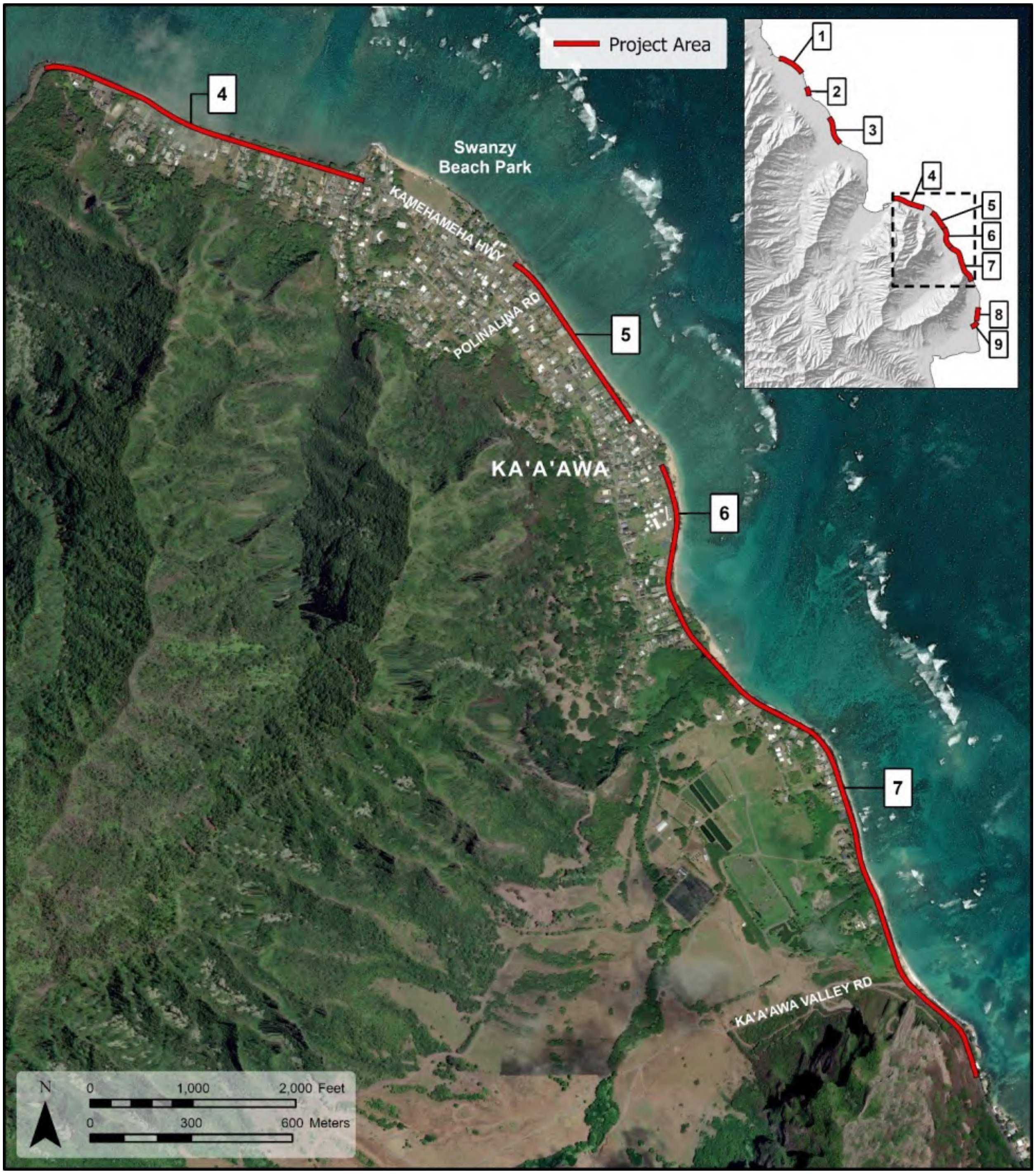

Figure 4. Aerial photograph showing location of Sheet 2 (sections 4–7) and selected roads, place names, and other landmarks (base image source: ESRI's ArcMap 2.2)

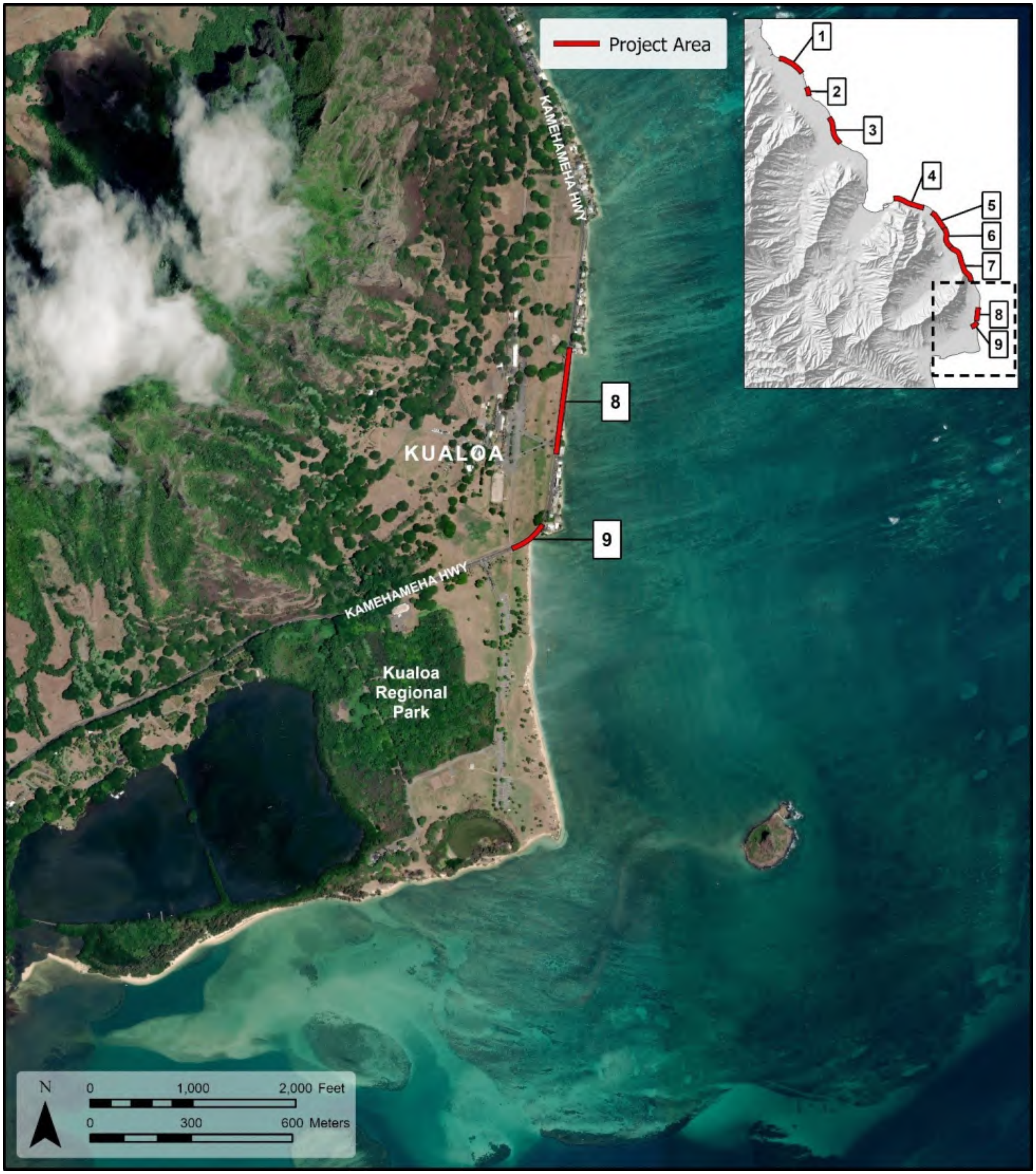

Figure 5. Aerial photograph showing location of Sheet 3 (sections 8–9) and selected roads, place names, and other landmarks (base image source: ESRI's ArcMap 2.2)

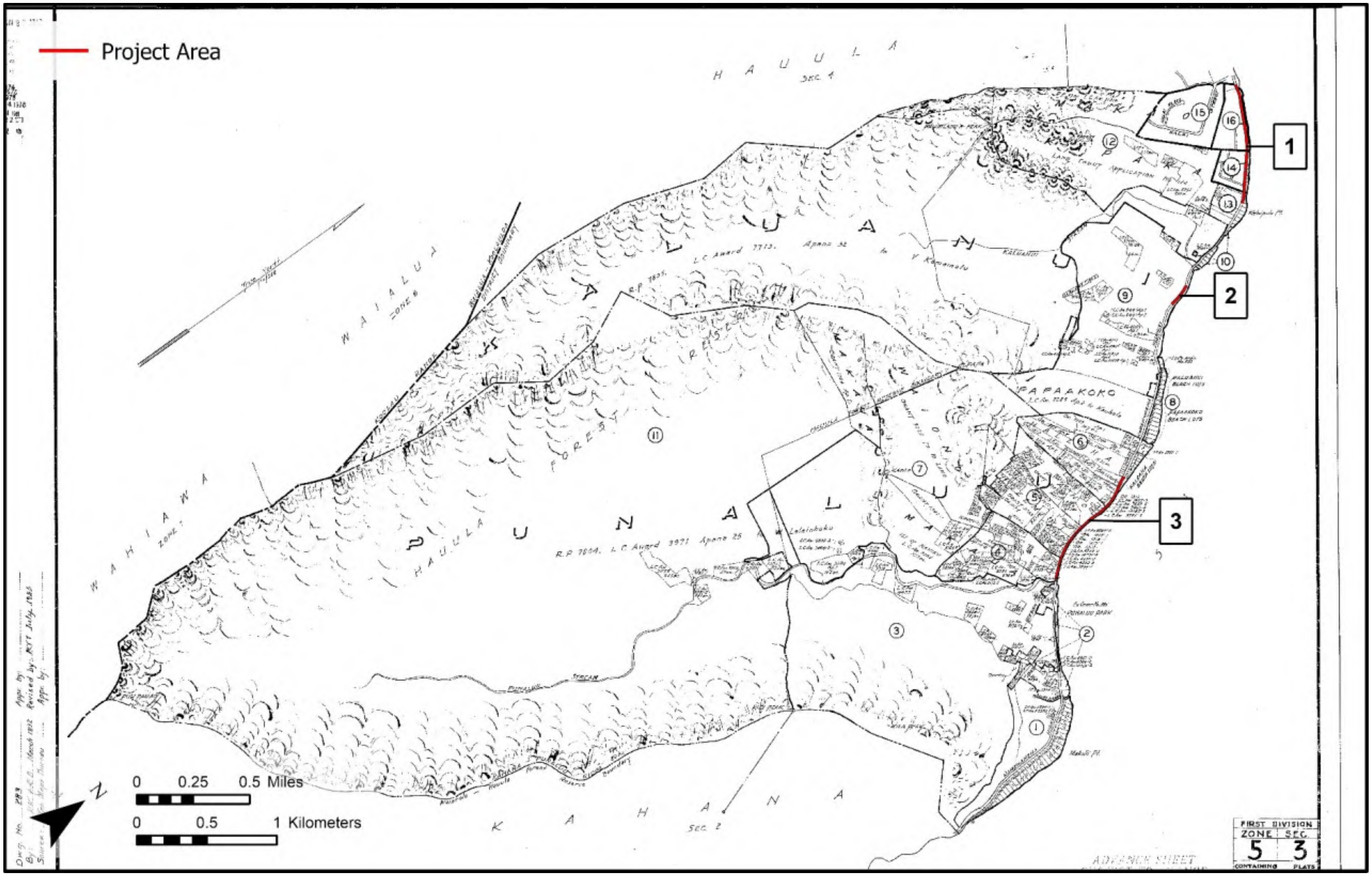

Figure 6. Tax Map Key (TMK): [1] 5-3 showing sections 1–3 (base map source: Hawaiʻi TMK Service n.d.)

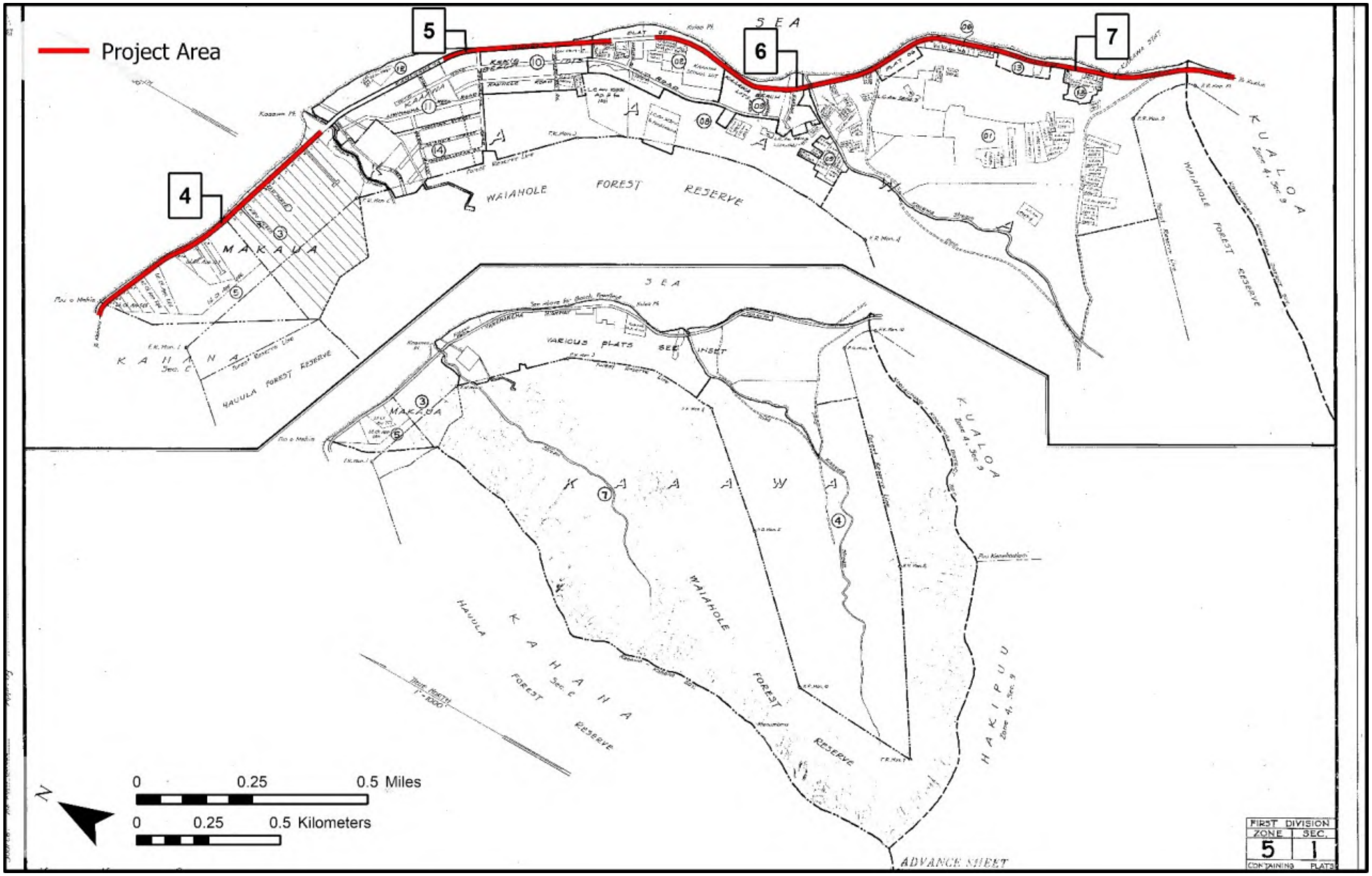

Figure 7. Tax Map Key (TMK): [1] 5-1 showing sections 4–7 (base map source: Hawai‘i TMK Service n.d.)

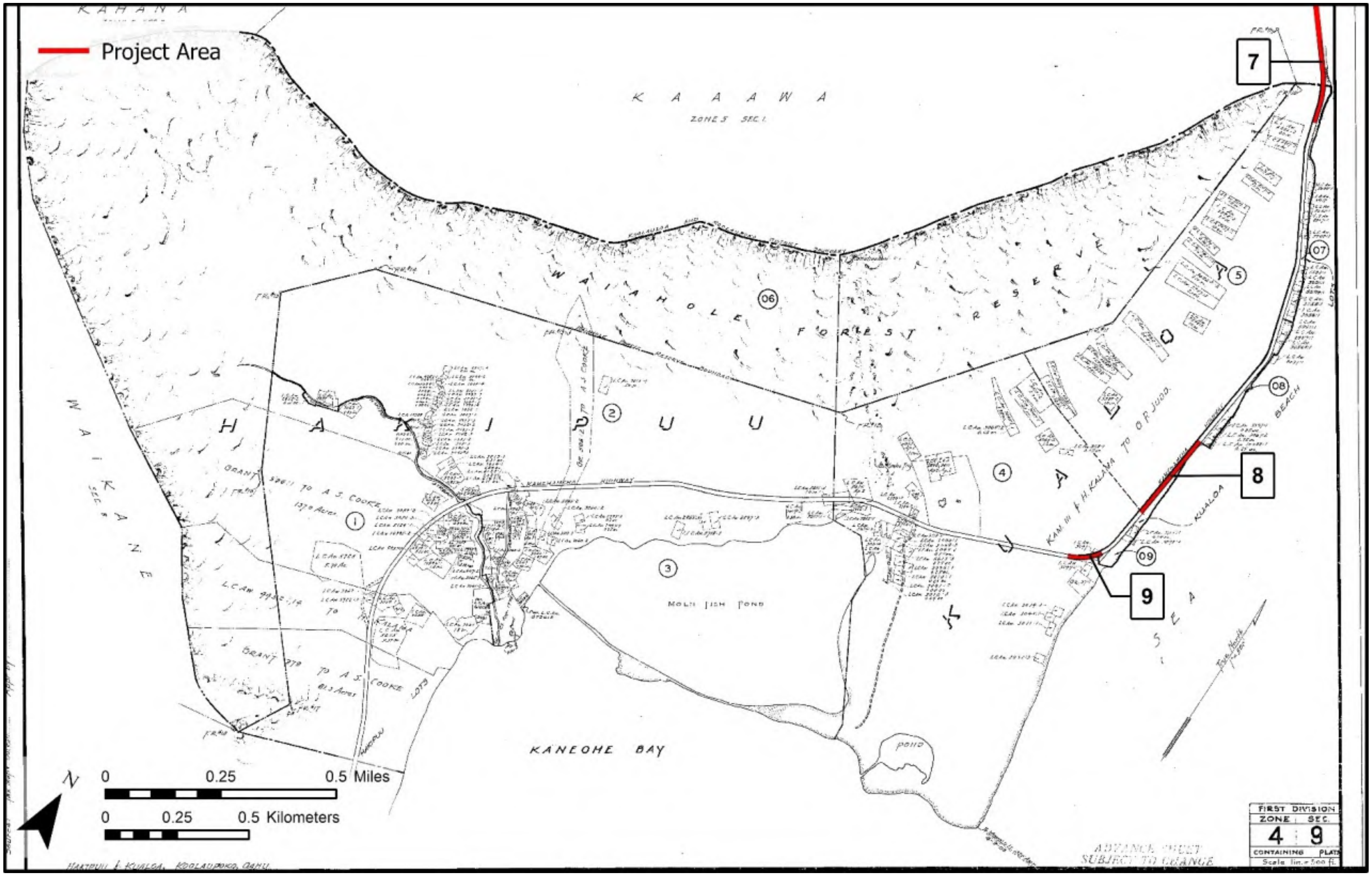

Figure 8. Tax Map Key (TMK): [1] 4-9 showing portion of section 7 and sections 8–9 (base map source: Hawai‘i TMK Service n.d.)

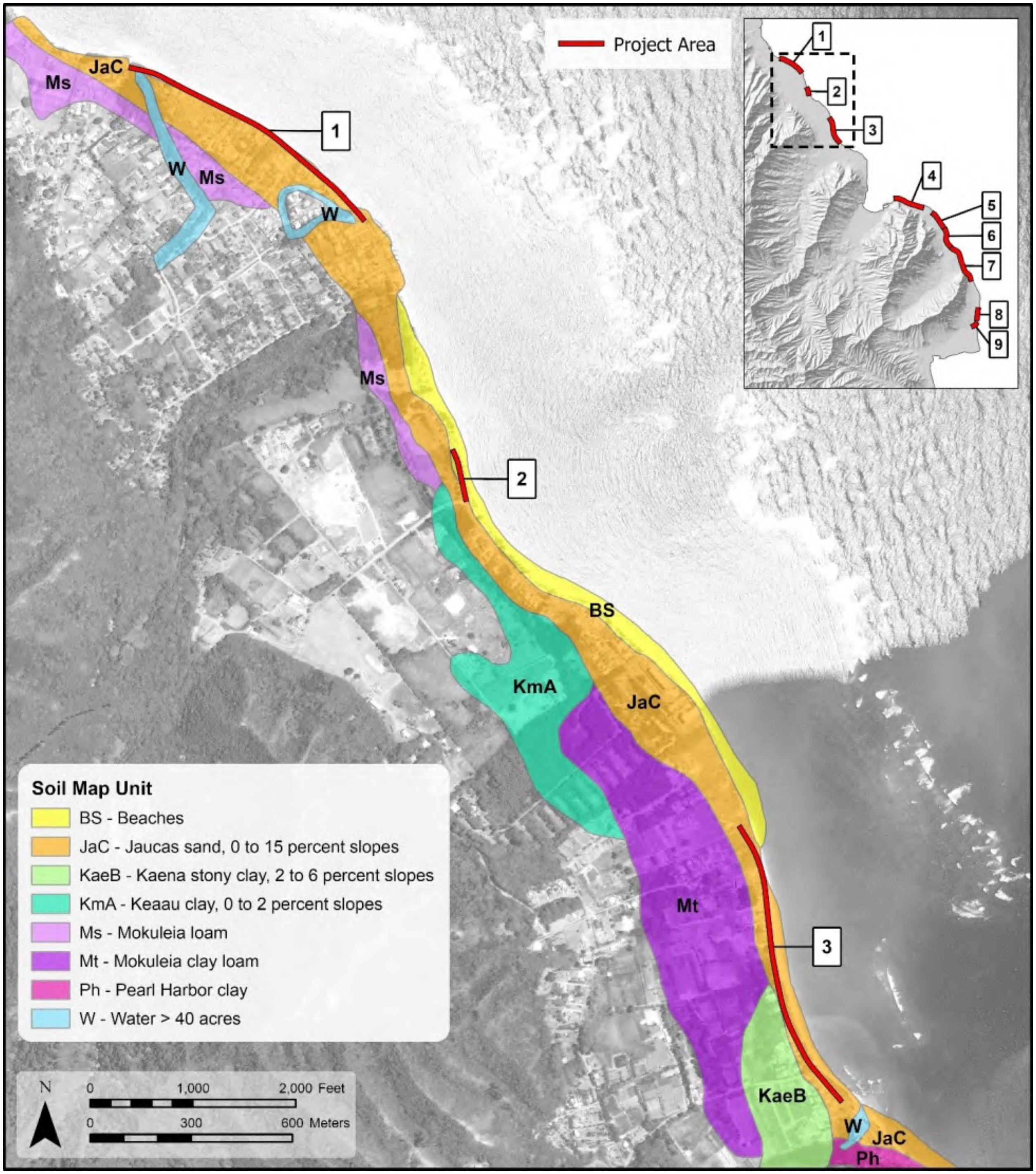

Figure 9. Soil survey data for sections 1–3 and environs (soils data from Foote et al. 1972)

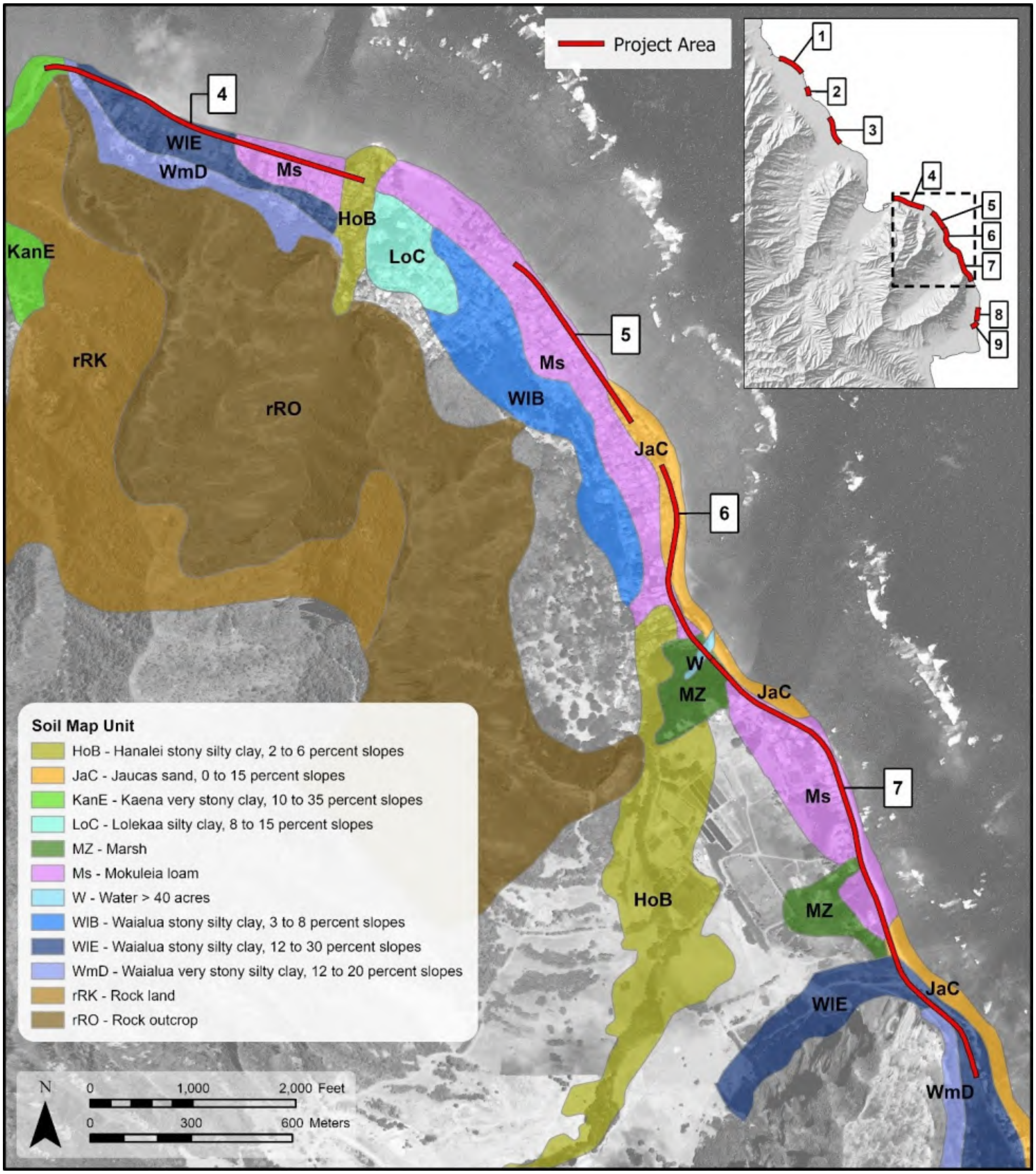

Figure 10. Soil survey data for sections 4–7 and environs (soils data from Foote et al. 1972)

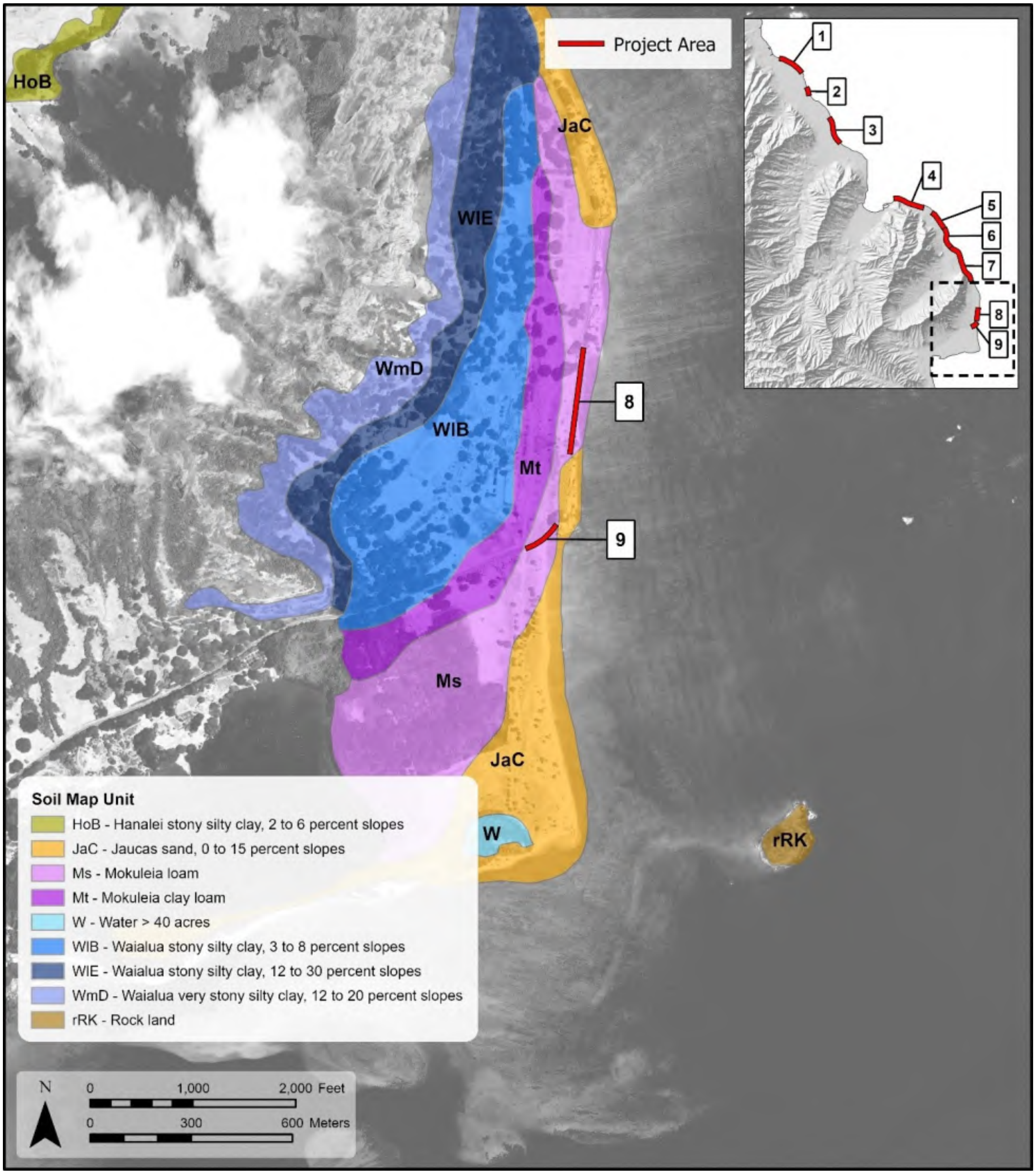

Figure 11. Soil survey data for sections 8–9 and environs (soils data from Foote et al. 1972)

Section 2 Summary of Previous Land Use in the Project Area

This section is a brief summary of pre-Contact to historic period land use in and near the project area. Given the specific objectives of the proposed shoreline mitigation project, the location of the project-area sections right along the coastline, and the fact that the project-area sections include portions of 13 ahupuaʻa over several miles of coastline, this summary is not a full-blown treatment of the cultural and historical context of these 13 windward ahupuaʻa. Rather, it focuses narrowly on information that may help inform what types of archaeological and other historical resources may be impacted or encountered during shoreline mitigation efforts.

In addition to conducting a records search at the SHPD's library in Kapolei and referencing Honua's proprietary database, we also utilized these on-line sources to obtain cultural, historical and archaeological data:

- OHA's Papakilo database (http://papakilodatabase.com/main/main.php)
- OHA's Kipuka database (http://kipukadatabase.com/kipuka/)
- Bernice P. Bishop Museum archaeological site database (http://has.bishopmuseum.org/index.asp)
- Bishop's Hawaii Ethnological Notes (http://data.bishopmuseum.org/HEN/browse.php?stype=3)
- University of Hawaiʻi-Mānoa's digital maps (http://magis.manoa.hawaii.edu/maps/index.html)
- DAGS' State Land Survey (http://ags.hawaii.gov/survey/map-search/)
- Waihona ʻAina website (www.waihona.com)
- Digital newspaper archive "Chronicling America, Historic American Newspapers" (http://chroniclingamerica.loc.gov/lccn/sn82014681/)
- Hawaiʻi State Archives digital collections (http://archives1.dags.hawaii.gov/)
- U.S. Library of Congress digital map collections (https://www.loc.gov/maps/)
- USGS Information Service, including digital map collections (https://nationalmap.gov/historical/index.html)
- AVA Konohiki's website (http://www.avakonohiki.org/)

2.1 Hawaiian Cultural Landscape

In general, the project-area sections were roughly in the location of the traditional (pre-Contact) Hawaiian coastal trail (ala hele or ala nui) where people could safely pass by and through their neighbors' ahupuaʻa without intruding upon house sites and main gardening areas, which were generally located just inland (mauka) of the main coastal trail.

Because much of the area in and around this coastal trail consisted of stabilized sand-dune deposits, and because such landscapes were not ideal for either planting (too sandy) or house sites (exposed to the trade winds, ocean waves and spray [ehu]), makaʻāinana (commoners) used these areas for unmarked burial sites whose general boundaries would have been known to those from the particular ahupuaʻa, but not necessarily identifiable to others.

These coastal setting were also utilized by fishermen as staging areas, places to finish and repair their tools and gear, etc., and by the community—along certain stretches of the coastline, in concert with fishpond work. Finally, many of these coastal sections were used as canoe landings and launch spots.

2.2 Historic Period

Starting in the nineteenth century, in concert with the advent of commercial sugar ventures along the windward coast, most of the current project-area sections were part of either the original Alanui Aupuni ("Government Road") or railroad bed that transported cane from the inland fields to the sugar cane mill at Kahuku. Many historical maps dating from the late 1800s show the "old government road" in many places along the windward coast. The earliest version of the Kamehameha Highway was first constructed along the windward coast in the late 1920s (Rieth et al. 2017).

Starting in the early 1900s, the Koʻolau Railway Company and the Koʻolau Agricultural Company were formed to facilitate economic development. Maps from the early 1900s shows a railway running from Kahuku down to Kahana Bay. The railway sometimes runs right along the government road, sometimes a bit mauka of it, and sometimes crossing over it. In any case, the current highway ROW has been built atop (in different places) the old government road and/or the old railway (Rieth et al. 2017).

Section 3 Previous Archaeological Studies and Findings

This section summarizes the results of previous archaeological studies in and near the current project area. The search area and description of previous archaeological studies is limited to 500 feet (ft.) around the project area. The results of this and the next section (Section 4 Results of Field Inspection) are used to develop project-specific recommendations (see Section 5) that may be useful for planning and design purposes.

3.1 Organization and Presentation of the Data in this Section

Table 1 summarizes the location and results of previous historic-preservation studies in and within 500 ft. of the project area.

Figure 12 to Figure 14 depict the location of relevant previous archaeological studies in sections 1–3, 4–7, and 8–9, respectively. Figure 15 to Figure 17 depict the location of known archaeological sites (and other historic properties) in sections 1–3, 4–7, and 8–9, respectively. As stated in the Introduction, historic bridges are not covered in this report.

The results for each of the nine sections are discussed separately below (starting with Section 3.3). In each section, the presentation of specific sites proceeds from north to south.

3.2 Overview of the Results of Previous Studies

The results of previous archaeological studies have yielded the following general conclusions:

1. Other than a few rock walls dating from the historic or early modern period and the ruins of an old sugar mill known as Wilikaʻai (at Kualoa), there are no above-ground archaeological sites or historic properties within, or in the immediate vicinity of, the highway ROW/project area;
2. Only one above-ground traditional Hawaiian site (a rock terrace, SIHP # 50-80-06-6850) has been documented within the 500-ft. buffer around the project area (and this site is about 500 ft. mauka of the highway); and
3. By far, the two most common archaeological site types within, or in the immediate vicinity of, the highway ROW/project area are (a) human burials in subsurface context (which include intact burials as well as a wide variety of disturbed sites with incomplete/fragmentary sets of human skeletal remains) and (b) subsurface cultural layers (i.e., intact soil-sediments [mostly Jaucas sand deposits] that are culturally-enriched with traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation), some of which also include human burials. Some of these sites with subsurface cultural layers and human burials are actively eroding into the ocean.

3.3 Section 1

A previous study in the highway ROW in this section in south Hauʻula yielded extensive subsurface deposits of traditional Hawaiian habitation and burials within the highway ROW (Masterson et al. 1997) (see Figure 12 and Figure 15). State Inventory of Historic Places (SIHP) # 50-80-05-4793 was a culturally-enriched Jaucas sand layer with several pit features and at least one traditional Hawaiian artifact. According to the authors (ibid.:38), “the *mauka/makai* extent of the cultural deposit is unknown." SIHP # 50-80-05-4792 was another culturally-enriched Jaucas sand layer; it contains abundant traditional Hawaiian artifacts—including formal tools and debitage—as well as seven human burials. Like SIHP # 4793, the lateral limits of this site are also unknown.

3.4 Section 2

Previous work in or immediately adjacent to the highway ROW in the section between Hauʻula and Punaluʻu (see Figure 12 and Figure 15) yielded an inadvertently-discovered human burial (no SIHP # was assigned) (Jourdane 2003); another study (Borthwick et al. 2005) resulted in no significant findings. The human burial documented by Jourdane (2003) was located along the makai side of the highway ROW.

3.5 Section 3

Several previous studies have been conducted in or adjacent to the highway ROW in this section in Punaluʻu (Smith et al. 1988; Jourdane 1995; Hammatt and Perzinski 2002; Perzinski and Hammatt 2004; Hunkin et al. 2012; Belluomini and Hammatt 2016) (see Figure 12 and Figure 15).

SIHP # 50-80-06-5308 was a human burial inadvertently-discovered at a private residence a short distance north and mauka of the highway (Jourdane 1995).

Archaeological monitoring reported by Perzinski and Hammatt (2004) documented an extensive subsurface cultural layer (SIHP # 50-80-06-6695) with 23 human burials as well as seven other human burial sites (SIHP #s 50-80-06-6574 through -6580) containing 35 individuals in section 3. SIHP # 6695 contained numerous pit features in addition to human burials, most of which appear to be pre-Contact or early historic in age (given the lack of coffins or historic artifacts, and the "generally flexed" position of most bodies) (ibid.:19). The burial sites (SIHP #s 6574–6580) contain the remains of seven (SIHP # 6574), seven (SIHP # 6575), six (SIHP # 6576), three (SIHP # 6577), one (SIHP # 6578), nine (SIHP # 6579) and two (SIHP # 6580) individuals, respectively. All of these burial sites were interpreted as dating from pre-Contact to early historic times.

Near the southern end of section 3, mauka of the highway, a human burial site (SIHP # 50-80-06-3977) consisting of the remains of three individuals was inadvertently discovered at a private residence (Smith et al. 1988).

Just beyond the southern end of section 3, Belluomini and Hammatt (2016) documented remnants of a historic (built in 1926) bridge (SIHP # 50-80-06-7932), which has been determined to be "no longer significant" (ibid.).

3.6 Section 4

Several previous studies have been conducted in or adjacent to the highway ROW in this section at Crouching Lion (Crozier 1971; Hommon and Barrera 1971; Denison 1975; O'Hare et al. 2006; Raff-Tierney and Hammatt 2017; Rieth et al. 2017) (see Figure 13 and Figure 16). Most of these projects were mauka of the highway. Rieth et al.'s project (2017) was conducted in the highway ROW. Cordle et al.'s (2009) work was just south of the southern end of section 4.

SIHP # 50-80-06-1540, a pair of rock walls attributed to the historic period, were identified by Hommon and Barrera (1971) mauka of the northern end of the highway ROW.

Rieth et al. (2017) documented two sites near the northern end of section 4: one (SIHP # 50-80-06-7921) was under the north bound lane and makai-side shoulder of the highway, and one (SIHP # 50-80-06-7922) was along the makai shoulder of the highway. SIHP # 7921 is a subsurface cultural layer dating to pre-Contact to early historic times. This layer contains abundant evidence of traditional Hawaiian artifacts and habitation. The site has been eroded on its makai side by wave action, and it originally would have extended further to the east. A 100-m (meter) long mortared rock wall dating from 1920s (SIHP # 7922) was also documented along the makai shoulder of the highway.

SIHP # 50-80-06-7952, identified by Raff-Tierney and Hammatt (2017), is a subsurface trash pit at a private residence mauka of the highway.

O'Hare et al. (2006) documented two above-ground sites on a private residence mauka of the highway: SIHP # 50-80-06-6849, a historic-period rock wall; and SIHP # -6850, a traditional Hawaiian terrace. Both of these sites are about 500 ft. inland of the current project area.

Finally, Cordle et al. (2009) identified a pair of historic-period masonry retaining walls (SIHP # 50-80-06-6934 and -6936) located just south of the southern end of this section.

3.7 Section 5

Several small studies—including inadvertent burial finds and work at private residences—have been conducted adjacent to this section (but not within the highway ROW) in Kaʻaʻawa (Kam 1987; Rosendahl 1988; Jourdane 1994; Collins 2002; Winburn and Desilets 2009) (see Figure 13 and Figure 16). These studies have resulted in the documentation of three human burial sites containing the remains of several individuals:

1. SIHP # 50-80-06-4889, representing the human skeletal remains of multiple individuals (Jourdane 1994) nearly 500 ft. north of the northern end of this section;
2. SIHP # 50-80-06-3749, one set of human skeletal remains interpreted as an *in situ* (undisturbed) discovered during house construction excavation in mauka of the highway (Kam 1987); and
3. SIHP # 50-80-06-6409, representing the human skeletal remains of three individuals on the mauka side of the highway between sections 5 and 6 (Collins 2002).

3.8 Section 6

In addition to the last study mentioned above (i.e., Collins 2002, which was halfway between sections 5 and 6), several previous archaeological studies have been conducted in two project areas in and near this section south of Kaʻaʻawa (see Figure 13 and Figure 16).

Whitehead and Cleghorn (2003) and Mooney and Cleghorn (2003) conducted archaeological inventory survey (AIS) and archaeological monitoring at Kaʻaʻawa Beach Park, at the north end of section 6, but found no significant sites.

Work at Kaʻaʻawa Elementary School (Guerriero and Kennedy 2005; Tulchin and Hammatt 2009; Groza and Hammatt 2010), on the mauka side of the highway, resulted in the documentation of two sites (Groza and Hammatt 2010) and three human burials (Guerriero and

Kennedy 2005) (no SIHP #s were assigned to these burials). Groza and Hammatt (2010) documented one set of inadvertently discovered human remains (SIHP # 50-80-06-7121) encountered during subsurface excavations in the northeast corner of the project area. A traditional Hawaiian cultural layer was also identified (SIHP # 50-80-06-7122) containing fire-pit features and a pit with dog bones; charcoal, midden, fire-affected rock and basalt debitage and traditional Hawaiian tools were also found in the cultural layer.

3.9 Section 7

Several small studies—including inadvertent burial finds and work at private residences—have been conducted in or adjacent to this section between south Kaʻaʻawa and Kualoa (Pietrusewsky and Lee 1988; Smith 1988; Cleghorn 1991; Pietrusewsky and Ikehara 1991; Jourdane 1993; Dye and Lee 1996; Hamano and Cleghorn 2003; Chinen 2006) (see Figure 13 and Figure 16). These studies have resulted in the documentation of three human burial sites containing the remains of several individuals:

1. SIHP # 50-80-06-4728, representing the human skeletal remains of one individual (Jourdane 1993) in a house-foundation/footing excavation just mauka of the highway in a private residential parcel;
2. SIHP # 50-80-06-3759, the remains of multiple individuals eroding out of the roadway on the makai side over the course of several years (Pietrusewsky and Lee 1988; Smith 1988; Cleghorn 1991; Pietrusewsky and Ikehara 1991; Dye and Lee 1996); and
3. SIHP # 50-80-06-6852, additional human skeletal remains eroding out of the makai side of the highway (Chinen 2006).

3.10 Section 8

Two studies have been completed in this section at Kualoa (see Figure 14 and Figure 17).

McElroy et al.'s (2016) AIS in a portion of Kualoa Ranch along the mauka side of the highway did not identify any historic properties. The ruins of an old sugar mill (known as Wilikaʻai) is near the northern end of this section, on the mauka side of the highway.

Van Ryzin et al.'s (2015) AIS of a private residence on the makai side of the highway, about 500 ft. south of the southern end of this section, identified one site (SIHP # 50-80-06-7913), a subsurface cultural layer dating from pre-Contact to early historic-period times.

3.11 Section 9

In addition to SIHP # 50-80-06-7913 (described in the previous paragraph summarizing section 8), which is about 200 ft. northeast of the north end of section 9, many previous archaeological studies in the Kualoa Beach Park/Point area have been completed since the mid-1970s. Table 1 lists 18 previous studies that are not systematically summarized in detail here (see Figure 14 and Figure 17).

Previous studies in the Kualoa Beach Park/Point area, in general, have yielded abundant evidence of traditional Hawaiian habitation and burial sites dating from pre-Contact times into the early historic period.

The following historic properties are located near section 9:

1. SIHP # 50-80-06-7397 and SIHP # 50-80-06-7752, which are two, discontinuous, laterally-extensive and partially-overlapping subsurface cultural layers (i.e., intact soil-sediments [mostly Jaucas sand deposits] that are culturally-enriched with traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation) – as depicted in Figure 17, these subsurface layers directly abut the southwest portion of section 9, and other portions of them extend to the west and south;
2. SIHP # 50-80-06-7123, previously-disturbed human skeletal remains eroding into the ocean that were recovered and re-located to the Kualoa Beach Park's storage unit (Clark and Lebo 2014); and
3. Subsurface features assigned to SIHP # 50-80-06-528 (which refers to the historic-property designation of the entire Kualoa Ahupuaʻa) documented in shovel-testing by Ahlo (1980) in which traditional cultural deposits were located. In addition, human skeletal remains eroding into the ocean documented by Vitousek (2010) were also identified in the area of the SIHP # 50-80-06-528 features identified by Ahlo (1980).

Table 1. Previous Archaeological Studies and Results in and near the Project Area

Author(s)	Date[1]	Type of Study[2]	Location & Notes	Results & Comments[3]
McAllister	1933	Survey of archaeological sites & legendary places	O‘ahu – Island-wide	**Site 1 – ruins of Wilika‘ai/old sugar mill (still existing), mauka side of highway, N end of section 8 (Kualoa 2)** Site 304 (heiau, same as SIHP # 514), located mauka of project area’s 500-ft. buffer (section 4, Makaua 2/Crouching Lion) Site 313 (Moli‘i fishpond extension) – abandoned by time of McAllister’s (1930s) survey – near Kualoa Point (section 9, Kualoa 1)
Hommon & Barrera	1971	Arch. Recon.	Kahana Valley	Identified 1 site within 500-ft. buffer around current project area: pair of rock walls (SIHP # 1540) mauka of highway ROW at N end of section 4 (Makaua 2)
Crozier	1971	Arch. Recon.	Makaua Property (Crouching Lion)	--
Barrera	1974	AIS	Preliminary investigations at Kualoa	Subsurface testing documented a cultural deposit w. pits, postholes, traditional Hawaiian & non-traditional artifacts, midden, & a human burial (no SIHP # assigned)
Denison	1975	AIS	Same project area as Crozier 1971 – focusing on SIHP # 514	SIHP # 514 (same as McAllister Site 304), located just mauka/beyond project area’s 500-ft. buffer
Clark & Connolly	1975	AIS Progress Report	Kualoa Regional Park	Identified a buried fishpond wall & submerged, traditional Hawaiian artifacts on the reef
Connolly et al.	1977	Other – Erosion Study		
Clark & Connolly	1978	Other – Interpretive Plan	Kualoa Regional Park	Recommendations for an interpretive program for archaeology
Ahlo	1980	Shovel Testing	Along shoreline S of section 9	**Identified 2 areas in which traditional subsurface cultural deposits were located (designated Features 2D-1 & 2D-2) S of section 9 – these features are considered part of SIHP # 528**
Gunness	1985a	AIS & Arch. Mon.	Kualoa Regional Park	Overview of Kualoa Archaeological Research Project results from 1974-1984

Author(s)	Date[1]	Type of Study[2]	Location & Notes	Results & Comments[3]
Gunness	1985b	AIS & Arch. Mon.	Kualoa Regional Park Road Improvements Project	Reported on results of subsurface testing
Gunness	1985c	Arch. Recon.		
Gunness	1985d	Arch. Mon.	Two days of bulldozing at Kualoa Regional Park	No sites recorded
Gunness	1986	AIS	Kualoa Regional Park Road Improvements Project	Reported on results of subsurface testing
Kam	1987	Burial Treatment	Private residence at 51-416 Kamehameha Hwy.	Identified 1 set of human skeletal remains (SIHP # 3749, interpreted as *in situ* burial) during house construction excavation – northern portion of section 5 mauka of highway
Gunness	1987a	Masters Thesis (summary of Kualoa archaeological finds)	Kualoa Regional Park	SIHP # 313 (eastern extension of Moliʻi fishpond noted) near Kualoa Point (section 9, Kualoa 1); also, in general, referring to the south beach area of park, Gunness recorded 98 subsurface features & ~3,400 traditional artifacts near South Beach access road
Gunness	1987b	AIS & Arch. Mon.		Update of the Kualoa Archaeological Research Project results up to 1987
Smith et al.	1988	Burial Treatment	Private residence at 53-368 Kamehameha Hwy., mauka side of highway	**3 human burials = SIHP # 3977, just mauka of highway ROW near S end of section 3 (Waiʻono)**
Smith	1988	Burial Treatment	Kaʻaʻawa	**Inspection of multiple individuals/human burial (SIHP # 3759) -- makai shoulder of current project area ROW (section 7)**
Pietrusewsky & Lee	1988			
Rosendahl	1988	AIS	Proposed Kaʻaʻawa Post Office	No sites recorded
Pietrusewsky & Douglas	1989	Osteological Report	Kualoa Regional Park	Human remains were not within the 500-ft. buffer of the current project area; their analyses included 42 sets of human skeletal remains (41 of which were interpreted as pre-Contact Hawaiians)
Goodman & Cleghorn	1991	Arch. Mon. & Salvage Excav.	Kualoa Regional Park	Identified 2 human burials, 1 historic-period rock wall, a row of post holes & artifacts – these are not within the 500-ft. buffer around current project area
Cleghorn	1991	Burial Treatment	Kanenelu Beach, Kaʻaʻawa	**Disinterment of eroding burial (part of**

Author(s)	Date[1]	Type of Study[2]	Location & Notes	Results & Comments[3]
Pietrusewsky & Ikehara	1991			**SIHP # 3759 – see Smith [1988], Pietrusewsky & Lee [1988] above)**
Meeker	1991	Arch. Mon.	Sand replenishment project at Kualoa Regional Park	No sites recorded, although some features were observed (i.e., disturbed midden deposit, 2 pits & 2 post holes)
Jourdane	1993	Burial Treatment	Private residence at 51-170 Kamehameha Hwy. (Kaʻaʻawa)	**Identified 1 set of human skeletal remains (SIHP # 4728) in house foundation footings excavation – mauka of highway (section 7)**
Jourdane	1994		Private residence at 57-471 Kamehameha Hwy. (Kaʻaʻawa)	Identified human skeletal remains of multiple individuals = SIHP # 4889 – nearly 500 ft. N of northern end of section 5
Jourdane	1995		Private residence at 53-504 Kamehameha Hwy. (Punaluʻu)	**Human burial = SIHP # 5308, a short distance N and mauka of current project area ROW (section 3)**
Dye & Lee	1996	Burial Treatment	Kaʻaʻawa	**Disinterment of 1 set of human skeletal remains eroding out (part of SIHP # 3759 – see Smith [1988], Pietrusewsky & Lee [1988] above)**
Masterson et al.	1997	Arch. Mon.	Linear corridor (waterline) from Kapaka to Lāʻie	**2 sites identified under highway ROW: subsurface cultural layer w. 7 human burials (SIHP # 50-80-05-4792) & subsurface cultural layer (SIHP # 50-80-05-4793) – both sites have pre-Contact components**
Hammatt & Perzinski	2002	Arch. Mon.	Geotechnical boring for South Punaluʻu Bridge Replacement project	No sites recorded
Collins	2002	Burial Treatment	51-338 Kamehameha Hwy. (Kaʻaʻawa)	Identified human skeletal remains of 3 individuals = SIHP # 6409, mauka side of highway ROW (between sections 5 & 6)
Hamano & Cleghorn	2003	Arch. Mon.	Wireless telecom. facility at Kualoa Bunkers site, Kualoa Ranch	Identified sites were not within the 500-ft. buffer of current project area
Whitehead & Cleghorn	2003	AIS	Proposed Kaʻaʻawa Beach Park comfort station & parking area improvements	No sites recorded
Mooney & Cleghorn	2003	Arch. Mon.		

Author(s)	Date[1]	Type of Study[2]	Location & Notes	Results & Comments[3]
Jourdane	2003	Burial Treatment	Kaluanui	**Human burial (no SIHP #) along makai shoulder of the highway (section 2, Kaluanui)**
Perzinski & Hammatt	2004	Arch. Mon.	Linear corridor (waterlines), Punaluʻu & Kahana	**8 sites identified under highway ROW: a series of human burials collectively containing at least 35 individuals (SIHP #s 6574 to 6580) & a subsurface cultural layer (SIHP # 6695) w. 23 human burials–all of these sites have pre-Contact components (section 3)**
Guerriero & Kennedy	2005	Burial Treatment	Kaʻaʻawa Elementary School	3 human burials identified (no SIHP #s), mauka of highway ROW near N end of section 6, Kaʻaʻawa)
Borthwick et al.	2005	AIS	3 beach lots fronting Kaluanui Beach Park	No sites recorded
O'Hare et al.	2006	AIS	Private residence at Kaʻaʻawa (Makaua)	2 sites identified: historic-period rock wall (SIHP # 6849) & traditional Hawaiian terrace (SIHP # 6850) ~500 ft. mauka of highway ROW (section 4, Makaua 2)
Chinen	2006	Burial Treatment	Kaʻaʻawa	**Human burial = SIHP # 6852, makai shoulder of highway ROW (section 7)**
Carson & Athens	2006	Arch. Mon. & Data Recov.	Kualoa Regional Park	Studied sites were not within the 500-ft. buffer of current project area
Tulchin & Hammatt	2009	AIS	Kaʻaʻawa Elementary School	No sites recorded
Cordle et al.	2009	AIS	Makaua Stream Restoration project, Kaʻaʻawa	3 sites identified: historic-period masonry retaining walls (SIHP # 6934 & 6936) & Makaua Stream Bridge (built 1927) (SIHP # 6935), just SE of SE end of section 4 (Kaʻaʻawa)
Winburn & Desilets	2009	AIS	Private residence (Kaʻaʻawa)	No sites recorded
Groza & Hammatt	2010	Arch. Mon.	Kaʻaʻawa Elementary School	2 sites identified: human burial (SIHP # 7121) & subsurface cultural layer (SIHP # 7122) w. pit features, dog remains, midden & traditional Hawaiian artifacts (section 6)

Author(s)	Date[1]	Type of Study[2]	Location & Notes	Results & Comments[3]
Vitousek	2010	Burial Treatment	Kualoa Beach Park Report Memorandum	**Identified 1 burial – considered a feature of SIHP # 528 (i.e., the historic property designation for all of Kualoa Ahupuaʻa)**
Hunkin et al.	2012	Arch. Mon.	Punaluʻu Shore Protection project	No sites recorded
Clark & Lebo	2014	Burial Treatment	Kualoa Beach Park Report Memorandum	**Identified previously-disturbed human burials = SIHP # 7123, ~300 ft. S of section 9 along the shoreline**
Van Ryzin et al.	2015	AIS	Private residence at 49-555 Kamehameha Hwy. (Kualoa)	1 site identified: subsurface cultural layer dating from pre-Contract to historic times (SIHP # 7913), approximately 500 ft. S of S end of section 8 (Kualoa 1)
Belluomini & Hammatt	2016	Arch. Mon.	South Punaluu Stream Bridge project	1 site identified: remnants of Punaluʻu Bridge (built 1926) – no longer historically-significant (SIHP # 7932), S of S end of section 3 (Punaluʻu)
McElroy et al.	2016	AIS	Kualoa Ranch improvements (Kualoa 1 & 2 Ahupuaʻa)	No sites recorded
Raff-Tierney & Hammatt	2017	AIS	Private residence at 51-666 Kamehameha Hwy.	Identified 1 site: subsurface trash deposit (SIHP # 7952), mauka of the highway ROW near N end of section 4 (Makaua 2)
Rieth et al.	2017	Arch. Mon. & Data Recov.	Kamehameha Highway Emergency Shoreline Improvements (Makaua 2 Ahupuaʻa)	**Identified 2 sites under N-bound lane of highway & along makai highway shoulder near N end of section 4 (Makaua 2): subsurface cultural layer dating to pre-Contact to early historic times (SIHP # 7921) & 100-m long mortared rock wall dating from 1920s (SIHP # 7922)**

[1] Arranged chronologically.

[2] Abbreviations: Arch. Mon. = archaeological monitoring, Arch. Recon. = archaeological reconnaissance survey, AIS = archaeological inventory survey, Data Recov. = data recovery, Salvage Excav. = salvage excavation.

[3] SIHP = State Inventory of Historic Places; sites/entries in **bold** are in and/or immediately adjacent to the highway ROW/current project area; unless indicated otherwise, all SIHP #s in this table are formally preceded by "50-80-06-".

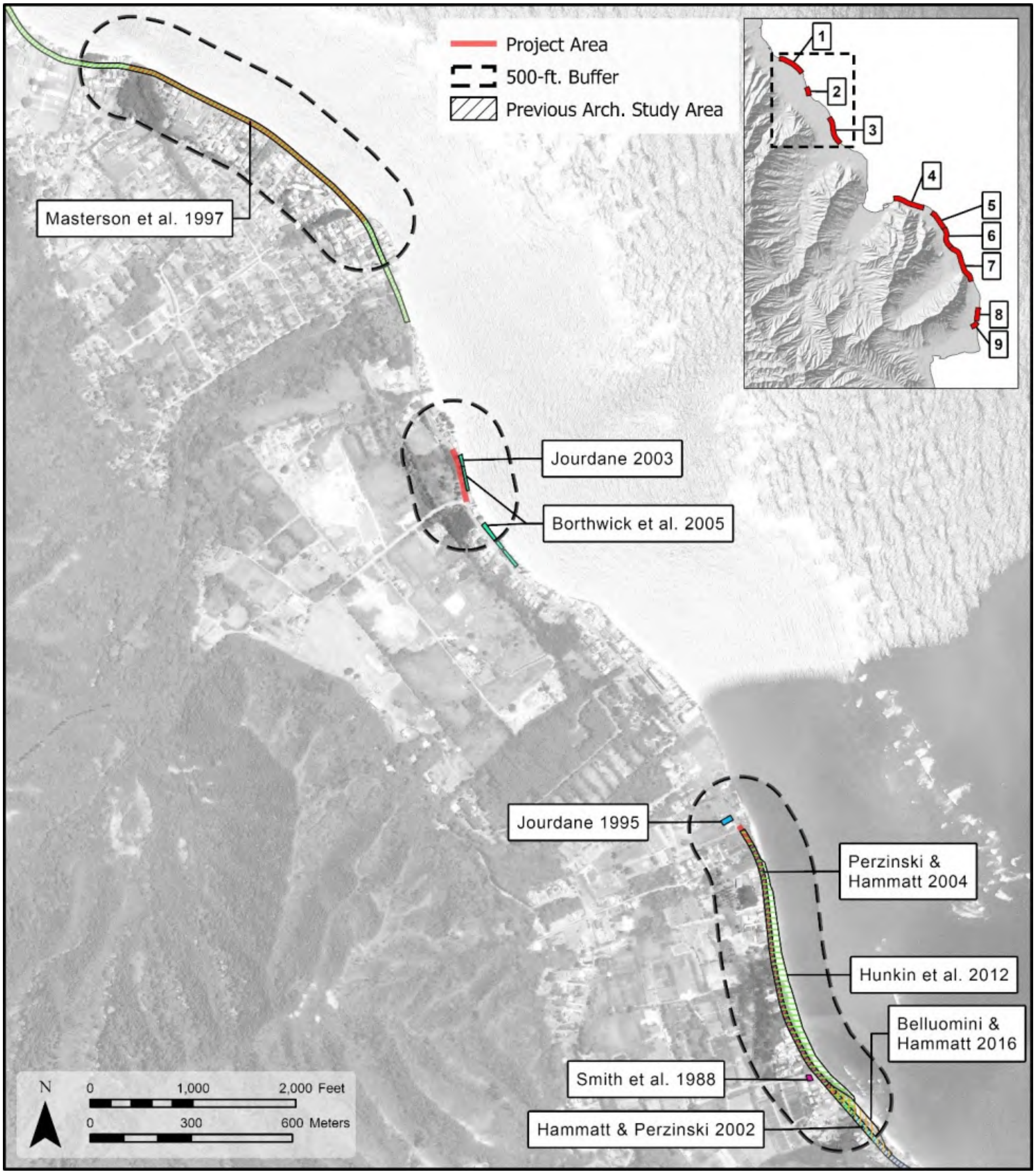

Figure 12. Previous archaeological studies in sections 1–3 and environs (see table and text above for details)

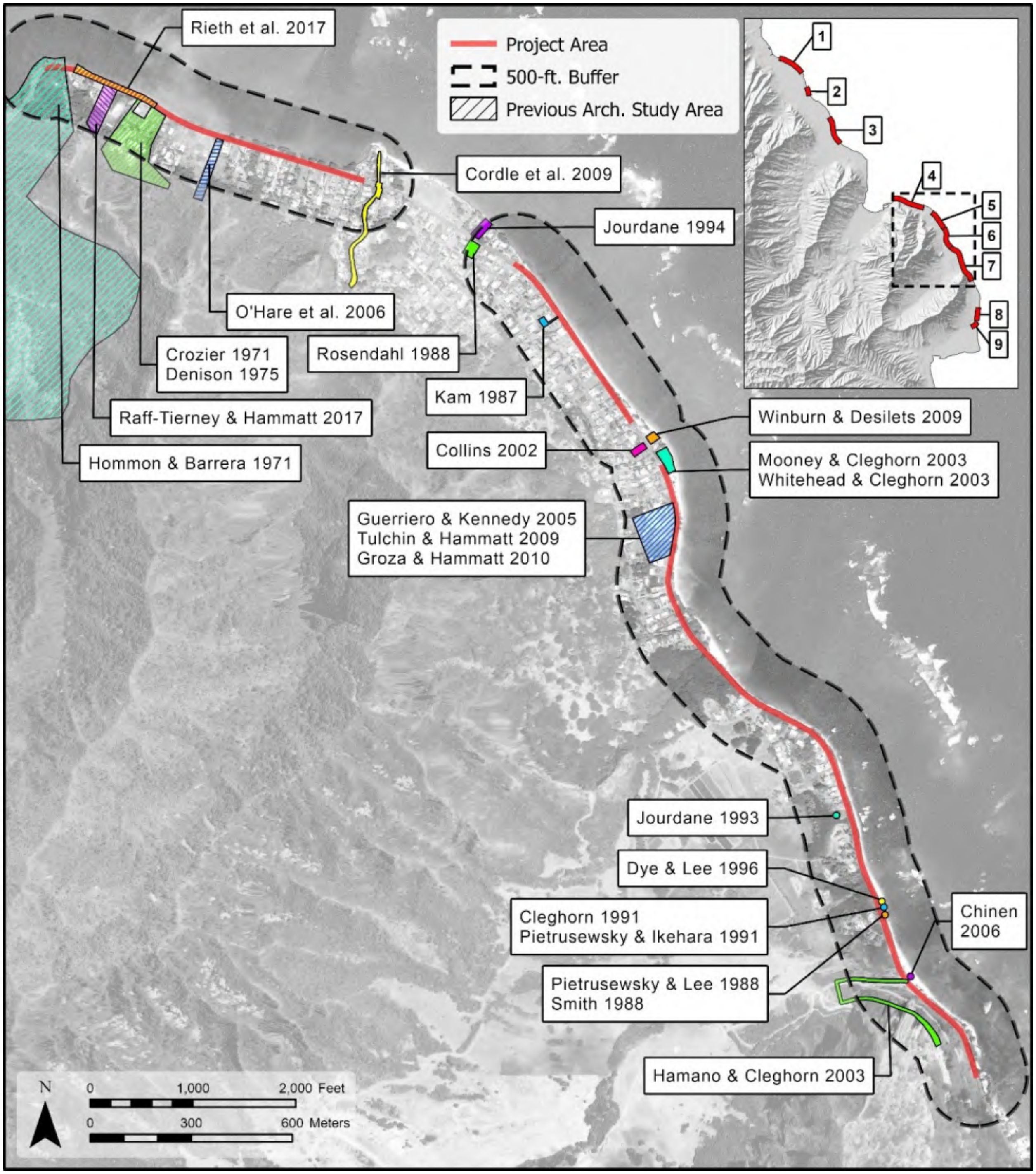

Figure 13. Previous archaeological studies in sections 4–7 and environs (see table and text above for details)

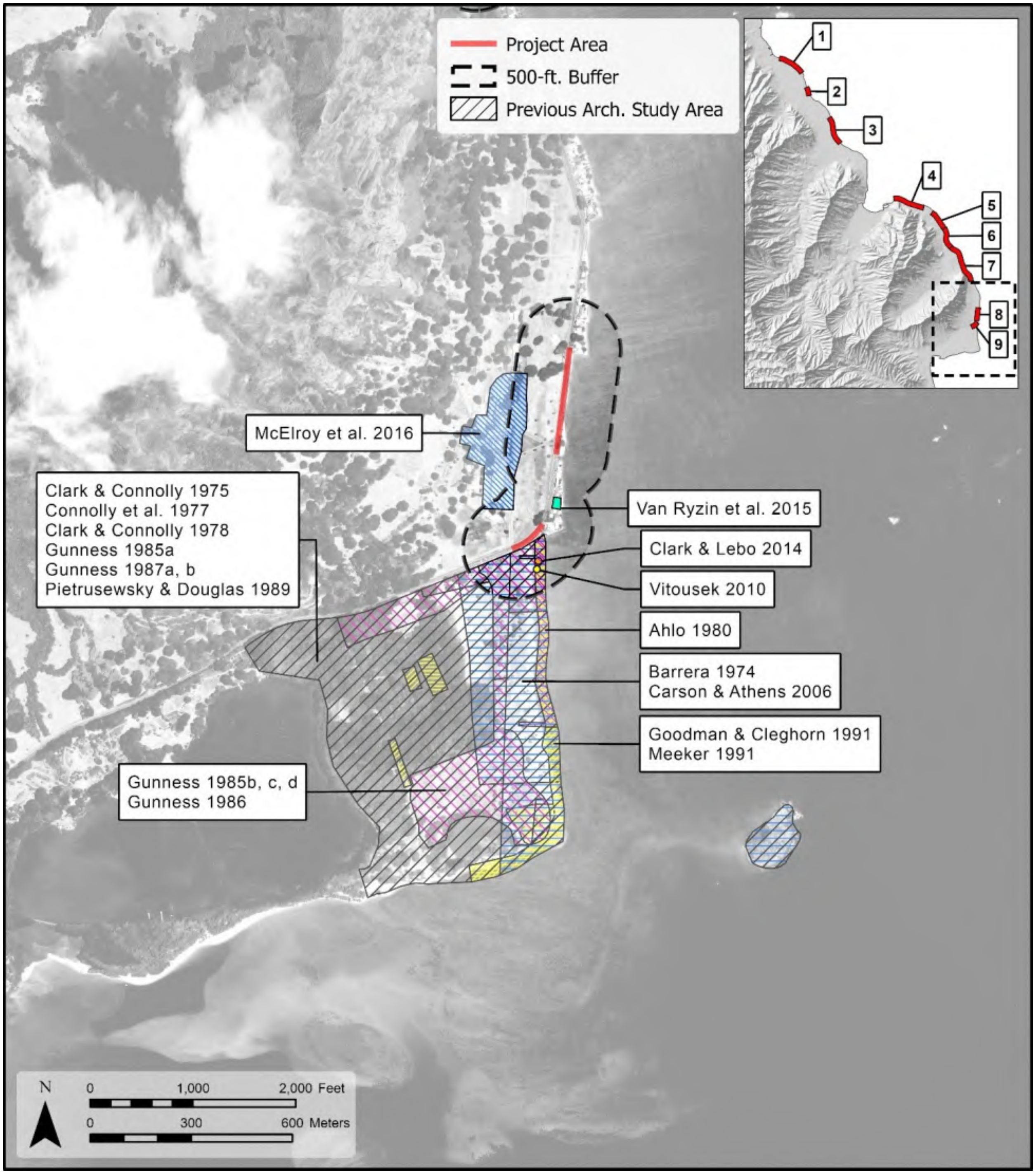

Figure 14. Previous archaeological studies in sections 8–9 and environs (see table and text above for details)

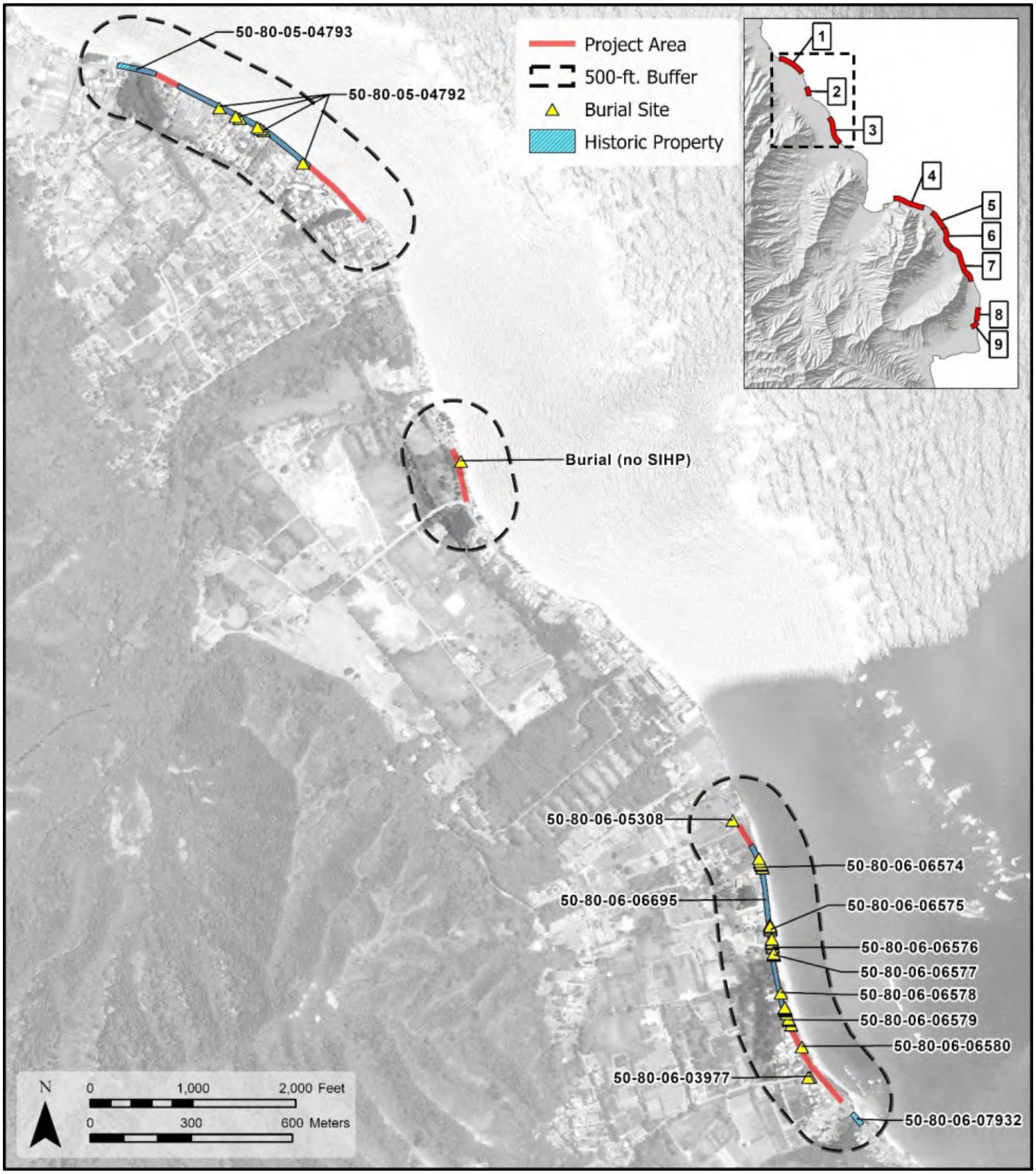

Figure 15. Previously-identified archaeological sites in sections 1–3 and environs (see table and text above for details)

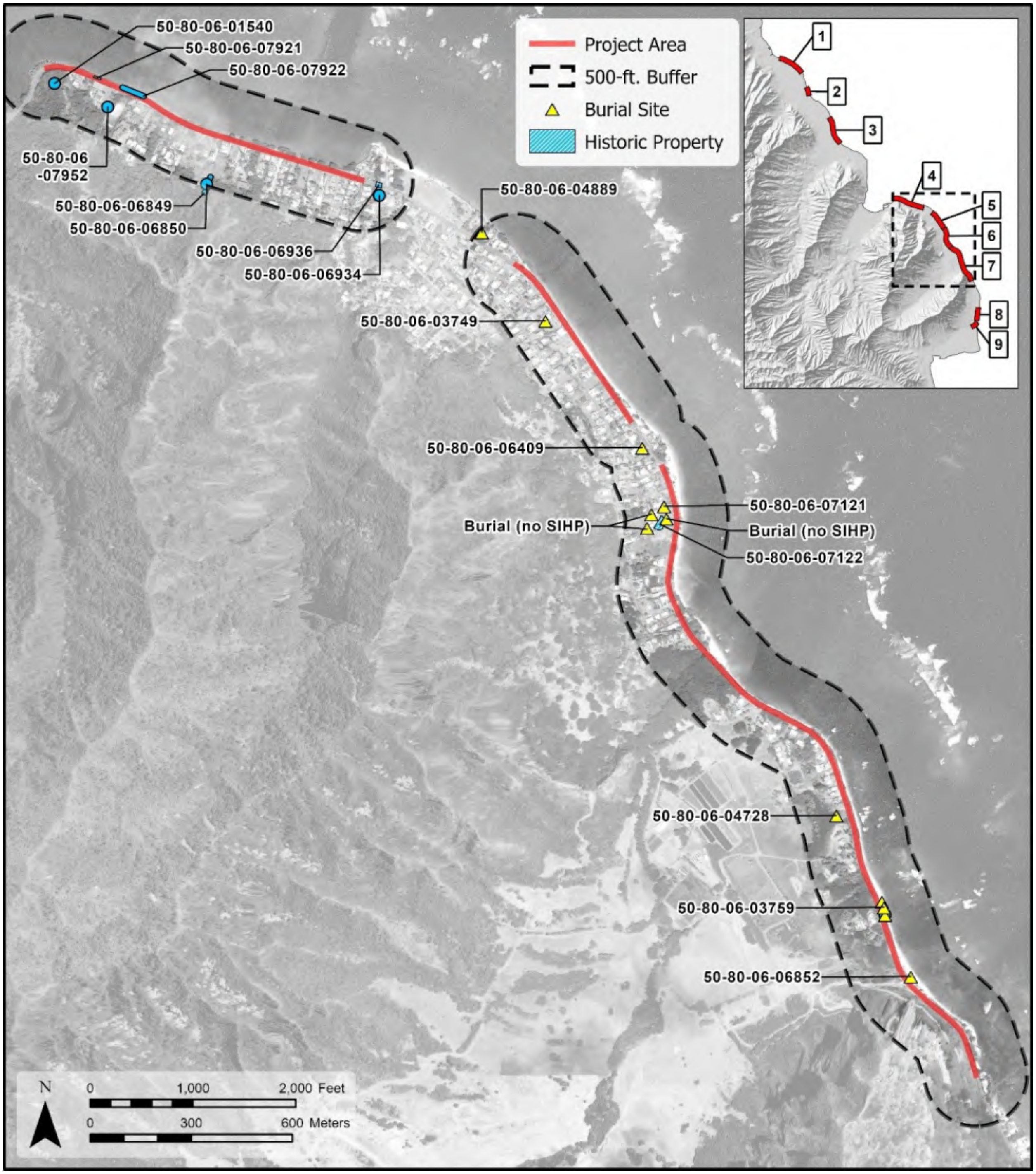

Figure 16. Previously-identified archaeological sites in sections 4–7 and environs (see table and text above for details)

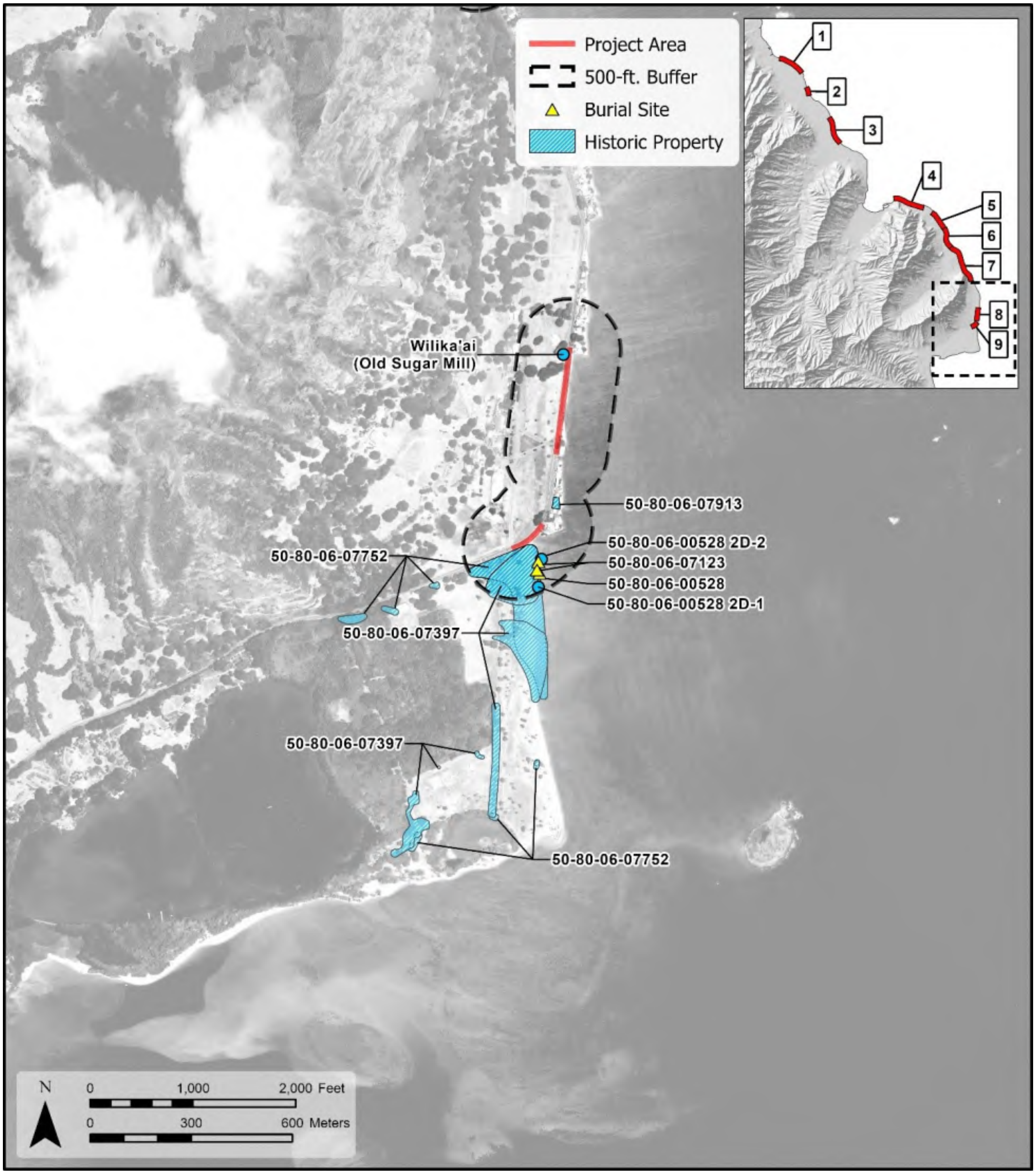

Figure 17. Previously-identified archaeological sites in sections 8–9 and environs (see table and text above for details)

Section 4 Results of Field Inspection

Fieldwork for this project was conducted on January 15, 2022, by Frederick LaChance, B.A., under the supervision of Christopher M. Monahan, Ph.D. (principal investigator). Fieldwork required approximately one (1) person day to complete. Fieldwork for this project was performed under the archaeological permit number 22-26 issued to Honua Consulting by the SHPD/DLNR in accordance with HAR Chapter 13-282.

4.1 Methodology

The archaeological field inspection consisted of a 100% pedestrian survey of the project area. The main objective was to identify any historic properties, or potential historic properties, along the makai (seaward) side of the highway ROW/project area.[1]

The project-area sections (1–9) were recorded using a hand-held Trimble GeoXT device that maintained an accuracy ranging between 1 to 3 meters (3–10 feet). In addition, field notes were recorded, more than 30 photographs were taken, and a detailed photo log (captions) was created. The locations of the photographs were recorded using the Trimble GeoXT. All data are stored and backed-up in Honua's database.

Figure 18 to Figure 43 are photographs of the project area from north (section 1) to south (section 9).

- For section 1, see Figure 18 to Figure 20;
- For section 2, see Figure 21 and Figure 22;
- For section 3, see Figure 23 and Figure 24;
- For section 4, see Figure 25 and Figure 26;
- For section 5, see Figure 27 and Figure 28;
- For section 6, see Figure 29 to Figure 31;
- For section 7, see Figure 32 to Figure 38;
- For section 8, see Figure 39 to Figure 41;
- For section 9, see Figure 42 and Figure 43.

4.2 Survey Results

The discussion below integrates the previous archaeological findings (Section 3) with soil mapping data (Section 1) and observations made during the fieldwork for this project. For each section, these integrated data sets are used to model the likelihood that additional (as-yet undiscovered) archaeological sites are located near the highway ROW. These modeling conclusions are in italics below.

4.2.1 Section 1

The makai side of the northern end of section 1 (see Figure 18) may include as-yet undocumented portions of SIHP # 50-80-05-4793, a culturally-enriched subsurface layer previously documented by Masterson et al. (1997). This subsurface layer contained at least one

[1] Under the laws and rules of historic preservation in Hawai‘i, objects, sites or other physical remains older than 50 years ago may qualify as "significant historic properties." Therefore, the current "cut off" date is now 1971.

traditional Hawaiian artifact as well as pit features that are typical of pre-Contact to early historic-period use of this area. Masterson et al. (1997:38) stated that the lateral limits of this site could not be determined and may extent in both the makai and mauka directions. In Figure 18, a portion of this makai-extension may be under the dense green vegetation to the right in the image.

The makai side of the middle portion of section 1—which is currently reinforced with wrapped (netted) boulders (see Figure 19)—may include as-yet undocumented portions of SIHP # 50-80-05-4792, a culturally-enriched subsurface layer previously documented by Masterson et al. (1997). This subsurface layer contained abundant traditional Hawaiian artifacts—including formal tools and debitage—as well as seven human burials. Masterson et al. (1997) stated that the lateral limits of this site could not be determined and may extent in both the makai and mauka directions.

The entire section 1 is within Jaucas sand (JaC—see Figure 9). These deposits are generally the most archaeologically sensitive on O‘ahu since they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The entire section 1 should be treated as highly likely to contain significant historic properties, or component features therein, in subsurface context—most likely associated with SIHP #s 50-80-05-4792 and/or -4793; and consisting of human burials and/or subsurface cultural layers.

4.2.2 Section 2

A human burial was documented by Jourdane (2003) near the northern end of section 2, along the makai side if the highway. An archaeological inventory survey (AIS) by Borthwick et al. (2005) of three beach lots within and just south of section 2 (between the highway and Kaluanui Beach Park) yielded no significant finds.

Section 2 is largely within the “Beaches” (BS) soil map unit (see Figure 9) and/or straddling the Beaches/Jaucas sand boundary. In general, the Beaches soil map unit refers to places of higher energy deposition and more prone to erosion compared with more geomorphologically stable Jaucas sand. Traditional Hawaiian land use generally avoided lands classified under the beaches soil map unit given its relative instability compared with Jaucas sand.

Section 2 has a moderate potential to contain additional significant historic properties, or component features therein, in subsurface context. The presence of mostly Beaches soil in this section lessens the chance of finding traditional (Hawaiian) sites.

4.2.3 Section 3

The human skeletal remains of at least 61 individuals have been identified in subsurface contexts along different locations of nearly the entire section 3 (SIHP # 50-80-06-5308 consisting of the remains of one individual [Jourdane 1995]; SIHP # 50-80-06-6695 with 23 individuals [Perzinski and Hammatt 2004]; SIHP #s 50-80-06-6574 through -6580 with 35 individuals [ibid.]; and SIHP # 50-80-06-3977 consisting of the remains of three individuals [Smith et al. 1988]). In addition, more than half of the entire length of section 3 was also identified as a subsurface (archaeological) cultural layer with numerous subterranean pit features, which are typical of pre-Contact to early historic-period use of this area. Since Perzinski and

Hammatt's archaeological monitoring project was confined to the highway ROW, the lateral limits of these subsurface cultural deposits—in particular, their makai limits—are unknown.

As with section 1 (above), the entire section 3 is within Jaucas sand (JaC—see Figure 9). These deposits are generally the most archaeologically sensitive on O'ahu since they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The entire section 3 should be treated as highly likely to contain significant historic properties, or component features therein, in subsurface context—most likely associated with SIHP #s 50-80-06-6695 and/or one of the many burial sites along this section.

4.2.4 Section 4

For the purposes of the subject project, the most relevant previous archaeological findings are those of Rieth et al. (2017) who documented SIHP # 50-80-06-7921, a subsurface cultural layer dating to pre-Contact to early historic times (with abundant evidence of traditional Hawaiian artifacts and habitation), under the north bound lane and makai-side shoulder of the highway; and, also, SIHP # 50-80-06-7922, a 100-m (meter) long mortared rock wall dating from 1920s along the makai shoulder of the highway near the northern end of section 4. The subsurface cultural layer (SIHP # 7921), an unusually rich collection of traditional Hawaiian artifacts, marine fauna and other midden dating from as early as the 1500s, is currently below the asphalt, confined by a shoreline boulder retaining structure (see Figure 25). Rieth et al. (2017) noted that this subsurface layer is in danger of being completely eroded away by rising sea levels, and that any future construction in this area should make every effort to salvage what may be left of this cultural deposit. They also reported that the mortared rock wall (SIHP # 7922) dating from the original construction of the Kamehameha Highway in the 1920s was partially shored up/reinforced during the highway construction project that was the subject of their archaeological work, and that this wall should not be disturbed without consultation with the State Historic Preservation Division (SHPD).

Unlike most other sections in the project area—which are dominated by sandy deposits—the entire section 4 consists of varieties of stony silty clay, very stony silty clay, very stony clay and loam (which is a mixture of clay, silt and sand) (see Figure 9). In general, and particularly at coastal locations, these soils are less likely to contain Hawaiian burials.

Section 4 has two known sites (SIHP # 7921 and 7922) that will be impacted by any significant alteration to the makai side of the highway. The rest of this section has a moderate potential to contain as-yet unidentified historic properties, or component features therein, in subsurface context.

4.2.5 Section 5

Several small studies near this section (but not within the highway ROW) have resulted in the documentation of three human burial sites containing the remains of several individuals: SIHP # 50-80-06-4889, representing the remains of multiple individuals (Jourdane 1994) north and just mauka of this section; SIHP # 50-80-06-3749, one set of remains mauka of the highway (Kam 1987); and SIHP # 50-80-06-6409, representing the remains of three individuals mauka of the highway between sections 5 and 6 (Collins 2002).

The soil data (see Figure 9) show that Mokuleia loam (Ms) characterizes most of section 5, with a short section of Jaucas sand (JaC) at its southern end.

Section 5 has a moderate potential to contain additional significant historic properties, or component features therein, in subsurface context, including human burials and/or subsurface cultural layers.

4.2.6 Section 6

In addition to the human burial (SIHP # 50-80-06-6409) cited above—which is halfway between sections 5 and 6, the other place where archaeological sites have been documented in this section is on the grounds of Ka‘a‘awa Elementary School. Guerriero and Kennedy (2005) documented three human burials (Guerriero and Kennedy 2005) (no SIHP #s were assigned to these burials); and Groza and Hammatt (2010) documented one set of human remains (SIHP # 50-80-06-7121) encountered during subsurface excavations in the northeast corner of the project area. A traditional Hawaiian cultural layer was also identified (SIHP # 50-80-06-7122) in subsurface context. This cultural layer contained fire-pit features and a pit with dog bones; charcoal, midden, fire-affected rock and basalt debitage and traditional Hawaiian tools.

Nearly the entire section 6 is within Jaucas sand (JaC—see Figure 9). These deposits are generally the most archaeologically sensitive on O‘ahu since they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The entire section 6 should be treated as highly likely to contain significant historic properties, or component features therein, in subsurface context, likely consisting of human burials and/or subsurface cultural layers.

4.2.7 Section 7

Several small studies near this section have resulted in the documentation of three human burial sites: SIHP # 50-80-06-4728, representing the remains of one individual (Jourdane 1993) just mauka of the highway; SIHP # 50-80-06-3759, the remains of multiple individuals eroding out of the roadway on the makai side over the course of several years (Pietrusewsky and Lee 1988; Smith 1988; Cleghorn 1991; Pietrusewsky and Ikehara 1991; Dye 1996); and SIHP # 50-80-06-6852, the remains of one individual eroding out of the makai side of the highway (Chinen 2006).

Section 7 traverses a variety of soil map units, but both its northern and southern ends are in, or immediately adjacent to, Jaucas sand (JaC—see Figure 9), which is generally the most archaeologically sensitive on O‘ahu since it frequently contains traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The entire section 7 should be treated as highly likely to contain significant historic properties, or component features therein, in subsurface context, likely consisting of human burials and/or subsurface cultural layers.

4.2.8 Section 8

To the best of our knowledge, no previous archaeological studies have been conducted in the highway ROW at section 8. Van Ryzin et al.’s (2015) AIS of a private residence on the makai side of the highway, about 500 ft. south of the southern end of this section, identified one site

(SIHP # 50-80-06-7913), a subsurface cultural layer dating from pre-Contact to early historic-period times.

The soil data (see Figure 9) show that Mokuleia loam (Ms) characterizes most of section 8, but both of the ends transition into nearby Jaucas sand (JaC), which typically means it underlies the loam.

Section 8 has a moderate potential to contain additional significant historic properties, or component features therein, in subsurface context, including human burials and/or subsurface cultural layers.

4.2.9 Section 9

In addition to SIHP # 50-80-06-7913 (described above for section 8), which is about 200 ft. northeast of the north end of section 9, the following historic properties are located near section 9: (1) SIHP # 50-80-06-7397 and SIHP # 50-80-06-7752, which are two, discontinuous, laterally-extensive and partially-overlapping subsurface cultural layers (i.e., intact soil-sediments [mostly Jaucas sand deposits] that are culturally-enriched with traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation) – as depicted in Figure 17, these subsurface layers directly abut the southwest portion of section 9, and other portions of them extend to the west and south; (2) SIHP # 50-80-06-7123, previously-disturbed human skeletal remains eroding into the ocean that were recovered and re-located to the Kualoa Beach Park's storage unit (Clark and Lebo 2014); and (3) Subsurface features assigned to SIHP # 50-80-06-528 (which refers to the historic-property designation of the entire Kualoa Ahupua'a) documented in shovel-testing by Ahlo (1980) in which traditional cultural deposits were located. In addition, human skeletal remains eroding into the ocean documented by Vitousek (2010) were also identified in the area of the SIHP # 50-80-06-528 features identified by Ahlo (1980)

The soil data (see Figure 9) show that Mokuleia loam (Ms) characterizes section 9, but its northeast end is adjacent to Jaucas sand (JaC), which typically means it underlies the loam.

Section 9 has a high potential to contain additional significant historic properties, or component features therein, in subsurface context, including human burials and/or subsurface cultural layers.

Figure 18. Northern end of section 1 at the boundary of Hau‘ula and Mākao ahupua‘a, a short distance east of Hauula Homestead Road; view east

Figure 19. Middle of section 1, near the boundary of Mākao and Kapaka ahupuaʻa, just south of Makao Road; view northwest

Figure 20. Southern end of section 1, in Kapaka Ahupua‘a, just north of Kalaipaloa Point; view northwest

Figure 21. Northern end of section 2, Kaluanui Ahupua‘a, just south of Kaluanui Beach; view south

Figure 22. Southern end of section 2, Kaluanui Ahupuaʻa, just north of Puhuli Street; view north

Figure 23. Northern end of section 3, Hale‘aha Ahupua‘a, south of Kaya’s Restaurant and the north end of Punalu‘u Beach; view south

Figure 24. Southern end of section 3, Wai‘ono Ahupua‘a, near Ching’s Store and the southern end of Punalu‘u Beach; view north-northwest

Figure 25. Northern end of section 4, near boundary of Kahana and Makaua 2 Ahupua‘a, makai of Crouching Lion; view east

Figure 26. Southern end of section 4, near boundary of Ka'a'awa and Makaua 1 Ahupua'a, near Ka'a'awa Point; view north

Figure 27. Northern end of section 5, Ka‘a‘awa Ahupua‘a, at the southern end of several residential structures just south of Swanzy Beach Park; view southeast

Figure 28. Southern end of section 5, Ka‘a‘awa Ahupua‘a, between Puakenikeni and ‘Ōhelokai roads; view north

Figure 29. Northern end of section 6, Ka‘a‘awa Ahupua‘a, at the northern end of Ka‘a‘awa Beach; view south-southeast

Figure 30. Middle of section 6, Ka‘a‘awa Ahupua‘a, across from Ka‘a‘awa Elementary School; view south

Figure 31. Southern portion of section 6, Ka‘a‘awa Ahupua‘a, southeast of Ka‘a‘awa Elementary School; view south

Figure 32. View of area around bridge spanning Ka‘a‘awa Stream (Ka‘a‘awa Ahupua‘a) at the northern end of Section 7; view west

Figure 33. Boulder sea-wall structure at the southern end of Kalae‘ō‘io Beach Park (near northern end of section 7), Ka‘a‘awa Ahupua‘a; view southeast

Figure 34. Failing retaining-wall structure at the southern end of Ka‘a‘awa Bay (Ka‘a‘awa Ahupua‘a), middle of section 7; view east-southeast

Figure 35. Severe beach-front erosion near the southern end of section 7, adjacent to Ka‘a‘awa Valley Road (near boundary of Ka‘a‘awa and Kualoa 2 Ahupua‘a); view southwest

Figure 36. View from the roadway of severe beach-front erosion near the southern end of section 7, adjacent to Ka‘a‘awa Valley Road (near boundary of Ka‘a‘awa and Kualoa 2 Ahupua‘a); view north

Figure 37. View of mitigation effort to combat severe beach-front erosion near the southern end of section 7, adjacent to Ka‘a‘awa Valley Road (near boundary of Ka‘a‘awa and Kualoa 2 Ahupua‘a); view west

Figure 38. Southern end of section 7, Kualoa 2 Ahupuaʻa; view west-northwest

Figure 39. Retaining structures at northern end of section 8 (Kualoa 2 Ahupuaʻa), makai of the old sugar mill ruins; view south

Figure 40. Retaining structures near the southern end of section 8 (Kualoa 2 Ahupuaʻa); view north

Figure 41. View near the southern end of section 8 (Kualoa 2 Ahupuaʻa); view north

Figure 42. View of section 9 near Kualoa Point (Kualoa 1 Ahupuaʻa); facing southwest

Figure 43. Another view of section 9 near Kualoa Point (Kualoa 1 Ahupuaʻa); facing northeast

Section 5 Conclusion

This report was completed at the request of AECOM Corp., in support of the Hawaiʻi Department of Transportation's project to develop mitigation solutions to ocean-wave erosion and undermining of Kamehameha Highway along portions of the windward Oʻahu coastline. The project area generally extends from Hauʻula Homestead Road (Hauʻula town) to Kualoa Point.

Because the project area consists of nine (9) sections extending several miles from Hauʻula to Kualoa, it has been divided into three Sheets (designated Sheets 1–3) for reporting and analytical purposes. The project area traverses coastal portions of the following 13 ahupuaʻa (in order from north to south):

Sheet 1 (see Figure 3)
- Section 1 - Hauʻula, Mākao and Kapaka
- Section 2 - Kaluanui
- Section 3 - Haleʻaha, Kapano, Puheʻemiki and Waiʻono

Sheet 2 (see Figure 4)
- Section 4 – Kahana, Makaua 2, Makaua 1 and Kaʻaʻawa
- Section 5 – Kaʻaʻawa
- Section 6 – Kaʻaʻawa
- Section 7 – Kaʻaʻawa and Kualoa 2

Sheet 3 (see Figure 5)
- Section 8 – Kualoa 2 and Kualoa 1
- Section 9 – Kualoa 1

Soils data demonstrate that a high proportion of the project area sections are within or immediately adjacent to Jaucas sand. These deposits are generally the most archaeologically sensitive on Oʻahu since they frequently contain traditional Hawaiian burials and cultural layers dating from pre-Contact to early historic times.

The objectives of this Archaeological Literature Review and Field Inspection (ALRFI) were to: (1) document and describe the project area's land-use history in the context of both its traditional Hawaiian character as well as its historic-period changes; (2) identify any archaeological historic properties or component features in and immediately adjacent to the project area; and (3) prove information relevant to the likelihood of encountering historically-significant cultural deposits in subsurface context during potential erosion-mitigation activities.

Historic bridges are not covered under this report.

This ALRFI is not an archaeological inventory survey (AIS), and it is not intended for formal review by the State Historic Preservation Division (SHPD). It may be used, however, to support the project proponent's consultation with the SHPD in compliance with applicable state and federal historic preservation and environmental laws.

As described in this report, archival research and fieldwork demonstrate several relevant findings: (1) Other than a few rock walls dating from the historic or early modern period and the ruins of an old sugar mill known as Wilikaʻai (at Kualoa), there are no above-ground archaeological sites or historic properties within, or in the immediate vicinity of, the highway ROW/project area; (2) Only one above-ground traditional Hawaiian site (a rock terrace, SIHP #

50-80-06-6850) has been documented within the 500-ft. buffer around the project area (and this site is about 500 ft. mauka of the highway); and (3) By far, the two most common archaeological site types within, or in the immediate vicinity of, the highway ROW/project area are (a) human burials in subsurface context (which include intact burials as well as a wide variety of disturbed sites with incomplete/fragmentary sets of human skeletal remains) and (b) subsurface cultural layers (i.e., intact soil-sediments [mostly Jaucas sand deposits] that are culturally-enriched with traditional Hawaiian and/or historic artifacts, midden and other evidence of occupation), some of which also include human burials. Some of these sites with subsurface cultural layers and human burials are actively eroding into the ocean.

5.1 Recommendations

Based on all available evidence, including project-specific findings outlined in Section 4.2 (Survey Results), which integrated previous archaeological findings (Section 3) with soil mapping data (Section 1) and observations made during the fieldwork for this project, our recommendations are as follows:

1. Sections 1, 3, 6, 7 and 9 are highly likely to contain significant historic properties, or component features therein, in subsurface context, likely consisting of human burials and/or subsurface cultural layers. In some cases, as outlined in Section 4.2, it is expected that lateral extensions of previously-identified sites will be encountered if ground disturbance takes places along the mauka or makai edges of the highway ROW. All work in these sections should be subject to archaeological monitoring.
2. The remaining sections (2, 4, 5 and 8) have a moderate potential to contain additional significant historic properties, or component features therein, in subsurface context, including human burials and/or subsurface cultural layers. All work in these sections should be subject to archaeological monitoring.
3. An approximately 100-meter long mortared rock wall (SIHP # 50-80-06-7922) dating from the original construction of the Kamehameha Highway in the late 1920s (documented by Rieth et al. 2017) along the makai shoulder of the highway in section 4 needs to be taken into account (i.e., not altered or damaged without express written consent of the SHPD). This wall is depicted in Figure 44 and Figure 45.
4. The SHPD-Archaeology Branch should be consulted on archaeological matters associated with proposed ground disturbance associated with the proposed shoreline mitigation project.

Figure 44. View of mortared rock wall (SIHP # 50-80-06-7922) dating from the original construction of the Kamehameha Highway in the late 1920s along the makai shoulder of the highway in section 4; facing south

Figure 45. View of mortared rock wall (SIHP # 50-80-06-7922) dating from the original construction of the Kamehameha Highway in the late 1920s along the makai shoulder of the highway in section 4; facing north

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Appendix D:
Cultural Impact Assessment

Cultural Impact Assessment for the Kamehameha Highway – Windward Coast Shoreline Mitigation Project Multiple Ahupuaʻa, Koʻolauloa & Koʻolaupoko Districts, Oʻahu Island
TMK: (1) 4-9, 5-1 & 5-3-various plats & parcels

Prepared for
AECOM

Prepared by

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Note on Hawaiian Language Use

In keeping with other Hawaiian scholars, we do not italicize Hawaiian words. Hawaiian is both the native language of the paeʻāina of Hawaiʻi and an official language of the State of Hawaiʻi. Some authors will leave Hawaiian words italicized if part of a quote; we do not. In the narrative, we use diacritical markings to assist our readers, except in direct quotes, in which we keep the markings used in the original text. We provide translations contextually when appropriate. Unless otherwise noted, all translations are by Honua Consulting authors.

Front Cover Credit

Kaaawa Valley Coastline

Executive Summary

This cultural impact assessment (CIA) was completed at the request of AECOM Corp., in support of the Hawaiʻi Department of Transportation's (HDOT's) project to develop mitigation solutions to ocean-wave erosion and undermining of Kamehameha Highway along portions of the windward Oʻahu coastline. The project area generally extends from Hauʻula Homestead Road (Hauʻula town) to Kualoa Point. The project area consists of nine (9) sections extending several miles from Hauʻula to Kualoa. The project area traverses coastal portions of 13 ahupuaʻa.

Research in preparation of this report consisted of a thorough search of Hawaiian language documents, including but not limited to the Bishop Museum Mele Index and Bishop Museum archival documents, including the Hawaiian language archival cache. All Hawaiian language documents were reviewed by Hawaiian language experts to search for relevant information to include in the report. Documents considered relevant to this analysis are included herein, and translations are provided when appropriate to the discussion. Summaries of interviews with lineal and cultural descendants with ties to the project area are included in the study, and information on other past oral testimonies are also provided herein. Data was extrapolated from these sources that provide an unprecedented comprehensive look at the previous cultural resources on this ʻāina.

This survey thoroughly identified valued cultural, historical, and natural resources in the project area, including the extent to which traditional and customary Native Hawaiian rights are exercised in the project area.

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Abbreviations and Acronyms

AIS: Archaeological Inventory Survey
BMP: Best Management Practice
CIA: Cultural Impact Assessment
ESP: Environmental Review Project, Office of Planning and Sustainable Development
HAR: Hawaii Administrative Rules
HDOT: Hawaii Department of Transportation
HRS: Hawaii Revised Statutes
ILK: Indigenous Local Knowledge
Ka Paʻakai: *Ka Paʻakai O Ka ʻĀina v. Land Use Commission*, 94 Haw. 31 (2000)
LRFI: Literature Review and Field Investigation
OEQC: Office of Enviornmental Quality and Control
SHPD: State Historic Preservation Division
SIHP: State Inventory of Historic Places
SLH: Session Laws of Hawaii
TEK: Traditional Ecological Knowledge
TMK: Tax Map Key
USGS: U.S. Geological Survey

1.0 Project Description and Compliance

This cultural impact assessment (CIA) was completed at the request of AECOM Corp., in support of the Hawaiʻi Department of Transportation's (HDOT's) project to develop mitigation solutions to ocean-wave erosion and undermining of Kamehameha Highway along portions of the windward Oʻahu coastline. The project area generally extends from Hauʻula Homestead Road (Hauʻula town) to Kualoa Point. Because the project area consists of nine (9) sections extending several miles from Hauʻula to Kualoa, it has been divided into three Sheets (designated Sheets 1–3) for reporting and analytical purposes. The project area traverses coastal portions of the following 13 ahupuaʻa (in order from north to south):

Sheet 1 (see Figure 3)
- Section 1 - Hauʻula, Mākao and Kapaka
- Section 2 - Kaluanui
- Section 3 - Haleʻaha, Kapano, Puheʻemiki and Waiʻono

Sheet 2 (see Figure 4)
- Section 4 – Kahana, Makaua 2, Makaua 1 and Kaʻaʻawa
- Section 5 – Kaʻaʻawa
- Section 6 – Kaʻaʻawa
- Section 7 – Kaʻaʻawa and Kualoa 2

Sheet 3 (see Figure 5)
- Section 8 – Kualoa 2 and Kualoa 1
- Section 9 – Kualoa 1

1.1 Project Description

The proposed project will develop mid-term shoreline mitigation solution(s) to address current undermining of Kamehameha Highway due to wave erosion. Nine (9) locations along the Windward Coast of Oʻahu have been identified for mitigation – located in stretches of unimproved shoreline (i.e., no development) where existing erosion measures are currently failing or non-existent. It is anticipated that mitigation solutions will consider rock revetment, vertical sheet pile, beach fill, etc. The exact treatment, or combination of treatments, at each area will be determined upon site condition and coordination with HDOT. Minor roadway realignment (horizontal and vertical) may need to be considered in the environmental evaluation, but it is not anticipated to be a viable mid-term solution (and should rather be considered as a long-term solution).

Figure 1. Portion of 2017 U.S. Geological Survey (USGS) topographic map (Kahana and Hauula quadrangles) showing project area as nine (9) sections (base map source: USGS online at http://ngmdb.usgs.gov/topoview)

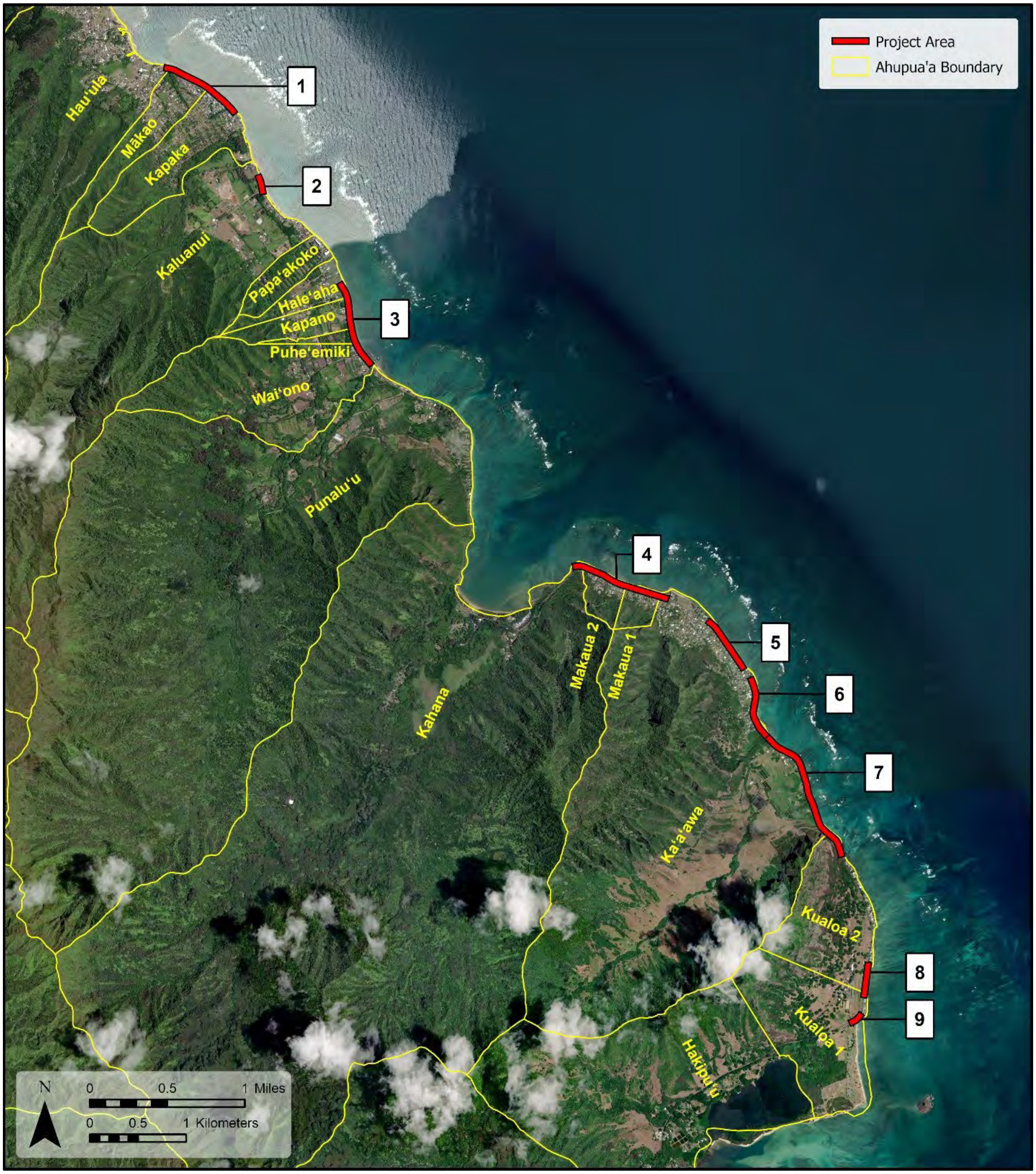

Figure 2. Aerial photograph showing location of project area (nine [9] sections) and the various ahupuaʻa (base image source: ESRI's ArcMap 2.2)

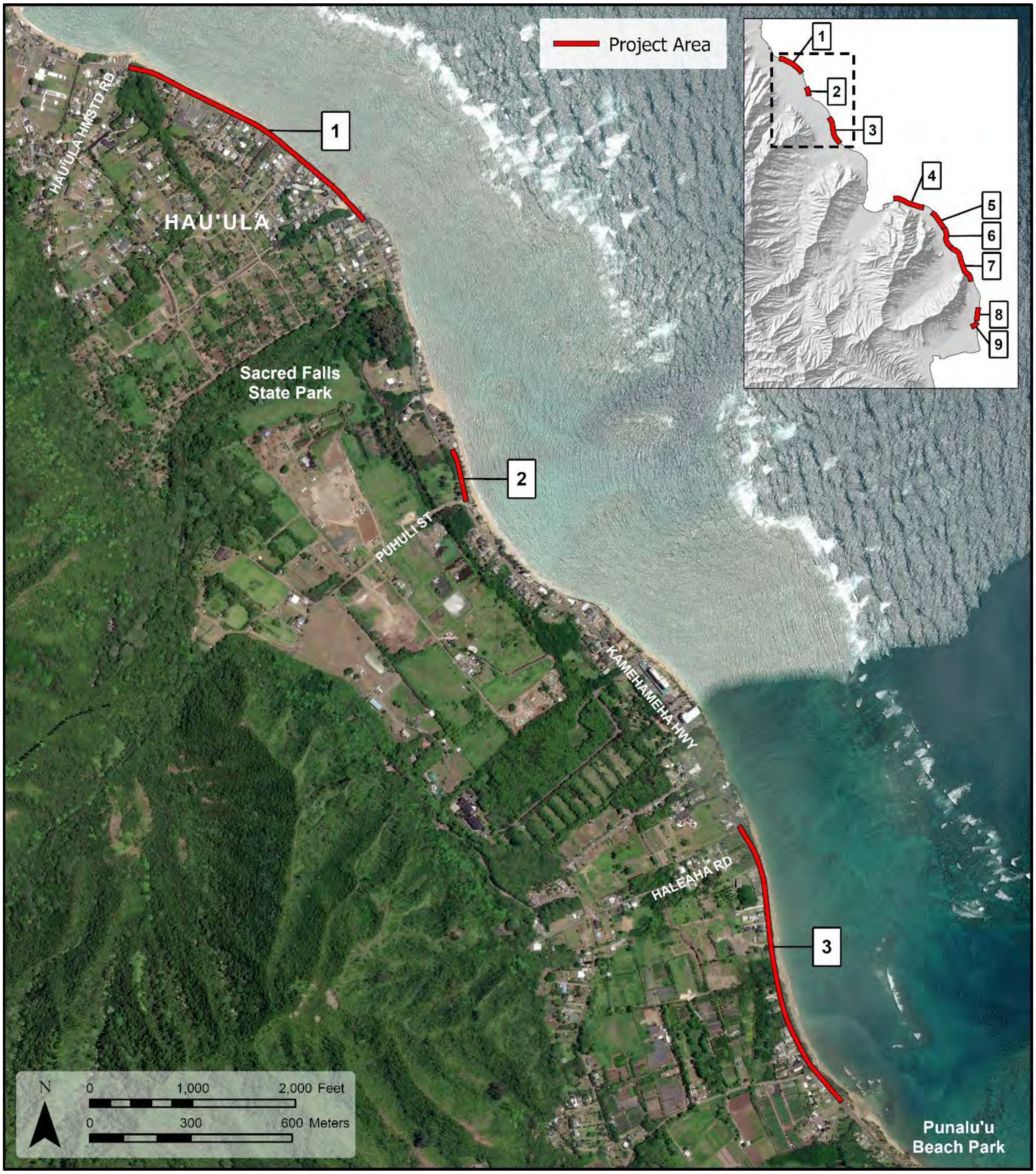

Figure 3. Aerial photograph showing location of Sheet 1 (sections 1–3) and selected roads, place names, and other landmarks (base image source: ESRI's ArcMap 2.2)

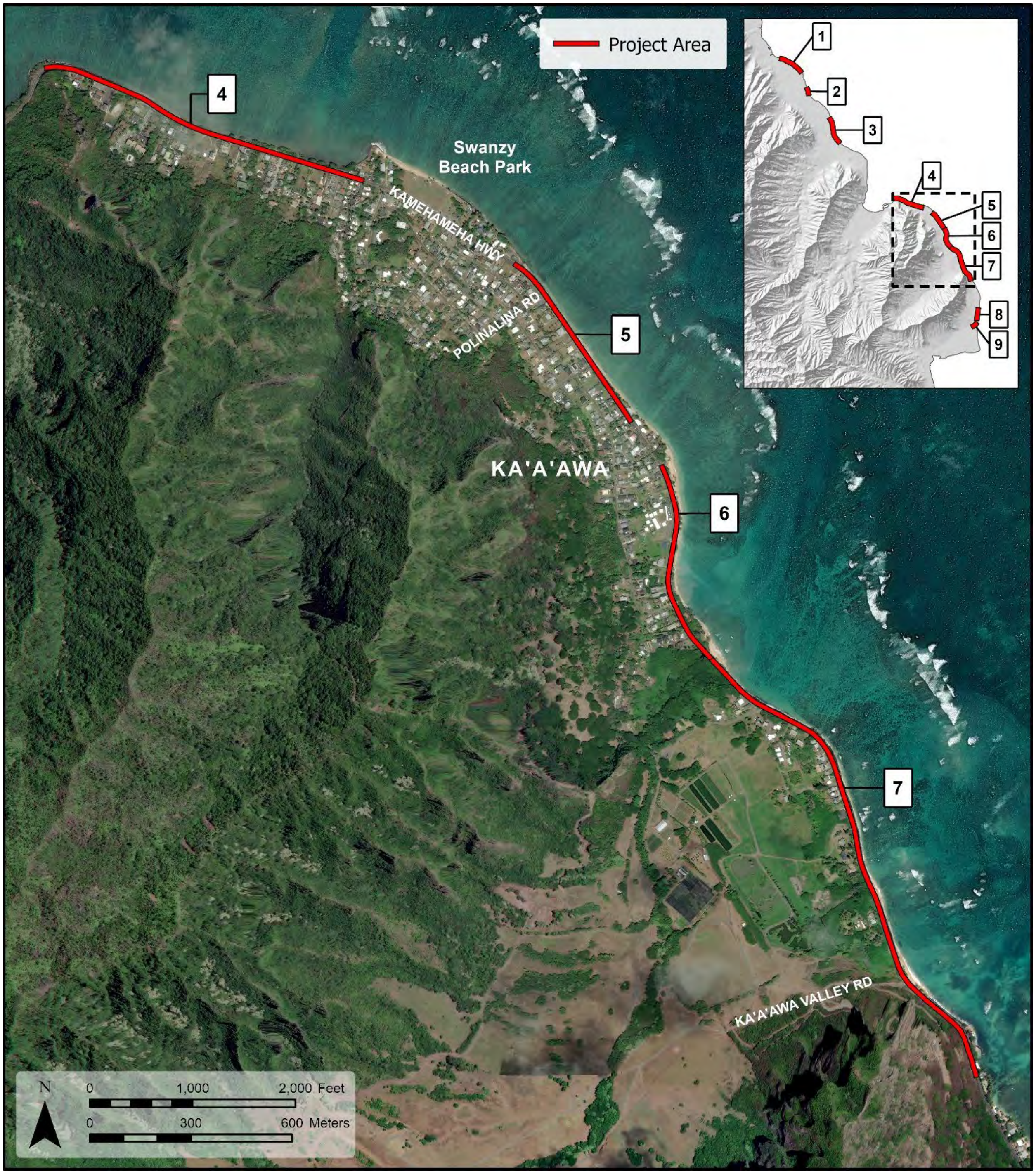

Figure 4. Aerial photograph showing location of Sheet 2 (sections 4–7) and selected roads, place names, and other landmarks (base image source: ESRI's ArcMap 2.2)

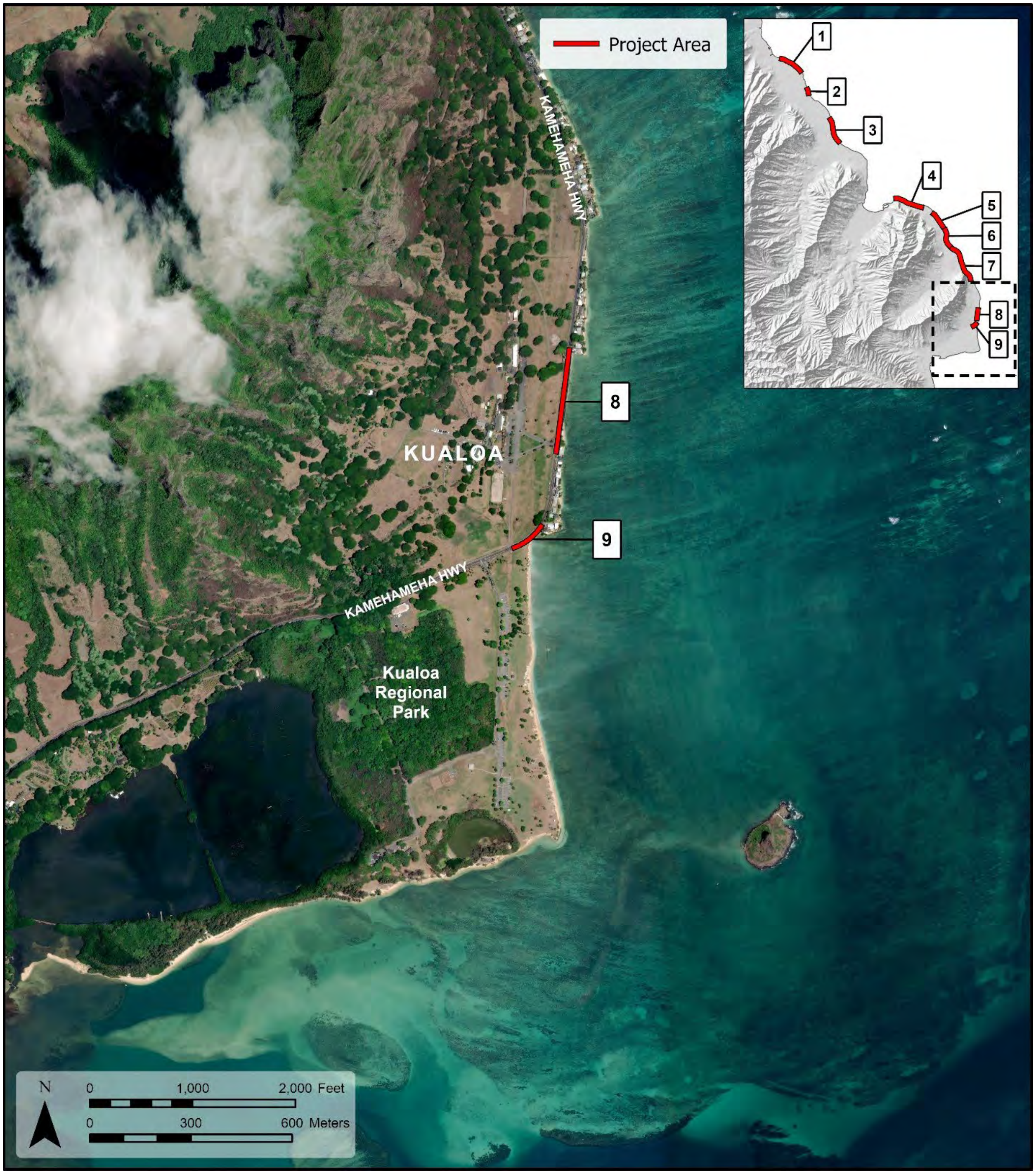

Figure 5. Aerial photograph showing location of Sheet 3 (sections 8–9) and selected roads, place names, and other landmarks (base image source: ESRI's ArcMap 2.2)

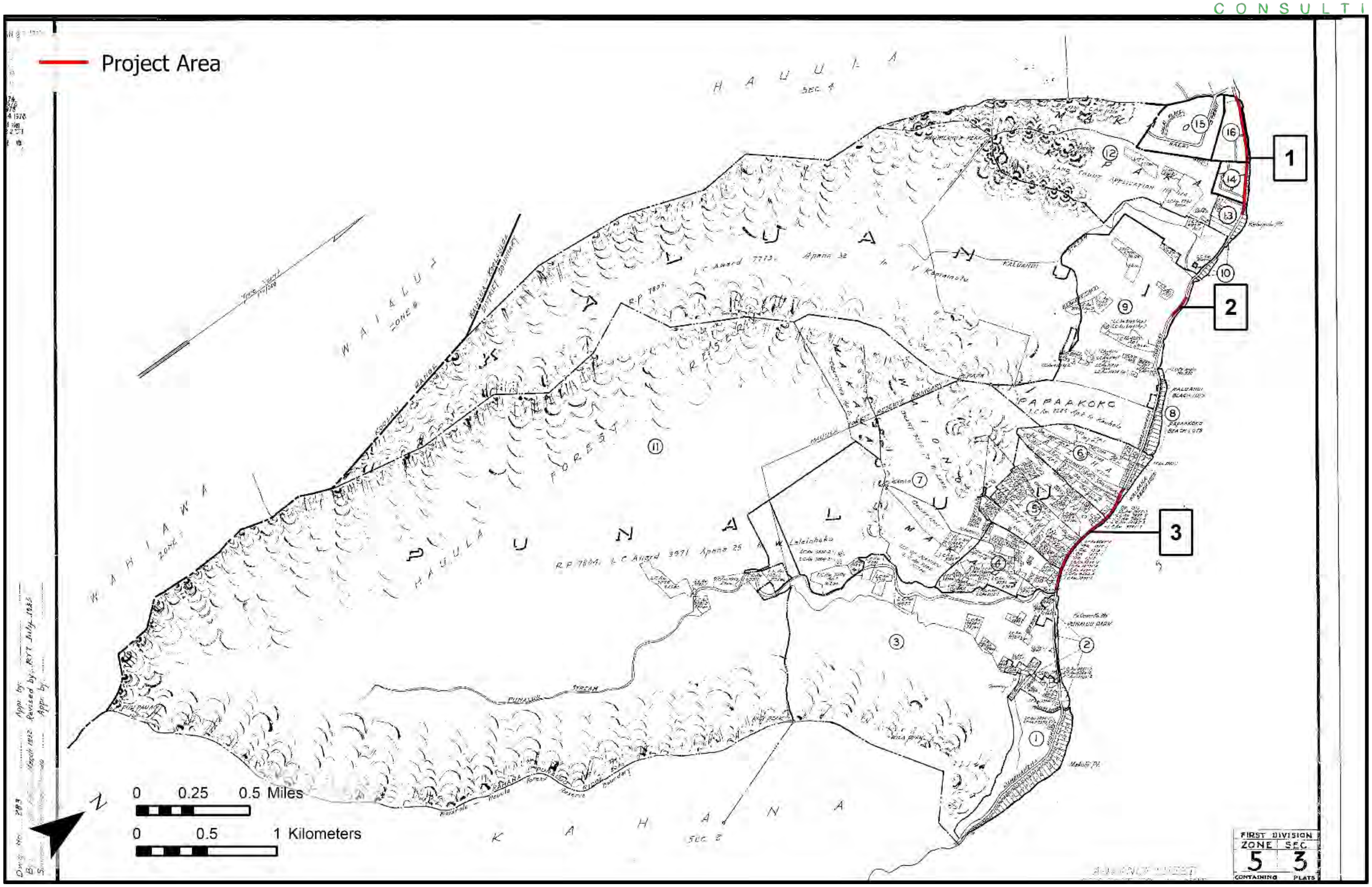

Figure 6. Tax Map Key (TMK): [1] 5-3 showing sections 1–3 (base map source: Hawai‘i TMK Service n.d.)

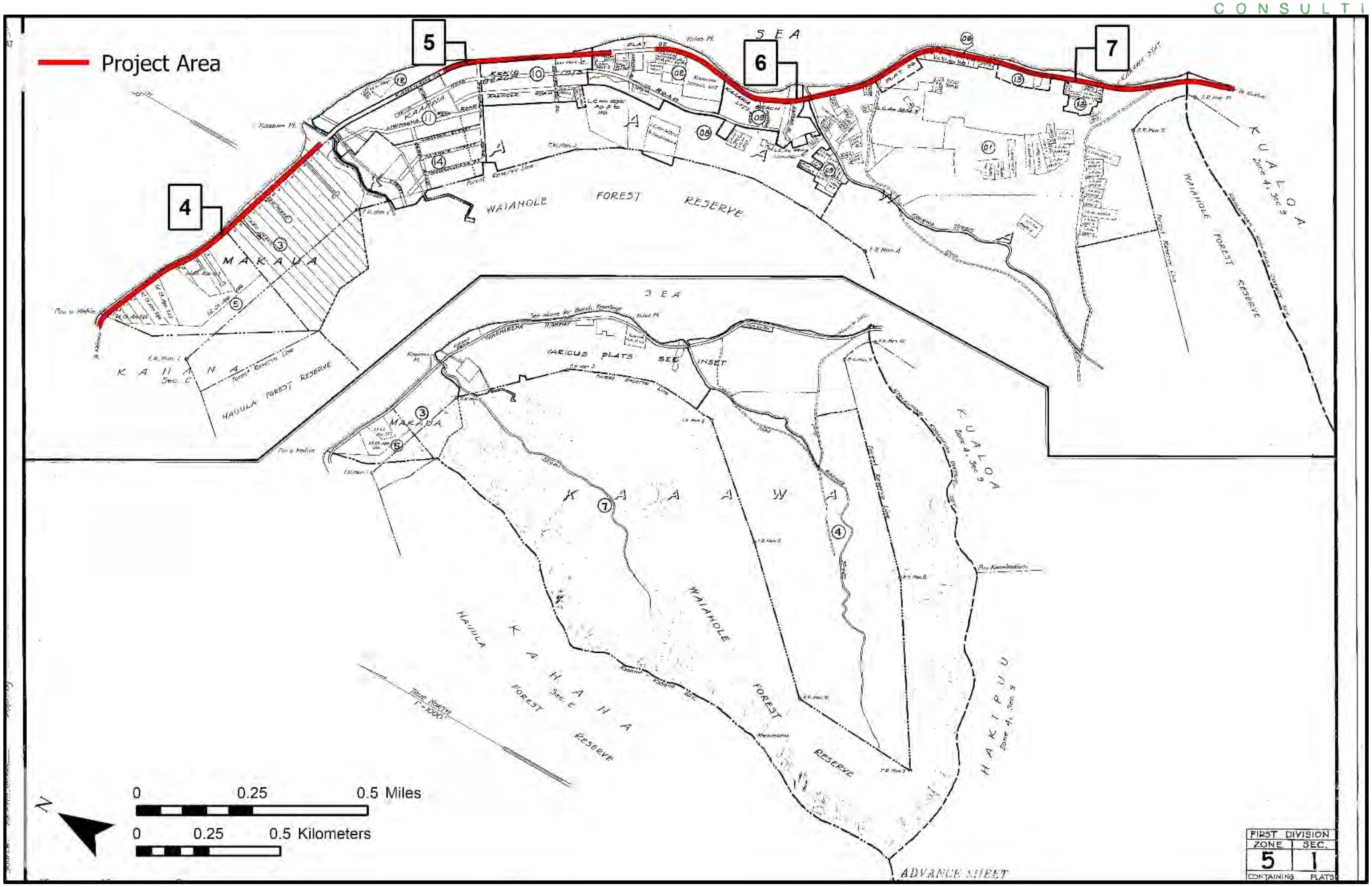

Figure 7. Tax Map Key (TMK): [1] 5-1 showing sections 4–7 (base map source: Hawai‘i TMK Service n.d.)

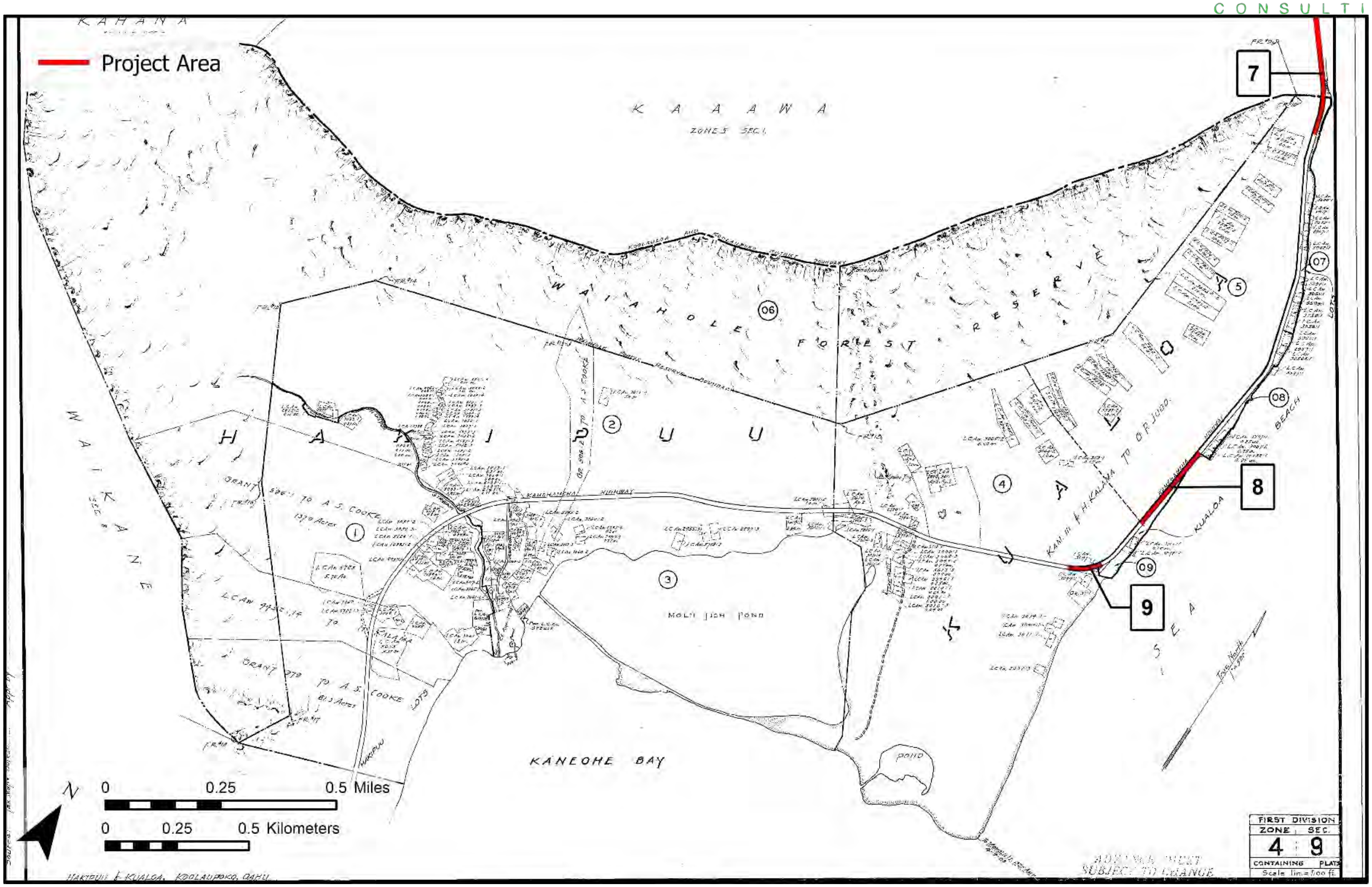

Figure 8. Tax Map Key (TMK): [1] 4-9 showing portion of section 7 and sections 8–9 (base map source: Hawai'i TMK Service n.d.)

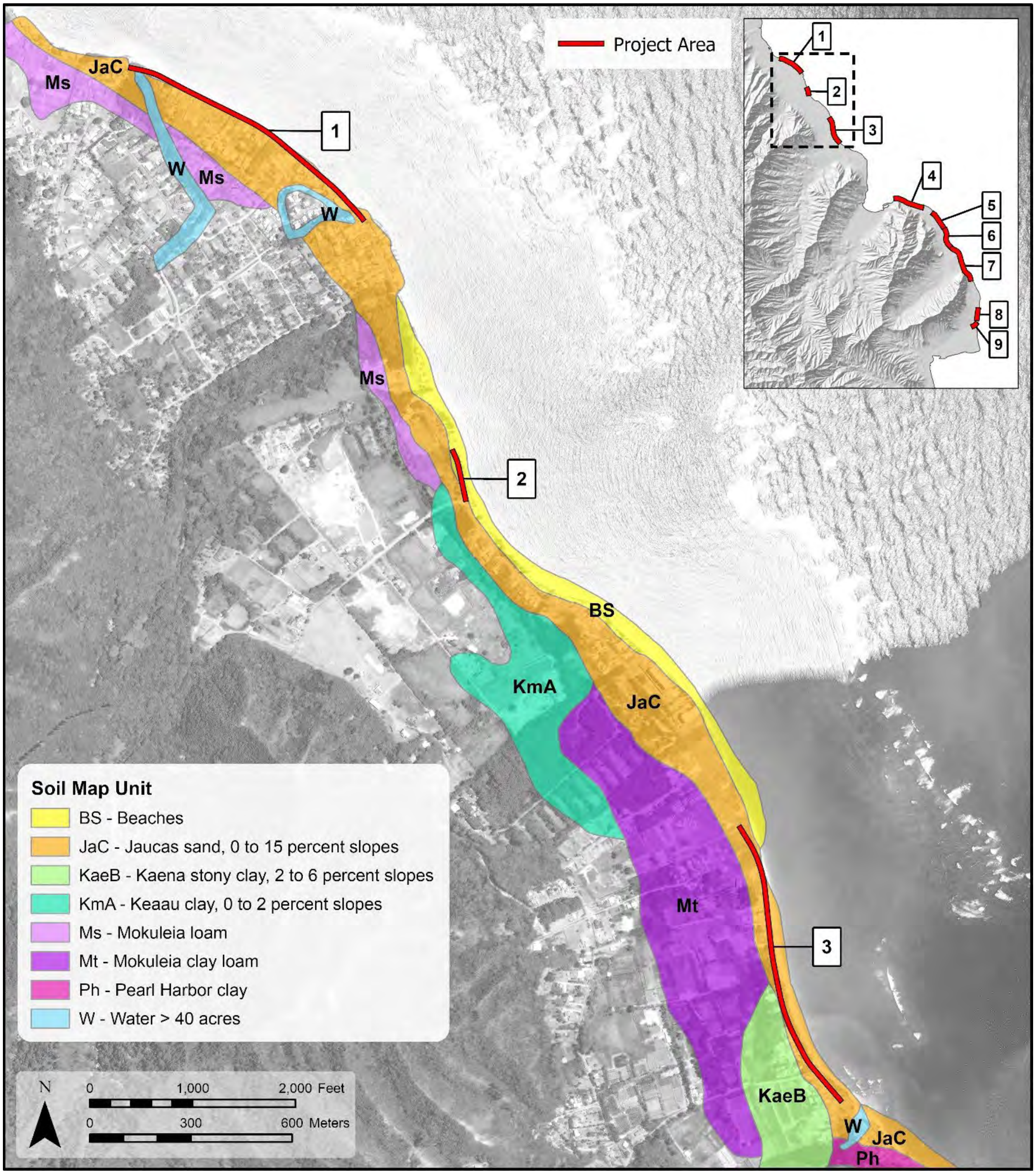

Figure 9. Soil survey data for sections 1–3 and environs (soils data from Foote et al. 1972)

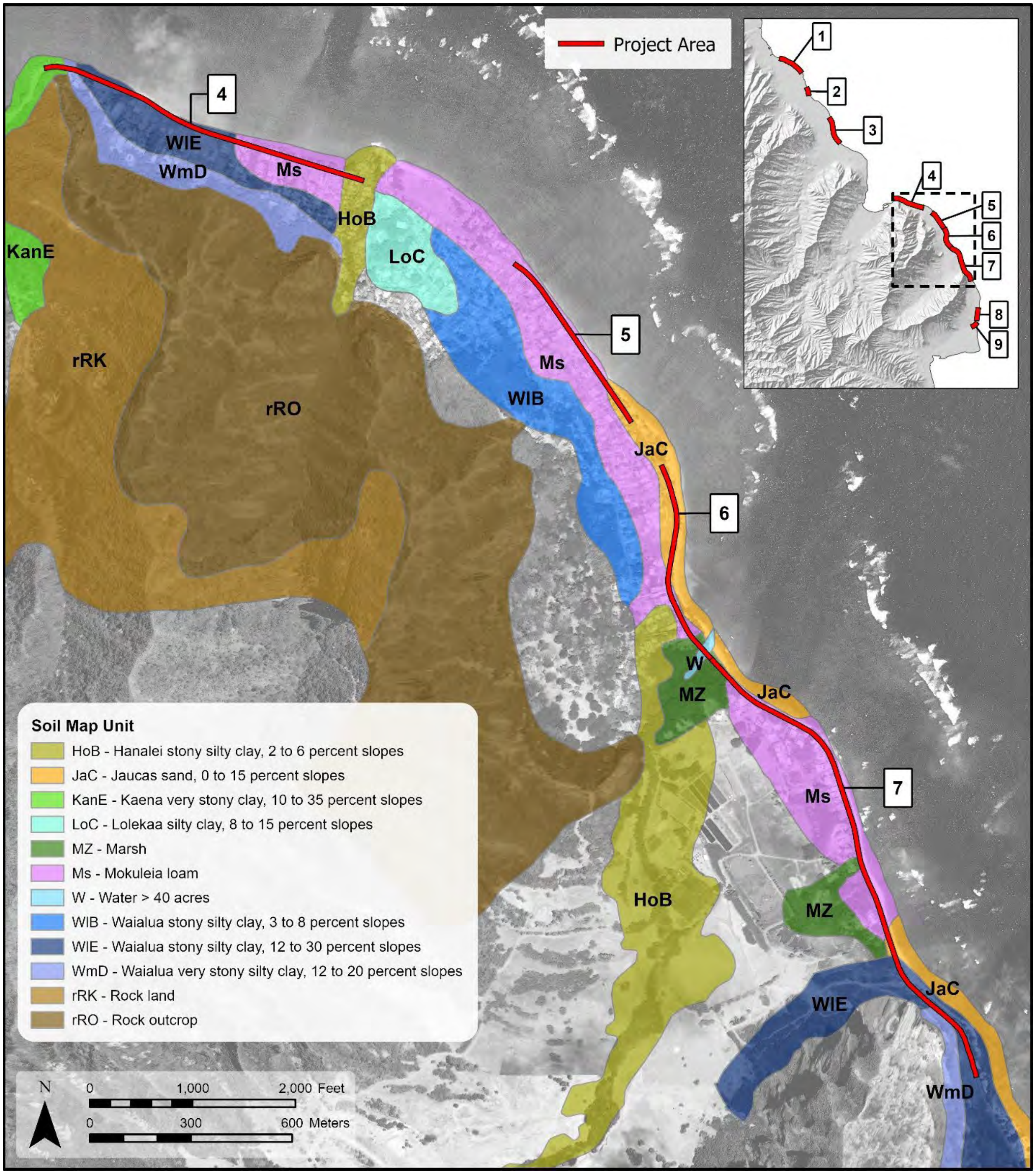

Figure 10. Soil survey data for sections 4–7 and environs (soils data from Foote et al. 1972)

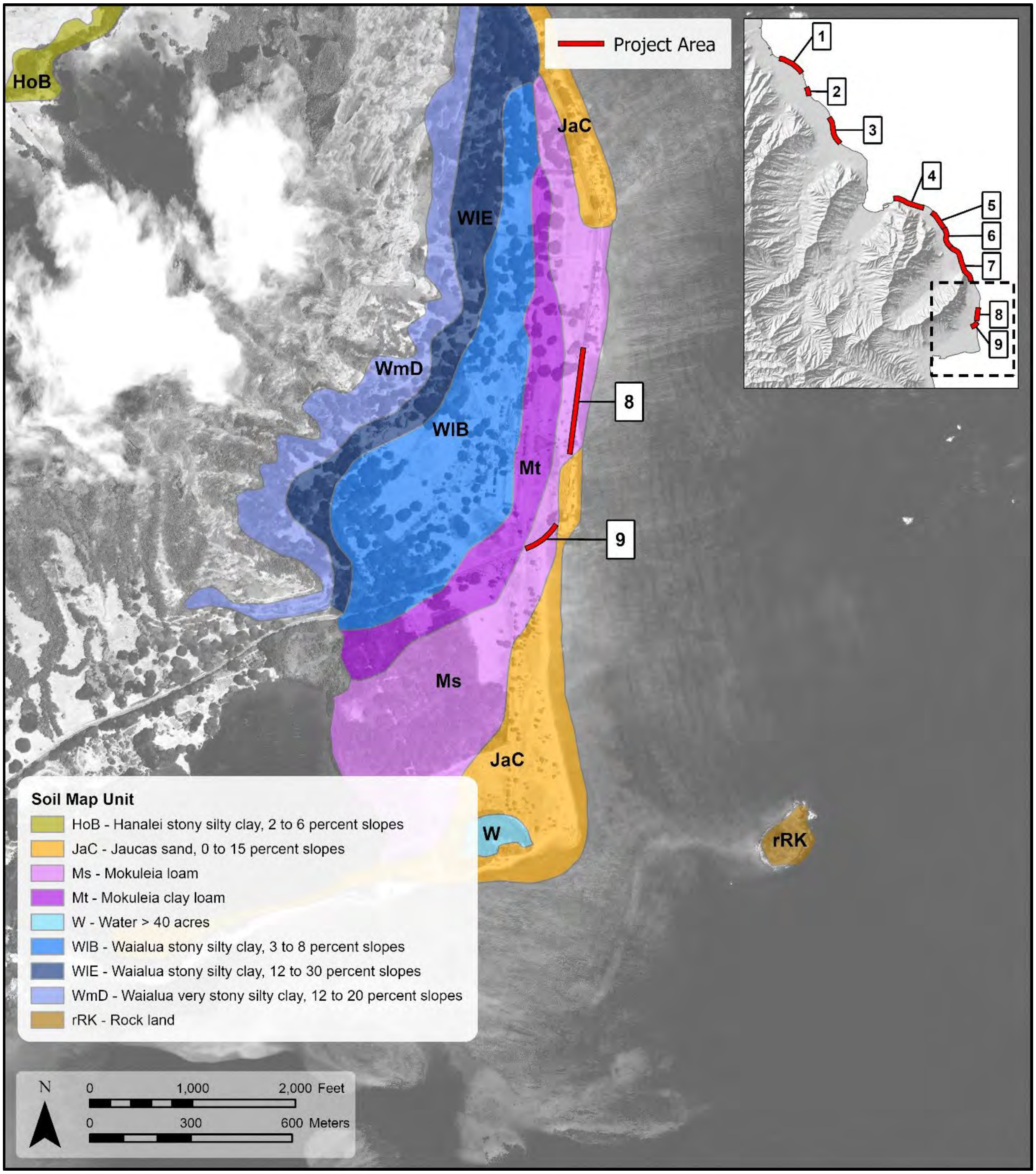

Figure 11. Soil survey data for sections 8–9 and environs (soils data from Foote et al. 1972)

1.2 Background

The State and its agencies have an affirmative obligation to preserve and protect Native Hawaiians' customarily and traditionally exercised rights to the extent feasible.[1] State law further recognizes that the cultural landscapes provide living and valuable cultural resources where Native Hawaiians have and continue to exercise traditional and customary practices, including hunting, fishing, gathering, and religious practices. In *Ka Paʻakai*, the Hawaiʻi Supreme Court provided government agencies an analytical framework to ensure the protection and preservation of traditional and customary Native Hawaiian rights while reasonably accommodating competing private development interests. This is accomplished through:

1) The identification of valued cultural, historical, or natural resources in the project area, including the extent to which traditional and customary Native Hawaiian rights are exercised in the project area;
2) The extent to which those resources—including traditional and customary Native Hawaiian rights—will be affected or impaired by the proposed action; and
3) The feasible action, if any, to be taken to reasonably protect Native Hawaiian rights if they are found to exist.

The appropriate information concerning the region has been collected, focusing on areas near or adjacent to the project area. A thorough analysis of this project and potential impacts to cultural resources, historical resources, and archaeological sites is included in this survey.

This ethnographic survey provides an overview of cultural and historic resources in the project area using thorough literature review, community and cultural practitioner consultation, and high-level, project-specific surveys.

1.3 Geographic Extent

This CIA primarily researches and reviews the range of biocultural resources identified through historical documents, traditional knowledge, information found in the Hawaiian language historical cache, and oral histories and knowledge collected from cultural practitioners and experts.

The best practice for ethnographic surveys is to define a geographic extent beyond the identified or typical boundaries of the geographic project area. The recommended area is

[1] Article XII, Section 7 of the Hawaiʻi State Constitution, *Ka Paʻakai O Ka ʻĀina v. Land Use Commission*, 94 Haw. 31 [2000] (Ka Paʻakai), Act 50 SLH 2000.

typically the size of the traditional land area (ahupuaʻa) or region (moku), but this can be larger or smaller depending on what best helps to identify the resources appropriately.

The geographic extent of the survey is based on the position that the "Project Area(s)" is part of a cultural landscape or cultural landscapes that therefore it is most appropriate to set and study the proposed alternatives within that cultural context.

1.4 Goal of Ethnographic Survey

This survey, along with the archaeological work, looks to fulfill the requirement of taking into account the Project's potential impacts on historic and cultural resources and, at a minimum, describe: a) any valued cultural, historic, or natural resources in the area in questions, including the extent to which traditional and customary native Hawaiian rights are exercised in the area, b) the extent to which those resources – including traditional and customary native Hawaiians rights – will be affected or impaired by the Project; and c) the feasible action, if any, to be taken to reasonably protect native Hawaiian rights if they are found to exist.

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2.0 Methodology

The approach to developing the ethnographic survey is as follows:

1) Gather Best Information Available
    a) Gather historic cultural information from stories and other oral histories about the affected area to provide cultural foundation for the report;
    b) Inventory as much information as can be identified about as many known cultural, historic, and natural resources, including previous archaeological inventory surveys, CIAs, etc. that may have been completed for the possible range of areas; and
    c) Update the information with interviews with cultural or lineal descendants or other knowledgeable cultural practitioners.
2) Identify Potential Impacts to Cultural Resources
3) Develop Reasonable Mitigation Measures to Reduce Potential Impacts
    a) Involve the community and cultural experts in developing culturally appropriate mitigation measures; and
    b) Develop specific Best Management Practices (BMPs), if any are required, for conducting the project in a culturally appropriate and/or sensitive manner as to mitigation and/or reduce any impacts to cultural practices and/or resources.

While numerous studies have been conducted on this area, very few have effectively utilized Hawaiian language resources and Hawaiian knowledge. This appears to have impacted modern understanding of this location, as many of the relevant documents are native testimonies given by Kanaka Hawaiʻi (Hawaiians) who lived on this land.

While hundreds of place names and primary source historical accounts (from both Hawaiian and English language narratives) are cited on the following pages, it is impossible to tell the whole story of these lands in any given manuscript. A range of history, spanning the generations, has been covered. Importantly, the resources herein are a means of connecting people with the history of their communities—that they are part of that history. Knowledge of place will, in turn, promote appreciation for place and encourage acts of stewardship for the valued resources that we pass on to the future.

Background research for the literature review was conducted using materials obtained from the State Historic Preservation Division (SHPD) library in Kapolei and the Honua Consulting LLC. report library. On-line materials consulted included the Ulukau Electronic Hawaiian Database (www.ulukau.com), Papakilo Database (www.papakilodatabase.com), the State Library on-line (http://www.librarieshawaii.org/ Serials/databases.html), and Waihona ʻĀina Māhele database (http://www.waihona.com). Hawaiian terms and place names were translated using the on-line Hawaiian dictionaries (Nā Puke Wehewehe ʻŌlelo Hawaiʻi) (www.wehewehe.com), *Place Names of Hawaiʻi* (Pukui et al. 1974), and *Hawaiʻi Place Names* (Clark 2002). Historic maps were obtained from the State Archives, State of Hawaiʻi Land Survey Division website (http://ags.hawaii.gov/survey/map-search/), UH-Mānoa Maps, Aerial Photographs, and GIS (MAGIS) website (http://guides.library.manoa.hawaii.edu/magis). Maps were geo-referenced for this report using ArcGIS 10.3. GIS is not 100% precise and historic maps were created with inherent flaws; therefore, geo-referenced maps should be understood to have some built-in inaccuracy.

While conducting the research, primary references included, but were not limited to: land use records, including the Hawaiian L.C.A. records from the Māhele ʻĀina (Land Division) of 1848; the Boundary Commission Testimonies and Survey records of the Kingdom and Territory of Hawaiʻi; and historical texts authored or compiled by: David Malo (1987); Samuel M. Kamakau (1964, 1991, 1992); records of the American Board of Commissioners of Foreign Missions (A.B.C.F.M.) (1820–1860); Charles Wilkes (1845); Alexander & Preston (1892–1894); Abraham Fornander (1916–1919); and many other native and foreign writers. The study also includes several native accounts from Hawaiian language newspapers (primarily compiled and translated from Hawaiian to English by K. Maly), and historical records authored by nineteenth century visitors, and residents of the region.

Historical and archival resources were located in the collections of the Hawaiʻi State Archives, Survey Division, Land Management Division, Survey Division, and Bureau of Conveyances; the Bishop Museum Library and Archives; the Hawaiian Historical Society and the Hawaiian Mission Childrenʻs Society Library; University of Hawaiʻi-Hilo Moʻokini Library; the National Archives and Records Administration (NARA), Maryland; the Library of Congress, Washington D.C.; the National Oceanic and Atmospheric Administration National Library, Maryland; the Smithsonian Institution Natural History and National Anthropological Archives libraries, Washington, D.C.; the Houghton Library at Harvard; the United States Geological Survey (USGS) Library, Denver; the Paniolo Preservation Society and Parker Ranch collections; private family collections; and in the collection of Kumu Pono Associates LLC. This information is generally cited in categories by chronological order of the period depicted in the narratives.

M. P. Nogelmeier (2010) discusses the adverse impacts of methodology that fails to properly research and consider Hawaiian language resources. He strongly cautions against a mono-rhetorical approach that marginalizes important native voices and evidence from consideration, specifically in the field of archaeology. For this reason, Honua Consulting consciously employs a poly-rhetorical approach, whereby all data, regardless of language, is researched and considered. To fail to access these millions of pages of information within the Hawaiian language cache could arguably be a violation of Act 50, as such an approach would fundamentally fail to gather the best information available, especially considering the voluminous amounts of historical accounts available for native tenants in the Hawaiian language.

Hawaiian culture views natural and cultural resources as largely being one and the same: without the resources provided by nature, cultural resources could and would not be procured. From a Hawaiian perspective, all natural and cultural resources are interrelated, and all natural and cultural resources are culturally significant. Kepā Maly (2001), ethnographer and Hawaiian language scholar, points out, "In any culturally sensitive discussion on land use in Hawaiʻi, one must understand that Hawaiian culture evolved in close partnership with its natural environment. Thus, Hawaiian culture does not have a clear dividing line of where culture ends and nature begins" (Maly 2001:1).

This study also specifically looks to identify intangible resources. Tangible and intangible heritage are inextricably linked (Bouchenaki 2003). Intangible cultural resources, also identified as intangible cultural heritage (ICH), are critical to the perpetuation of cultures globally. International and human rights law professor Federico Lenzerini notes that, "At present, we are aware on a daily basis of the definitive loss—throughout the world—of language, knowledge, knowhow, customs, and ideas, leading to the progressive impoverishment of human society" (Lenzerini 2011:12). He goes on to warn that:

> The rich cultural variety of humanity is progressively and dangerously tending towards uniformity. In cultural terms, uniformity means not only loss of cultural heritage—conceived as the totality of perceptible manifestations of the different human groups and communities that are exteriorized and put at the others' disposal—but also standardization of the different peoples of the world and of their social and cultural identity into a few stereotyped ways of life, of thinking, and of perceiving the world. Diversity of cultures reflects diversity of peoples; this is particularly linked to ICH, because such a heritage represents the living expression of the idiosyncratic traits of the different communities. Preservation of cultural diversity, as emphasized by Article 1 of the UNESCO Universal Declaration on Cultural Diversity, 'is embodied in the uniqueness and plurality of the identities of the groups and societies making up humankind'. Being a 'source of exchange, innovation and creativity', cultural diversity is vital to humanity and is inextricably linked to the safeguarding of ICH. Mutual recognition and respect for cultural diversity—and, *a fortiori*, appropriate safeguarding of the ICH of the diverse peoples making up the world—is essential for promoting harmony in intercultural relations, through fostering better appreciation and understanding of the differences between human communities. (Lenzarini 2011:103)

Therefore, tradition and practice, as elements of Hawaiian ICH, are essential to the protection of Hawaiian rights and the perpetuation of the Hawaiian culture.

2.1 Identifying Traditional or Customary Practices

It is within this context that traditional or customary practices are studied. The concept of traditional or customary practices can often be a challenging one for people to grasp. Traditional or customary practices can be defined as follows:

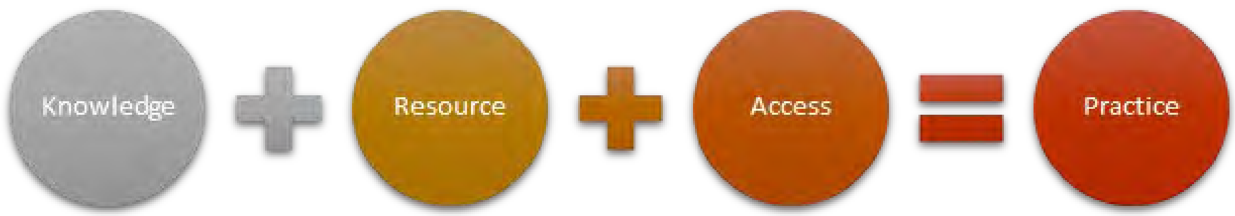

Figure 12. Diagram of elements that contribute to traditional or customary practices (Honua Consulting)

The first element is knowledge. This has been referred to as traditional ecological knowledge (TEK), Indigenous local knowledge (ILK), or ethnoscience. In the context of this study, it is the information, data, knowledge, or expertise Native Hawaiians or local communities possessed or possess about an area's environment. In a traditional context, this would have included information Hawaiians possessed in order to have the skills to utilize the area's resources for a range of purposes, including, but not limited to, travel, food, worship or habitation. This element is largely intangible.

The second element are the resources themselves. These are primarily tangible resources, either archaeological resources (i.e., habitation structures, walls, etc.) or natural resources (i.e., plants, animals, etc.). These can also be places, such as a sacred or culturally important sites or wahi pana. Sometimes these wahi pana are general locations; this does not diminish their importance or value. Nonetheless, it is important to recognize that potential eligibility as a "historic site" on the National Register of Historic Places (NRHP) would require identifiable boundaries of a site.

The third element is access. The first two elements alone are not enough to allow for traditional or customary practices to take place. The practitioners must have access to the resource in order to be able to practice their traditional customs. Access does not just mean the ability to physically access a location, but it also means access to resources. For example, if a particular plant is used for medicinal purposes, there needs to be a sufficient amount of that plant available to practitioners for us. Therefore, an action that would adversely impact the population of a particular plant with cultural properties would impact practitioners' ability to access that plant. By extension, it would adversely impact the traditional or customary practice.

Traditional or customary practices are, therefore, the combination of knowledge(s), resource(s) and access. Each of these individual elements should be researched and identified in assessing any potential practices or impacts to said practices.

2.2 Traditional Knowledge, or Ethnoscience, and the Identification of Cultural Resources

The concept of ethnoscience was first established in the 1960s and has been defined "the field of inquiry concerned with the identification of the conceptual schemata that indigenous peoples use to organize their experience of the environment" (Roth 2019). Ethnoscience includes a wide range of subfields, includes, but is not limited to, ethnoecology, ethnobotany, ethnozoology, ethnoclimatology, ethnomedicine and ethnopedology. All of these fields are important to properly identify traditional knowledge within a certain area.

Traditional Native Hawaiian practitioners were scientists and expert natural resource managers by necessity. Without modern technological conveniences to rely on, Hawaiians developed and maintained prosperous and symbiotic relationships with their natural environment for thousands of years. Their environments were their families, their homes, and their laboratories. They knew the names of every wind and every rain. The elements taught and inspired. The ability of Indigenous people to combine spirituality and science led to the formation of unique land-based methologides that spurred unsurpassed innovation. Therefore, identifying significant places requires a baseline understanding of what made places significant for Hawaiians.

Hawaiians were both settlers and explorers. In *Plants in Hawaiian Culture,* B. Krauss explains: "Exploration of the forests revealed trees, the timber of which was valuable for building houses and making canoes. The forests also yielded plants that could be used for making and dying tapa, for medicine, and for a variety of other artifacts" (Krauss 1993). Analysis of native plants and resource management practices reveals the depth to which Hawaiians excelled in their environmental science practices:

> [Hawaiians] demonstrated great ability in systematic differentiation, identification, and naming of the plants they cultivated and gathered for use. Their knowledge of the gross morphology of plants, their habits of growth, and the requirements for greatest yields is not excelled by expert agriculturists of more complicated cultures. They worked out the procedures of cultivation for every locality, for all altitudes, for different weather conditions and exposures, and for soils of all types. In their close observations of the plants they grew, they noted and selected mutants (spores) and natural hybrids, and so created varieties of the plants they already had. Thus over the years after their arrival in the Islands, the Hawaiians added hundreds of named varietis of taro, sweet

potatoes, sugarcane, and other cultivated plants to those they had brought with them from the central Pacific (Krauss 1993).

Thus, Native Hawaiians reinforced the biodiversity that continues to exist in Hawaiʻi today through their customary traditional natural resource management practices.

The present analyses of archival documents, oral traditions (oli or chants, mele or songs, and/or hula dances and haʻi moʻolelo or storytelling performances), and Hawaiian language sources including books, manuscripts, and newspaper articles, are focused on identifying recorded cultural resources present on the landscape, including: Hawaiian and non-Hawaiian place names; landscape features (ridges, gulches, cinder cones); archaeological features (kuleana parcel walls, house platforms, shrines, heiau [places of worship], etc.); culturally significant areas (viewsheds, unmodified areas where gathering practices and/or rituals were performed); and significant biological, physiological, or natural resources. This research also looks to document the wide range of Hawaiian science that existed within the geographic extent. Additionally, Matthew Kawaiola Sproat, an author on this report is himself a cultural practitioner from Hauʻula and contributed his cultural knowledge to the research for this CIA.

2.3 Moʻolelo ʻĀina: Native Traditions of the Land

Among the most significant sources of native moʻolelo are the Hawaiian language newspapers which were printed between 1838 and 1948, and the early writings of foreign visitors and residents. Most of the accounts that were submitted to the papers were penned by native residents of areas being described and noted native historians. Over the last 30 years, Kepā Maly has reviewed and compiled an extensive index of articles published in the Hawaiian language newspapers, with particular emphasis on those narratives pertaining to lands, customs, and traditions. Many traditions naming places around Hawaiʻi are found in these early writings. Many of these accounts describe native practices, the nature of land use at specific locations, and native moʻolelo (history, narrative, story). Thus, we are given a means of understanding how people related to their environment and sustained themselves on the land.

2.4 Historic Maps

There are also numerous, informative historic maps for the region. Surveyors of the eighteenth and nineteenth centuries were skilled in traversing land areas and capturing important features and resources throughout Hawaiʻi's rich islands. Historic maps were carefully studied, and the features detailed therein were aggregated and categorized to help identify specific places, names, features, and resources throughout the study area. From these, among other documents, new maps were created that more thoroughly capture the range of resources in the area.

2.5 Archaeological and Biological Studies

A literature review and field investigation were conducted by Honua Consulting, LLC. While the archaeological resources in the project area itself may be limited, the region has an important archaeological history.

Archaeologists and historians describe the habitation of these islands in the context of settlement which resulted from voyages taken across the open ocean. For many years, archaeologists have proposed that early Polynesian settlement voyages between Kahiki (the ancestral homelands of the Hawaiian gods and people) and Hawaiʻi were underway by AD 300, with long distance voyages occurring fairly regularly through at least the thirteenth century. It has been generally reported that the sources of the early Hawaiian population – the Hawaiian Kahiki – were the Marquesas and Society Islands (Emory in Tatar, 1982:16-18).

For generations following initial settlement, communities were clustered along the watered, windward (koʻolau) shores of the Hawaiian Islands. Along the koʻolau shores, streams flowed, rainfall was abundant, and agricultural production was established. The koʻolau region also offered sheltered bays from which deep-sea fisheries could be easily accessed. Also, near-shore fisheries, enriched by nutrients carried in the fresh water running from the mountain streams, could be maintained in fishponds and coastal fisheries. It was around these bays that clusters of houses where families lived could be found (see McEldowney 1979). In these early times, the residents generally engaged in subsistence practices in the forms of agriculture and fishing (Handy et al. 1972:287).

Over several centuries, areas with the richest natural resources became populated and perhaps crowded, and by ca. AD 900 to 1100, the population began expanding to the kona (leeward side) and more remote regions of the island (Cordy 2000:130). Kirch reported that by ca. AD 1200, there were small coastal settlements at various areas along the western shoreline of Hawaiʻi (1979:198). In this system of settlement and residency, the near-shore communities shared extended familial relations with those of the uplands.

By the 1400s, upland regions to around the 3,000-foot elevation were being developed into areas of residence and a system of agricultural fields. By the 1500s to 1600s, residency in the uplands was becoming permanent, and there was an increasing separation of royal class from the common working class. During the latter part of this period, the population stabilized, and a system of land management was established as a political and socio-economic factor (see Kamakau 1961; Ellis 1963; Handy et al. 1972; Tomonari-Tuggle 1985; Cordy 2000).

Traditions and historical records show that the deification and personification of the land and natural resources, and the practices of district subdividing and land use as described above, were integral to Hawaiian life, and were the product of strictly adhered to resource management planning. In this system, the people learned to live within the wealth and limitations of their natural environment and were able to sustain themselves on the land and ocean.

AECOM completed an analysis of biological resources for the environmental assessment. Biological resources are analyzed in the environmental assessment and excluded from this CIA.

2.6 Ethnographic Methodology

Information from lineal and cultural descendants is instrumental in procuring information about the project area's transformation over time and its changing uses. The present analyses of archival documents, oral traditions (including oli or chants, mele or songs), and/or hula dance), and Hawaiian language sources including books, manuscripts, and newspaper articles, are focused on identifying recorded cultural and archaeological resources present on the landscape, including: Hawaiian and non-Hawaiian place names; landscape features (ridges, gulches, cinder cones); archaeological features (kuleana parcel walls, house platforms, shrines, heiau or places of worship, etc.); culturally significant areas (viewsheds, unmodified areas where gathering practices and/or rituals were performed); and significant biocultural resources. The information gathered through research helped to focus interview questions on specific features and elements within the project area. Descendants and cultural practitioners from the area were contacted and interviewed for this CIA.

3.0 Historic Background

Traditionally, the project area, located in the Koʻolauloa Moku (traditional district), was inhabited and stewarded by Native Hawaiians for centuries.

3.1 Traditional Period

The longest period of human history in this area is the traditional era, which, according to radiocarbon dating (Bath et al. 1984), extended from as early as B.C. 115 – A.D. 82 through 1778. Additional data from the region (specifically Haleʻiwa) shows possible Hawaiian habitation in the area as early as B.C. 1607 – B.C. 1291 (BPBM ^{14}C File). Despite this, due to the lack of written record collection during the period, written documentation about this period would not begin until the 19th century, which may limit the detailed information available about the areas.

As previously noted, the project areas traverse two moku: Koʻolauloa and Koʻolaupoko. Within those two moku, 14 ahupuaʻa are crossed.

Table 1. Listing of all the moku and ahupuaʻa in project area

Traditional Areas in Project Area
Koʻolauloa Moku
Hauʻula
Mākao
Kapaka
Kaluanui
Haleʻaha
Kapano
Puheʻemiki
Waiʻono
Kahana
Makaua 2
Makaua 1
Kaʻaʻawa
Koʻolaupoko Moku
Kualoa 2

Kualoa 1

As shown in Table 1 above, the majority of the project area is within the Koʻolauloa moku, and accordingly, the majority of the ahupuaʻa are within that moku. Within the moku, some ahupuaʻa are more storied than others, as shown from the documented traditional history. The following section includes histories and descriptions of some of the larger and more documented areas within the project area.

The first part of the project will occur in the Hauʻula ahupuaʻa. It will extend into other ahupuaʻa, but the area is also commonly known as Hauʻula to its local residents, who do not contemporaneously utilize ahupuaʻa as frequently as these names were used in the past. Hauʻula is long-standing traditional name that has been retained into the present, while other place names in the region have largely been lost in the rapid development of mass agricultural plantations at the beginning of the 20th century when Hawaiʻi became a U.S. Territory. Hauʻula has a rich and interesting cultural history, and there are myriad mele, ʻōlelo noʻeau, and moʻolelo associated with this region, although the neighboring Kahuku is often the more common known area, likely due to the location of the area high school and football team being located in Kahuku. The name "Hauʻula" comes from the red hau (*Hibiscus tiliaceus*). While usually the hau is more commonly known to bear a yellow flower, the hau in Hauʻula are known for their red flowers. It is said among the people that when the red hau blooms, the wana (sea urchin) is ripe (Sproat, pers.).

The traditional knowledge imbedded in place names reveals the history of place, people, and the depth of their traditions. Although fragmented, the surviving place names describe a rich culture. On these lands are found many place names that have survived the passing of time. The occurrence of place names demonstrates the broad relationship of the natural landscape to the culture and practices of the Hawaiian people. In *A Gazetteer of the Territory of Hawaii*, J. W. Coulter observed that Hawaiians had place names for all manner of features, ranging from "outstanding cliffs" to what he described as "trivial land marks" (1935:10). In 1902, W.D. Alexander, former Surveyor General of the Kingdom (and later Government) of Hawaiʻi, wrote an account of "Hawaiian Geographic Names." Under the heading "Meaning of Hawaiian Geographic Names" he observed:

> It is very difficult, if not impossible, to translate most of these names, on account of their great antiquity and the changes of which many of them have evidently undergone. It often happens that a word may be translated in different ways by dividing it differently. Many names of places in these islands are common to other groups of islands in the South Pacific, and were probably brought here with the earliest colonists. They have been used for centuries without any thought of their original meaning. (Alexander 1902:395)

Moreover, historically named locations were significant in past times and it has been observed that "Names would not have been given to [or remembered if they were] mere[ly] worthless pieces of topography" (Handy et al. 1972:412).

The other ahupuaʻa within Section 1 of the project (Figure 2) are Mākao and Kapaka. Section 2 takes place in Kaluanui. Section 3 crosses Haleʻaha, Kapono, Puheʻemiki and Waiʻono. Section 4 begins at the southern portion of Kahana where the road turns out of Kahana Valley into Makaua, which is more commonly known as Kaʻaʻawa although the names of these two ahupuaʻa between Kahana and Kaʻaʻawa are Makaua 2 and Makaua 1 (going from north to south).

Native Hawaiians settled in Kahana Valley and practiced subsistence farming, fishing, and gathering of resources from both the land and sea. The fertile land allowed them to cultivate kalo, ʻuʻala, maia, and other crops essential for their sustainable use of, and survival on, the land. The sea provided an abundance of fish and other seafood that provided them with protein. This was supported by the construction and active use of Huilia fishpond.

Figure 13. The bay at Kahana Valley. Huilua Fishpond can be seen on the far end of the bay. (Photo DLNR)

Kahana Valley was, and remains, a place of spiritual significance for Hawaiians. The valley's lush environment, streams, and waterfalls were believed to be inhabited by ancestral spirits and deities. These natural features were often considered sacred and were the focus of rituals and ceremonies. Like other Hawaiian communities, Kahana Valley had a structured konohiki system led by aliʻi and supported by mahaʻai (farmers) and lawaiʻa (fisherman). The inhabitants of the valley lived in kauhale.

Kahana is particularly important for traditional and customary practices because of the many cultural practices who continue to reside there and practice their culture. Kahana Valley State

Park was established to protect and preserve the cultural and natural resources of the valley. The park encompasses the Kahana ahupuaʻa, a traditional Hawaiian land division that extends from the mountains to the sea. It was officially designated as a state park to ensure the conservation of the valley's unique ecosystem and cultural sites.

Kahana Valley is home to a diverse range of native Hawaiian plants and animals, including endangered species. The park's management focuses on maintaining the native ecosystem by controlling invasive species and restoring native vegetation. This approach helps protect the valley's natural beauty and ecological balance. In addition to preserving the natural environment, efforts have been made to restore and interpret cultural sites within the park. This includes traditional Hawaiian agricultural terraces (loʻi), heiau, and other structures that reflect the valley's historical significance. Interpretive programs and educational initiatives help visitors learn about the cultural history of the area.

Kahana Valley State Park collaborates with local communities and cultural practitioners to ensure that management decisions align with traditional practices and values. This involvement helps to maintain a strong connection between the park and the people whose cultural heritage it represents. The park provides opportunities for visitors to enjoy recreational activities such as hiking, picnicking, and learning about Hawaiian culture and history. Interpretive signs, guided tours, and educational programs help visitors gain a deeper understanding of the valley's past and present.

A portion of Section 4, all of Section 5, all of Section 6 and the majority of Section 7 will occur in Kaʻaʻawa. Kaʻaʻawa, named for the ʻaʻawa fish (a wrasse), is a predominately coastal community, as the ahupuaʻa is comparatively shallow in geographic nature due to the nearby cliffs that back this community.

Figure 14. Image of Ka‘a‘awa, showing the coastline where the project will occur (Alamy 2015)

Sections 8 and 9 will take place within Kualoa, which is the first ahupu‘a within the moku of Ko‘olaupoko as you leave Ko‘olauloa (headed north to south). Kualoa is a wahi pana, a storied place of significant historical and cultural importance and has a rich history that spans centuries and is deeply intertwined with the history and culture of the Hawaiian people.

Like other locations along the coast, Kualoa has long been inhabited. Native Hawaiians were the first to reside there, and there lived a thriving community of Hawaiians who engaged in farming, fishing, and other traditional activities. Ali‘i particularly enjoyed Kualoa and there are numerous histories associated with chiefs in Kualoa.

3.2.1 Mo‘olelo

Mo‘olelo (traditional narratives, stories, history) were once passed down through oral tradition and later recorded in print upon the arrival of the printing press in the 1830s. One of the beautiful elements of Hawaiian storytelling is that many versions of mo‘olelo exist, told from the perspective of storytellers who are native to varying areas. By collecting and celebrating the multiple versions of mo‘olelo, the depth and breadth of Native Hawaiian perspective about ‘āina can be understood. Information about culture, language, and places are held within those stories, and can continue to live on through those mo‘olelo.

Portions of many famous mo‘olelo take place in Ko‘olauloa, some sections of which will be presented in this section in order to demonstrate the cultural significance of this ‘āina.

3.2.1.1 Kaao no Halemano

Koʻolauloa is part of the setting of the moʻolelo (story) of Halemano, a chief of Oʻahu.

> ...pii o Kamalalawalu i luna o na waa; a hiki ia i luna, kahea o Halemano i ka poe hoewaa e hoe, ia wa lilo laua elua i Oahu nei. Hahai mai la o Puna a me Hilo, aohe launa mai, hao mai la ka mana o na waa o Halemano a me Laenihi.
>
> Ma keia holo ana, pae ae la kekahi waa me Kumukahi i Hauula ma Koolauloa. Ilaila kekahi kii e ku ana, o Malaekahana ka inoa, hoohihi iho la o Kumukahi i ke kii, noho iho la i laila. O Halemano, holo loa aku la lakou a pae ma Waialua i Ukoa, me Kamalalawalu. Ma keia pae ana, ua holo koke ka luna kala a puni o Waialua a me Waianae, e hele mai laua e hookupu ia Kamalalawalu.
>
> A pau ka hookupu ana, ekolu la i hala, haohao o Kamalalawalu ia Kumukahi i ka ike ole ia aku. Ninau aku la ia ia Halemano a me Laenihi: “Auhea o Kumukahi ?” “Aia i Hauula, ua noho ia puni ana o ke kii.” I aku o Kamalalawalu: “E kii aku a hoi mai.” A hoi mai la o Kumukahi, olelo aku la o Kamalalawalu: “E hoi oe me ka waiwai i Hawaii, i na makua o kaua a me na makaainana, o poino mai kekahi o lakou.” Ia wa, hoi aku la o Kumukahi i Hawaii.
>
> * * *
>
> ...Kamalalawalu went aboard one of the canoes; whereupon Halemano gave orders to the paddlers that they start on their return, and the two were thus carried off to Oahu. The people of Puna and Hilo pursued them but could not come near them, as by the power of Halemano and Laenihi they were soon left far to the rear.
>
> In this flight to Oahu, one canoe, the one in which was Kumukahi, landed at Hauula, Koolauloa. There was at this place an image standing, Malaekahana by name; upon seeing this image, Kumukahi took such a fancy to it that he remained there. Halemano and the others, together with Kamalalawalu, continued on their way and landed at Ukoa at Waialua. As soon as the canoe in which Kamalalawalu was a passenger landed, a crier[16] was sent out to make a circuit of Waialua and Waianae with orders to the people to come and give presents[17] to Kamalalawalu.
>
> About three days after the *hookupu*, Kamalalawalu for the first time missed Kumukahi, so she asked of Halemano and Laenihi: ”Where is Kumukahi?” “He is at Hauula where he is enraptured by an image that is there.” Kamalalawalu then said: “Go and bring him here.” When Kumukahi arrived, Kamalalawalu said to him: “You had better return to Hawaii with the presents to our parents and to our people, else some of them will

feel troubled over us." Kumukahi in obedience to his sister returned to Hawaii (Fornander 1916).

3.2.1.2 Kamapuaʻa

Kamapuaʻa is a famous kupua, son of Hina and Kahikiʻula and grandson of Kamaunuaniho. This kupua takes many bodily forms, one of which is a pig. Kamapuaʻa was found stealing the chickens of the ruling chief, Olopana. Oloapana, not to be taken advantage of by this youth, set out to kill Kamapuaʻa, who was fiercely protected by his grandmother and his gods.

3.2.1.3 Pāʻao and Makuakaumana

The legend of Pāʻao is one of the most well-known and published stories of traditional Hawaiian history. The legend provides a late Polynesian connection with the Hawaiian homeland, referred to as Kahiki. Pāʻao is a legendary chief and *kahuna* (priest) from Kahiki who sailed to Hawaiʻi in a canoe of notable travelers, including an important prophet named Makuakaumana (also spelled Makuakaʻūmana [S. Kamakau 1991:97]) (Emerson 1893, Kamakau 1991). It is thought that the Hawaiian Islands were well populated by the time Pāʻao landed. Pāʻao is accredited with promoting stringent religious practices and a chiefly lineage from Kahiki. Pukui and Elbert (1984:395) describe Pāʻao as:

> Paʻao. A priest from Tahiti who landed at Puna, Hawaii. He built the *heiau* Moʻo-kini at Hawaii, and is said to have introduced human sacrifice, walled *heiaus*, red- feather girdles as a sign of rank, taboo songs, the prostrating taboo, and the feather god Kāʻili. He made a return trip to Kahiki.

The legend of Pāʻao tells of a quarrel between him and his brother Lonopele, over the accusation that Pāʻao's son stole Lonopele's fruits (Stokes 1927:42-43, Beckwith 1970:371, Kamakau 1991:3-5 and 97-99, Henry 1995). In order to prove his son's innocence, Pāʻao cut open his son's stomach finding no fruit. Upon building voyaging canoes, Pāʻao killed Lonopele's son and placed his body under a canoe for ritual use to release *kapu* (taboo) associated with newly crafted canoes. Lonopele found his son encompassed in a swarm of flies and told Pāʻao to leave their home island. The canoes were named Kanaloamuia (the swarming of flies). As Pāʻao was sailing out of the bay, prophets who wanted to join his voyage attempted to leap from the top of a cliff named Kaʻakōheo. Three prophets attempted and were killed by rocks below. Then Makuakaumana called out to join the canoe.

References of the legend of Makuakaumana are somewhat inconsistent (Beckwith 1970, Kamakau 1991). However, all researched accounts agree that just when Pāʻao's canoes were nearly out of sight, Makuakaumana called from on top of Kaʻakōheo.

He called two or three times before Pāʻao heard the faint sound of his voice. He looked back and saw the man on the cliff. He asked, "What are you?" "A prophet." Pāʻao asked again, "What is your name?" "Makuakaʻūmana," answered the prophet. Pāʻao said, "The canoe is full; there is only one place left –the *momoa*, the projection at the stern." That will be my place," was the answer. Pāʻao told him to leap. Makuakaʻūmana did so, flying like a bird, and perched on the *momoa* and held onto the *manu*, the endpeice of the canoe. He said, "Here I am; where shall I go? "Onto the *pola*, the platform between the canoes," said Pāʻao. (Kamakau 1991:99)

Beckwith (1970:374) suggests this leaping event may have had a strong symbolic meaning. The leap tests Makuakaumana's divinity and proves his courage and worthiness. As a prophet, Makuakaumana would have been regarded as a living embodiment of the gods, as spirits could possess a prophet's body and faculties (Handy 1927:159). Therefore, it is possible his presence on the canoe may have helped to overcome obstacles encountered during the voyage.

Makuakaumana is also referenced in several chants. The success of Makuakaumana's leap is referenced in the following chant:

You are like a flying fish
Skimming easily through the sky,
Traversing the dark waters of the ocean,
O Halulu at the foundation house of heaven,
Kane, Makua-kau-mana,
The prophet who made the circuit of the island,
Who circled the pillars of Kahiki (Beckwith 1970:371)

In the wānana of Kalai-kua-hulu, Makuakaumana is quoted as chanting the following:

A fragile tailed fish am I,
Moving swiftly before the heavens,
Traveling the dark, dark ocean That roars at Halekumukalani.
I am the man, Makuakaʻūmana,
The prophet who traveled the islands,
Who went ʻround the back of the Pillars of Kahiki,
Who leapt and sat on Kaulia ["a perching place"] (Kamakau 1991:99-100)

The Legend of Makuakaumana continues with his life on Oʻahu (Rice 1923:116-132, Pukui and Curtis 1960:55). Beckwith (1970:69-70) presents multiple versions of this legend told by Rice (1923), Green (1928), Westervelt (1915), and others, indicating continued reflection on this myth and its high significance in Hawaiian mythology. The most complete version of the legend is told by Rice (1923):

> Makua-kau-mana is a pious worshiper of Kane and Kaneloa who lives in north Oahu at Kaulua-nui with his only son, whose mother died at his birth, and cultivates daily his garden patch, being careful always to call upon his gods in so doing. The two gods visit him in the disguise of strangers, note his piety and his hospitality to strangers, and give him a digging stick and a carrying pole to relieve his labor. They come again disguised as old men and teach him how to pray, offer sacrifices, and keep the *tapus* for Kane-huli-honua, giver of land, and Kane-pua'a, god of rich crops; for Hina-puku-ai, goddess of vegetable food, and Hina-puku- i'a, who gives abundance of fish. A third time they come dressed like chiefs and bring a red loincloth (*malo pukuai*) and a colored bedspread (*kuina-kapa-papa'u*). To test Makua's steadfastness they complain that his son has broken the eating *tapu* of the gods. Makua would have slain his son, but the gods stay his hand. They send a great fish and when Makua goes to dive from its back, they cause the fish to swallow him and bear him away to the hidden land of Kane-huna- moku...[He is then] borne back to his old home and cast upon the beach, where his son rejoices over him but his friends reproach him for losing the joys of that good land. He lives to a good old age and is buried on Oahu. (116-132, and quoted in Beckwith 1970:69)

The Rice (1923:132) version ends with Makuakaumana's death and his son wrapping the body in tapa and carrying him to a cave near Ko'olaupoko.

This legend as told by Pukui and Curtis (1960) tells of Makuakaumana praying for training of his son in the ways of the gods. Rather than Makuakaumana being eaten by the whale, it was his son who was swallowed. The son was brought to Kahiki to be trained by Kāne and Kanaloa. He was then brought back to O'ahu where he became a great *kahuna* and wise leader (Pukui and Curtis 1960:58).

The Legend of Pā'ao tells us that he returned to Kahiki to find a high ranking chief who could be brought to Hawai'i, for he found Hawai'i to be devoid of a proper ruler (Emerson 1893:9). A chant, performed by Makuakaumana, offers the throne of Hawai'i to the high chief of Kahiki (Henry 1995:158-159, Fornander 1998:18-19). The chief, Lono Kaeho, refused and offered another priest, Pilika'ai'ea, instead (Fornander 1880:22). They then returned to Hawai'ī where Pilika'ai'ea became chief and his descendants continued to rule until the last Kamehameha (Emerson 1893:11, Kamakau 1961:235, Fornander 1880:22,33).

Pilikaʻaiʻea is thought to have introduced *ʻaha aliʻi*, a chiefly council, to Hawaiʻi (Abad 2000:275). The *ʻaha aliʻi* served to trace pure bloodlines and preserve legitimate leadership within the highest ranked *aliʻi* (royalty).

Makuakaumana is tied to the history of Hauʻula through place names and mythology as well as through oral tradition. Respected *kahuna*, Cy Bridges, relates that Makuakaumana was the caretaker of several *heiau* in Hauʻula (McGregor 2011).

3.2.1.4 He Inoa No Kūaliʻi

"He Inoa no Kūaliʻʻi" is a name chant for the Oʻahu high chief Kūaliʻi. Such name chants were a common practice among Hawaiians to celebrate their aliʻi. The chant itself is over 600 lines long and details his life and accomplishments. Much of the setting of the chant occurs in Koʻolauloa and Koʻolaupoko.

4.0 Cultural Resources

Cultural resources can be natural, tangible or intangible. They are most commonly considered phyasical evidence of past human activitity site, object, landscape, structure; or a site, structure, structure, landscape, object or natural feature of significance to a group of people traditionally associated with it. A more comprehensive definition also considers places of cultural importance and biological resources of cultural importance. There are also intangible cultural resources, which may have not have physical form, but contribute to the cultural identify of a group.

4.1 Historic and Cultural Sites

Archaeological sites, including identification of historic sites, are discussed in the project LRFI. Additional information on historic sites is also provided in the ethnographic data.

4.2 Natural Resources with Cultural Significance

Hawaiians, like most indigenous and local communities, ascribe great cultural value to the natural resources in the environment around them.

Koʻolauloa and Koʻolaupoko are known for their wet, lush land areas. The abundance of fresh water which run from the mountains to the sea allowed for the extensive cultivation that would support the residents of the area. This region enjoys numerous fresh water springs, which also support farming, but also support a healthy nearshore coastal environment.

4.2.1 Wind

Winds, like rains, can be unique and distinctive to an individual location. The most famed of Hawaiian moʻolelo about winds is by Moses Kuaea Nakuina, *Moolelo Hawaii o Pakaa a me Ku-a-Pakaa, na Kahu Iwikuamoo o Keawenuiaumi, ke Alii o Hawaii, a o na Moopuna hoi a Laamaomao* (The Hawaiian Story of Pakaʻa and Kuapakaʻa, the Personal Attendants of Keawenuiaʻumi, the Chief of Hawaiʻi, and the Descendants of Laʻamaomao), published in Hawaiian in 1901. This moʻolelo was later translated into English as *The Wind Gourd of Laʻamaomao* by Sarah Nākoa and Esther T. Mookini (1992). Thus, this important moʻolelo has remained in print for over a century, and is an important cultural source text within the discourse on Hawaiian history and natural resource management. Many have written about the gourd's mythical properties, which is believed to contain all the winds of Hawaiʻi. More than myth, the gourd itself exists in physical form and was last owned by King David Kalākaua. Today, it is held in the collection of the Bishop Museum

According to this moʻolelo, the descendants of Laʻamaomao, the wind god, used the wind gourd, Ka Ipu Makani o Laʻamaomao, to control the winds and cause the demise of their enemies. Pākaʻa and his son Kūapākaʻa, Laʻamaomao's descendants, control the winds by chanting the wind name, which recalls that particular wind from the gourd. Each wind name is associated with a specific ahupuaʻa or ʻāina. Pākaʻa passed on his knowledge of the wind names and the gourd to Kūapākaʻa, who called on all of the winds to destroy the canoe fleet of Pākaʻa's enemies in the Kaiwi Channel separating Oʻahu and Molokaʻi.

According to this moʻolelo, the primary wind of Hauʻula is called Lanakila.

4.2.2 Rain

In *Hānau Ka Ua: Hawaiian Rain Names* (2015), C.L. Akana and K. Gonzalez explain the significance of the wind and rain in Native Hawaiian culture:

> In the mind...of our Hawaiian kūpuna [ancestors], every being and everything in the universe was born. Our kūpuna respected nature because we, as kānaka, are related to all that surrounds us—to plants and creatures, to rocks and sea, to sky and earth, and to natural phenomena, including rain and wind. This worldview is evident in a birth chant for Queen Emma, "Hānau ke aliʻi, hānau ka ua me ka makani" (The chiefess was born, the rain and wind, too, were born). Our kūpuna had an intimate relationship with the elements. They were keen observers of their environment, with all of its life-giving and life-taking forces. They had a nuanced understanding of the rains of their home. They knew that one place could have several different rains, and that each rain was distinguishable from another. They knew when a particular rain would fall, its color, duration, intensity, the path it would take, the sound it made on the trees, the scent it carried, and the effect it had on people. (Akana and Gonzalez 2015:xv)

To Native Hawaiians, no two rains are ever the same. Rain can be distinguished based on its intensity, the way it falls, and its duration, among other things. This section contains a selection of known rains associated with the Hauʻula ahupuaʻa. The primary name of the rain in Hauʻula is Maʻakua.

Maʻakua. Rain associated with Hauʻula and Makaua, Oʻahu.

Rain of Hauʻula, Oʻahu

1. Aloha ʻino nō kuʻu wahine
   ....
   Kuʻu wahine mai ka ua maʻakua o Hauʻula
   What great pity for my darling wife
   ..
   My beloved wife from the Maʻakua rain of Hauʻula

From a kanikau, or lament for Luakauwahine. Hawaiian source: Pawai. English trans. by author.

2. He hiwahiwa nui ʻoe na kuʻu kini
ʻO kuʻu kino kai mehana i kō poli
Ua ka ua Maʻakua, e pehi ana i ka ʻilikai o ka moana
Auē kuʻu kāne, kuʻu kāne hoʻi ē
You were a great adornment for my body
My body was warmed in your arms
The Maʻakua rain comes down, pelting the surface of the ocean
Pity for my dear husband! Oh, my beloved husband!
From a kanikau, or lament, for John Kealoha. Hawaiian source: Kaaikaula. English trans. by author.

Rain of Makaua, Oʻahu

3. Iā kākou e hele aku ai e hōʻea aku ana kākou i Makaua, ka ʻāina o ka ua Maʻakua. Aia i laila kahi i noho ai ʻo ka ʻīlio hā a Kāne, nona ka inoa ʻo Kauhikeʻīmakaokalani, a he makua kāne nō naʻe ia no kākou....
I ia wā, pane akula ʻi Hiʻiaka, "E noho nō ʻoe i ke kai o Makaua, e walea hoʻi i ke pehia e ka ua Maʻakua, e hoʻomanawanui ana hoʻi i ka hau anu o nā pali hāuliuli."
As we go along we will reach Makaua, land of Maʻakua rain. That is where the ʻīlio hā of Kāne dwells, name Kauhikeʻīmakaokalani, an uncle of ours....
Hiʻiaka replied, "You must stay here at the shore of Makaua, enjoy the pelting Maʻakua rain, and patiently endure the cold dew of the verdant cliffs."
In the first paragraph Hiʻiakaikapoliopele is speaking to Wahineʻōmaʻo. In the second paragraph she is speaking to her uncle Kauhikeʻīmakaokalani. Hawaiian source: Hoʻoulumāhiehie, *Ka Moʻolelo* 160, 162. English trans.: Hoʻoulumāhiehie, *Epic* 151, 153.

4.2.3 Water

Fresh water (wai) is of tremendous significance to Native Hawaiians. It is closely associated with many Hawaiian gods. According to traditional accounts, Kāne and Kanaloa were the "water finders:" "Ka-ne and Kanaloa were the water-finders, opening springs and pools over all the islands, each pool known now as Ka-Wai-a-ke-Akua (The water provided by a god)" (Westervelt 1915:38). Kāne is widely known to be closely associated with all forms of water, as outlined in the mele "He Mele No Kane."

There was no element more important or precious than water. There was no god more powerful than Kāne. Pua Kanahele recounts the oli "ʻO Kāne, ʻo wai ia aliʻi o Hawaiʻi?" and notes of the oli: "The chant begins with Kāne and focuses on this deity as the connective force of all the poʻe akua, or god family. All the entities mentioned in each paukū, or verse, are a manifestation of Kāne" (Kanahele 2011:24). The association between water and Kāne is logical considering certain interpretations of Hawaiian mythology identify Kāne as the most powerful of all the Hawaiian gods.

Further investigation into the relationship between Kāne and Pele would be appropriate and helpful. Some interpretations identify Kāne as Pele's father (Westervelt 1915). A full analysis of the different perspectives on Pele and Kāne would be helpful to refining an approach in developing community education programs for geothermal energy and culture. A brief analysis is provided below.

He Mele No Kāne

E ui aku ana au iā ʻoe,	One question I ask of you:
Aia i hea ka Wai a Kāne?	Where flows the water of Kane?
Aia i lalo, i ka honua, i ka Wai hū,	Deep in the ground, in the gushing spring,
I ka wai kau a Kāne me Kanaloa-	In the ducts of Kane and Kanaloa,
He waipuna, he wai e inu,	A well spring of water, to quaff,
He wai e mana, he wai e ola,	A water of magic power- The water of life!
E ola no, ʻea!	Life! O give us this life!

This mele and other moʻolelo are clear: Kāne is water. It is deeply valued among the Hawaiian people. The only exceptions may be mist, known to be associated with Lilinoe, and snow, associated with Poliʻahu. There is an extensive body of traditional knowledge about the expeditions of Kāne and Kanaloa during which Kāne drove his ʻōʻō (digging stick) into the earth in search of water.

4.3 Intangible Cultural Resources

It is important to note that Honua Consulting's unique methodology divides cultural resources into two categories: biocultural resources and built environment resources. We define biocultural resources as elements that exist naturally in Hawaiʻi without human contact. These resources and their significance can be shown, proven, and observed through oral histories and literature. We define built environment resources as elements that exist through human interaction with biocultural resources whose existence and history can be defined, examined, and proven through anthropological and archaeological observation. Utilizing this methodology is critical in the preparation of a CIA as many resources, such as those related to akua, do not necessarily result in material evidence, but nonetheless are significant to members of the Native Hawaiian community.

Hawaiian culture views natural and cultural resources as being one and the same: without the resources provided by nature, cultural resources could and would not be procured. From a Hawaiian perspective, all natural and cultural resources are interrelated, and all natural and cultural resources are culturally significant. Kepā Maly, ethnographer and Hawaiian language scholar, points out, “In any culturally sensitive discussion on land use in Hawaii, one must understand that Hawaiian culture evolved in close partnership with its natural environment. Thus, Hawaiian culture does not have a clear dividing line of where culture ends and nature begins” (Maly 2001:1).

4.3.1 ʻŌlelo Noʻeau

ʻŌlelo noʻeau are another source of cultural information about the area. ʻŌlelo noʻeau literally means “wise saying,” and they encompass a wide variety of literary techniques and multiple layers of meaning common in the Hawaiian language. Considered to be the highest form of cultural expression in old Hawaiʻi, ʻōlelo noʻeau brings us closer to understanding the everyday thoughts, customs, and lives of those that created them.
Pukui (1983) only identified one ʻōlelo noʻeau from Hauʻula:

> #1314 - Ka hilu pani wai o Hauʻula.
>
> The water-damming hilu fish of Hauʻula.

The ʻōlelo noʻeau references a famed moʻolelo from Hauʻula. It is said that in ancient times, near the time when Hawaiians first came to Hawaiʻi from Kahiki, two brothers came to Hawaiʻi from Kahiki as hilu fish. As they approached the island of Oʻahu, the two brothers separated. One brother went to the east side of the island, while the other brother went to the west side of the island.[2]

The moʻolelo says that the brother who headed west was caught in a fisherman‘s net at Hauʻula. His body was then cut into pieces and shared among the fishing families in Hauʻula who relied on fish for subsistence.

The older brother, who went east, came looking for his brother. Upon arriving in Hauʻula, he found the pieces of his brother‘s body throughout the fishing village. In his grief, the older brother traveled mauka into the uplands and dammed one of the streams in the valley with his own body. He waited until the stream built behind him before removing himself from the stream and allowing a flood to sweep through the village. The pieces of his brother‘s body swept out to sea and rejoined in the ocean, once again becoming a hilu fish.

There are two ʻōlelo noʻeau from Kahana:

> #653 - He kai ʻaʻai ko Kaʻaʻawa.
>
> Kaʻaʻawa has a sea that wears away the land.

[2] Other versions of this same story having the brothers heading north and south.

#2245 – Na kupa heʻe ʻĀhiu I ka laʻI o Kahana.

The native sons who surf in the ʻĀhiu wind in the peaceful land of Kahana.

There are two ʻōlelo noʻeau from Kaʻaʻawa:

#652 – He kai ʻaʻai ko Kaʻaʻawa.

Kaʻaʻawa has a sea that weat wears away the land.

#821 – He moe kai no Kaʻaʻawa.

A sleeper in the sea of Kaʻaʻawa.

The ʻōlelo noʻeau is said to be applied to someone who breaks the law and is put to death.

4.3.2 Mele (Songs)

There are numerous mele composed for Hauʻula in more contemporary times, some of which are included below.

The *Buke Mele Lahui* (Hawaiian National Songbook), published in 1895, is "the largest number of political and patriotic Hawaiian songs ever printed in one place," featuring mele that "echo the steadfast resilience of Hawaiians of that time as they weathered the political turbulence of the 1880s and 1890s that completely altered their world" through the overthrow and establishment of a foreign-led provisional goverment and subsequent annexation to the U.S. (Nogelmeier and Stillman 2003:xii).

4.3.2.1 Hauʻula Smiles

Composed by Moe Keale

Hau'ula smiles fair and bright
Mountains are green
Valleys are white
We love them all, we love them all
H-A-U-U-L-A Hau'ula

4.3.2.2 Eia Mai ʻo Hauʻula

Composed by Matt Sproat with the students of Ke Kula Kaiapuni ʻo Hauʻula

Eia mai ʻo Hauʼula I ka malu o nā Koʼolau
Ke kai mālie, lako ka ʻupena
Me nā pua, lei aloha i ke kaiaulu

E mā kaʼikaʼi aku kakou, i Wahiopua
Ke ʻala līpoa, e welina mai nei
Ke walea, nei koʼu mau kūpuna

Ke oli aku pā ʻoluʼolu ka Lanakila ʻo Maunawila
Ka leo nahenahe i koʼu naʼau
Pili pū me ko makua Kaʼumana

I ke aku i ka nani ka wailele ʻo Kaliuwaʼa
Wehiwehi I ka nahele, ka uhi paʼa i ka noe
He wehi laʼa, ka home a o Kamapuaʼa

Puana ka inoa ʻo Hauʼula i ka malu ʻo nā Koʼolau
Ke kai mālie, lako ka ʻupena
Me nā pua lei aloha i ke kaiaulu

Here is Hauʼula, in the shade of the Koʼolau mountains
With its calm ocean, the nets are full
The people thrive beautifully in this community

Let's ready ourselves to head to Wahiopua
Welcoming is the fragrant scent of seaweed
It's a familiarity known to my ancestors

The welcoming chant is carried through the winds in Maunawila
The answer back rivets my soul
Feeling a close relationship to my ancestor Kaʼumana

I see the beautiful waterfall of Kaliuwaʼa
Beautifully decorated is the trail blanketed by the mist
The sacred home of Kamapuaʼa

Tell the refrain of Hauʼula in the shade of the Koʼolau mountains
With its calm ocean, the nets are full
The people thrive beautifully in this community

This song was written by the children from Kula Kaiapuni ʻo Hau'ula, a Hawaiian language charter school, in a small Hawaiian community on the Northeastern side of the island of ʻOahu. The was the community which Matt (Sproat)was born and raised in, and his mother was a teacher at that elementart school for 38 years. She just retired in the fall of 2020. The teachers from that school asked Matt if he could write a song for the school. He politely declined and insisted that he would spend a couple of days with the students to help them write their own song for their school and community. This song was entirely written by the students from the 3rd-6th grade classes.

1st verse:

Eia mai ʻo Hau'ula, "Here is Hau'ula" a simple yet powerful phrase the students wanted to begin the song with sharing their pride for the town they are from. Hau'ula sits right at the base of the Ko'olau mountain range with its tall cliffs and sweeping valleys which provide many sources of fresh water that feeds the community. Hauula's oceans are famous for its fishing primarily because of its calm oceans. Malie is often a term used for describing the ocean and or its winds which is extremely favorable for fishing conditions. "Lako ka upena" is also a famous saying in Hau'ula for generations which mean, "the nets are full." The Kupuna or ancestors would say this after the nets are brought up and the boats are full of fish with a gleaming smile on their face, because they knew they would be able to share this bounty with the community.

2nd verse:

There is a reef area in Hau'ula called Wahiopua. All the people of Hau'ula have been going there for many generations to walk on to pick the bounties of the sea such as octopus, reef fish, crab, lobster, and also many types of seaweed. The smell of the seaweed wafts throughout Wahiopua, an extremely desirable scent for the elders. That scent would bring forth a happy feeling and a welcoming call to gather those precious gifts of the sea. One of the children in the class said, "this is what my ancestors did, and I do the same. This tradition will also continue on with my children one day doing the same thing my ancestors did."

3rd verse:

Approximately 800 years ago, a high priest from Tahiti named Ka'umana, came to Hau'ula and constructed a heiau called Maunawila. For centuries, the heiau was covered up be a dense canopy of trees and overgrowth along with the overflowing rivers which concealed the features of the heiau with sediment. For the past five years, native Hawaiians, archaeologists, anthropologists, and community members have worked tirelessly to restore this ancient and sacred landscape. The students have made multiple trips to Maunawila with community leaders and also with local Hau'ula historian, Cy Bridges to learn of its history. It is protocol when entering any heiau, to ask to enter with a chant or an oli. The chant would then be returned with another oli given by the caretaker to welcome into the sacred area. The students say that when they are giving their oli to enter into Maunawila, they would often hear a faint oli in the wind which gives them the feeling that the welcoming chant was being given by Ka'umana. That beautiful welcoming chant they hear would rivet their soul giving them a connection to that ancestor, Ka'umana.

<u>4th verse:</u>
One of the most famous icons of Hau'ula is an ancient waterfall called Kaliuwa'a, otherwise known as sacred falls. In Hawaiian folklore, lived a mischievous yet powerful demi-god called Kamapua'a who was half pig and half man who was born in Hau'ula. In the ancient chants, Kamapua'a was Pele's lover, however, he was also a lover boy who would spread his love to many other women which would anger Pele. One ancient chant speaks of Pele chasing Kamapua'a in an attempt to consume him with fire. He escapes her by climbing up Kaliuwa'a, and during this attempt, his feet carve out tall yet thin canyons along the side of mountain walls from the base of the waterfall all the way to the top of the mountain range. Unfortunately, these children have never been to the base of that waterfall and experienced her beautiful bathing pools. Since 1999, the State of Hawai'i has closed off access to the Sacred Falls trail, however, the waterfall could be seen faintly from the school grounds. The children were told stories of the mist that would gather along the trail and as the morning sun would peak into the valley, the misty air would shine and sparkle making it a magical and reminding them that Kaliuwa'a is a sacred area.

<u>5th verse:</u>
This verse is a revamp of the first verse reminding the listeners that this is their home which they love.

4.3.2.4 Hanohano Hauʻula

Composed by Matt Sproat

Hui: ʻO ka makani Lanakila hoʻohihi puʻuwai ē - - -
I ke one kaulana o kuʻu home hānau ē - - -

Kaulana ē, ke kai i ka mālie ē
Ka nani o nā pua, ka wai o ke ola, uluwehiwehi ʻo Hauʻula ē

Hoʻohihi ē, ka nani o Kaliuwaʻa ē,
Wai kahe mālie i nēia wahi kapu, nani wale ʻo Hauʻula ē

Hui

Mau loa ē, nā minoʻaka o ka hoʻokipa ē -
Nā hoaloha, kānaka haʻaheo, lua ʻole ʻo Hauʻula ē

Poinaʻole ē ka makani nihinihi pali ē
Ke ʻala onaona o ka hala i ka uka, hanohano ʻo Hauʻula ē

Chorus:
The Lanakila wind of Hauʻula enraptures my heart
The famous sands of my birth.

Famous are your gentle seas
The beauty of the flowers, the waters of life, lush and beautiful is Hauʻula

Captivating is the beauty of Kaliuwaʻa
Your gentle stream flows into this sacred place, splendid is Hauʻula

Never ending are the welcoming smiles
From the many friends and proud kanaka, incomparable is Hauʻula

Unforgettable are the winds that traverse the cliffs
The scent of the hala in the uplands, glorious is Hauʻula

4.3.2.5 Home Kapaka

Composed by Mary Pukui

Hanohano ʻia home aʻo Kapaka
E kipa aʻe e nā pua a ke Lehulehu

Ka nehe o ke kai lana mâlie
Ke ʻala līpoa e moani nei

A ʻike ka nani o Kaliʻuwaʻa
Ka beauty aʻo Sacred Falls au uʻi aloha

Hoʻi au i ka home o nā makua
Nanea e hauʻoli me nā hoaloha

Puana kuʻu mele no Kapaka
E kipa aʻe e nā pua a ka Lehulehu

Proud are we of our home, Kapaka
Where there is welcome for all

The lapping of the sea is gentle
The fragrance of seaweed is in th air

Behold the splendor of Kaliʻuwaʻa
The beauty of Sacred Falls, that I love

I go to the home of my parents
To relax and be happy with loved ones

My song is a story for Kapaka
Where there is welcome for all
This mele by Mary Pukui is named for a small ahupuaʻa near Hauʻula, Kapaka, after the tobacco crop that grew in the area. This mele also incorporates other moʻolelo about Hauʻula.

4.3.2.6 Uluwehi o ke Kai

Composed by Edith Kanakaole

Many will likely be surprised to learn that this famous mele was actually composed for Hauʻula. Renouned Kumu Hula Edith Kanakaole lived on Hawaii Island, but it is said that on a trip to north shore, she was inspired by the rich ocean environment of Hauʻula. That environment inspired this mele, which continues to be widely sung and danced throughout the islands today.

He hoʻoheno ke ʻike aku
Ke kai moana nui lā
Nui ke aloha e hiʻipoi nei
Me ke ʻala o ka līpoa

He līpoa i pae i ke one
Ke one hinuhinu lā
Wela i ka lā ke hehi aʻe
Mai manaʻo he pono kēia

Hoʻokohukohu e ka limu kohu
Ke kau i luna o nā moku lā
ʻO ia moku ʻula lā e hō!
ʻOni ana i ʻō i ʻaneʻi

Haʻina mai ka puana

Ka līpoa me ka limu kohu
Hoa pili ʻoe me ka pahe'e
ʻĀnoni me ka līpalu

Translation:

So precious to witness
The great expansive ocean
A great affeection is nourished within
With the fragrance of the līpoa seaweed

The līpoa washes up on the sand
The glittering sand
Scoraching hot from the sun to step on
Don't think that this is what must be

The limu kohu so alluring
Set atop the reef rocks
Those clumps, ʻula lā e hō!
Waving back and forth

The refain is told
Of the līpoa and the limu kohu seaweeds
You are companion to the pahe'e
Mixed together with the līpalu

4.3.2.7 Beautiful Kahana

Beautiful Kahana - Words & music by Mary J. Montano

Mau loa nō koʻu mahalo nui	I admire everlastingly
I ka nani pūnono o Kahana	The glowing beauty of Kahana
Ka moani ʻaʻala anuhea	The sweet wind borne perfume
O na pali aʻo Koʻolauloa	Of the cliffs of Koʻolauloa
Hui:	Chorus:
ʻO ka home ia o ka wahine	This is the home of the lady
Puʻuwai aloha a ʻĪnia	Of the loving heart of India
He pua ua mili ani ʻia	A flower lovingly fondled
E ka Mālualua kiʻi wai	By the Mālualua kiʻi wai breeze
ʻO Kalāhikiola nō ka ʻoi	Kalāhikiola is the greatest

He puʻulena ia na ka maka	It holds one's admiration
Kohu kihene pua ka uʻi	As pretty as a basket of flowers
I luluhe i ka ʻae o ke kai	Leaning over at the edge of the sea
Hui:	Chorus:
He maile kaluhea ia laʻi	Like the large leaved maile in the calm
Haʻaheo a ke ao nāulu	Proud in the presence of the rain clouds
Ulu aʻe ka manaʻo he aloha	It inspires an expression of love
Ia kuini pua ʻo Kahana	For the flower queen of Kahana

Huapala, a mele repository, explains that this mele was written for Mary E. Foster and her beautiful country home, Kalāhikiola, on the windward side of Oʻahu at Kahana (Huapala, n.d.).

4.3.2.7 Nani Oʻahu

Nani Oʻahu - Words by Mary Pukui, Music by Maddy Lam

Nani wale ʻoe e Oʻahu
Ka heke o na ailana
E lei ohuohu nei
I ka pua a o ka ʻilima

Aia no i ka poli
Kapu ihi o Ewa
Ke awa lau o Puʻuloa
Me ka iʻa hamau leo

Ua nani no na Koʻolau
Ike koʻa o Heʻeia
Ka laʻi olu o Kahana
Kai holu a o Laniloa

Kaulana o Honolulu
I ka ua Kukalahale
Ke ka ona hanohano
O na moku o Hawaiʻi

Haʻina mai ka puana
No ka nani o Oʻahu
E lei ohuohu nei
I ka pua a o ka ilima

Translation:

Beautiful are you Oʻahu
Greatest of islands
You are now bedecked
With the blossom of the ʻilima

There in the bosom
Sacred (bosom) of Ewa
Rests Pearl Harbor
And the fish that silences the voice

Beautiful are the Koʻolau districts
With the reefs at Heʻeia
The peaceful calm of Kahana
The swaying surf of Laniloa

Famed is Honolulu
In the Kukalahale rain
A town that is honored
In the islands of Hawaiʻi

Thus ends my song
Of the beauty of Oʻahu
Who is bedecked
With the blossom of the ilima

Source: Pamai Tenn Collection

5.0 Traditional or Customary Practices

In traditional (pre-western contact) culture, named localities served a variety of functions, informing people about: (1) places where the gods walked the earth and changed the lives of people for good or worse; (2) heiau or other features of ceremonial importance; (3) triangulation points such as koʻa (fishing markers) for fishing grounds and fishing sites (4) residences and burial sites; (5) areas of planting; (6) water sources; (7) trails and trail side resting places (oʻioʻina), such as a rock shelter or tree shaded spot; (8) the sources of particular natural resources/resource collections areas, or any number of other features; or (9) notable events which occurred at a given area. Through place names, knowledge of the past and places of significance was handed down across countless generations. There is an extensive collection of native place names recorded in the moʻolelo (traditions and historical accounts) published in Hawaiian newspapers.

Hawaiian environmental resilience was a regular part of traditional life. Famed anthropologist Marion Kelly wrote:

> Changes made by Hawaiians, as in the case of fishpond building, enhance the food productivity for the people as they modify or adapt some elements of the environment, without creating unplanned, extensive and irreversible destructions of other important elements of the original environment. … The dedication of Hawaiian society to the concept of *malama* (caring) is basically a conservation value. Sometimes it is explained as a belief that the land and sea in the last analysis "belonged" to the gods. Permission for the use of the gods' domain was continually asked of them through religous ceremonies, large and small. Works of Hawaiians, both on land and in the sea, were so carefully planned, engineered and executed that they enhanced productively without massive environmental degradation following as a result… (Kelly 2000).

As shown on Figure 15, the historical map of the area shows a number of pond fields (whether in rice or kalo) that would have served to manage water in the area. There is also a "water run" shown in the same ʻili (Hanaimoa) as the project area that may have served as flood control. The current status of this water run is unknown.

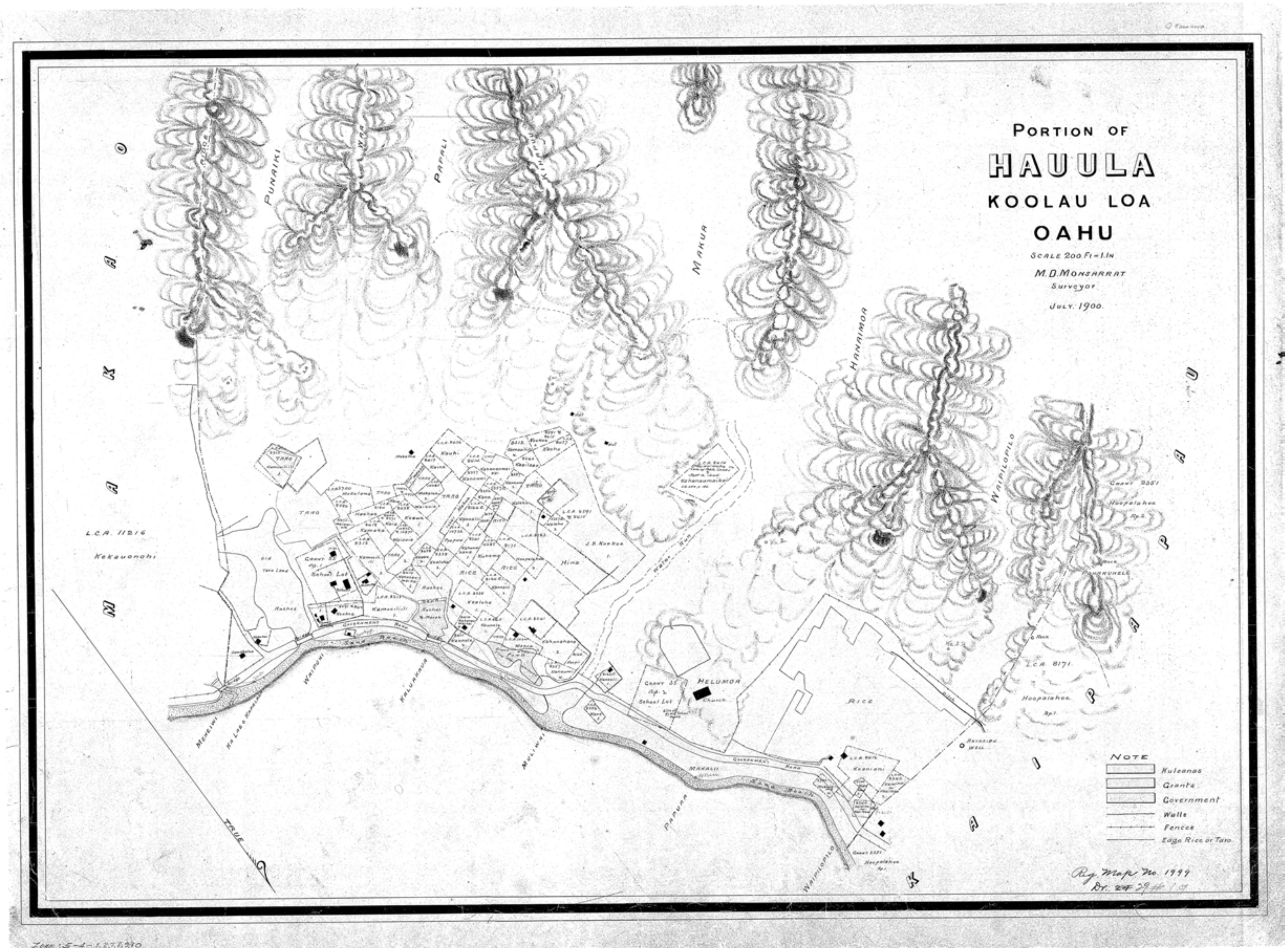

Figure 15. Registered map 1999 of Hau'ula showing different land uses in the region

This is not intended to be a comprehensive list of all the practices that historically or contemporaneously occur in Hauʻula. This is meant to show the range of traditional or customary practices that took place in the larger geographic extent.

5.1 Moʻolelo

Moʻolelo is the practice of storytelling and developing oral histories for the purpose of transmitting knowledge information and values intergenerationally. Moʻolelo are particularly critical in protecting and preserving traditional culture in that they are the primary form through which information was transmitted over many generations in the Hawaiian Islands and particularly in the Native Hawaiian community.

Storytelling, oral histories, and oration are widely practiced throughout Polynesia and important in compiling the ethnohistory of the area. The Native Hawaiian newspapers were particularly valued for their regular publication of different moʻolelo about native Hawaiian history. Were it not for the newspapers having the foresight to allow for the printing and publication of moʻolelo, far less information about the cultural history of the Hawaiian people would be available today.

There are numerous moʻolelo about Hauʻula and the geographic extent. These moʻolelo are provided in **Sections 3.2 (Traditional Period)** and in **Section 4.0 (Cultural Resources)**.

5.2 Habitation

Hawaiians lived extensively throughout the islands. Handy, Handy, and Pukui (1991) identify how different kānaka and their ʻohana lived in accordance with what the authors termed "occupational contrasts" (286), meaning that based on occupation (i.e., planter or fisherman, for example), habitation systems differed. They describe, "The typical homestead or *kauhale*… consisted of the sleeping or common house, the men's house, women's eating house, and storehouse, and generally stood in relative isolation in dispersed communities. It was only when topography or the physical character of an area required close proximity of homes that villages existed. There was no term for village. *Kauhale* meant homestead, and when there were a number of *kauhale* close together the same term was used. The old Hawaiians, in other words, had no conception of village or town as a corporate social entity. The terrain and the subsistence economy natural created the dispersed community of scattered homesteads" (284).

The previous archaeology for the Project Area shows that habitation sites have been identified in the area.

Figure 16. Image of Kahana Bay from 1885 (Images of Old Hawaii)

5.3 Fishing, Spearfishing, and Limu Picking

Koʻolauloa is a fishing community. The nearshore reef environment provides a rich biodiversity that has helped to sustain this community for generations. The Hauʻula area is known for fishing and diving, especially for heʻe (octopus). This area is also known historically for limu picking, although limu has become more scarce in recent times, likely from development and environmental degradation. Kahana and Kaʻaʻawa also have very active fishing communities, with a fishpond located in Kahana. There are also fishponds in Kualoa. All these resources are along the shoreline near the project areas.

Figure 17. Kualoa Ranch showing Moli'i Fishpond (Alamy 2019)

This ocean expertise was critical to traditional Hawaiian practices. In *Hawaiian Fishing Traditions*, Moses Manu and Others write,

> With a knowledge of fishing areas and seasons and an array of implements that included hooks and lines, lures, nets, basket traps, poisonous plants, and spears, a fisher supplied his family or his ali'i with fish and shellsih from streams, fishponds, reefs, and ocean. Sometimes the catch was so huge, fish could be fed to teh pigs and dogs, with some left over to dry as food or fuel for fire; some was left to rot. Those fishers that could supply large amounts of fish from ponds or catches at sea were belieed to possess mana kupua, or supernatural power, to attract fish at will or make them multiply. Successful fishing implements, such as hooks or cowry shell lures became famous and were prised, passed on to heirs, and sometimes fought over (Manu 2006, ix).

This ocean-based lifestyle remains vibrant in Ko'olauloa. It is not uncommon to see fisherman or spearfisherman walking along the road with their fresh catch. These small communities still rely on the environment for subsistence.

Figure 18. Author Matt Sproat spearfishing in front of his family home in Hau'ula. (Photo by Kirsten Carlson for Hakai Magazine, 2015)

5.4 Lāʻau Lapaʻau

Lāʻau lapaʻau is the practice of traditional Hawaiian medicine. For centuries, native Hawaiians relied upon the environment around them to provide them medicine. It is still actively taught and practiced today. Medicinal experts or healers have intimate knowledge about plants and other resources to cure ailments, illnesses and sicknesses. Traditional medicine is practiced by native peoples and local communities around the world. Similarly, Native Hawaiians, over many generations, have learned how to properly care for, utilize, and prepare plants to maintain the community's health.

It was important to not only have plants and have access to plants but to ensure that these plants were healthy and in good condition. In the list of biological resources, plants with medicinal capacity and components are identified. These resources are cultural resources. They are critical to the ongoing practice of traditional medicine and healing within the Native Hawaiian community. There are still many traditional medicine practitioners in the Hawaiian community and throughout the Hawaiian Islands today. It is a practice that is still taught to the younger generation, and it is a practice that is still honored and utilized in many Hawaiian households throughout the state.

It was important that medicinal plants existed throughout the Hawaiian Islands so that when people traveled throughout different places on in the islands, they would always have access to the medicine they needed. In some cases, some plants were extremely rare, and, in those cases, it was particularly important to make sure that these populations were well protected and well cared for. There were also numerous gods associated with health, healing, and medicine. They are listed in **Table 4**.

Table 2. Hawaiian Gods Associated with Health, Healing and Medicine

Hawaiian gods associated with health, healing, and medicine (Pukui, 1971)
Hiʻiakaikapolio Pele
Lonopūhā
Maʻiola
Hiʻiakaikapuaʻenaʻena
Hauwahine
Hina
Hinaʻea
Hinalaulimukala
Kamakanuiʻahuʻilono
Kanaloa
Kū
Kūkeoloʻewa
Mauliola
ʻŌpeluhuikauhaʻailo

Koʻolauloa has an active community of healing practitioners. Kūpuna like Creighton Mattoon was a strong advocate for health and traditional practices in this region through his entire life. While he has passed, his work is still carried on and influence in this region. Practitioners actively practice in the Koʻolauloa and Koʻolaupoko moku, although there is no indicator that the project area is currently used for any of these practices. Although ocean access is important to health and well-being, and the ocean is an important resource in lāʻau lapaʻau practices.

5.5 Kilo

Kilo are observational traditions and people who examine, observe, or forecast are identified as kilo and serve as traditional climate and weather experts. Kilo "references a Hawaiian observation approach which includes watching or observing [the] environment and resources by listening to the subtleties of place to help guide decisions for management and pono practices" (ʻĀuamo Portal 2021). The practice of kilo is seeing a resurgence on Hawaiʻi Island and in the Hawaiian Islands.

Kilo hōkū are traditional astronomers, or those who study the stars. A hale kilo or hale kilo hōkū were observatories or star observatories respectfully. Kilo makani were those who traditionally observed the winds. Kilo moana were traditionally oceanographers. Kilo ʻuhane were those who observed and communicated with spirits.

Traditionally the practice of kilo or observation was critical to the management of traditional Hawaiian landscapes. This practice is very closely tied to traditional or customary access as observers would require access to specific vistas, viewsheds or areas in order to observe environmental phenomenon.

As illustrated in the proceeding section, Native Hawaiians created a wide range of terms for the environment and understanding the ecosystems around them. These terms were often quite specific, and many were tied closely to a specific geographic area. This level of specify illustrated the close kinship Hawaiians shared to their surrounding environment. The ability to observe and understand all elements of their ecosystem was essential to both the successful care of natural resources and the survival of the Hawaiian people.

The ability to effectively and accurately read weather phenomena was essential to the ability of Hawaiian people who farm, fish, navigate, and conduct any number of practices in a sustainable and successful manner. The knowledge Hawaiians acquired about their environment around them, including weather phenomena were the result of multi-generational observations that comprised an extensive body of information passed down through oral traditions. The following Hawaiians names and their descriptions of weather phenomena include words for clouds, rains, and winds that are utilized by kilo to help guide activities and practices:

ao akua – godly cloud, figurative representative of a rainbow.
ao loa – long cloud or high, distant cloud. Status cloud along the horizon.
ao ʻōnohi – cloud with rainbow, ʻōnohi, colors contained within it.
ao puaʻa – cumulus clouds of various sizes piled together, like a mother pig with piglets clustered around her. The Kona coast is famous for ao puaʻa, a sign of good weather and no impending storms.
ao pehupehu – continually growing cumulus typical of summer. Drifting with the tradewinds, these clouds pick up moisture and darken at their base, finally releasing their rain on the windward mountain cliffs.
hoʻomalumalu – sheltering cloud.
hoʻoweliweli – threatening cloud.
ānuenue – rainbow, a favorable omen.
ua loa – extended rainstorm.
ua poko – short rain spell.

Kilo has been traditionally practiced in the area and is still practiced in the area. Kilo iʻa is the practice of observing fisheries. Areas in Kahana were particularly known for this (see **Appendix A**).

5.6 Ceremonial Practices

The ceremonial practices of traditional Hawaiians are extensive. Throughout the course of Hawaii's history, traditional Hawaiians have integrated religious, spiritual, and ceremonial practices in their daily lifestyle. Traditional or customary practices are then not distinct ceremonial practices but rather a part of their way of life. Therefore, it is challenging to define in discrete terms ceremonial practices associated with traditional Hawaiian customs. For the purpose of this section, the ceremonial practices discussed here focus primarily on customs carried out by general populations of Hawaiians, as opposed to activities or rituals carried out by trained and recognized specialists, kahuna. Those practices are discussed in a separate section.

Ceremonial practices are incorporated throughout numerous, if not all, of the activities identified in this section. For example, there is a great level of ceremonial practice and ritual associated with the care of the dead, burial remains, and funerary objects. Native Hawaiians as with most Iindigenous people integrated ceremony into most of their practices especially those that occurred out in the natural landscape or related to their way of life. There was no specific site or materials required for the ceremony *per se*.

Nonetheless, shrines were sometimes associated with ceremonial practices. Shrines for the purpose of this assessment are distinct from heiau, which were places of worship. Again, the distinction is the nature in which these features or sites were created. Heiau required the advice and guidance of a kahuna, who would help aliʻi determine the best location in which to erect a heiau. Conversely, shrines were erected by makaʻāinana (working class) as part of their daily or occupational functions.

Makahiki is one example of a practice that has taken place prior to contact and continues post-contact and involves ceremonial elements. One of these elements is the akua loa, described by Malo as "the image of the Makahiki god, Lono-makua … This work was called ku-i-ke-pa-a" (Malo, 1951: 143). Further described by Malo:

> 22. This Makahiki idol was a stick of wood having a circumference of about ten inches and a length of about two fathoms. In form, it was straight and staff-like, with joints carved at intervals and resembling a horse's leg; and it had a figure carved at its upper end.
>
> 23. A cross piece was tied to the neck of this figure, and to this cross piece, kea, were bound pieces of the edible pala[3] fern. From each end of this cross piece were hung feather lei that fluttered about, also feather imitations of the kaupu bird[4], from which all the flesh and solid parts had been removed.

[3] Native fern (*Marattia douglasii)* used for medicinal purposes as well as in ceremony.

[4] Laysan albatross (*Diomedea immutabilis*), written with diacritical markings as kaʻupu.

> 24. The image was also decorated with a white tapa cloth made from wauke[5] kakahi[6], such as was grown at Kuloli[7]. ... One end of this tapa was basted to the cross piece, from which it hung down in one piece to a length greater than that of the pole. The width of this tapa was the same as the length of the cross piece, about sixteen feet.
>
> 25. The work of fabricating this image, I say, was called kuikepaa. The following night the chiefs and people bore the image in grand procession, and anointed it with cocoanut (sic) oil. Such was the making of the Makahiki god. It was called Lono-makua (father Lono), also the akua loa. This name was given it because it made the circuit of the land (Malo, 1951: 144-145).

The akua loa was taken to each ahupuaʻa. This custom was important to the care, stewardship, and worship of the gods. These practices were intimately tied to the proper care and sustainable stewardship of all cultural and natural resources. Ethnographic data indicates that such practices take place within the Project Area or Study Area.

As with many concepts of traditional Hawaiian living and practices, the contemporaneous concept of the kahuna has been largely influenced by Western thought. The roles and responsibilities of the kahuna are well explained by Professor Terry Kanalu Young in his text, *Rethinking the Native Hawaiian Past*, in which he writes:

> As recipients of hana lawelawe[8], the Aliʻi Nui were themselves serves of a sort. They were responsible for maintaining a positive spiritual relationship with the Akua through pono conduct. Pono was defined for individuals of that era within the context of a particular task specialty. Kahuna who functioned as experts in specific skill areas like medicinal healing, canoe building, or spiritual advising were consulted by leaders. The experts were looked to as responses for what was considered pono in their respective realms of knowledge (Young 1998).

Kahuna were critical to traditional Hawaiian lifeways as their extensive expertise helped to provide sound and strategic advice to aliʻi and other leaders on proper spiritual, cultural, and ecological management. There are numerous types of kahuna in Hawaiian traditions. including, but not limited to:

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[5] Paper mulberry (*Broussonetia papyrifera*)
[6] Meaning outstanding or of high quality, as in reference to the white kapa (tapa) made from these fibers.
[7] Likely a reference to the place in Pelekunu Valley at Kamalō, Molokaʻi, located between the peaks of Kaunuohua and Pēpēʻōpae.
[8] Hana lawelawe are defined by Young as "service tasks" by which kaukau aliʻi (lower ranked chiefs) served the Aliʻi Nui (high chiefs). These hana lawelawe were critical to the ability of the Aliʻi Nui to effective govern (Young 1989).

kahuna ʻanāʻanā - sorcerer who practices black magic and counter sorcery

kahuna aʻo - teaching preacher, minister, sorcerer.

kahuna hāhā - an expert who diagnoses, as sickness or pain, by feeling the body.

kahuna haʻiʻōlelo - preacher, especially an itinerant preacher.

kahuna hoʻohāpai keiki - medical expert who induced pregnancy.

kahuna hoʻopiʻopiʻo - malevolent sorcerer, as one who inflicts illness by gesture.

kahuna hoʻoulu ʻai - agricultural expert.

kahuna hoʻoulu lāhui - priest who increased population by praying for pregnancy.

kahuna hui - a priest who functioned in ceremonies for the deification of a king.

kahuna kālai - carving expert, sculptor.

kahuna kālai waʻa - canoe builder.

kahuna kiʻi - caretaker of images, who wrapped, oiled, and stored them, and carried them into battle ahead of the chief.

kahuna kilokilo - priest or expert who observed the skies for omens.

kahuna lapaʻau - medical doctor, medical practitioner, healer. Lit., curing expert.

kahuna makani - a priest who induced spirits to possess a patient so that he might then drive the spirits out.

kahuna nui - high priest and councilor to a high chief; office of councilor.

kahuna poʻo - high priest.

kahuna pule - preacher, pastor, minister, parson, priest. clergyman. Lit., prayer expert.

kahuna pule kaʻahele - preacher

kahuna pule wahine – priestess

Ceremonial activities are practiced throughout the area, but Kualoa is particularly known for its Makahiki festivities.

5.7 Haku Mele, Haku Oli, and Hula

This practice is related to the composition of songs and chants. this is a practice that has existed for many centuries in the Hawaiian culture. When the Hawaiian culture primarily relied on an oral tradition to pass on knowledge and information, the ability to create songs and chants was essential to pass information from one generation to the next. As Donaghy (2013) notes, Hawaiians had hundreds of terms associated with this practice.
Songs and chants are largely influenced by the environment around them. As a pedagogical device it was important if not imperative that these songs or chants effectively captured data from the environment around the composer and passed on this information for others to utilize when managing natural resources. In a very real sense, the land and natural resources act as a muse for composers. The category of songs that provide information on or speak to natural resources are called mele ʻāina (songs of the land). As shown in the previous section, there are numerous traditional chants and songs about the project area and its surrounding landscape.

Much like mele and oli, hula serves as a way of both honoring a place and telling the story of place. Many hula, especially those based on mele ʻāina, require intimate understanding of the place where the mele was composed, including the natural elements of that ʻāina. Hula hālau will regularly take huakaʻi, or journeys, to visit and honor the place a particular mele speaks of. The ability to visit the place and learn about it is important to the practice of hula.

Hula, as well as mele or oli, are also offered as gifts to kupuna or gods. This practice also requires access to traditional sites, including ocean and coastal areas.

6.0 Ethnographic Data

As discussed previously in **Section 2.6 (Ethnographic Methodology)**, information was collected from a wide range of individuals and sources. The findings of those efforts are discussed in this section. Ethnographic data is utilized to supplement the other research methods utilized. It is one in a range of research tools employed to gather information about the project area.

Honua Consulting was tasked with gathering information from individuals with lineal and cultural ties to the area and its vicinity regarding regional biocultural resources, potential impacts to these biocultural resources, and mitigation measures to minimize and/or avoid these impacts.

The bulk of the information available from practitioners and kūpuna were drawn from native testimonies and Hawaiian language sources and integrated into the cultural and historic overview section of this survey. Those sources, along with responses to this project, were considered when researching the traditional or customary practices discussed in a previous section.

Interviews were conducted with five (5) individuals are included in this section. This data helped to identify additional resources and practices in the area; this information also helped to confirm research conducted for this report.

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6.1 Interview with Anuenue Kamakaʻala

Interviewer: Mathew Sproat
Interviewee: Anuenue Kamakaʻala
Date: 10/28/2022
Location: via telephone

Biography
Ms. Kamakaʻala is a professional babysitter. She was born in Punaluʻu and raised in Hauʻula. She currently lives in Punaluʻu. Ms. Kamakaʻala noted that when she was growing up, the area was a pasture.

Overview
Ms. Kamakaʻala believes that the project will be good for the community, noting that Hauʻula can be isolated and cut-off from important emergency services during emergencies and disasters.

General Discussion
Ms. Kamakaʻala is grew up near the project area, where her family still lives. She knows the area very intimately.

Cultural Resources
Ms. Kamakaʻala is not aware of any cultural resources in the immediate project area. There are freshwater springs in the vicinity but is not aware of any at that specific area we were talking about (project site).

Traditions and Customs
Ms. Kamakaʻala is not aware of any traditions or customs that take place in the area.

Impacts
Ms. Kamakaʻala is not aware of any cultural resources that could be impacted by the project. She is further not aware of any traditions to customs that could be impacted by the project.

Mitigation Measures and Recommendations

Ms. Kamakaʻala did not provide any recommendations. She didn't raise any concerns regarding the removal of anything discovered of historic value, however, she expressed hope that they would be cared for.

6.2 Interview with Brenda Glasco

Interviewer: Mathew Sproat
Interviewee: Brenda Glasco
Date: 10/31/2022
Location: In person

Biography

Ms. Glasco is retired but formerly worked for a doctor in Haleʻiwa. She was born and raised in Hauʻula, where she currently lives.

Overview

Given Ms. Glasco's lifelong association with the project area, she bring helpful context and information. She is supportive of the project and believes it will help the community.

General Discussion

Ms. Glasco is associated with the project area through being a lifelong community member. At one point in the interview, Ms. Glasco purported that the mana in the area was good.

Cultural Resources

Ms. Glasco noted that the general area of Hauʻula is known for its natural springs and water resources. That said, she is not aware of any river beds in the actual project area. However, much of the water present on the project area must be underground given the nearby ditches.

Ms. Glasco noted that there could be iwi, native plants, or native birds in the area, and that the project area should be examined. She noted that the area previously was a dairy farm.

Traditions and Customs

Ms. Glasco is not aware of any traditions or customs that take place in the project area.

Impacts

Ms. Glasco believes that the project could impact water resources depending on how deep the water table is. Further, Ms. Glasco believes that if there are traditions or customs present in the area, it is possible that the project may have an impact.

Mitigation Measures and Recommendations

Ms. Glasco expressed hope that if there are any cultural resources, traditions, or customs present on the project area, that the project developers would be aware.

6.3 Interview with JC Chang[9]

Interviewer: Mathew Sproat
Interviewee: JC Chang
Date: 10/29/2022
Location: via telephone

Biography

Mr. Chang is retired from the City and County of Honolulu. Here, he was a heavy equipment supervisor. Mr. Chang was born in Kahuku and raised in Lāʻie. He currently resides in Lāʻie.

Overview

With personal associations to Hau'ula, Mr. Chang brings helpful context and information regarding the project area. He does not know of any specific cultural resources in the project area, and does not believe there are any traditions or customs which take place in the project area.

General Discussion

Mr. Chang explained that he has many years of association with Hauʻula. He went to Hauʻula elementary school from kindergarten to sixth grade where his grandparents were educators. Mr. Chang also noted that he was married into a family that is deeply rooted in Hauʻula. Further, Mr. Chang coached at the playground and elementary.

Mr. Chang recounted that his cousin lived across from the project area, where he spent time in the general area. He is also familiar with the project area through his career with the City and County of Honolulu. He noted that the area was a pasture, previously.

Cultural Resources

Mr. Chang did not immediately know of any cultural resources in the project area. That said, he explained that there was a possibility that there could be native plants in the area. Regarding water resources, Mr. Chang explained that there are a lot of springs in Hauʻula, in general. He noted that the water table is high.

Importantly, Mr. Chang shared that from his experience as an excavator with the City and County, there have always been archaeologists on site during similar work and projects. Iwi are commonly buried in sand, which the project should be aware of.

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[9] The authors note that Mr. Chang graciously agreed to be interviewed while terminally ill. He has since passed. The summary is included with his permission.

Traditions and Customs

Mr. Chang was not aware of any traditions or customs that take place in the project area.

Impacts

Mr. Chang believes that impact on cultural resources could be possible from the project (including iwi or native plants). If the project hits the water table, they will need to do something to stabilize the ground. He did not believe there would be an impact to traditions or customs.

Mitigation Measures and Recommendations

Mr. Chang noted that there are several families from Hauʻula he would recommend consulting regarding mitigation measures or recommendations.

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6.4 Interview with Kekoa Desilva

Interviewer: Mathew Sproat
Interviewee: Kekoa Desilva
Date: 10/31/2022
Location: In person

Biography

Mr. Desilva was born and raised in Hauʻula. He currently lives in Kahuku.

General Discussion

Mr. Desilva is associated with the project area through being a community member. Regarding stories, he shared a story from his childhood where the kids were told a "apuaʻa man" (Kamapuaʻa) would come out at night, in addition to night marchers.

Cultural Resources

Mr. Desilva explained that growing up, there were natural spring waters in the general area.

Traditions and Customs

Mr. Desilva is not aware of any traditions or customs that take place in the project area.

Impacts

Mr. Desilva shared that there could be an impact on the springs from the project. He explained that the impact is contingent on variables of the project including how deep the pillars go, how much is excavated, etc.

Mitigation Measures and Recommendations

Mr. Desilva could not share any specific mitigation measures for the project. He recommended that there be a solution for the runoff caused by the project's structures.

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6.5 Interview with Ronnie Huddy

Interviewer: Mathew Sproat
Interviewee: Ronnie Huddy
Date: 11/1/2022
Location: Phone Interview

Biography
Ms. Huddy was born and raised most of her life in Hauʻula. She currently lives in Hau'ula .

General Discussion

Ronnie is a member of the community emergency response team, and an active member of the Hau'ula community association, and is also an active member of the community and Ko'olauloa limu resuscitation program restoring limu in her community. Ms Huddy is concerned about the location of the HUB, but also knows that Hau'ula is in desperate need of a HUB station.

She shares stories of Hau'ula, but one in particular is a menehune built structure in the ocean just off of Wahi'opua (the reef area found in Hau'ula). That menehune built structure is connected to the heiau which is found mauka of the project site.

Cultural Resources
Ms Huddy states that there is a graveyard with a Hawaiian structure and an unnamed heiau "Ma'akua" which she is currently doing vegetation removal and researching its age. Ms Huddy states that this heiau is connected to the 'iwi located above and on the upper part of the 5-acre property that has been recorded with SHPD member Garnette Clark who spearheaded those findings and the Board of Water Supply back in the 1990's. She also states that approximately 200 yards above this heiau is another heiau called "Kauniho". Other nearby heiau which are noted are Maunawila and Kapoho heiau which are found on the nearby ridges of Hau'ula. Ronnie claims that there is a 100% chance that there are 'iwi on the proposed site

Ms Huddy also makes notes of 5 known rivers and water sources found throughout Hau'ula which intersect near the project area.

Traditions and Customs
Ms. Huddy is not aware of any traditions or customs that take place in the project area.

Impacts

Ms Huddy states that the proposed project could pose threats to exposing the historical and archaeological sites particularly the ‘iwi. Her concerns would be the building of a structure over unknown burial sites and possibly other archaeological sites in that 5 acre parcel.

Mitigation Measures and Recommendation

Ms Huddy states that she understands the importance of this HUB station and that the community of Hau’ula needs this building, but wants to mention that we also need to acknowledge our ancestors in that area. We need to give them recognition. If there is a call to reinter the ‘iwi, there needs to be a proper burial treatment plan, reinterment on the property, a proper ‘ahu built, and some sort of recognition for the ‘iwi kupuna in the form of a story in the building or on property.

Ms. Huddy recommends that there be an archaeological survey done in that area prior to the building of the resiliency center.

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7.0 Ka Paʻakai Analysis

It has long been the law of the land that the State of Hawaiʻi has an "obligation to protect the reasonable exercise of customary and traditionally exercised rights of Hawaiians to the extent feasible" *Public Access Shoreline Hawaiʻi v. Hawaiʻi County Planning Commission ("PASH")* 79 Hawaiʻi 425, 450 n. 43, 903 P.2d 1246, 1271 n. 43 (1995). In 2000, in the *Ka Paʻakai* decision, the Court established a framework "to help ensure the enforcement of traditional and customary Native Hawaiian rights while reasonably accommodating competition private development interests." 94 Hawaiʻi 31, 35, 7 P.3d 1068, 1972 (2000).

Based on the guidelines set forth in *Ka Paʻakai*, the Hawaiʻi Supreme Court provided government agencies an analytical framework to ensure the protection and preservation of traditional and customary Native Hawaiian rights while reasonably accommodating competing private development, or other, interests. The Court has stated: "that in order to fulfill its duty to preserve and protect customary and traditional Native Hawaiian rights to the extent feasible, as required by Article XII, Section 7 of the Hawaiʻi Constitution, an administrative agency must, at minimum, make specific findings of fact and conclusions of law as to the following:

1) The identification of valued cultural, historical, or natural resources in the project area, including the extent to which traditional and customary Native Hawaiian rights are exercised in the project area.
2) The extent to which those resources—including traditional and customary Native Hawaiian rights—will be affected or impaired by the proposed action; and
3) The feasible action, if any, to be taken to reasonably protect Native Hawaiian rights if they are found to exist. *Ka Paʻakai*, 94, Hawaii at 47, 7 P.3d at 1084. Cited in *Matter of Contested Case Hearing Re Conservation District Use Application (CDUA) HA-3568 for the Thirty Meter Telescope at the Mauna Kea Science Reserve, Kaʻohe Mauka, Hāmākua, Hawaiʻi*, 143 Hawaiʻi 379, 431 P.3d 752 (2018) ("*Mauna Kea II*").

In order to complete a thorough CIA that complies with statutory and case law, it is necessary to fully consider information available from, and provided by, Native Hawaiian cultural practitioners and cultural descendants from the project area. From thorough research, data was extrapolated that provides a comprehensive look at the cultural resources in this ʻāina. Through this research, the factors from *State v Hanapi* are met. These factors are: "to establish that his or her conduct is constitutionally protected as a native Hawaiian right, he or she must show, at minimum, the following three factors. First, he or she must qualify as a "native Hawaiian" within the guidelines set out in PASH . . . [as] "those persons who are 'descendants of native Hawaiians who inhabited the islands prior to 1778,' … regardless of their blood quantum." Second, once a defendant qualifies as a native Hawaiian, he or she must then establish that his or her claimed right is constitutionally protected as a customary or traditional native Hawaiian practice.... Finally, a defendant claiming his or her conduct is constitutionally protected must also prove that the exercise of the right occurred on undeveloped or "less than fully developed property."" 89 Hawai'i 177, 185-86, 970 P.2d. 485, 493-94 (1998).

The *Ka Pa'akai* analysis is largely a legal analysis, as the applicable tests are legal standards. Therefore, a strong analysis is one conducted by someone with sufficient legal training. Additionally, at the core of a thoughtful *Ka Pa'akai* analysis is a comprehensive understanding of traditional and customary practices. In breaking down the Court's tests, it is important to the different elements that contribute to each test.

The first test - "The identification of valued cultural, historical, or natural resources in the project area, including the extent to which traditional and customary Native Hawaiian rights are exercised in the project area" – actually consists of two separate elements. First, the simple identification and existence of valued cultural, historical, or natural resources. These resources are tangible in nature. They can include sacred places, culturally valuable plants, or a religious or historic site. This survey sought to exhaustively identified the great multitude of resources that may exist in the project area or adjacent areas.

As to this test, this survey shows there are potential resources within the project area. Archaeological survey work will be conducted and any impacts to historic sites and properties will be formally assessed through the HRS 6E-42 process, which is required for this project.

The second element of this first test is access. Access requires two things to occur. One is the existence of a resource. Whether a plant, an animal, a place, or site, the resource must exist in order for a practitioner to access it. The second thing is physical access. This includes, but it is not limited to, the ability to physically access a plant, animal, site, or location associated with a particular practice. This can also include the traditional and customary route or path taken to access the resource. This can also include cultural protocols that existed in accessing a resource. These are often temporal, in that access protocols can be at a certain time of day or year. Makahiki would be a good example of a traditional custom that has specific cultural protocols associated with access. In the case of Makahiki, the custom takes place at a certain time of year.

Therefore, the first test under *Ka Pa'akai* should include not only a listing of resources, but the identification of ways in which those resources are accessed and utilized in association with a traditional and customary practice.

Therefore, the second test – "The extent to which those resources—including traditional and customary Native Hawaiian rights—will be affected or impaired by the proposed action" – also looks at two separate elements. First, does the proposed action and its alternatives have an adverse impact on the existence of resources? This would include the alteration, destruction, modification, or harm of sites, including biological resources, sacred places, burial sites, etc. It also includes a loss of species. Any adverse impact or harm to resources is alone an affect or impairment caused by the proposed action.

Under this element, adverse impacts to historic sites or marine resources used by practitioners would all be identified adverse impacts. Under this same element, any indirect or cumulative effects would create an adverse impact under *Ka Paʻakai* if those actions harmed resources. It is not currently anticipated that any of these impacts would occur on this project.

In addition to this, any action that impacts traditional and customary access to resources, even if there is not direct adverse impact to the resource itself, would result in an affect or impairment resulting from the proposed action. Therefore, the limitations on access that could result from development or use of the project area could create an adverse impact under *Ka Paʻakai.* Again, it is not anticipated any impacts to cultural access would result from this project.

The third part of the *Ka Paʻakai* framework aims to identify "[t]he feasible action, if any, to be taken to reasonably protect Native Hawaiian rights if they are found to exist." Determining whether or not action has been suitably "feasible" is a matter for the State. These feasible actions could include continued access to the project as needed to conduct cultural practices.

As potential adverse effects can be avoided through the implementation of best management practices, the third part of the *Ka Paʻakai* framework becomes moot.

8.0 Conclusion

In Hawaiian culture, natural and cultural resources are largely viewed as being one and the same. Without the resources provided by nature, cultural resources could not and would not be procured. From a Hawaiian perspective, all natural and cultural resources are interrelated, and all natural and cultural resources are culturally significant. Ethnographer and Hawaiian language scholar Kepā Maly observed, "In any culturally sensitive discussion on land use in Hawaii, one must understand that Hawaiian culture evolved in close partnership with its natural environment. Thus, Hawaiian culture does not have a clear dividing line of where culture ends and nature begins" (Maly, 2001:1).

The kinship between Hawaiians and their land extends back across many generations, and it was the depth and intimacy of this relationship that enabled Hawaiians to thrive sustainability in the islands for hundreds of years prior to the arrival of Europeans. Therefore, Hawaiians are entitled to the pain and anguish they feel at the loss of their lands and resources.

This loss lies at the heart of Hawaiian struggles for traditional or customary access. Therefore, the obligation of the state to ensure that these rights are protected is much more than a legal obligation, as such rights are a necessity of indigenous human life. Recognition and respect for these rights also enables a more mutually respectful and beneficial relationship between the military and Hawaiians.

Act 50 was passed by the state recognizing:

> … the past failure to require native Hawaiian cultural impact assessments has resulted in the loss and destruction of many important cultural resources and has interfered with the exercise of native Hawaiian culture. The legislature further finds that due consideration of the effects of human activities on native Hawaiian culture and the exercise thereof is necessary to ensure the continued existence, development, and exercise of native Hawaiian culture (Act 50, SLH 2000).

The CIA is a construct of state law and a requirement of HRS Chapter 343. The legislative intent quoted above is critical to the due consideration of the effects the proposed action has and will have on cultural practices, because it specifies the importance of ensuring "the continued existence, development, and exercise" of culture. This recognizes that culture is not static; it is dynamic. It changes over time. Act 50 specifically calls for consideration of the effects a proposed action may have on the continued "development" of native Hawaiian culture. Which means it is insufficient to simply look back to historic practices. Considering effects to the continued development of culture means the state, specifically the governing state agency, as the accepting authority of the Chapter 343 EIS, of which this CIA is a requirement, must contemplate how an action may affect a culture's ability to evolve, innovate, and develop.

Additionally, OEQC (now ERP) offers specific guidelines for what elements and issues a CIA should address. The section of this CIA which addresses that element is also provided.

Table 3. Table listing OEQC compliance requirements and their corresponding sections in this assessment

OEQC notes that in addition to the content requirements for the draft EIS, which are set out in HAR §11-200.1 et seq., the assessment concerning cultural impacts should address, but not necessarily be limited to, the following matters:	
A. A discussion of the methods applied and results of consultation with individuals and organizations identified by the preparer as being familiar with cultural practices and features associated with the project area, including any constraints or limitations which might have affected the quality of the information obtained.	A detailed methodology section is provided in **Section 2**, *Methodology*.
B. A description of methods adopted by the preparer to identify, locate, and select the persons interviewed, including a discussion of the level of effort undertaken.	A discussion of the effort to gather into from persons familiar with the area or other stakeholders is provided in **Section 2.6**, *Ethnographic Methodology*.
C. Ethnographic and oral history interview procedures, including the circumstances under which the interviews were conducted, and any constraints or limitations which might have affected the quality of the information obtained.	A discussion of procedures, including constraints or limitations, is provided in **Section 2.6**.
D. Biographical information concerning the individuals and organizations consulted, their expertise, and their historical and genealogical relationship to the project area, as well as information concerning the persons submitting information or interviewed, their particular knowledge and cultural expertise, if any, and their historical and genealogical relationship to the project area.	Biographical information was provided for each interviewee in **Section 6.0**.

E. A discussion concerning historical and cultural source materials consulted, the institutions and repositories searched, and the level of effort undertaken. This discussion should include, if appropriate, the perspective of the authors, any opposing views, and any other relevant constraints, limitations or biases.	A discussion of the materials consulted is provided in **Section 2**. An extensive cultural and historical overview, which uses both Hawaiian and English language resources is also provided in **Section 2**. Stakeholders are given significant consideration. Petitions and other materials by project opponents are included in the appendices and are addressed in the context of this assessment.
F. A discussion concerning the cultural resources, practices and beliefs identified, and, for resources and practices, their location within the broad geographical area in which the proposed action is located, as well as their direct or indirect significance or connection to the project site.	In addition to the cultural and historical overview, an extensive discussion concerning cultural resources, practice and beliefs are provided throughout the document by subfield.
G. A discussion concerning the nature of the cultural practices and beliefs, and the significance of the cultural resources within the project area affected directly or indirectly by the proposed project.	Will be included in the Environmental Assessment.
H. An explanation of confidential information that has been withheld from public disclosure in the assessment.	There is no confidential information withheld from public disclosure, except for personal emails, addresses, or phone numbers.
I. A discussion concerning any conflicting information regarding identified cultural resources, practices and beliefs.	There was no conflicting information regarding cultural resources, practices, or beliefs.
J. An analysis of the potential effect of any proposed physical alteration on cultural resources, practices or beliefs; the potential of the proposed action to isolate cultural resources, practices or beliefs from their setting; and the potential of the proposed action to introduce elements which may	Will be included in the Environmental Assessment.A.

alter the setting in which cultural practices take place.	
K. A bibliography of references and attached records of interviews which were allowed to be disclosed.	References are included in **Section 9.0**.

The standard under which an EIS is considered sufficient is also well-established in Hawaii state case law. The court has held:

> …an EIS need not be exhaustive to the point of discussing all possible details bearing on the proposed action but will be upheld as adequate if it has been compiled in good faith and sets forth sufficient information to enable the decision-maker to consider fully the environmental factors involved and to make a reasoned decision after balancing the risks of harm to the environment against the benefits to be derived from the proposed action, as well as to make a reasoned choice between alternatives" *Price v Obayashi Hawaii Corp*, 81 Hawaii 171, 182 (1996), upheld in *Kaleikini v Yoshioka*, 283 P. 3d 60, 74 (2012).

It is the obligation of the CIA to disclose information as required under Act 50 sufficiently and in good faith such that the state may consider all impacts when acting as decision-maker to this proposed action. This assessment is not a policy document, nor does it intend to influence decision-making in any fashion. Rather, it has sought to document the complex, and often elusive, history of past and present cultural practices within the project area and larger region. It is ultimately the responsibility of the state to accept or reject the adequacy of this assessment, and then, if accepted, consider the information disclosed herein when deciding on the proposed action.

Koʻolauloa and Koʻolaupoko are rich with both pre-contact and post-contact histories. In applying *Ka Paʻakai*, cultural, historical, or natural resources have been identified in the project area and traditional or customary Native Hawaiian rights are currently exercised in the project area and its adjacent coastal areas.

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Appendix I: Glossary of Hawaiian Terms

The following list of terms were used throughout this report. All definitions were compiled using Pukui and Elbert's *Hawaiian Dictionary* (1986).

Ahupuaʻa	Land division usually extending from the uplands to the sea, so called because the boundary was marked by a heap (ahu) of stones surmounted by an image of a pig (puaʻa), or because a pig or orther tribute was laid on the altar as tax to the chief.
ʻĀina	Land, earth.
Akua	1. God, goddess, spirit, ghost. 2. Divine, supernatural, godly.
Ala	Path, road, trail.
Aliʻi	1. Chief, chiefess, ruler, monarch. 2. Royal, regal. 3. To act as chief, reign.
ʻAumakua	Family or personal gods, deified ancestors who might assume the shape of sharks, owls, hawks, dogs, plants, etc. A symbiotic relationship existed; mortals did not harm or eat them, and the ʻaumakua warned or reprimanded mortals in dreams, visions, and calls.
ʻAumākua	Plural of ʻaumakua.
ʻAuwai	Irrigation ditch, canal.
Haku mele	Poet, composer; to compose song or chant.
Hālau	1. Long house, as for canoes or hula instruction; meeting house. 2. Large, numerous; much.
Hale	House, building, institution, lodge, station, hall.
Hale pili	House thatched with pili grass.
Heiau	Pre-Christian place of worship, shrine. Some heiau were elaborately constructed stone platforms, other simple earth terraces.
Hula	A Polynesian dance form accompanied by chant or song.
ʻIli	Land section, next in importance to ahupuaʻa and usually a subdivision of an ahupuaʻa.
ʻIli kūpono	A nearly independent ʻili land division within an ahupuaʻa, paying tribute to the ruling chief and not to the chief of the ahupuaʻa. Transfer of the ahupuaʻa from one chief to another did not include the ʻili kūpono located within its boundaries.
Iwi	Bone, carcass. The bones of the dead, considered the most cherished possession, were hidden, and hence there are many figurative expressions with iwi meaning life, old age.
Kalo	Taro (*Colocasia esculenta*), a kind of aroid cultivated since ancient times for food, spreading wildly from the tropics of the Old World. In Hawaiʻi, taro has been the staple from earliest times to the present, and

	here its culture developed greatly, including more than 300 forms. All parts of the plant are eaten, its starchy root principally as poi, and its leaves as lūʻau.
Kanaka	Human being, man, person, individual, party, mankind, population.
Kānaka	Plural of kanaka.
Kāne	Male, husband, male sweetheart, man; brother-in-law of a woman.
Kanikau	1. Dirge, lamentation, chant of mourning, lament. 2. To chant, wail, mourn.
Kapu	1. Taboo, prohibition. 2. Special privilege or exemption from ordinary taboo. 3. Sacredness, prohibited, forbidden, sacred, holy, consecrated. 4. No trespassing, keep out.
Kuleana	Right, privilege, concern, responsibility, title, business, property, estate, portion, jurisdiction, authority, liability, interest, claim, ownership, tenure, affair, province.
Kumu	Teacher, tutor, manual, primer, model, pattern.
Kumu hula	Hula teacher.
Kupuna	Grandparent, ancestor, relative or close friend of the grandparent's generation, grandaunt, granduncle.
Kūpuna	Plural of kupuna.
Limu	A general name for all kinds of plants living under water, both fresh and salt, also algae growing in any damp place in the air, as on the ground, on rocks, and on other plants; also mosses, liverworts, lichens.
Loʻi	Irrigated terrace, especially for taro, but also for rice and paddy.
Loko iʻa	Traditional Hawaiian fishpond.
Lua	A type of dangerous hand-to-hand fighting in which the fighters broke bones, dislocated bones at the joints, and inflicted severe pain by pressing on nerve centers. There was much leaping, and (rarely) quick turns of spears. Many of the techniques were secret. Lua holds were named. Lua experts were bodyguards to chiefs.
Mahi ʻai	Farmer, planter; to farm, cultivate; agricultural.
Makai	On the seaside, toward the sea, in the direction of the sea.
Māla	Garden, plantation, patch, cultivated field, as māla ʻai, māla kalo, māla kō, māla kūlina.
Mālama	To take care of, tend, attend, care for, preserve, protect, beware, save, maintain.
Manaʻo	Thought, idea, belief, opinion, theory, thesis, intention, meaning, suggestion, mind, desire, want; to think, estimate, anticipate, expect, suppose, mediate, deem, consider.
Mauka	Inland, upland, towards the mountain.
Mele	1. Song, anthem, or chant of any kind. 2. Poem, poetry. 3. To sing, chant.
Mele mākaʻikaʻi	Travel chant.

Mōʻī	King, sovereign, monarch, majesty, ruler, queen.
Moku	1. District, island, islet, section, forest, grove, clump, fragment. 2. To be cut, severed, amputated, broken in two.
Moʻo	Lizard, reptile of any kind, dragon, serpent.
Moʻolelo	Story, tale, myth, history, tradition, literature, legend, journal, log, yard, fable, essay, chronicle, record, article.
Moʻowahine	Female lizard deity.
Nīʻau-piʻo	Offspring of the marriage of a high-born brother and sister, or half-brother and half-sister.
ʻOhana	Family, relative, kin group; related.
ʻŌlelo noʻeau	Proverb, wise saying, traditional saying.
Oli	Chant that was not danced to, especially with prolonged phrases chanted in one breath, often with a trill at the end of each phrase; to chant thus.
ʻŌʻō	Digging stick, digging implement, spade.
Pae ʻāina	Group of islands, archipelago.
Piʻo	Marriage of full brother and sister of nīʻaupiʻo rank, presumably the highest possible rank. Their offspring had the rank of naha, which is less than piʻo but probably more than nīʻaupiʻo. Later piʻo included marriage with half-sibling.
Pueo	Hawaiian short-eared owl (*Asio flammeus sandwichensis*), regarded often as a benevolent ʻaumakua.
Wai	Water, liquid or liquor of any kind other than sea water.
Wahi pana	A sacred and celebrated/legendary place.
Wahine	Woman, lady, wife; sister-in-law, female cousin-in-law of a man.
Wao	1. Realm. 2. A general term for inland region usually forested but not precipitous and often uninhabited.

Appendix E:
Draft EA Pre-Assessment Consultation Comments and Responses

BOARD OF WATER SUPPLY

CITY AND COUNTY OF HONOLULU
630 SOUTH BERETANIA STREET
HONOLULU, HI 96843
www.boardofwatersupply.com

September 28, 2022

Mr. Dennis Silva, Jr.
AECOM
1001 Bishop Street, Suite 1600
Honolulu, Hawaii 96813

Dear Mr. Silva:

Subject: Your Letter Dated August 29, 2022 Requesting Comments on the State Department of Transportation's Environmental Assessment Pre-Consultation for Kamehameha Highway Coastal Highway Mitigation in the Vicinity of Kualoa, Kaaawa, Punaluu, and Hauula, HWY-L 2.8591

Thank you for the opportunity to comment on the proposed Kamehameha Highway erosion mitigation and protection improvements project.

The Board of Water Supply (BWS) has water transmission and distribution mains traversing through the entire length of the proposed project site along Kamehameha Highway. These water mains should be located within paved roadways and made accessible for repairs and maintenance. Any structures should be adequately set back from the water main easements for the safety of the public and to prevent damage to the structures in the event of main breaks, repair, and maintenance.

For your information, the BWS has an ongoing water system improvement project to replace a water main within the limits of the project area in the vicinity of Puhuli Street and the Punaluu area. This project is tentatively scheduled for construction in 2027. A map of the proposed water system improvement project area is attached.

To obtain copies of as-builts for existing BWS water facilities along Kamehameha Highway, you may contact the Support Branch of our Capital Projects Division at (808) 748-5740.

The construction drawings should be submitted for our review and the construction schedule should be coordinated to minimize impact to the water system.

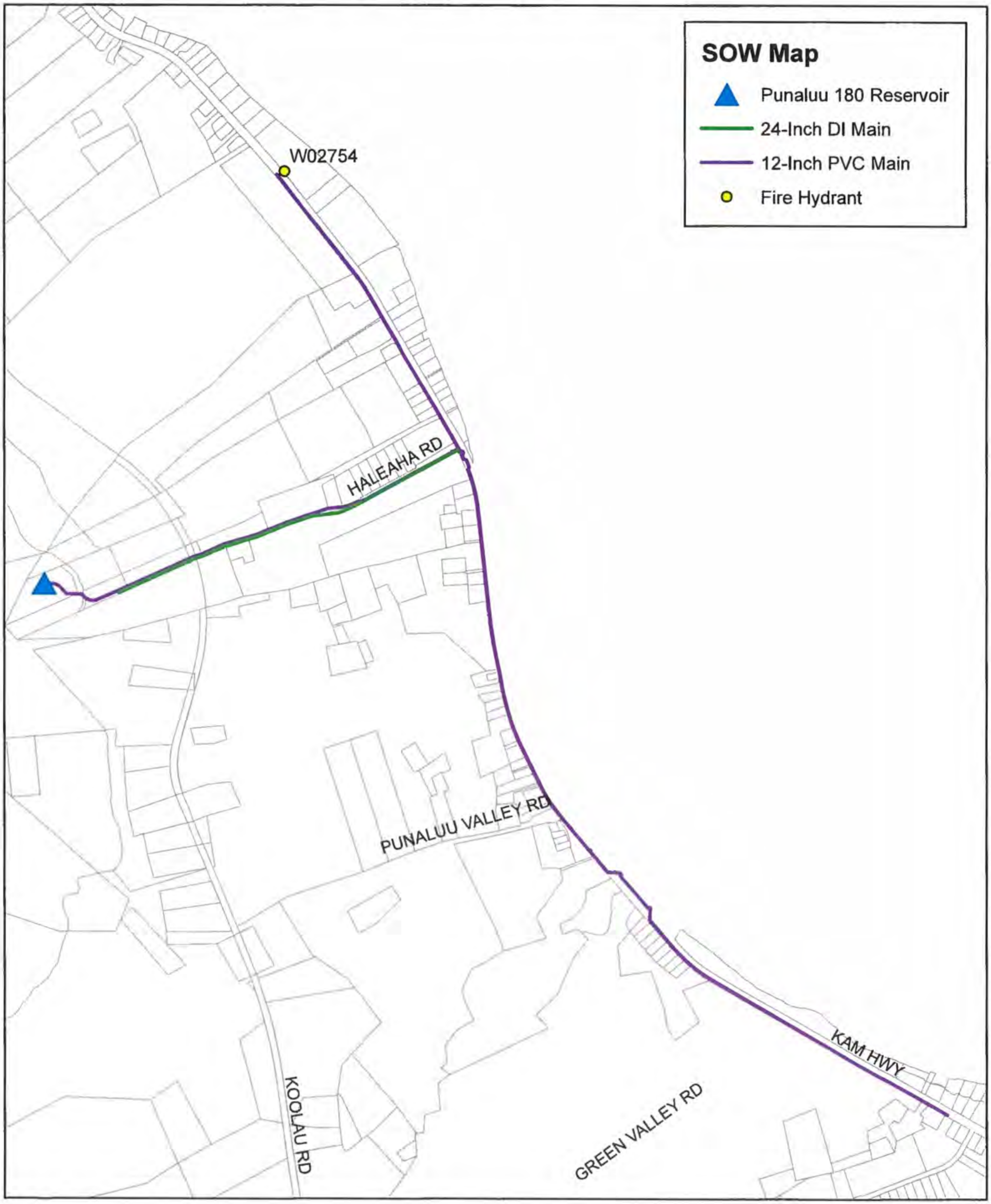
If you have any questions, please contact Robert Chun, Project Review Branch of our Water Resources Division at (808) 748-5443.

Very truly yours,

ERNEST Y. W. LAU, P.E.
Manager and Chief Engineer

Attachment

Kamehameha Highway WSI, Puhuli St Vicinity



JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
DIRECTOR
KA LUNA HOʻOKELE

Deputy Directors
Nā Hope Luna Hoʻokele
DREANALEE K. KALILI
TAMMY L. LEE
ROBIN K. SHISHIDO

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

Mr. Ernest Y. W. Lau, P.E.
Manager and Chief Engineer
City and County of Honolulu
Board of Water Supply
630 South Beretania Street
Honolulu, Hawaii 96843

Dear Mr. Lau:

Subject: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation, in the Vicinity of
Kualoa, Kaaawa, Punaluu and Hauula,
Oahu, Hawaii

Thank you for your letter dated September 28, 2022, regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

We understand that the Board of Water Supply (BWS) has water transmission and distribution mains traversing through the entire length of the project area along Kamehameha Highway. Copies of as-builts will be obtained and used to identify and avoid conflicts with transmission and distribution mains. The proposed project will include installation of shoreline stabilization measures makai of the shoulder. These measures are intended to protect the highway and associated utility infrastructure in the near to mid-term until a long-term solution to coastal erosion and sea level rise is identified and implemented.

Thank you for providing information regarding the ongoing BWS water system improvement project to replace a water main in the vicinity of Puhuli Street in Punaluu. The Hawaii Department of Transportation will coordinate with the BWS to avoid conflicts between the two projects. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

Sincerely,

Mung Fa Chung

MUNG FA CHUNG
Highways Engineering Program Manager
Materials Testing and Research Branch

DAVID Y. IGE
GOVERNOR

CURT T. OTAGURO
COMPTROLLER

AUDREY HIDANO
DEPUTY COMPTROLLER

STATE OF HAWAII
DEPARTMENT OF ACCOUNTING AND GENERAL SERVICES
P.O. BOX 119, HONOLULU, HAWAII 96810-0119

(P)22.181

OCT 17 2022

Dennis Silva, Jr., AICP
AECOM
1001 Bishop Street, Suite 1600
Honolulu, Hawaii 96813

Dear Mr. Silva:

Subject: Pre-Assessment Consultation for Draft Environment Assessment for Kamehameha Highway, Coastal Highway Mitigation, Vicinity of Kualoa, Kaaawa, Punaluu, and Hauula, Oahu, Hawaii
TMK: Various

Thank you for the opportunity to comment on the subject project. We have no comments to offer at this time as the proposed project does not impact any of the Department of Accounting and General Services' projects or existing facilities.

If you have any questions, your staff may call Ms. Gayle Takasaki of the Planning Branch at (808) 586-0584.

Sincerely,

CHRISTINE L. KINIMAKA
Public Works Administrator

GT:mo

JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
DIRECTOR
KA LUNA HOʻOKELE

Deputy Directors
Nā Hope Luna Hoʻokele
DREANALEE K. KALILI
TAMMY L. LEE
ROBIN K. SHISHIDO

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

TO: CHRISTINE L. KINIMAKA
PUBLIC WORKS ADMINISTRATOR
DEPARTMENT OF ACCOUNTING AND GENERAL SERVICES

FROM: MUNG FA CHUNG *Mung Fa Chung*
ENGINEERING PROGRAM MANAGER
MATERIALS TESTING AND RESEARCH BRANCH
HAWAII DEPARTMENT OF TRANSPORTATION

SUBJECT: PRE-ASSESSMENT CONSULTATION FOR DRAFT ENVIRONMENTAL ASSESSMENT
KAMEHAMEHA HIGHWAY, COASTAL HIGHWAY MITIGATION, VICINITY OF KUALOA, KAAAWA, PUNALUU AND HAUULA
OAHU, HAWAII

Thank you for your letter dated October 17, 2022, regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

We understand that the Department of Accounting and General Services does not have any comment on the proposed project at this time. Your letter and this response will be reproduced and included in the forthcoming Draft and the Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

November 04, 2022

LD 0335e

Dennis Silva, Jr., AICP
AECOM
1001 Bishop Street, Suite 1600
Honolulu, HI 96813

Via email: dennis.silvajr@aecom.com

Dear Sirs:

SUBJECT: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation
Vicinity of Kualoa, Kaawa, Punaluu and Hauula, Island of Oahu, State of Hawaii

Thank you for the opportunity to review and comment on the subject project. The Land Division of the Department of Land and Natural Resources (DLNR) distributed copies of your request to DLNR's various divisions for their review and comment.

Enclosed are comments received from our (a) Engineering Division, (b) Division of Forestry and Wildlife, and (c) Land Division - Oahu District Land Office. Should you have any questions, please feel free to contact Barbara Lee via email at *barbara.j.lee@hawaii.gov*. Thank you.

Sincerely,

Russell Tsuji

Russell Y. Tsuji
Land Administrator

Attachments
cc: Central Files

3844

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

October 07, 2022

LD 0335e
HWY-L 2.8997

MEMORANDUM

FROM: **DLNR Agencies:**
X Div. of Aquatic Resources *(via email: kendall.l.tucker@hawaii.gov)*
__ Div. of Boating & Ocean Recreation
X Engineering Division *(via email: DLNR.engr@hawaii.gov)*
X **Div. of Forestry & Wildlife** *(via email: rubyrosa.t.terrago@hawaii.gov)*
X Div. of State Parks *(via email: curt.a.cottrell@hawaii.gov)*
X Commission on Water Resource Management *(via email: DLNR.CWRM@hawaii.gov)*
X Office of Conservation & Coastal Lands *(via email: sharleen.k.kuba@hawaii.gov)*
X Land Division – Oahu District *(via email: barry.w.cheung@hawaii.gov)*

Russell Tsuji

TO: Russell Y. Tsuji, Land Administrator
SUBJECT: **Pre-Assessment Consultation for Draft Environmental Assessment**
Kamehameha Highway, Costal Highway Mitigation
LOCATION: Vicinity of Kualoa, Kaawa, Punaluu and Hauula, Island of Oahu, State of Hawaii
(Refer to enclosed Location Map, Sections 1-9 of red line along the coast)
APPLICANT: **State of Hawaii Department of Transportation**

Transmitted for your review and comment is information on the above-referenced project. Please review the attached information and submit any comments by the internal deadline of **November 02, 2022,** to *barbara.j.lee@hawaii.gov* at the Land Division.

If no response is received by the above due date, we will assume your agency has no comments at this time. Should you have any questions about this request, please contact Barbara Lee at the above email address. Thank you.

BRIEF COMMENTS:

( ) We have no objections.
( ) We have no comments.
( ) We have no additional comments.
(✔) Comments are included/attached.

Signed: Lainie Berry
Print Name: LAINIE BERRY, Wildlife Program Mgr.
Division: Division of Forestry and Wildlife
Date: Nov 1, 2022

Attachments
Cc: Central Files

DAVID Y. IGE
GOVERNOR OF HAWAII

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF FORESTRY AND WILDLIFE
1151 PUNCHBOWL STREET, ROOM 325
HONOLULU, HAWAII 96813

November 1, 2022

MEMORANDUM *Log no. 3844*

TO: RUSSELL Y. TSUJI, Land Administrator
Land Division

FROM: LAINIE BERRY, Wildlife Program Manager
Division of Forestry and Wildlife

SUBJECT: **Division of Forestry and Wildlife Comments for the Pre-Assessment Consultation for the Draft Environmental Assessment (DEA) of the Kamehameha Highway Coastal Highway Mitigation Project on Oʻahu**

The Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW) has received your pre-assessment consultation request for the preparation of a DEA regarding the State of Hawaiʻi Department of Transportation's (HDOT's) coastal highway mitigation project along the Kamehameha Highway in the vicinity of Kualoa, Kaʻaʻwa, Punaluʻu, and Hauʻula, on the island of Oʻahu; TMK: Non-assigned. The proposed project consists of implementing roadway protection measures due to shoreline erosion to prevent the near-term collapse of the Highway into the ocean and to ensure accessibility of various road users to the area until a long-term shoreline erosion mitigation solution can be developed.

The State listed Hawaiian Hoary Bat or ʻŌpeʻapeʻa (*Lasiurus cinereus semotus*) could potentially occur at or in the vicinity of the project and may roost in nearby trees. Any required site clearing should be timed to avoid disturbance to bats during their birthing and pup rearing season (June 1 through September 15). During this period woody plants greater than 15 feet (4.6 meters) tall should not be disturbed, removed, or trimmed. Barbed wire should also be avoided for any construction because bats can become ensnared and killed by such fencing material during flight.

Artificial lighting can adversely impact seabirds that may pass through the area at night by causing them to become disoriented. This disorientation can result in their collision with manmade structures or the grounding of birds. It is DOFAW's stance that **permanent lighting would pose a very high risk of seabird attraction on the proposed stretch of road.** New highway lights, therefore, should not be installed in this area to protect seabird flyways and preserve the night sky. For nighttime work that might be required, DOFAW recommends that all lights used to be fully shielded to minimize the attraction of seabirds. Nighttime work that requires outdoor lighting should be avoided during the seabird fledging season from September 15 through December 15. This is the period when young seabirds take their maiden voyage to the open sea. For illustrations and guidance related to seabirdfriendly light styles that also protect seabirds and the dark starry skies of Hawai‘i, please visit https://dlnr.hawaii.gov/wildlife/files/2016/03/DOC439.pdf.

The State endangered Hawaiian Monk Seal (*Monachus schauinslandi*) and threatened Green Sea Turtle (*Chelonia mydas*) could potentially occur or haul out onshore within the vicinity of the proposed project site. If either species is detected within 100 meters of the project area all nearby construction operations should cease and not continue until the focal animal has departed the area on its own accord.

State-listed waterbirds such as the Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian gallinule (*Gallinula chloropus sandvicensis*), and Hawaiian Duck (*Anas wyvilliana*), could potentially occur at or in the vicinity of the proposed project site. It is against State law to harm or harass these species. If any of these species are present during construction, then all activities within 100 feet (30 meters) should cease, and the bird or birds should not be approached. Work may continue after the bird or birds leave the area of their own accord. If a nest is discovered at any point, please contact the O‘ahu Branch DOFAW Office at (808) 973-9778.

DOFAW recommends using native plant species for landscaping that are appropriate for the area (i.e., climate conditions are suitable for the plants to thrive, historically occurred there, etc.). Please do not plant invasive species. DOFAW also recommends referring to www.plantpono.org for guidance on the selection and evaluation of landscaping plants and for consulting the Hawai‘i-Pacific Weed Risk Assessment to determine the potential invasiveness of plants proposed for use in the project.

DOFAW recommends minimizing the movement of plant or soil material between worksites. Soil and plant material may contain pathogens, pests such as Little Fire ants and/or Coconut Rhinoceros beetles, or invasive plant parts that could harm our native species and ecosystems. We recommend consulting the O‘ahu Invasive Species Committee (OISC) at (808) 266-7994 to help plan, design, and construct the project, learn of any high-risk invasive species in the area, and ways to mitigate their spread. All equipment, materials, and personnel should be cleaned of excess soil and debris to minimize the risk of spreading invasive species.

We appreciate your efforts to work with our office for the conservation of our native species. These comments are general guidelines and should not be considered comprehensive for this site or project. It is the responsibility of the applicant to do their own due diligence to avoid any negative environmental impacts. Should the scope of the project change significantly, or should it become apparent that threatened or endangered species may be impacted, please contact our staff as soon as possible. If you have any questions, please contact Paul Radley, Protected Species Habitat Conservation Planning Coordinator at (808) 295-1123 or paul.m.radley@hawaii.gov.

Sincerely,

LAINIE BERRY
Wildlife Program Manager

JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
DIRECTOR
KA LUNA HOʻOKELE

Deputy Directors
Nā Hope Luna Hoʻokele
DREANALEE K. KALILI
TAMMY L. LEE
ROBIN K. SHISHIDO

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

TO: LAINIE BERRY, WILDLIFE PROGRAM MANAGER
DIVISION OF FORESTRY AND WILDLIFE
DEPARTMENT OF LAND AND NATURAL RESOURCES

FROM: MUNG FA CHUNG *Mung Fa Chung*
ENGINEERING PROGRAM MANAGER
MATERIALS TESTING AND RESEARCH BRANCH
HAWAII DEPARTMENT OF TRANSPORTATION

SUBJECT: PRE-ASSESSMENT CONSULTATION FOR DRAFT ENVIRONMENTAL ASSESSMENT
KAMEHAMEHA HIGHWAY, COASTAL HIGHWAY MITIGATION, VICINITY OF KUALOA, KAAAWA, PUNALUU AND HAUULA, OAHU, HAWAII

Thank you for your response dated November 1, 2022 (Log No. 3844) regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

Your recommended measures for the avoidance and minimization of potential impacts to the State listed Hawaiian hoary bat or ʻōpeʻapeʻa, Hawaiian waterbirds, Hawaiian seabirds, sea turtles, and the Hawaiian monk seal, as well as your guidance regarding invasive species, will be incorporated into the Draft EA. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

October 07, 2022

LD 0335e
HWY-L 2.8997

MEMORANDUM

FROM: ~~TO:~~ **DLNR Agencies:**
_X_ Div. of Aquatic Resources *(via email: kendall.l.tucker@hawaii.gov)*
__ Div. of Boating & Ocean Recreation
_X_ Engineering Division *(via email: DLNR.engr@hawaii.gov)*
_X_ Div. of Forestry & Wildlife *(via email: rubyrosa.t.terrago@hawaii.gov)*
_X_ Div. of State Parks *(via email: curt.a.cottrell@hawaii.gov)*
_X_ Commission on Water Resource Management *(via email: DLNR.CWRM@hawaii.gov)*
_X_ Office of Conservation & Coastal Lands *(via email: sharleen.k.kuba@hawaii.gov)*
_X_ Land Division – Oahu District *(via email: barry.w.cheung@hawaii.gov)*

TO: ~~FROM:~~ Russell Y. Tsuji, Land Administrator Russell Tsuji
SUBJECT: **Pre-Assessment Consultation for Draft Environmental Assessment**
Kamehameha Highway, Costal Highway Mitigation
LOCATION: Vicinity of Kualoa, Kaawa, Punaluu and Hauula, Island of Oahu, State of Hawaii
(Refer to enclosed Location Map, Sections 1-9 of red line along the coast)
APPLICANT: **State of Hawaii Department of Transportation**

Transmitted for your review and comment is information on the above-referenced project. Please review the attached information and submit any comments by the internal deadline of **November 02, 2022,** to *barbara.j.lee@hawaii.gov* at the Land Division.

If no response is received by the above due date, we will assume your agency has no comments at this time. Should you have any questions about this request, please contact Barbara Lee at the above email address. Thank you.

BRIEF COMMENTS:

( ) We have no objections.
( ) We have no comments.
( ) We have no additional comments.
(✓) Comments are included/attached.

Signed: [signature]
Print Name: Carty S. Chang, Chief Engineer
Division: Engineering Division
Date: Oct 26, 2022

Attachments
Cc: Central Files

DEPARTMENT OF LAND AND NATURAL RESOURCES
ENGINEERING DIVISION

LD/Russell Y. Tsuji
Ref: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation
Location: Vicinity of Kualoa, Kaawa, Punaluu and Hauula, Island of Oahu, State of Hawaii
Applicant: State of Hawaii Department of Transportation

COMMENTS

The rules and regulations of the National Flood Insurance Program (NFIP), Title 44 of the Code of Federal Regulations (44CFR), are in effect when development falls within a Special Flood Hazard Area (high-risk areas). State projects are required to comply with 44CFR regulations as stipulated in Section 60.12. Be advised that 44CFR, Chapter 1, Subchapter B, part 60 reflects the minimum standards as set forth by the NFIP. Local community flood ordinances may stipulate higher standards that can be more restrictive and would take precedence over the minimum NFIP standards.

The owner of the project property and/or their representative is responsible to research the Flood Hazard Zone designation for the project. Flood Hazard Zones are designated on FEMA's Flood Insurance Rate Maps (FIRM). The official FIRMs can be accessed through FEMA's Map Service Center (msc.fema.gov). Our Flood Hazard Assessment Tool (FHAT) (http://gis.hawaiinfip.org/FHAT) could also be used to research flood hazard information.

If there are questions regarding the local flood ordinances, please contact the applicable County NFIP coordinating agency below:

- Oahu: City and County of Honolulu, Department of Planning and Permitting (808) 768-8098.
- Hawaii Island: County of Hawaii, Department of Public Works (808) 961-8327.
- Maui/Molokai/Lanai County of Maui, Department of Planning (808) 270-7139.
- Kauai: County of Kauai, Department of Public Works (808) 241-4896.

The applicant should include water demands and infrastructure required to meet project needs. Please note that all State projects requiring water service from their local Department/Board of Water Supply system will be required to pay a resource development charge, in addition to Water Facilities Charges for transmission and daily storage.

The applicant is required to provide water demands and calculations to the Engineering Division so it can be included in the State Water Projects Plan Update projections.

Signed: ______________________
CARTY S. CHANG, CHIEF ENGINEER

Date: Oct 26, 2022

JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
DIRECTOR
KA LUNA HOʻOKELE

Deputy Directors
Nā Hope Luna Hoʻokele
DREANALEE K. KALILI
TAMMY L. LEE
ROBIN K. SHISHIDO

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

TO: CARTY S. CHANG, CHIEF ENGINEER
ENGINEERING DIVISION
DEPARTMENT OF LAND AND NATURAL RESOURCES

FROM: MUNG FA CHUNG *Mung Fa Chung*
ENGINEERING PROGRAM MANAGER
MATERIALS TESTING AND RESEARCH BRANCH
HAWAII DEPARTMENT OF TRANSPORTATION

SUBJECT: PRE-ASSESSMENT CONSULTATION FOR DRAFT ENVIRONMENTAL ASSESSMENT
KAMEHAMEHA HIGHWAY, COASTAL HIGHWAY MITIGATION, VICINITY OF KUALOA, KAAAWA, PUNALUU AND HAUULA
OAHU, HAWAII

Thank you for your response dated October 26, 2022 regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project. We offer the following responses to your comments:

We acknowledge that the rules and regulations of the National Flood Insurance Program, Title 44 of the Code of Federal Regulations, are in effect when development falls within a Special Flood Hazard Area (high-risk areas). The Draft EA will include a discussion of Flood Hazard Zones. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
LAND DIVISION

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

October 07, 2022

LD 0335e
HWY-L 2.8997

MEMORANDUM

TO: **DLNR Agencies:**
X Div. of Aquatic Resources *(via email: kendall.l.tucker@hawaii.gov)*
__ Div. of Boating & Ocean Recreation
X Engineering Division *(via email: DLNR.engr@hawaii.gov)*
X Div. of Forestry & Wildlife *(via email: rubyrosa.t.terrago@hawaii.gov)*
X Div. of State Parks *(via email: curt.a.cottrell@hawaii.gov)*
X Commission on Water Resource Management *(via email: DLNR.CWRM@hawaii.gov)*
X Office of Conservation & Coastal Lands *(via email: sharleen.k.kuba@hawaii.gov)*
X Land Division – Oahu District *(via email: barry.w.cheung@hawaii.gov)*

FROM: Russell Y. Tsuji, Land Administrator Russell Tsuji
SUBJECT: **Pre-Assessment Consultation for Draft Environmental Assessment**
Kamehameha Highway, Costal Highway Mitigation
LOCATION: Vicinity of Kualoa, Kaawa, Punaluu and Hauula, Island of Oahu, State of Hawaii
(Refer to enclosed Location Map, Sections 1-9 of red line along the coast)
APPLICANT: **State of Hawaii Department of Transportation**

Transmitted for your review and comment is information on the above-referenced project. Please review the attached information and submit any comments by the internal deadline of **November 02, 2022,** to *barbara.j.lee@hawaii.gov* at the Land Division.

If no response is received by the above due date, we will assume your agency has no comments at this time. Should you have any questions about this request, please contact Barbara Lee at the above email address. Thank you.

BRIEF COMMENTS:

Any work and/or use of State land makai of the title boundary and/or certified shoreline shall require a disposition from the Board of Land and Natural Resources.

( ) We have no objections.
( ) We have no comments.
( ) We have no additional comments.
(X) Comments are included/attached.

Signed: [signature]
Print Name: Patti Miyashiro
Division: DLNR/LAND DIV/ODLO
Date: Oct 11, 2022

Attachments
Cc: Central Files

JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
DIRECTOR
KA LUNA HOʻOKELE

Deputy Directors
Nā Hope Luna Hoʻokele
DREANALEE K. KALILI
TAMMY L. LEE
ROBIN K. SHISHIDO

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

TO: PATTI MIYASHIRO, CHIEF ENGINEER
LAND DIVISION
DEPARTMENT OF LAND AND NATURAL RESOURCES

FROM: MUNG FA CHUNG *Mung Fa Chung*
ENGINEERING PROGRAM MANAGER
MATERIALS TESTING AND RESEARCH BRANCH
HAWAII DEPARTMENT OF TRANSPORTATION

SUBJECT: PRE-ASSESSMENT CONSULTATION FOR DRAFT ENVIRONMENTAL ASSESSMENT
KAMEHAMEHA HIGHWAY, COASTAL HIGHWAY MITIGATION, VICINITY OF KUALOA, KAAAWA, PUNALUU AND HAUULA
OAHU, HAWAII

Thank you for your response dated October 11, 2022, regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project. We offer the following responses to your comments:

We acknowledge that any work and/or use of State land makai of the tidal boundary and/or certified shoreline shall require a disposition from the Board of Land and Natural Resources. The draft EA will include discussions on this matter. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 7TH FLOOR • HONOLULU, HAWAII 96813
PHONE: (808) 768-8000 • FAX: (808) 768-6041
DEPT. WEB SITE: www.honoluludpp.org • CITY WEB SITE: www.honolulu.gov

RICK BLANGIARDI
MAYOR

DAWN TAKEUCHI APUNA
ACTING DIRECTOR

September 29, 2022

2022/ELOG-1815(bs)
2240120

Mr. Dennis Silva, Jr., AICP
AECOM
1001 Bishop Street, Suite 1600
Honolulu, Hawaii 96813

Dear Mr. Silva:

SUBJECT: Pre-Assessment Consultation for Draft Environmental Assessment Kamehameha Highway, Coastal Highway Mitigation, Vicinity of Kualoa, Kaaawa, Punaluu and Hauula, Oahu, Hawaii

This is in response to your letter dated August 31, 2022, seeking input for the preparation of a Draft Environmental Assessment (EA), to initiate roadway protection measures (Project). The State of Hawaii Department of Transportation is proposing to implement the Project along Kamehameha Highway, from the south end of Kualoa Ranch to Hauula town, due to shoreline erosion.

The Department of Planning and Permitting has the following comments:

1. The Draft EA should include a discussion on how the proposed Project addresses the policies and guidelines of the Oahu General Plan, the Koolau Poko Sustainable Communities Plan, and the Koolau Loa Sustainable Communities Plan. If relevant, describe how the Project may impact makai view openings, public access to the shoreline, traditional cultural practices, the quality of recreational resources, and sandy beaches.

2. The Draft EA should specify if any roadways under the City's jurisdiction will be affected. Bus stops which may be affected along Kamehameha Highway should be coordinated with the City's Department of Transportation Services.

3. The Project site is within the Special Management Area (SMA) and additional information is needed to determine if an SMA Use Permit is required.

4. The Draft EA should disclose how the Project will be consistent with Chapter 205A, Hawaii Revised Statutes, and Chapter 25, Revised Ordinances of Honolulu (ROH). The Draft EA should also identify any significant adverse environmental or ecological effects and specify which elements of the Project, if any, would be considered "development" for purposes of Section 25-1.3, ROH.

5. The Draft EA should discuss Chapter 23, ROH, and reference the location of the regulatory shoreline for each site. The Draft EA should describe and include a figure for each alternative, clearly showing which elements of the Project would be makai of the certified shoreline or within the shoreline setback.

6. The Draft EA should include a discussion of any other land use permits anticipated to be required prior to Project implementation.

Should you have any questions, please contact Brandon Soo, of our staff, at brandon.soo@honolulu.gov or (808) 768-8051.

Very truly yours,

Dawn Takeuchi Apuna
Acting Director

DTA:ah

JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
DIRECTOR
KA LUNA HOʻOKELE

Deputy Directors
Nā Hope Luna Hoʻokele
DREANALEE K. KALILI
TAMMY L. LEE
ROBIN K. SHISHIDO

STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

Ms. Dawn Takeuchi Apuna, Director
City and County of Honolulu
Department of Planning and Permitting
650 South King Street, 7th Floor
Honolulu, Hawaii 96813

Dear Ms. Apuna:

Subject: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation, in the Vicinity of
Kualoa, Kaaawa, Punaluu and Hauula
Oahu, Hawaii

Thank you for your letter dated September 29, 2022, (2022/ELOG-1815(bs) 2240120) regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

The Draft EA will include a discussion the project's consistency with policies and guidelines of the Oahu General Plan, the Koolau Poko Sustainable Communities Plan, and the Koolau Loa Sustainable Communities Plan, including discussions on how the project may affect makai views, public access to the shoreline, traditional cultural practices, the quality of recreational resources, and sandy beaches. The Draft EA acknowledges that Kamehameha Highway is the primary access for police, fire, and emergency medical vehicles. While construction will cause temporary delays and interruptions to traffic along Kamehameha Highway, the overall purpose of the project is to maintain use of the highway in the near to mid-term for emergency services, residents, and visitors. The Draft EA will discuss how the City's roadway and bus stops will be affected during construction.

The Hawaii Department of Transportation will have further coordination with the City and County of Honolulu Department of Planning and Permitting to determine if a Special Management Area (SMA) Use Permit will be required. The certified shoreline survey will not be completed until after publication of the Draft EA and within in one-year of the submittal of the SMA Permit application if required.

The Draft EA will include a discussion of the project's consistency with Hawaii Revised Statutes Chapter 205A and Revised Ordinance of Honolulu Chapter 25, including potential environmental and ecological effects. The Draft EA will also discuss all permits that are anticipated to be required. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

Sincerely,

Mung Fa Chung

MUNG FA CHUNG
Highways Engineering Program Manager
Materials Testing and Research Branch

DEPARTMENT OF PARKS & RECREATION

CITY AND COUNTY OF HONOLULU

1000 Uluohia Street, Suite 309, Kapolei, Hawaii 96707
Phone: (808) 768-3003 • Fax: (808) 768-3053
Website: www.honolulu.gov

RICK BLANGIARDI
MAYOR

LAURA H. THIELEN
DIRECTOR

KEHAULANI PU'U
DEPUTY DIRECTOR

November 9, 2022

SENT VIA EMAIL

Mr. Dennis Silva, Jr., AICP
AECOM
dennis.silvajr@aecom.com

Dear Mr. Silva:

SUBJECT: Pre-Assessment Consultation for Draft Environmental Assessment (EA) Kamehameha Highway, Coastal Highway Mitigation, Vicinity of Kualoa, Kaaawa, Punaluu and Hauula, Oahu, Hawaii

Thank you for the opportunity to review and comment on the subject Environmental Assessment (EA).

The proposed coastal highway mitigation measures along Kamehameha Highway have the potential to impact six highly used City parks, Kualoa Regional Park, Kalaeoio Beach Park, Kaaawa Beach Park, Swanzy Beach Park, Makaua Beach Park, and Punaluu Beach Park, as well as, beach rights-of-ways and various undeveloped park properties.

The Department of Parks and Recreation (DPR) requests that the draft EA clearly address the following:

Impacts to park properties: How will the proposed coastal highway mitigation measures impact park properties, both in the short term (during construction) and in the long-term (post construction)? Detailing how proposed coastal highway mitigation measures may impact parks in the long-term is needed to ensure these measures are not built at the expense of future park use.

Public access: How will public access to parks be impacted during construction activities? These parks are heavily used by the community and outreach should be done to inform communities of any disruptions to park use.

Vegetation removal/relocation: How will vegetation and trees be affected by the proposed coastal highway mitigation measures? Early consultation with the DPR-Division of Urban Forestry (DUF), is essential if any vegetation and/or trees will be affected by the proposed project. The Department of Design and Construction (DDC) can provide the recently approved version of the DPR Notes and Tree Protection and Preservation Notes to add to the project plans when developed. Landscaping including, dune restoration practices and installation of new and/or replacement trees will be required to mitigate hardscape and pavement effects.

Work within City Parks: What type of work is planned within park properties? Will park properties be used for staging and/or storage areas during construction? The Park Maintenance and Recreation Services (PMRS) Division, Department of Parks and Recreation (DPR) requires a Right-of-Entry (ROE) permit for any work within any of the afore-mentioned parks. Early consultation with PMRS is essential if any work will be done within park properties including use for staging and/or storage.

Other DOT projects: How do other DOT projects along Kamehameha Highway fit into this project, including DOT's Kamehameha Highway at Kaaawa Erosion Mitigation project?

Should you have any questions, please contact Jason Woll, Windward Oahu District Manager at (808) 768-8985 or Brandon Au, Acting Landscape Architect III of DUF at (808) 971-7151.

Sincerely,

Laura H. Thielen
Director

LHT:jb
(888760)

cc: Jiangli Guo, HDOT HWY-DS
Christine Ching, PMRS Administrator
Jason Woll, PMRS, Windward Oahu District Manager
Brandon Au, DUF
Jennifer Barra, ESD

JOSH GREEN, M.D.
GOVERNOR
KE KIAʻĀINA

EDWIN H. SNIFFEN
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Deputy Directors
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STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
869 PUNCHBOWL STREET
HONOLULU, HAWAII 96813-5097

IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

Ms. Laura H. Thielen, Director
City and County of Honolulu
Department of Parks and Recreation
1000 Uluohia Street
Kapolei, Hawaii 96813

Dear Ms. Thielen:

Subject: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation, in the Vicinity of
Kualoa, Kaaawa, Punaluu and Hauula
Oahu, Hawaii

Thank you for your letter dated November 9, 2022, regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the Kualoa, Kaaawa, Punaluu, and Hauula (KKPH) Shoreline Erosion Mitigation Project. The EA will include a discussion of potential short term and long-term impacts to park properties, public access, and affects to vegetation and trees.

The project will include construction of an approximately 220-foot-long hybrid seawall with stone apron at the northern end of Kualoa Regional Park and an approximately 820-foot-long rock revetment along a narrow strip of shoreline at Kaaawa Beach Park between Pohuehue Road and Kaaawa Elementary. This will require the removal of beach naupaka, false kaimani trees, hau trees, palm trees, and ironwood trees growing along the shoreline. There are no suitable locations for replacement planting within project area or adjacent Hawaii Department of Transportation (HDOT) Right-of-Way. We understand that a right-of-entry permit and potentially other land use approves from the Department of Parks and Recreation (DPR) will be required. The HDOT will work with DPR Park Maintenance and Recreation Services and Division of Urban Forestry to discuss and evaluate potential opportunities for replacement planting on park properties.

The project may include some temporary staging at Kualoa Park, Kaaawa Beach Park and possibly Swanzy Beach Park during construction. The other park properties would not be impacted. The location and extent of temporary staging area would be selected to minimize impacts to public access and park resources in consultation with and as approved by DPR. Construction activities at the nine project sites will be phased to avoid cumulative impacts to parks and public assess.

Shoreline erosion mitigation measures have only been proposed at locations where the highway is in direct contact with an eroding shoreline. The proposed stabilization measures are intended to mitigate shoreline erosion in the near to mid-term, up to 25-years, until a permanent solution is identified and implemented, at which time these temporary shoreline stabilizations measures would be reauthorized, modified, or removed.

The need for the Kaaawa Erosion Mitigation Project was identified and proposed prior to the KKPH Shoreline Erosion Mitigation Project. The HDOT has been addressing shoreline erosion on an individual site by site basis. The KKPH Shoreline Erosion Mitigation Project is intended to encompass all site along the windward coast where shoreline erosion mitigation measures are needed to protect the highway in the near to mid-term.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

Sincerely,

Mung Fa Chung

MUNG FA CHUNG
Highways Engineering Program Manager
Materials Testing and Research Branch

From: David Delaney - NOAA Federal <david.delaney@noaa.gov>
Sent: Wednesday, September 28, 2022 6:59 PM
To: Silva Jr, Dennis <dennis.silvajr@aecom.com>
Cc: Gerry Davis - NOAA Federal <gerry.davis@noaa.gov>; Malia Chow - NOAA Federal <malia.chow@noaa.gov>; Stuart Goldberg - NOAA Federal <stuart.goldberg@noaa.gov>
Subject: Re: Re: KKPH Draft EA Pre-Consultation letter

Aloha Mr. Silva,

On August 29, 2022, the National Marine Fisheries Service (NMFS), Pacific Islands Regional Office (PIRO), and Habitat Conservation Division (HCD), received the State of Hawaiʽi, Department of Transportation (hereafter, HDOT) request for comments for the Pre-Assessment Consultation for Draft Environmental Assessment (EA) for the Kamehameha Highway, Coastal Highway Mitigation, and Vicinity of Kualoa, Kaʽaʽawa, Punaluʽu and Hauʽula, Oʽahu. Below we provide technical assistance intended to help you integrate EFH considerations as you start the scoping process for this study. The technical assistance does not fulfill any federal responsibilities and does not constitute an EFH consultation. In addition to being the federal regulatory agency responsible for implementing the Magnuson-Stevens Fishery Conservation and Management Act (MSA), including the EFH provisions described by Federal regulations (50 CFR 600.920), PIRO oversees consultations for compliance with the Endangered Species Act and other statutory mandates. Compliance with the EFH provisions of the MSA can also be achieved through pursuance to the Fish and Wildlife Coordination Act (FWCA, 16 U.S.C. 661-666c; see below). For all questions related to consultations with us in the future, please contact us through the email address EFHESAconsult@noaa.gov.

The marine water column from the surface to a depth of 1,000 m from shoreline to the outer boundary of the EEZ (200 nautical miles), and the seafloor from the shoreline out to a depth of 700 m around each of the Hawaiian Islands, have been designated as EFH. As such, the water column and bottom of the Pacific Ocean in Hilo Harbor, the surrounding waters, and submerged lands are designated as EFH, and support various life stages for the management unit species (MUS) identified under the Western Pacific Fishery Management Council's Pelagic and Hawaiʽi Archipelago Fishery Ecosystem Plans. The MUS and life stages found in these waters include eggs, larvae, juveniles, and adults of Bottomfish, Crustacean, and Pelagic MUS. Specific types of habitat considered as EFH include coral reef, patch reefs, hard substrates, artificial substrates, seagrass beds, soft substrates, lagoons, estuaries, surge zones, deep-slope terraces and pelagic/open oceans.

The State of Hawaii Department of Transportation (HDOT) proposes to implement roadway protection measures along Kamehameha Highway, from the south end of Kualoa Ranch to Hauʻula town, due to shoreline erosion. The proposed project involves roadside erosion mitigation and protection improvements for the primary access road for windward Oʻahu communities. The goal is to prevent the near-term collapse of the highway into the ocean and ensure accessibility of various road users to/in the area until a long-term shoreline erosion mitigation solution is developed. The current phase of the proposed project, Phase I, will include the preparation of a draft EA and associated draft permits. Phase II of the project will include the completion of the EA process.

There is uncertainty as to the specifics of the proposed action, and the potential impacts to the marine environment as little details are provided. The potential environmental stressors of concern include: physical damage to the benthos (e.g., corals and seagrass), sedimentation and turbidity, introduction of chemical contaminants, introduction of invasive species, and noise. Below we cover the broad adverse effects to EFH due to potential activities, and provide the best management practices (see Enclosure) and control measures to consider when developing the EA.

Expected General Activities and Equipment
Activities: Excavating, bulldozing, dredging, installation of rock/fill revetment/groins, staging of equipment, installing silt containment, pouring cement, removing vegetation, engaging in revegetation, and anchoring vessels/barges.
Equipment: Bulldozers, excavators, trucks, drills, silt curtains/fences, cranes, and handheld drills and saws.

Physical damage to the benthos (e.g., corals and seagrass)
Physical damage to corals may occur due to abrasion or breaking of colonies. Activities that may impart physical damage from the project action include dredging, filling discharge (e.g., rocks, dirt, cement etc.), anchoring vessels/barges and silt curtains, and using heavy equipment in-water. Improperly deployed sediment and erosion control measures may result in the removal and/or degradation in the state of seagrasses, facilitating the recolonization of fast growing native and/or invasive algae that may outcompete native species (Short and Neckles 1999). Because of the way that seagrasses establish themselves in an area, the area where they have been removed may take years to recover (Williams 1990; van Tussenbroek 1994, Creed and Amado Filho 1999). Habitat conversion may lead to a reduction in biodiversity (Alvarez-Filip *et al.* 2009) and further reduction of the overall productivity of the marine ecosystem. Man-made structures in the marine environment typically recruit corals, algae, sponges, as well as other components of successional communities. Maintenance and repair of those structures and/or actions designed to increase the efficiency of channelized runoff into the marine environment may result in physical damage to corals, or impact corals through the introduction of sediment, nutrients, pesticides and/or metals into their environment.

Sedimentation and Turbidity
Increased sedimentation and turbidity can cause smothering of benthic species and block sunlight necessary for species that rely on photosynthesis. In corals, sedimentation has been shown to

reduce species diversity, change growth patterns, and reduce growth and survival (Rogers 1990), while in seagrass beds, sedimentation can result in covering plants and eventually lead to their mortality. For fish, sedimentation is less likely to cause significant impacts because of their mobility, but some effects are still possible. Fish may be displaced from their normal home range which could result in negative intra- and interspecies interactions and impact fitness, leading to lower reproductive success, and making individuals less able to find prey or avoid predators (Kjelland *et al.* 2015). Coral reef organisms are easily smothered by sediment (Golbuu et al. 2003), and minimal rates of sediment can affect multiple life stages of coral. Sedimentation can also reduce photosynthetic rates (Philipp and Fabricius 2003), disrupt polyp gas exchange, inhibit nutrient acquisition (Richmond 1996), cause tissue damage (Rogers, 1990), reduce recruitment success (Hodgson 1990; Gilmour 1999), and increase metabolic costs due to enhanced mucus production (Telesnicki and Goldberg 1995). Increase in suspended sediments and turbidity will reduce the depth that sunlight can penetrate to, which changes the wavelengths of light reaching benthic species. Corals are especially sensitive to the amount and wavelengths of sunlight they receive. Increase in sunlight energy have been linked to coral bleaching (Jones *et al.* 1998; Hoegh-Guldberg 1999); while its decrease have been shown to affect settlement of coral larvae (Mundy and Babcock 1998). Decrease in the amount of sunlight reaching corals have also been shown to reduce the amount of photosynthesis corals are able to carry out, resulting in lower calcification rates and impact the thickness of tissue a coral can produce (Telesnicki and Goldberg 1995). For seagrasses, light levels have been shown to be a major factor in distribution and species composition of seagrass beds, with low light levels resulting in reduced plant biomass and altered growth rates (Dennison 1987, Abal and Dennison 1996, Campbell *et al.* 2007).

Introduction of Nutrients, Chemical Contaminants, and Freshwater

Increases in nutrients (i.e., from earth moving), pollutants and contaminants (i.e., from earthmoving and equipment), and freshwater to the marine environment can reduce fitness and cause mortality of exposed organisms. Increase of land-based runoffs and discharges can subject benthic communities to adverse exposures and potential degradation of condition and mortality. In addition, when not properly maintained, equipment could release contaminants (oil, fuel, etc.) into the marine environment. Accidental releases or spills due to unanticipated circumstances are also possible. Structures consisting of treated wood should exclude treatment using any chemicals and/or compounds that have been banned by the EPA, or local or state agency, for use in the US marine waters. For a list of chemicals that have been shown to negatively impact coral processes in the water column, see Nalley *et al*. (2021).

With the repair or maintenance of structures designed to funnel stormwater to the marine environment, there is a chance of a surge of freshwater input to the nearshore marine environment, which may significantly lower the salinity of the water or its temperature and consequently affect corals and seagrasses.

Introduction of Invasive Species

Introduced species are organisms that have been moved, intentionally or unintentionally, into areas where they do not naturally occur. Species can be introduced to new biogeographies, typically via transport on vessel hulls, in ballast waters, oron equipment, such as those that may be used in the program activities. Nearly 500 introduced species have been identified in

Hawaii (Randall 1987; Diaz andRosenberg 1995; Coles and Eldredge 2002; Carlton and Eldredge 2009). Invasivespecies rapidly increase in abundance to the point that they come to dominate their new environment, creating adverse ecological effects to other species of the ecosystem and the functions and services it may provide. Invasive species can decrease species diversity, change trophic structure, and diminish physical structure, but adverse effects are highly variable and species-specific.

Noise

Noise has a broad range of potential effects, especially when it is very loud and has high amplitude (Casper *et al.* 2016), or when it is less intense but long-lasting (Popper and Hastings 2009). For fish, intense, high amplitude sounds can cause immediate death or tissue damage that may ultimately result in mortality (McCauley *et al.* 2003), but at the very least it may impact its fitness (Casper *et al.* 2016). Alternatively, chronic noise will not likely result in mortality, but may mask biologically important sounds and alter the natural soundscape, cause hearing loss, have an adverse effect on an organism's stress levels and immune system, and affect coral spawning (Minton 2017, Lecchini et al. 2018). Masking of the normal reef sounds by artificial sounds may have an impact on species abundance and numbers on coral reefs. Research has shown that larvae of several reef fish families preferentially select traps emitting high frequency sounds over traps emitting sounds similar in frequency to normal background frequencies (Simpson *et al*. 2008). Studies on an invertebrate species has shown that chronic exposure to noise may lead to increased metabolic rates, causing a reduction in growth and reproduction (Lagardère 1982).

General Concerns

Marine Resource Surveys: Marine surveys may be needed if the activities may directly or indirectly impart adverse effects to EFH in the nearshore marine environment. If these effects are expected, conduct preliminary benthic marine surveys of the entire area, where in-water work activities occur and in areas where sediment models predict deposition (see below) before finalizing the marine survey. Ensure that hard-bottom EFH is sufficiently sampled during benthic marine surveys; areas of unconsolidated sediment should not be oversampled. Prioritize hard-bottom EFH surveys. While it will be important to gain a representation of NOAA trust resources and EFH, including seagrass, in unconsolidated sediment, prioritizing the quantitative assessment of hard-bottom coral reef habitat would reduce uncertainty and inform potential EFH offset determinations. Surveys would start with qualitative photos/videos, and if there is evidence of greater densities of corals and/or seagrass, quantitative surveys would be appropriate. We are happy to continue coordinating during this process. Conducting a preliminary benthic marine survey of the entire area would improve the accuracy of where potential benthic survey transects are laid, thereby reducing uncertainty, and better informing potential EFH offset determinations.

Predictive Modelling: Consider conducting modelling to predict how the proposed activities will influence sediment transport and water motion before finalizing the marine survey. Particularly sediment plume modeling may be appropriate in the case of revetments, groins, and dredging work that may occur. Models should include current dynamics and expected sediment size fractions and deposition sites. Sediment transport and water current modelling would improve the accuracy of where potential survey transects are laid. More specifically, if there is a high probability that sediment deposition will occur over sensitive and hard-to-replace hard-bottom habitat, corals, and seagrass, these should be priority survey areas. Completing these modelling efforts prior to finalizing the marine survey would help reduce uncertainty and better inform potential EFH offset determinations.

Mitigation

Coral Transplantation Minimization: If activities may result in adverse effects to corals and seagrass, transplantation minimization may be necessary. If this is the case, please ensure that a coral transplantation and post-relocation monitoring plan is provided for NMFS to review with the EFH consultation package. Coral transplantation should strive to achieve ≥70% survivability after one year, with regular monitoring (e.g., 3, 6, and 12 months) after relocation. NMFS is ready and willing to provide further support and coordination, as requested.

Offset: If loss of corals and seagrass is unavoidable and substantial, restoration activities to offset the loss of ecosystem services and function will need to be considered. We recommend coordinating with NMFS to hold further discussions prior to finalizing the EA and initiating any potential EFH consultation.

NMFS appreciates the opportunity to provide technical assistance. We are committed to providing continued cooperation and subject matter technical expertise that result in beneficial outcomes for NOAA trust resources and sufficiently comply with relevant mandates. All while achieving the project goals effectively and expeditiously. Please contact David Delaney at David.Delaney@noaa.gov with any comments, questions, or to request further technical assistance.

David

Enclosure: Draft BMPs

A. Conservation Recommendations for Physical Impacts to Benthic Communities

1. Restrict all physical contact with the bottom to devoid unconsolidated sediments of coral and seagrass.
2. Perform pre-deployment reconnaissance (e.g., divers, drop cameras) to ensure that all anchors are set on hard or sandy bottom devoid of corals and seagrass and that chosen anchor locations take into consideration damage that could occur from the anchor chain if the vessel swings due to currents or tides.
3. Prior to mobilizing, ensure all construction equipment, ballast, and vessel hulls do not pose a risk of introducing new invasive species and will not increase abundance of invasive species present at the project location.
4. Relocate infrastructure materials (e.g., riprap, piles, boulders) that are colonized with benthic communities according to an approved relocation plan. If infrastructure materials (e.g., riprap, piles, boulders) that are colonized with benthic communities will be removed or destroyed as part of permitted activities, relocate these materials to an appropriate receiving site. Equipment, anchors, structures, or fills shall not be deployed in project areas containing live corals, seagrass beds, or visible benthic organisms. Perform pre-deployment reconnaissance (e.g., divers, drop cameras, etc.) to ensure these resources are avoided.
5. Minimize direct impact (direct or indirect contact causing damage) by divers and construction related tools, equipment, and materials with benthic organisms, regardless of

size, especially corals and seagrass.

6. Prevent trash and debris from entering the marine environment during the project.

7. Maintain all structures, gears, instrument, mooring lines, and equipment to prevent failures.

8. All objects lowered to the bottom shall be lowered in a controlled manner. Note: This can be achieved using buoyancy controls such as lift bags, or the use of cranes, winches, or other equipment that affect positive control over the rate of descent. This often requires skilled in-water observation.

9. Select work platforms based on the following preferential hierarchy:

   A. conduct all work from land or an existing structure;

   B. use a barge with auto-positioning systems where thrusters will not cause increased turbidity;

   C. anchor barges to (1) shoreline infrastructure; (2) nearby existing moorings; and, (3) anchors or spuds on sand only (as possible, have SCUBA divers lay anchors by hand in sand areas).

10. Ensure new structures minimize shading impacts to marine habitats.

11. Mooring systems (e.g., buoys, chains, ropes) must:

   A. be kept taut to the minimum length necessary.

   B. employ the minimum line length necessary to account for expected fluctuations in water depth due to tides or waves.

   C. use a mid-line floats or other buoyancy devices to prevent contact with the ocean floor.

   D. be properly maintained.

12. Ensure structures are properly weighted to prevent movement from currents or waves and implement a maintenance plan to ensure integrity over time.

13. Require a long-term maintenance plan for gear, instrument, and equipment to prevent failures leading to permanent adverse effects to EFH (e.g., vessel groundings).

14. All temporary structures must be removed at the completion of construction.

B. Conservation Recommendations for Increase in Sedimentation and/or Turbidity

1. Install sediment, turbidity, and/or pneumatic curtains, and use real-time monitoring (automated or manual) to detect failure and implement stop-work processes if pre-determined project thresholds are reached (use standards from Clean Water Act 401 water quality certification). In areas of soft sediment, consider partial length turbidity curtains to reduce resuspension of sediment during high winds and currents.

2. Collect all accumulated sediment and/or debris and remove them entirely from the water and place onto a surface vessel; debris should not be towed outside a containment.

3. Debris and sediment that is removed from the water shall be disposed of at an appropriate upland location. Sediment and debris must be contained while in transit or on the shore.

4. Project operations must cease under unusual conditions, such as large tidal events, storms, and high surf conditions.

5. Conduct intertidal work at low and/or slack tide to the greatest extent feasible.

6. To minimize impacts to coral larvae, you should avoid in-water work during mass-coral spawning times or peak coral spawning seasons. Permittees should coordinate with local

NMFS Habitat Conservation Division representatives to determine the exact period when coral spawning would occur for the given year at the project site.

7. Maintain baseline water flow, volume, and velocity of the waterbody.
8. Use natural or bio-engineered solutions when feasible.
9. Fully stabilize disturbed upland areas prior to removing silt fences and erosion prevention measures.
10. Temporary fills must be removed in their entirety and the affected areas returned to pre-construction conditions and elevations.
11. Use cofferdams to dewater the project impact site for activities.
12. Utilize environmental clamshell buckets for mechanical dredging.
13. Minimize disturbances to stream banks, and place abutments outside of the floodplain whenever possible. Seek to maintain baseline water flow volume and velocity within the system.
14. Utilize environmental clamshell buckets for mechanical dredging.
15. Design the structure to maintain or replicate natural stream channel and flow conditions to the greatest extent practicable.
16. Revegetate shoreline areas with appropriate native species and fully stabilize disturbed upland areas prior to removing silt fences and erosion prevention measures.

C. Conservation Recommendations for Increase in Nutrients, Pollution, Contaminants, and Freshwater

1. Conduct work during the dry season when possible; stop work during storms or heavy rains.
2. Prevent discharges into the water.
3. Inspect all equipment prior to beginning work each day to ensure the equipment is in good working condition, and there is no contaminant (e.g., oil, fuel) leaks. Work must be stopped until leaks are repaired, and equipment is cleaned. Equipment should always be stored in appropriate staging area designed to be preventative in terms of containing unexpected spills when equipment is not in use or during fueling.
4. All fueling or repairs to equipment must be done in a location with the appropriate controls that prevents the introduction of contaminants to marine environment
5. Fueling of project-related vehicles and equipment shall take place at least 50 feet, or the maximum distance possible, from the water and within a containment area, preferably over an impervious surface.
6. Use of treated wood that would be in contact with the water is not authorized.
7. Use materials that are nontoxic to aquatic organisms, such as untreated wood, concrete, or steel (avoid pressure treated lumber).
8. Use diffusers on the end of subtidal discharge pipes to minimize impacts from discharges.
9. Prevent bentonite and other drilling fluids from contacting benthic organisms.
10. Prevent discharges of chemicals and other fluids dissimilar from seawater into the water column.
11. Use diffusers on the end of subtidal discharge pipes to minimize impacts from discharges.

D. Conservation Recommendations for Increase in Acoustic Impacts

1. Use a vibratory hammer to install piles when possible. Under conditions where impact hammers are required, drive as deep as possible with a vibratory hammer prior to the use of an impact hammer.
2. Implement measures to attenuate the sound or minimize impacts to aquatic resources during pile installation. Methods to mitigate sound impacts include, but are not limited to the following: surround the pile with a dewatered cofferdam and/or air bubble curtain system.

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STATE OF HAWAIʻI | KA MOKUʻĀINA ʻO HAWAIʻI
DEPARTMENT OF TRANSPORTATION | KA ʻOIHANA ALAKAU
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IN REPLY REFER TO:

HWY-Y 23-2.30028

February 16, 2024

Mr. David Delaney, Ph.D., Fish Biologist
U.S. Department of Commerce
National Oceanic and Atmospheric Administration Fisheries
Pacific Islands Regional Office
Habitat Conservation Division
1845 Wasp Boulevard, Building 176
Honolulu, Hawaii 96818

Dear Mr. Delaney:

Subject: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation, in the Vicinity of
Kualoa, Kaaawa, Punaluu and Hauula
Oahu, Hawaii

Thank you for your email response dated September 28, 2022, regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

Thank you for the technical assistance. The Draft EA will include a discussion of potential direct and indirect effect to Essential Fish Habitat (EFH) from the proposed action. Applicable conservation recommendations will be incorporated into the project to avoid and minimize effects to EFH. Your letter and this response will be included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

Sincerely,

Mung Fa Chung

MUNG FA CHUNG
Highways Engineering Program Manager
Materials Testing and Research Branch

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
OFFICE OF CONSERVATION AND COASTAL LANDS
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

REF:OCCL:CM

Correspondence: OA 23-80

Nov 1, 2022

Dennis Silva, Jr.
AECOM
1001 Bishop Street, Suite 1600
Honolulu, Hawai'i 96813
dennis.silvajr@aecom.com

SUBJECT: Pre-Assessment Consultation for Draft Environment Assessment Kamehameha Highway, Coastal Highway Mitigation, Vicinity of Kualoa, Ka'a'awa, Punalu'u and Hau'ula; O'ahu

Dear Mr. Silva:

The Office of Conservation and Coastal Lands (OCCL) has reviewed your correspondence regarding the State of Hawai'i, Department of Transportation's (DOT) proposed roadway protection measures along Kamehameha Highway, from the south end of Kualoa Ranch to Hau'ula town, due to shoreline erosion. Accordingly, the project will involve roadside erosion mitigation and protection improvements to Kamehameha Highway in the subject areas to prevent near-term collapse of the highway, until a long-term shoreline erosion mitigation solution can be developed. Your correspondence also states that the current phase of the proposed project, Phase I, is the preparation of a draft Environment Assessment (EA).

The OCCL regulates land uses in the State Land Use Conservation District that includes submerged lands, located makai of the shoreline, and may include fast lands. Staff research revealed the shoreline area along the project coastline would most likely be impacted by future climate changes and sea level rise. A cursory review of the Hawai'i State Sea Level Rise Viewer (https://www.pacioos.hawaii.edu/shoreline/slr-hawaii/) indicates that the subject roadway area is within the 3.2-feet sea level rise exposure area (SLR-XA). The OCCL has attached **Exhibit 1** regarding the SLRXA for your information. We suggest that you include a thorough discussion of coastal hazards, climate change, sea level rise, and associated impacts in the EA. As DOT's consultant, AECOM may want to consider reviewing the Hawai'i Sea Level Rise Vulnerability and Adaptation Report (2017). A copy of the report can be obtained at https://climateadaptation.hawaii.gov/wp-content/uploads/2017/12/SLR-Report_Dec2017.pdf .

The OCCL suggests the EA disclose any potential impacts to lateral shoreline access that the project may pose, as well as how the DOT intends to support shoreline access along this stretch of coast. Also, the OCCL recommends the mitigation supports the re-alignment of the roadway further inland as means to resolve both short and long-term objectives, to address future sea-level rise concerns, and to comply with Act 16 (2020) that amended HRS 205A – minimize the construction of public shoreline hardening structures at sites having sand beaches.

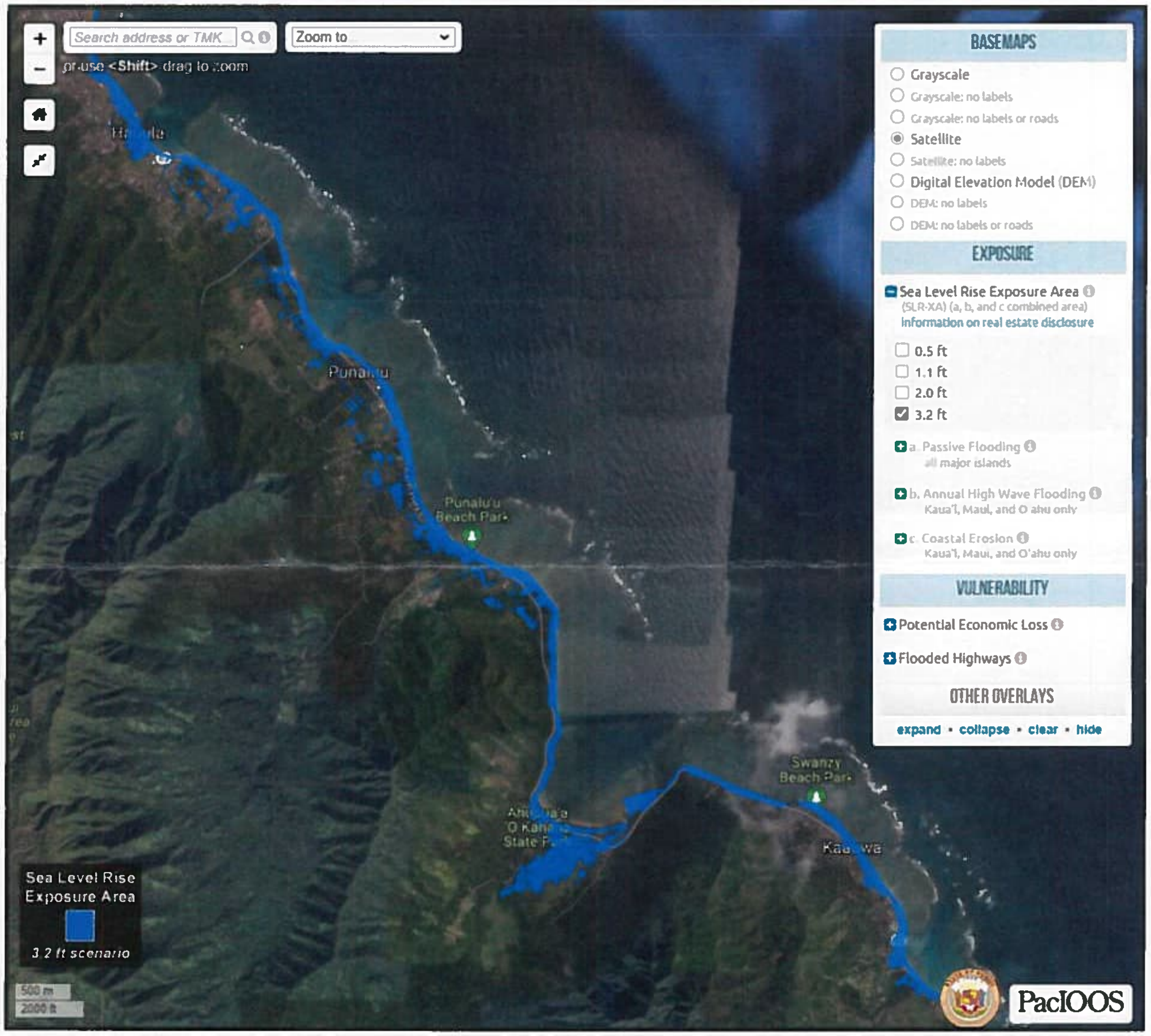
In addition, prior to applying for any land uses in the Conservation District, the requirements of HRS 6E regarding historic properties must be completed. The DOT should initiate community conversations now to address community concerns. These conversations should be added to the draft EA.

Should you have any questions regarding this correspondence, contact Cal Miyahara of the Office of Conservation and Coastal Lands at (808) 798-6147 or calen.miyahara@hawaii.gov.

Sincerely,

for Michael Cain, Administrator
Office of Conservation and Coastal Lands

C: ODLO
City-DPP



Note: 3.2-ft. seal level rise forecast shown in blue (approx. 2100). Kamehameha Highway coastal roadway mitigative project.

Exhibit 1

JOSH GREEN, M.D.
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IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

TO: MICHAEL CAIN, ADMINISTRATOR
OFFICE OF CONSERVATION AND COASTAL LANDS
DEPARTMENT OF LAND AND NATURAL RESOURCES

FROM: MUNG FA CHUNG *Mung Fa Chung*
ENGINEERING PROGRAM MANAGER
MATERIALS TESTING AND RESEARCH BRANCH
HAWAII DEPARTMENT OF TRANSPORTATION

SUBJECT: PRE-ASSESSMENT CONSULTATION FOR DRAFT ENVIRONMENTAL ASSESSMENT
KAMEHAMEHA HIGHWAY, COASTAL HIGHWAY MITIGATION, VICINITY OF KUALOA, KAAAWA, PUNALUU AND HAUULA
OAHU, HAWAII

Thank you for your letter dated November 1, 2022 (OA 23-80) regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

We acknowledge that the shoreline in the project areas will most likely be impacted by future climate changes and sea level rise, and that the subject roadway area is within the 3.2-feet sea level rise exposure area. The draft EA will include discussions on coastal hazards, climate change, sea level rise, and associated impacts. Information from the 2017 Hawaii Sea Level Rise Vulnerability and Adaptation Report will be incorporated in the draft EA.

Potential impacts to shoreline access and measures intended to minimize those impacts will be described in the draft EA. A managed retreat alternative will be discussed. The proposed shoreline stabilization intended to protect the highway in the near to mid-term would not preclude re-alignment of the highway in the long-term to address future sea level rise.

The project will include use of submerged lands in the State Land Use Conservation District that are regulated by the Office of Conservation and Coastal Lands. Consultation with the State Historic Preservation Division in accordance with Hawaii Revised Statutes Chapter 6E-8 will be completed prior to applying for a Conservation District Use Permit.

Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA. We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

STATE OF HAWAIʻI
OFFICE OF PLANNING
& SUSTAINABLE DEVELOPMENT

DAVID Y. IGE
GOVERNOR

MARY ALICE EVANS
ACTING DIRECTOR

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Coastal Zone Management Program

Environmental Review Program

Land Use Commission

Land Use Division

Special Plans Branch

State Transit-Oriented Development

Statewide Geographic Information System

Statewide Sustainability Branch

DTS 202210031622NA

November 2, 2022

Mr. Dennis Silva, Jr., AICP
AECOM
1001 Bishop Street, Suite 1600
Honolulu, Hawaii 96813

Dear Mr. Silva:

Subject: Pre-Assessment Consultation for a Draft Environmental Assessment on the Kamehameha Highway, Coastal Highway Mitigation Project in the Vicinity of Kualoa, Kaʻaʻawa, Punaluʻu and Hauʻula, Oʻahu, Hawaiʻi

Thank you for the opportunity to provide comments on a Pre-assessment consultation for a Draft Environmental Assessment (Draft EA) for the proposed Kamehameha Highway coastal highway erosion mitigation project located along the north shore of Oʻahu in the vicinity of Kualoa, Kaʻaʻawa, Punaluʻu and Hauʻula. The Pre-Assessment consultation review material was received by our office via memo dated October 5, 2022.

It is our understanding the State of Hawaii Department of Transportation (HDOT) is proposing to implement roadway protection measures along Kamehameha Highway, from the south end of Kualoa Ranch to Hauula town, due to shoreline erosion. The proposed project will involve roadside erosion mitigation and protection improvements for the primary access road for Windward Oʻahu communities, aiming to prevent the near-term collapse of the Highway into the ocean and to ensure accessibility of various road users to/in the area until a long-term shoreline erosion mitigation solution can be developed.

We note that our office reviewed and commented on a HDOT project earlier this year involving shoreline erosion mitigation along Kamehameha Highway near Kaʻaʻawa, Oʻahu, DTS202201120748NA, dated February 7, 2022.

The Office of Planning and Sustainable Development (OPSD) has reviewed the transmitted material, and have the following comments to offer:

1. Coastal Zone Management Act (CZMA) Federal Consistency
   We note that typical coastal highway repair and mitigation projects are often subject to federal permits such as a Department of the Army (DA) Permit. If it is deemed federal approval, such as a DA permit is required, then this project may be subject to CZMA federal consistency.

   OPSD is the lead state agency with the authority to conduct CZMA federal consistency reviews. We recommend that HDOT consult with our office on the policies and procedures applicable to CZMA federal consistency reviews, if it is deemed that the proposed action requires federal permitting.

2. The Hawaii Coastal Zone Management Program
   Hawaiʻi Revised Statutes (HRS) § 205A-4(a) states that in implementing the objectives of the CZM program, agencies shall give full consideration to ecological, cultural, historic, esthetic, recreational, scenic, and open space values, coastal hazards, and economic development. Additionally, HRS § 205A-5(b) requires all state and county agencies to enforce the CZM objectives and supporting policies.

   As this project is being proposed by a State agency, the subject EA should include a full assessment as to how the proposed action conforms with the provisions of HRS § 205A-2. Furthermore, HRS § 205A-2 forms the foundation of the enforceable policies of the Hawaiʻi CZM Program. If a federal consistency review is needed, the EA's detailed examination can be used as support material by HDOT in the federal consistency determination.

3. Special Management Area (SMA) / Shoreline Setback Variance (SSV)
   As the proposed action is situated along the shoreline, we recommend that HDOT consult with the City and County of Honolulu, Department of Planning and Permitting on the applicability of SMA Use permitting, and Shoreline Setback Variances, and whether the EA would be used as a supporting document if a SMA use permit is required.

4. Sea Level Rise (SLR)/Climate Change Adaptation
   The project area is within close proximity to a lengthy stretch of beaches along the Koʻolauloa coast and the Pacific Ocean. As this proposed action is intended to mitigate shoreline erosion concerns that undermine the integrity and viability of Kamehameha Highway, analysis of SLR impacts is a critical component of the EA. Furthermore, this stretch of roadway is highly susceptible to coastal hazards such as seasonal inundation, storm surges, erosion, saltwater intrusion, and related natural disasters associated with sea level rise. To assess potential impacts of SLR and vulnerability of the roadway to SLR, we suggest the EA refer to the findings of the

Hawaiʻi Sea Level Rise Vulnerability and Adaptation Report 2017 (Report), accepted by the Hawaiʻi Climate Change Mitigation and Adaptation Commission.

The Report and the Hawaii Sea Level Rise Viewer at https://www.pacioos.hawaii.edu /shoreline/slr-hawaii/ particularly identifies a 0.5-foot, 1.1-foot, 2.0-foot, and 3.2-foot sea level rise exposure area, respectively, across the main Hawaiian Islands, which may occur in the mid to latter half of the 21st century. The EA should provide a map of 0.5-foot, 1.1-foot, 2.0-foot, and 3.2-foot sea level rise exposure area, respectively, in relation to the project area, and consider site-specific mitigation measures, including elevation and setbacks from the shoreline erosion during the life of the proposed structure, to respond to the potential impacts of sea level rise.

If you have any questions, please contact Joshua Hekekia on EA concerns as they relate to this OPSD response letter at (808) 587-2845, or Debra Mendes on CZMA federal consistency at (808) 587-2840.

Sincerely,

Mary Alice Evans

Mary Alice Evans,
Acting Director

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IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

TO: MARY ALICE EVANS, INTERIM DIRECTOR
OFFICE OF PLANNING AND SUSTAINABLE DEVLOPMENT

FROM: MUNG FA CHUNG *Mung Fa Chung*
ENGINEERING PROGRAM MANAGER
MATERIALS TESTING AND RESEARCH BRANCH

SUBJECT: PRE-ASSESSMENT CONSULTATION FOR DRAFT ENVIRONMENTAL ASSESSMENT
KAMEHAMEHA HIGHWAY, COASTAL HIGHWAY MITIGATION, VICINITY OF KUALOA, KAAAWA, PUNALUU AND HAUULA
OAHU, HAWAII

Thank you for your letter dated November 02, 2022, (DTS 202210031622NA) regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

An analysis on the projects consistency with the objectives and supporting policies of the Hawaii Coastal Zone Management Program will be included in the Draft EA. The EA will include a description of the mitigation measures to be implemented to control pollution and sediment runoff. The Hawaii Sea Level Rise report will be reviewed, and applicable information will be incorporated into the EA and design. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawaiʻi 96850

In Reply Refer To:
2022-0082655-S7

September 7, 2022

Dennis Silva Jr.
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1001 Bishop Street, Suite 1600
Honolulu, HI 96813

Subject: Draft Environmental Assessment for Kamehameha Highway, Coastal Highway Mitigation, Vicinity of Kualoa, Kaʻaʻawa, Punaluʻu and Hauʻula, (HWY-L 2.8591), Oʻahu

Dear Dennis Silva:

The U.S. Fish and Wildlife Service (Service) received your August 29, 2022, e-mail request for comments about the State of Hawaiʻi Department of Transportation (HDOT) proposed roadway protection measures along Kamehameha Highway, Oʻahu. The State of Hawaii Department of Transportation is preparing a draft Environmental Assessment for the proposed coastal highway protection measures along Kamehameha Highway on the island of Oʻahu from the southern end of Kualoa Ranch to the town of Hauʻula. Roadside erosion mitigation and protection improvements are proposed to prevent additional road erosion into the ocean. In addition, the project aims to improve user accessibility of the Highway until a long-term shoreline erosion mitigation solution can be developed. This letter has been prepared under the authority of, and in accordance with, provisions of the Endangered Species Act (Act) of 1973 (16 U.S.C. 1531 et seq.), as amended.

There are no areas designated as critical habitat within the project area. Our data indicate the following species may occur in, or transit through, the vicinity of the proposed project:

- Hawaiian hoary bat or ʻōpeʻapeʻa (*Lasiurus cinereus semotus*), endangered
- Hawaiian waterbirds:
    - Hawaiian stilt or aeʻo (*Himantopus mexicanus knudseni*), endangered
    - Hawaiian coot or ʻalae keʻokeʻo (*Fulica alai*), endangered
    - Hawaiian duck or koloa (*Anas wyvilliana*) endangered and,

  - Hawaiian common gallinule or ʻalae ʻula (*Gallinula galeata sandvicensis*), endangered
- Hawaiian seabirds:
  - Hawaiian petrel or ʻuaʻu (*Pterodroma sandwichensis*), endangered
  - Newell's shearwater or ʻaʻo (*Puffinus auricularis newelli*), threatened
  - Hawaiʻi distinct population segment (DPS) of band-rumped storm petrel or ʻakē ʻakē (*Oceanodroma castro*), endangered
- Sea turtles, including the Central North Pacific Distinct Population Segment of the green sea turtle or honu (*Chelonia mydas*), endangered and the Hawksbill sea turtle or honuʻea (*Eretmochelys imbricata*), threatened.

The Service offers the following recommendations to avoid and minimize potential project impacts to these species:

Hawaiian Hoary Bat

The Hawaiian hoary bat roosts in both native and non-native woody vegetation across all islands and will leave young unattended in trees and shrubs when they forage. If trees or shrubs 15 feet or taller are cleared during the pupping season, there is a risk that young bats could inadvertently be harmed or killed since they are too young to fly or may not move away. Additionally, Hawaiian hoary bats forage for insects from as low as 3 feet to higher than 500 feet above the ground and can become entangled in barbed wire used for fencing.

To avoid and minimize impacts to the endangered Hawaiian hoary bat we recommend you incorporate the following applicable measures into the proposed project:

- Do not disturb, remove, or trim woody plants greater than 15 feet tall during the bat birthing and pup rearing season, June 1 through September 15.
- Do not use barbed wire for fencing.

Hawaiian Waterbirds

Hawaiian waterbirds are currently found in a variety of wetland habitats including freshwater marshes and ponds, coastal estuaries and ponds, artificial reservoirs, kalo or taro *(Colocasia esculenta)* loʻi or patches, irrigation ditches, sewage treatment ponds, and in the case of the Hawaiian duck, montane streams and marshlands. Hawaiian stilts may also be found wherever ephemeral or persistent standing water may occur. Threats to these species include non-native predators, habitat loss, and habitat degradation. Hawaiian ducks are also subject to threats from hybridization with introduced mallards.

Based on the project details provided, your project is in the vicinity of standing water or open water that could attract Hawaiian waterbirds to the project site. In particular, the Hawaiian stilt is known to nest in sub-optimal locations (e.g. any ponding water), if water is present. Hawaiian waterbirds attracted to sub-optimal habitat may suffer adverse impacts, such as predation and reduced reproductive success, and thus the project may create an attractive nuisance. Therefore, we recommend you work with our office during project planning so that we may assist you in developing measures to avoid impacts to listed species (e.g., fencing, vegetation control, predator management).

To avoid and minimize potential project impacts to Hawaiian waterbirds we recommend you incorporate the following measures into your project description:

- In areas where waterbirds are known to be present, post and implement reduced speed limits, and inform project personnel and contractors about the presence of endangered species on-site.
- If water resources are located within or adjacent to the project site, incorporate applicable best management practices regarding work in aquatic environments into the project design (see enclosure).
- Have a biological monitor that is familiar with the species' biology conduct Hawaiian waterbird nest surveys where appropriate habitat occurs within the vicinity of the proposed project site prior to project initiation. Repeat surveys again within 3 days of project initiation and after any subsequent delay of work of 3 or more days (during which the birds may attempt to nest). If a nest or active brood is found:
  - Contact the Service within 48 hours for further guidance.
  - Establish and maintain a 100-foot buffer around all active nests and/or broods until the chicks/ducklings have fledged. Do not conduct potentially disruptive activities or habitat alteration within this buffer.
  - Have a biological monitor that is familiar with the species' biology present on the project site during all construction or earth moving activities until the chicks/ducklings fledge to ensure that Hawaiian waterbirds and nests are not adversely impacted.

Hawaiian Seabirds

Hawaiian seabirds may traverse the project area at night during the breeding, nesting and fledging seasons (March 1 to December 15). Outdoor lighting could result in seabird disorientation, fallout, and injury or mortality. Seabirds are attracted to lights and after circling the lights they may become exhausted and collide with nearby wires, buildings, or other structures or they may land on the ground. Downed seabirds are subject to increased mortality due to collision with automobiles, starvation, and predation by dogs, cats, and other predators. Young birds (fledglings) traversing the project area between September 15 and December 15, in their first flights from their mountain nests to the sea, are particularly vulnerable to light attraction.

To avoid and minimize potential project impacts to seabirds we recommend you incorporate the following measures into your project description:

- Fully shield all outdoor lights so the bulb can only be seen from below.
- Install automatic motion sensor switches and controls on all outdoor lights or turn off lights when human activity is not occurring in the lighted area.
- Avoid nighttime construction during the seabird fledging period, September 15 through December 15.

Sea Turtles

The Service consults on sea turtles and their use of terrestrial habitats (i.e., beaches where nesting and/or basking is known to occur), whereas the National Oceanic and Atmospheric Administration (NOAA) Fisheries consults on sea turtles in aquatic habitats. We recommend consulting with NOAA Fisheries regarding the potential impacts from the proposed project if it may affect off-shore or open ocean habitats.

Green sea turtles may bask or nest on any sandy beach area in the Pacific Islands. Hawksbill sea turtles exhibit a wide tolerance for nesting substrate (ranging from sandy beach to crushed coral) with nests typically placed under vegetation. Both species exhibit strong nest-site fidelity. Nesting occurs on beaches from May through September, peaking in June and July, with hatchlings emerging through November and December.

To avoid and minimize project impacts to sea turtles and their nests we recommend incorporating the following measures into the project description:

- No vehicle use on, or modification of, the beach/dune environment during the sea turtle nesting or hatching season (May to December).
- Do not remove native dune vegetation.
- Have a biologist familiar with sea turtles conduct a visual survey of the project site to ensure no basking sea turtles are present.
    - If a basking sea turtle is found within the project area, cease all mechanical or construction activities within 100 ft until the animal voluntarily leaves the area.
    - Cease all activities between the basking turtle and the ocean.
- Remove any project-related debris, trash, or equipment from the beach or dune if not actively being used.
- Do not stockpile project-related materials in the intertidal zone, reef flats, sandy beach and adjacent vegetated areas, or stream channels.

Optimal sea turtle nesting habitat is a dark beach free of barriers that restrict sea turtle movement. Nesting turtles may be deterred from approaching or laying successful nests on lighted or disturbed beaches. They may become disoriented by artificial lighting, leading to exhaustion and placement of a nest in an inappropriate location (such as at or below the high tide line). Hatchlings that emerge from nests may also be disoriented by artificial lighting. Inland areas visible from the beach should be sufficiently dark to allow for successful navigation by hatchlings to the ocean.

To avoid and minimize project impacts to sea turtles from lighting we recommend incorporating the following applicable measures into the project description:

- Avoid nighttime work during the nesting and hatching season (May to December).
- Minimize the use of lighting on or near beaches and shield all project-related lights so the light is not visible from any beach.
    - If lights can't be fully shielded or if headlights must be used, fully enclose the light source with light filtering tape or filters.

We appreciate your efforts to conserve endangered species. If you have any questions, please contact Emma Gosliner at emma_gosliner@fws.gov or by telephone at 808-792-9450 and refer to project code 2022-0082655-S7.

Sincerely,

DAWN BRUNS

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IN REPLY REFER TO:

HWY-L 24-2.30028

February 16, 2024

Ms. Dawn Burns
Planning and Consultation Team Manager
Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawaii 96850

Dear Ms. Burns:

Subject: Pre-Assessment Consultation for Draft Environmental Assessment
Kamehameha Highway, Coastal Highway Mitigation, in the Vicinity of Kualoa, Kaaawa, Punaluu and Hauula
Oahu, Hawaii

Thank you for your letter dated September 7, 2022, (2022-0082655-S7) regarding the pre-assessment consultation for the Draft Environmental Assessment (EA) for the subject project.

We acknowledge that the following species may occur in, or transit through, the vicinity of the proposed project: Hawaiian hoary bat or 'ōpe'ape'a, Hawaiian waterbirds, Hawaiian seabirds, and sea turtles. The United States Fish and Wildlife Service Information for Planning and Consultation tool is being utilized in support of the EA and provided an Official Species List which included 8 Federally endangered plant species and 11 Federally threatened and endangered animal species that could potentially occur within the project area. The draft EA will include a discussion of potential effect to protected species and proposed measures to avoidance and minimize adverse effects. Your letter and this response will be reproduced and included in the forthcoming Draft and Final EA.

We appreciate your participation in the EA review process. We will notify you when the Draft EA is published for comment in *The Environmental Notice*. Should you have any questions please contact me at (808) 832-3405 extension 105 or by email at mungfa.chung@hawaii.gov.

Sincerely,

Mung Fa Chung

MUNG FA CHUNG
Highways Engineering Program Manager
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