DRAFT ENVIRONMENTAL ASSESSMENT
WAIKIKI BEACH MAINTENANCE

Honolulu, Hawaii

February 2010

Prepared for:
State of Hawaii
Department of Land and Natural Resources
P.O. Box 621
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SEI Job No. 25172

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PROJECT SUMMARY

Project:	Waikiki Beach Maintenance
Proposing and Approving Agency:	Department of Land and Natural Resources State of Hawaii 1151 Punchbowl Street, Room 131 Honolulu, Hawaii 96813 Contact: Sam Lemmo, Phone (808) 587-0377 Fax (808) 587-0322
Consultant:	Sea Engineering, Inc. Makai Research Pier 41-305 Kalanianaole Highway Waimanalo, HI 96744 Contact: Scott Sullivan, Phone (808) 259-7966, Ext. 22 Email: ssullivan@seaengineering.com
Location:	Waikiki Beach, Oahu, Hawaii
Tax Map Keys:	None
State Land Use District:	Conservation
County Zoning:	None
Proposed Action:	DLNR proposes to restore and maintain the 1,700-foot-long segment of Waikiki Beach between the Kuhio Beach crib wall and the Royal Hawaiian groin. Approximately 24,000 cubic yards of sand would be recovered from offshore deposits, and pumped to the shoreline where it would be dewatered and placed along the beach. The project would widen the beach by about 40 feet, restoring the beach to its approximate 1982 width. The project would also include an option for a second beach nourishment after approximately 10 years involving approximately 14,000 cubic

yards of sand recovered from the same offshore deposits. Also included in the initial project work would be the removal of two old deteriorated groin structures at the east end of the project area.

The project will not alter or affect presently on-going sand transport and shoreline processes, wave-driven currents, circulation patterns, overall water quality, or offshore wave breaking. Offshore surf sites are primarily influenced by the hard limestone fossil reef formations that are at slightly higher elevation than the intermittent sand channels and pockets, and thus would not be significantly affected by either the recovery of sand from offshore or its migration back offshore over time. Sand recovery operations will be designed so as to avoid and minimize impacts to marine biota so far as practicable, no long term impacts to marine biota are anticipated. Recovery of offshore sand may actually benefit the offshore ecosystem by creating some additional hard rock bottom area. The beach widening will take place on existing nearshore sand bottom, thus there will be no alteration of marine habitat. Construction BMP's will be used to avoid impacts to the protected green sea turtle. No effects on historic, cultural and archaeological resources are anticipated. Construction can be expected to result in some temporary disruption of beach use and recreational activities, and increased noise and short term degradation of air quality from the operation of construction equipment. Localized increases in water turbidity will occur in the immediate area of construction activity, however containment barriers and turbidity screens will be in place to control and minimize the area of impact.

Required Permits & Approvals: Environmental Assessment and FONSI (Chapter 343, HRS and§11-200, HAR)
Department of the Army Permit (Section 10 and Section 404),
Clean Water Act Section 401 Water Quality Certification
Coastal Zone Management Act Consistency Determination

Actions Requiring Environmental Assessment: Work within the State Conservation District and within navigable waters of the United States.

Anticipated Determination: Finding of No Significant Impact (FONSI)

Estimated Cost: $2,500,000 - $3,500,000

Time Frame: Construction will begin when the necessary permits and approvals are obtained and a construction contract is awarded, currently estimated for winter/spring 2011. The construction period is estimated to be about 90 days.

Unresolved Issues: Permit requirements

Consulted Organizations/ Individuals:

Federal

- U.S. Army Corps of Engineers, Honolulu District, Regulatory Branch
- U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office
- NOAA, National Marine Fisheries Service, Pacific Islands Regional Office
  - Pacific Islands Environmental Coordinator
  - Habitat Conservation Division
  - Protected Resources Division
- U.S. Environmental Protection Agency, Region IX, Honolulu Branch

State

- Office of Environmental Quality Control
- Department of Land and Natural Resources
  - Aquatic Resources Division
  - Historic Preservation Division
  - Office of Conservation and Coastal Lands
  - Engineering Division
- Department of Health, Clean Water Branch
- DBEDT, Office of Planning, Coastal Zone Management Program

City & County of Honolulu

Department of Planning and Permitting
Department of Design and Construction
Department of Emergency Services, Ocean Safety
Waikiki Neighborhood Board

Other

Waikiki Improvement Association

Brunetti, Vince. Manager of the food concession in the HPD Waikiki Substation building.
Bush, Ted. Owner, Waikiki Beach Services.
Carvalho, David. Manager, Hawaiian Oceans beach concession.
Chang, Hubert. Owner, Hawaiian Oceans beach concession.
Couch, Tom. Staff, Hawaiian Oceans beach concession.
Downing, George. Save Our Surf.
Goto, Ralph. Director, Ocean Safety Division, Honolulu Emergency Services.
Harada, Ivan. Waikiki Lifeguard, retired.
Howe, Jim. Operations Chief, Ocean Safety Division, Honolulu, Emergency Services.
Iaukea, Rocky. Manager, Mana Kai catamaran.
Lipton, Sheila. Owner, Kapoikai catamaran.
Merino, Paul. Waikiki District Lifeguard Captain, Ocean Safety Division, Honolulu Emergency Services.
Oahu District Manager, DOBOR.
Quintal, Sidney. Director, Department of Environmental Services.
Robello, Didi. Owner, Aloha Beach Services.
Santiago, Jay. Captain, Kapoikai catamaran.
Savio, John. Owner, Na Hoku and Manu Kai catamarans.
Shipley, Jack. Waikiki surf contest judge.
Star Beachboys.
Wright, Chalian. Concession Specialist, Department of Environmental Services.

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1. INTRODUCTION

1.1 Project Location and General Description

The project site is located on Waikiki Beach, along the shoreline of Mamala Bay on the south shore of Oahu, Hawaii. The shoreline under consideration for beach maintenance extends approximately 1,700 linear feet from the west end of the Kuhio Beach crib walls, near the Duke Kahanamoku statue, to the existing Royal Hawaiian groin between the Royal Hawaiian and Sheraton Waikiki hotels, as shown on Figure 1-1. The east end of the reach is open and landscaped between Kalakaua Avenue and the shoreline, and provides for three beach concession operations. The balance of the project backshore is occupied by resort hotels; from east to west, the Moana Surfrider, Outrigger Waikiki, and Royal Hawaiian. The Moana (1901) and the Royal (1927) are respectively the oldest and second oldest hotels in Waikiki.

Since 1982 the project area shoreline has been chronically eroding and receding, and today, at high tide, along much of it there is barely sufficient dry beach width seaward of the hotel property for one towel or beach mat. At higher tides the beach is almost completely submerged by wave runup. Figure 1-2 shows the beach fronting the Moana Surfrider on September 25, 2009, with a tide of about +0.5 feet mean sea level (MSL). While Waikiki Beach remains a symbol of Hawaii for many and is still the State's largest tourist destination, visitor surveys indicate that 12% of tourists who say they will not return to Waikiki cite the limited beach area and the resulting crowding as a reason for their decision (Lent, 2002; USACE, 2002).

1.2 Project Purpose and Objectives

The State has recognized that, given the chronic erosion potential, simply importing sand is not a permanent solution, and they desire to develop a strategy of regular beach maintenance using nearshore sand as a means for periodic beach nourishment. This will include periodic identification, mapping and analysis of offshore sand deposits, and recovery of this sand and its placement on the beach. This "recycling" strategy may be an efficient method of maintaining a recreational beach as well as mitigating some of the environmental effects of sand imported to the Waikiki ecosystem over the past 60 years. Wave induced currents predominate inside the breaker zone, generating both longshore (shore parallel) currents moving sand primarily from east to west, and offshore (rip) currents. During high wave conditions rip currents can form, resulting in a significant movement of sand offshore which is then lost to the beach. This sand can be periodically recovered and recycled back to the beach. In 2006 the State of Hawaii, Department of Land and Natural Resources recovered approximately 10,000 cubic yards of sand from the sea bottom seaward of Kuhio Beach and pumped it onto the shore within the confines of the Kuhio Beach crib walls.

The purpose of the proposed project is to restore and enhance recreational and aesthetic enjoyment of the project area by nourishing and maintaining the beach. The improved beach will enhance recreational opportunities, and facilitate lateral access along the shore. The objective is to simply restore and maintain the beach to its recent historical condition – the approximate 1982 shoreline. No enlargement of the beach or sand stabilizing structures are proposed. In order to support the State's goals, the project involves three primary work tasks:

1. obtain an approved Environmental Assessment (EA) and necessary permits for periodic beach nourishment and restoration for an approximate 20-year period using offshore sand,

2. design, permit and prepare construction documents for Waikiki Beach maintenance, and

3. complete construction of beach maintenance.

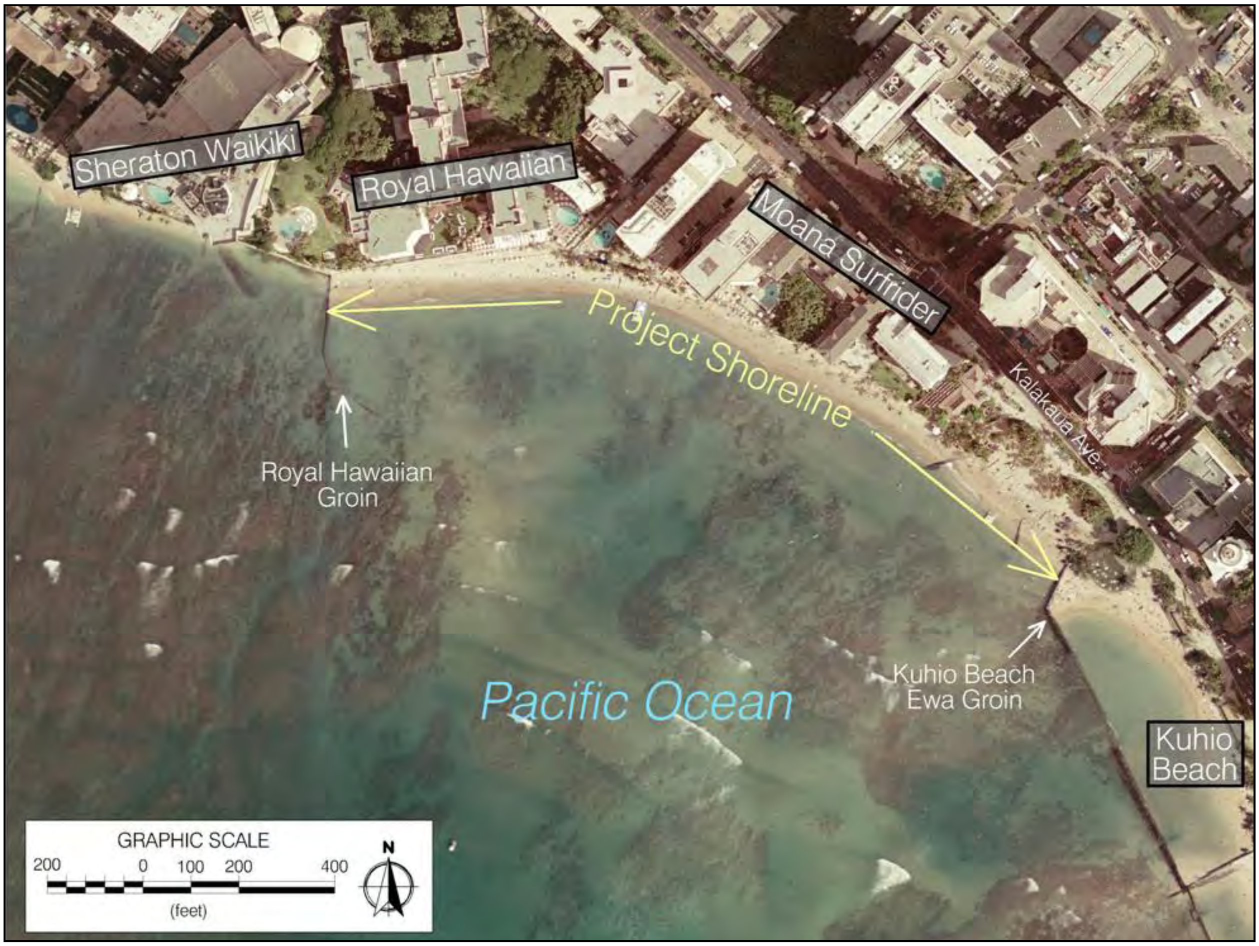

Figure 1-1 Overview of project site

Figure 1-2 Beach fronting Moana Surfrider Hotel

1.3 Summary Description of the Proposed Action

The proposed project includes the following primary components, which are the subject of this EA.

- The recovery of approximately 24,000 cubic yards (cy) of sand from deposits located 1,500 to 3,000 feet offshore of the project area in a water depth of about 10 to 20 feet.
- Pumping the sand to an onshore dewatering site to be located in an enclosed basin within the eastern Kuhio Beach crib walls.
- Transport of the sand along the shore in the project area and placement to the design beach profile.
- The removal of two old deteriorated groin structures located at the end of the project area.

The project would consist of an initial beach nourishment of 24,000 cubic yards, followed by a second nourishment of about 14,000 cy after approximately ten years. Thus the beach would initially be restored to the desired width, the approximate 1982 shoreline, which, based on historical erosion rates, would be reduced by about half in an estimated 10 years. The second nourishment would again return the beach to its 1982 position. The two nourishments would maintain the beach for an estimated 20 plus years.

The proposed action is simply maintenance of what is today essentially a man-made sandy shoreline. Shoreline alterations, the construction of various shoreline structures intended to stabilize the shoreline and retain sand, and the importation of large quantities of sand fill over the past 100 years has resulted in no natural shoreline between Honolulu Harbor and Diamond Head. Every foot of the existing Waikiki shoreline is man-made. The purpose of the proposed project is to maintain the beach in a reasonable condition such that it can provide its intended recreational and aesthetic benefits, facilitate lateral access along the shore, and provide a first line of defense to the backshore area in the event of storm wave attack. The beach would not be enlarged beyond its historical beach width or what is necessary for a reasonable periodic maintenance schedule. No new structures would be constructed along the shoreline, and two deteriorated remnant groin structures at the east end of the project area would be removed.

1.4 Alternatives Considered and Eliminated

1.4.1 Narrow Beach

The proposed project would widen the dry beach by a nominal 40 feet. The first alternative considered would widen the beach by only 20 feet. By doing so, the footprint of the project would be reduced, and the potential impacts would be reduced as a result of a smaller scale project.

Completion of this alternative would require all the same equipment to dredge the sand, while on-shore distribution equipment and time involved would be reduced. Since sand dredging and beach nourishment have an economy of scale, a 50% reduction in nourished width would have the same mobilization and demobilization costs, and the unit cost of sand would be greater than for the full project.

While this alternative might lessen the environmental impacts relative to the proposed project, it would diminish the intent of the project by producing a minimal widening of the beach with reduced recreational value. In addition, follow-up maintenance would be required on a more frequent schedule. The effort involved in conducting a project for a minimal increase in beach width is considered neither economical nor practical, and therefore was eliminated as an alternative.

1.4.2 Beach Nourishment with Stabilizing Structures

This design would call for the use of what coastal engineers refer to as “emergent T-head rock groins”. These would be constructed perpendicular to the shoreline to compartmentalize the beach and impound the sand. The tuned T-head groin approach would require approximately six to eight groins spaced along the project shoreline. Two of the groins would either replace or reinforce the Royal Hawaiian groin and the Ewa groin of Kuhio Beach Park at the ends of the 1,700-foot project reach.

The groins would extend as much as 200 feet from the shoreline and would be spaced approximately 300 feet between groin stems. Sand fill volumes would likely exceed the 24,000 cubic yards proposed by the project plan. The groin head length versus the space between adjacent groin heads would be about 40:60 so that the groins do not dominate the viewscape.

The groins would be constructed as rock rubblemound structures and the armor stone would have nominal diameters of approximately 2.5 to 3 feet. Design structure elevation would be about +4.5 feet MSL. The crest of the structure would have a nominal width of 3 stones, or approximately 8 to 9 feet. Construction of these groins would require about 10,000 cubic yards of rock.

The length of the groins would likely require placement of armor stone onto some hard limestone bottom in the offshore waters. Additionally, to produce a stable beach shape, the sand fill would need to extend into the lee of the groin heads, taking the sand fill substantially further from shore than in the proposed project, also possibly covering hard rock bottom. Beach nourishment and tuned T-head groins are typically used in tandem to construct new beaches, or restore and stabilize a beach subject to severe and chronic erosion. The proposed project is a maintenance project of an existing beach; it is not intended to create a new beach, and the erosion, while chronic, is not so severe that periodic nourishment alone is not an acceptable maintenance plan. Although structures could be designed to improve stability of the beach, this alternative is not considered feasible because of substantially greater cost and potential impacts versus the proposed project.

1.4.3 Alternative Sand Sources

The majority of Hawaii beaches are composed of calcareous (calcium carbonate) sand made up of skeletal fragments of marine organisms such as corals, coralline algae, mollusks, echinoids, and foraminifera. The density of calcium carbonate is more than $2.7 g/cm^3$, but the presence of microscopic pores and hollow grains make the effective density somewhat lower. The composition of sand is determined by the relative abundance of each species and therefore varies with location. Native calcareous sand is the only type of sand that the State of Hawaii allows for beach nourishment.

Since the 1950’s some 300,000+ cubic yards of sand have been placed on Waikiki Beach (Wiegel, 2002). Some of this came from dredged coralline material crushed to make sand, some came from other beaches around Oahu, and some came from fossil dunes and other on-land deposits. Some of the on-land sources were of excellent quality (Sea Engineering 2004; Sea Engineering 2007). For example, Mokuleia Inland Beach Sand, mined by Hawaiian Cement, was a high quality relic beach sand deposit found several hundred meters inland of the beach. It was used for nourishment projects at the Hilton Hawaiian Village, Kuhio Beach, and Makaha Surfside. However, while the deposit is still in existence, Hawaiian Cement reports that it is not actively being mined and is no longer available.

Maui Dune Sand, another source used in the past, is still being mined by Hawaiian Cement and Ameron. It is a fine to medium sand on the Wentworth scale with a D_{50} of 0.25 mm. This material contains a relatively high percentage of fines, and has a medium to dark brown color. It has not been used for beach nourishment projects on Oahu and there are additional issues including restricted supply that make its use on Oahu problematic.

In view of the foregoing, Sea Engineering’s 2007 analysis of potential sand sources concluded that there are no presently existing commercially available on-land sources of suitable beach sand. Thus the alternative of using sand from other than offshore deposits such as is being proposed is not considered viable, and has been eliminated from detailed consideration.

1.5 No Action

Measurements and observations of the nearshore waters in the project site indicate that there is some sand available to permit short-term and seasonal fluctuations in beach width. In general, however, there is very limited sand in the Waikiki littoral system to naturally feed the beach, and the long-term trend in Waikiki is a net reduction in sand supply. The last significant infusion of sand to the Waikiki Beach system was in the 1970's (Wiegel, 2008). Since the 1980's the beach in the project area has been chronically eroding, and the shoreline has been receding at rates of one to nearly three feet per year (see Figure 3-11). There is no reason to believe that this trend will not continue into the foreseeable future, and thus there is the very real possibility that without periodic beach maintenance the functional sandy shoreline will essentially disappear over time. This will obviously reduce the attractiveness of Waikiki as a beach resort, as shown by the two recent economic studies (Lent, 2002; and Hospitality Advisors, LLC, 2008), and will increase the threat of storm wave damage to valuable onshore infrastructure. However, as undesirable as it may be, No Action is an alternative, and is therefore carried through the EA evaluation in order to discuss the potential impacts of simply doing nothing. The No Action Alternative provides decision-makers with a benchmark against which to compare the magnitude of environmental effects of the action alternatives. The No Action Alternative represents a "future-without-project" scenario: a continuation of existing activities and natural processes that leads to a picture of the future conditions most likely to occur if the proposed action (issuance of a permit and the subsequent implementation of the applicant's proposed project) does not occur. Its purpose is to provide a "reasonable" baseline for assessing the impacts of the action alternative.

1.6 Required Federal and State Approvals, and Applicable Regulatory Requirements

1.6.1 Required Federal Approvals

Department of the Army (DA) permits are issued by the U.S. Army Corps of Engineers (COE) pursuant to Section 10 of the Rivers and Harbors Act of 1899 (33 USC 403) and Section 404 of the Clean Water Act (33 USC 1344). All work or structures in or affecting the course, condition, location or capacity of navigable waters, including tidal wetlands, require DA authorization pursuant to Section 10. In addition, activities involving the discharge of dredged or fill material into waters of the United States requires a DA permit pursuant to Section 404. As the proposed project will be constructed in navigable waters of the U.S. it will require a DA permit issued pursuant to Section 10 and Section 404.

1.6.2 Required State of Hawaii Approvals

The proposed project will require preparation of a Draft and Final Environmental Assessment (DEA and FEA) pursuant to the State of Hawaii's environmental impact assessment process, Chapter 343, Hawaii Revised Statutes, and its' implementing regulations. Hawaii Administrative Rules (HAR) Title 11, Chapter 200, addresses the determination of significance and contents of an environmental assessment. If the FEA and Finding of No Significant Impact (FONSI) is approved by the Department of Land and Natural Resources, the project can then proceed to implementation, once all other required permits and approvals are obtained.

The requirement for a DA permit pursuant to Section 404 of the Clean Water Act will also require a Section 401 Water Quality Certification to be issued by the State Department of Health.

1.6.3 Applicable Federal Laws, Regulations and Executive Orders

The approvals and consultations that will be needed from Federal agencies other than the Corps of Engineers include the:

Archaeological and Historic Preservation Act (16 U.S.C. § 469a-1);

National Historic Preservation Act (NHPA) of 1966 (16 U.S.C. § 470(f));

Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 (25 USC §3001);

Clean Air Act (42 U.S.C. § 7506(C));

Coastal Zone Management Act (16 U.S.C. § 1456(C) (1));

Endangered Species Act (16 U.S.C. 1536(A) (2) and (4));

Fish and Wildlife Coordination Act (FWCA) of 1934, as amended (16 USC §§661-666[C] et seq.);

Magnuson-Stevens Fishery Conservation and Management Act (16 USC §1801 ET SEQ.);

Marine Mammal Protection Act (MMPA) of 1972, as amended (16 USC §§1361-1421(H) et seq.);

EO 13089, Coral Reef Protection (63 FR 32701).

1.6.4 1928 Beach Agreement

The 1928 Beach Agreement illustrated the need to control and limit seaward development on Waikiki Beach. The agreement establishes limitations on construction along the beach in response to the proliferation of seawalls and groins in Waikiki. The agreement provides that the Territory would build a beach seaward from the existing high water mark and that title of the newly created beach would be vested by the abutting landowner. The Territory further agreed that it would not build any new structures on the beach in Waikiki. The private landowners agreed they would allow a 75 foot wide public easement along the beach measured from the new mean high water mark. The agreement covers the Waikiki beach area including the area from the Ala Wai to the Elks Club at Diamond Head. The 1928 agreement consists of a) the October 19, 1928 main agreement between the Territory and Waikiki landowners, b) the October 19, 1928 main agreement between the Territory and the Estate of Bernice Pauahi Bishop, and c) The July 5, 1929 Supplemental Agreement between the Territory and Waikiki landowners. The segment between the Royal Hawaiian Hotel and the Moana Surfrider is the subject of a separate agreement between the Territory and the subject Waikiki landowners entered into on May 28, 1965.

1.7 Decision to be Made

The Army Corps of Engineers, Honolulu District, the State of Hawaii accepting agency the Department of Land and Natural Resources, and the State Department of Health will review the analyses and conclusions drawn in this EA and decide whether to issue the necessary permits and approvals that the applicant has requested, to issue the permits and approvals with special conditions, or to deny the permits and approvals.

2. DETAILED DESCRIPTION OF THE PROPOSED ACTION

2.1 Beach Maintenance Sand Source

2.1.1 Required Sand Characteristics and Quality

The State Department of Land and Natural Resources (DLNR) beach nourishment guidelines specify that fill sand used to nourish a beach must meet several specific requirements:

- The sand shall contain no more than six percent silt material (sand grain size smaller than 0.074 mm).
- The sand shall contain no more than ten percent coarse material (sand grain size greater than 4.76 mm).
- The grain size distribution will fall within 20% of the existing beach grain size distribution.
- The overfill ratio of the fill sand to existing sand shall not exceed 1.5.
- The sand will be free of contaminants such as silt, clay, sludge, organic matter, turbidity, grease, pollutants, and others.
- The sand will be primarily composed of naturally occurring carbonate beach or dune sand.

The majority of the current fill sand requirements are related to grain size. In order to ascertain the grain size characteristics, a sieve analysis is performed, which is done by mechanically shaking a sand sample through a series of sieves of decreasing screen size. The material captured on each sieve is weighed, and this establishes the grain size distribution curves. The median diameter (grain diameter that is finer than 50% of the sample), or D_{50}, is often used by engineers to quantify the grain size of a sample. Similarly, D_{16} and D_{84} are obtained, and they are used to quantify the range of grain sizes present in a sample known as sorting, σ, defined by:

$$\sigma = \frac{\phi_{84} - \phi_{16}}{2}$$

where ϕ = $-\log_2$ (D in mm). Descriptive sorting values are presented in Table 2-1.

Table 2-1 Sorting value descriptions

Sorting Range	Description
0.00 – 0.35 Φ	very well sorted
0.35 – 0.50 Φ	well sorted
0.50 – 0.71Φ	moderately well sorted
0.71 – 1.00 Φ	moderately sorted
1.00 – 2.00 Φ	poorly sorted
2.00 – 4.00 Φ	very poorly sorted
4.00 – ∞ Φ	extremely poorly sorted

Color and abrasion resistance are also important characteristics of fill sand. While natural calcareous beaches range in color from light brown to white, sand in offshore deposits usually turns a gray color as a result of anaerobic conditions typically produced by a lack of sand movement and associated mixing. Even though an offshore sand source may be suitable in terms of grain size characteristics, a gray color can be undesirable. Past offshore sand recovery work in this area revealed a slight grey color that lightened after exposure to air and sunlight.

2.1.2 Existing Sand Characteristics

There is very little, if any, "native" beach sand along Waikiki Beach. Sand characteristics vary widely, primarily a result of differing sand sources used in numerous nourishment projects since the early 1900's. Some of the sources were from the same littoral cell, and some were from elsewhere. For example, in 1929, sand was pumped from a "reef flat" through the Halekulani Channel for beach fill at the Halekulani Hotel, while in 1938, 7,000 cubic yards of fill was placed on Kuhio Beach from "another part of Oahu." In 1960, pulverized coral was placed on the beach at Fort DeRussy. The resulting fill was described as "more like an airfield than a beach" (Wiegel, 2002).

In September 2009, Sea Engineering (SEI) obtained a set of beach sand samples along the project shoreline and in the offshore deposits. Samples were obtained from the beach faces in front of the Royal Hawaiian, the Outrigger Waikiki, and the Moana Surfrider hotels, as well the beach between the Moana Surfrider and Kuhio Beach Park (opposite the Hyatt Regency). Sample locations are shown in Figure 2-1. Grain size analyses were performed for each sample and the sediment characteristics are presented in Table 2-2, which shows the median diameter and sorting of the samples, and Figure 2-2 which presents the grain size distributions.

Table 2-2 shows the four beach samples to be well or moderately well sorted; additionally, none of the material is finer than 0.074 mm, which is the size limit between sand and silt. The sand near the two stub groins adjacent to Kuhio Beach Park was notably coarser (D_{50} = 0.80 mm) than along the rest of the project reach, where D_{50} ranged from 0.29 mm to 0.40 mm. The reason for this pocket of coarser material is unknown and is believed to be an anomaly confined to this specific location. For comparative purposes, the beach is characterized by the other three samples, which were used to produce the composite distribution shown in Figure 2-2.

2.1.3 Offshore Calcareous Sand Source Investigations

Offshore deposits present an alternative source of sand. These deposits can be dredged and pumped or transported to shore. Offshore sand deposits can present a suitable, cost-effective source of sand for beach fill and nourishment, particularly when considering the limited availability of suitable, natural sand from onshore sources. Offshore sand deposits occurring within the same littoral cell can often have grain size characteristics and composition that are very similar to the adjacent beach sand.

Jet probing is conducted to determine the thickness of sediments overlying consolidated or hard bottom substrate, and is therefore an important means of testing and verifying subbottom profiling accomplished by remote sensing equipment. The jet probe consists of a length of pipe

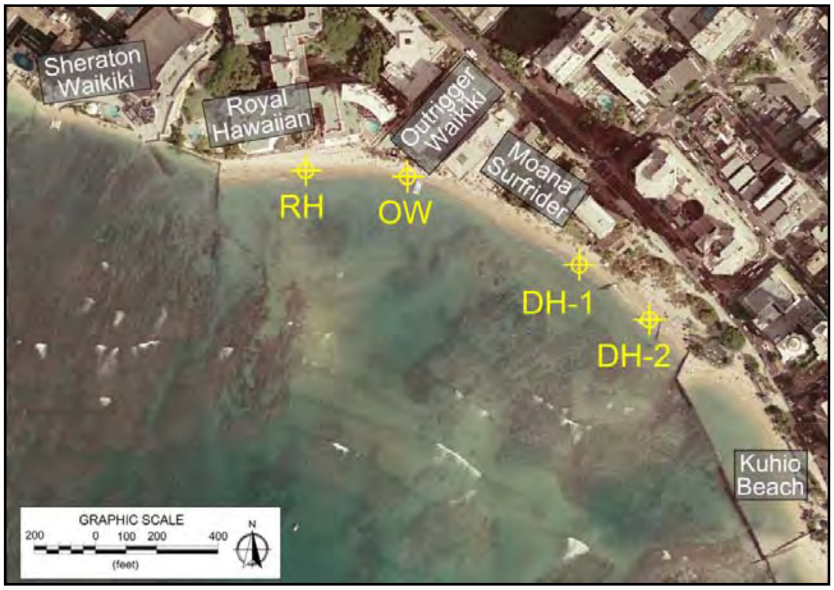

Figure 2-1 Beach sand sample locations (yellow)

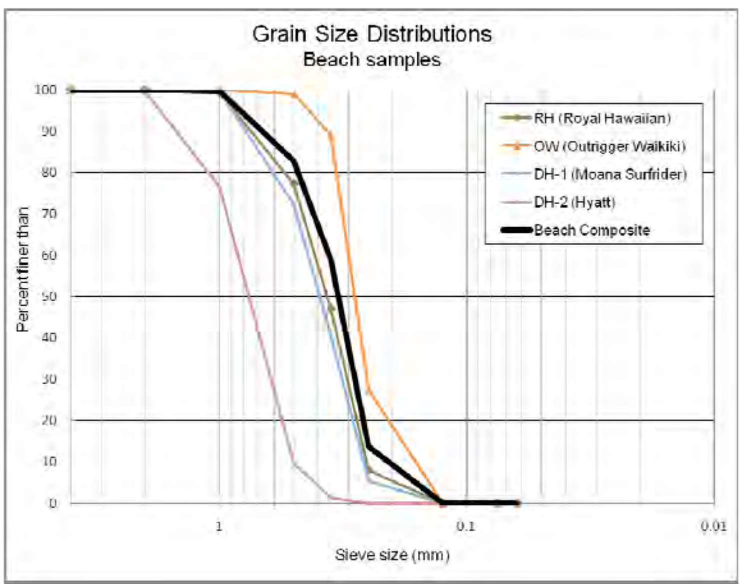

Figure 2-2 Sand grain distribution, beach samples

Table 2-2 Sediment size characteristics, beach samples

Location	D_{50} (mm)	Sorting (ϕ)	% Fine
RH (Royal Hawaiian)	0.37	0.70	0
OW (Outrigger Waikiki)	0.29	0.38	0
DH-1 (Moana Surfrider)	0.40	0.61	0
DH-2 (Hyatt Regency)	0.80	0.64	0

connected to a water pump by flexible hose. A diver jets the pipe and hose vertically into the sediment deposit until "refusal" is encountered. The refusal can be described as hard, crunchy, or soft; hard indicates a solid bottom, crunchy indicates a gravel layer, and soft indicates that the hole is collapsing and seizing the pipe or that there is insufficient hose to penetrate further.

The University of Hawaii Coastal Geology Group (CGG) performed extensive jet probing of sand deposits offshore of Waikiki in 2005. The 406 probe locations are shown in Figure 2-3 indicated by white markers. Sand thicknesses were measured to the depth where the probe encountered hard refusal or rubble. Sand thicknesses as great as 9 feet, though unusual, were measured. The probe data was used to produce estimates of sand volume for three sand deposits shown by the white lines in the figure. Based on the jet probe data, the CGG estimated these three sand deposits to contain 86,000 cubic yards of sand.

Figure 2-3 UH-CGG Jet probe locations

A field program was conducted in August and September of 2009 to verify the findings of the CGG data and estimate the amount of sand that is presently available in offshore deposits. Using aerial photography and a side-scan survey performed by the CGG as guides, geophysical investigations were performed on the offshore deposits using sub-bottom profiling and jet probes. The surveys were performed within practical limits for sand recovery, including water depth and proximity to shore.

Geophysical sub-bottom profiling systems are essentially echo-sounders that use lower acoustic frequencies to penetrate into the substrate. Where common echo-sounders may use an acoustic frequency in the vicinity of 200 kHz, sub-bottom system frequencies are typically between 500 Hz and 20 kHz. The term sub-bottom refers to a generally hard layer of sediment or rock that underlies recent soft sediment deposition. The lower the acoustic frequency, the deeper into the bottom the system can penetrate.

For this survey, an EdgeTech 0512i "chirp" sub-bottom profiler was used with an EdgeTech 3200XS processing system. The chirp processors use signal processing to shape the acoustic wavelets used to image the substrate, providing significantly greater image resolution than traditional impulsive systems such as boomers and sparkers. Different wavelets are available with the system for use in different terrains. After on-site system deployment, trial survey lines were conducted using various pulse configurations. The optimal pulse for the substrate in Waikiki was found to be a 20 ms pulse with a frequency range of 500 Hz to 7 kHz. This relatively low frequency range is necessary for penetration into the coralline limestone sands and gravels found in Hawaii. The EdgeTech 0512i system is in fact a specialty system for use in coarse sand environments.

Sub-bottom tracklines from the August 2009 sub-bottom survey are shown as the white and red lines in Figure 2-4. The sub-bottom data was reviewed with EdgeTech software, sub-bottom horizons were digitized for processing, and sand thicknesses were measured at discrete locations along the tracklines. The red lines shown in the figure are portions of four tracklines where sand was identified. These are not the only locations where sand was found; rather, these are examples shown to illustrate findings of the sub-bottom profiling. The sand thicknesses along the four red tracks, referred to as W-1 through W-4, are shown in Figure 2-5. For ease of visual comparison, the figures have the same vertical scale. In August and September of 2009, Sea Engineering revisited the sites using jet probing to verify the sand thicknesses identified by the sub-bottom profiling. Those investigations, shown as red markers in Figure 2-4, found sand thicknesses as great as 7 feet. Sand thicknesses measured using jet probing along tracklines W-3 and W-4 were compared with the results of the sub-bottom profiling. Table 2-2 shows a comparison of the findings; the jet probe data is also shown in Figure 2-5 where the jet probes were coincident with the sub-bottom tracklines.

Figure 2-5 shows lines W-2, W-3, and W-4 to have consistent deposits of sand greater than three feet thick and more than 300 feet wide. Portions of profiles W-1 and W-3 show great variability along the line, indicating that there is an irregular limestone layer beneath the sand. The jet probes show good correlation with the results of the sub-bottom profiling.

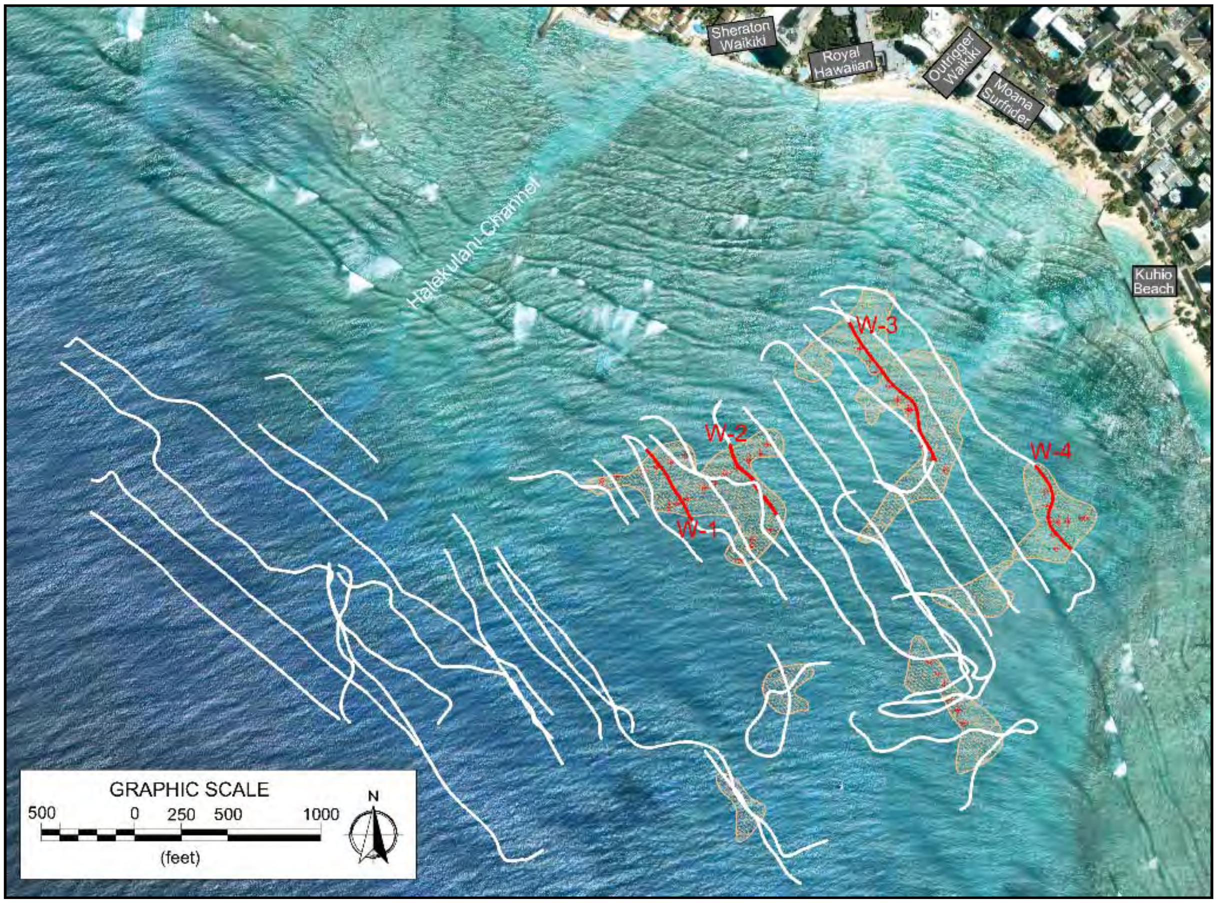

Figure 2-4 Sub-bottom tracklines (white and red lines), jet probe locations (red points), and visible sand deposits (tan outline and fill)

Table 2-3 Comparison of sand thicknesses (feet)

Trackline W-3		Trackline W-4	
Sub-bottom	Jet probe	Sub-bottom	Jet probe
5.2	6.5	4.6	5.5
5.9	7.5	3.6	4.0
6.2	7.0	3.0	4.0
2.0	3.0	4.3	5.0
2.3	2.0	3.9	4.0
2.6	2.0		

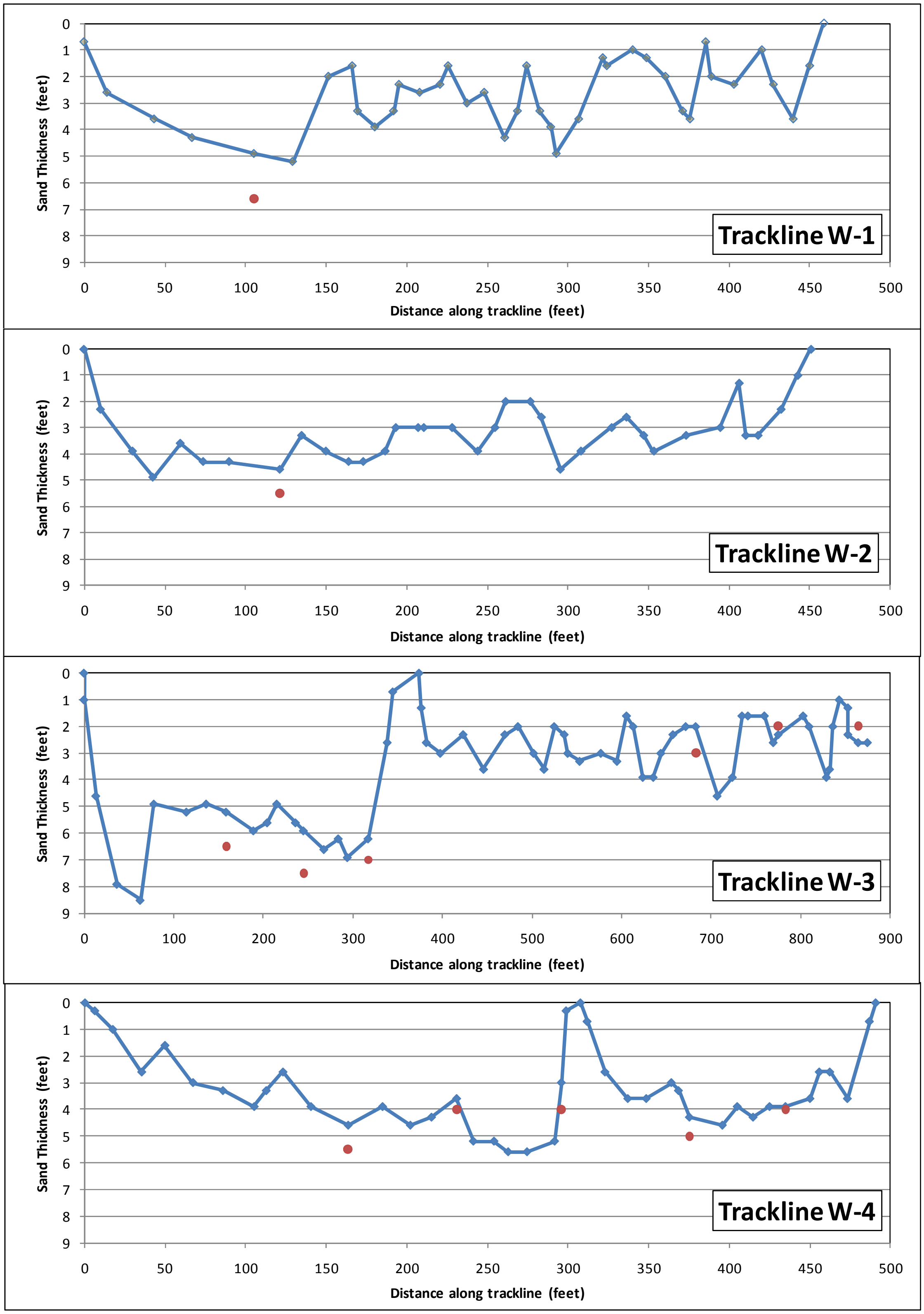

Figure 2-5 Sand thicknesses measured by sub-bottom profiler (blue) and jet probes (red). (Note: tracklines begin in the northwest and progress toward the southeast).

2.1.4 Selected Sand Deposits

Several sand deposits have been identified and quantified based on the sub-bottom profiling and jet probing; these deposits are shown as shaded regions in Figure 2-6. The figure also shows the location of offshore sand samples obtained in September of 2009. The sand samples were obtained with a mechanical push-core device that penetrated as far as three feet into the sand, producing a core of sand in an acrylic tube. Samples were obtained in six locations, and in four of those, the cores were divided into "top" and "bottom" samples. Table 2-4 shows the sand samples to have median diameter D_{50} ranging from 0.24 mm to 0.46 mm, and with the exception of "Waik 4 (bot)," the samples are classified as moderately well to well sorted. A composite grain size distribution was produced and is shown in Figure 2-7.

Figure 2-6 Location of Waikiki sand deposits

Table 2-4 Sediment characteristics, ocean samples

Location	D_{50} (mm)	Sorting (ϕ)	% Fine
Waik 1 (top)	0.46	0.57	0
Waik 1 (bot)	0.42	0.51	0
Waik 2	0.42	0.33	0
Waik 3	0.24	0.68	0
Waik 4 (top)	0.26	0.67	0
Waik 4 (bot)	0.34	1.15	0.4
Waik 5 (top)	0.38	0.38	0
Waik 5 (bot)	0.36	0.60	0
Waik 6 (top)	0.29	0.59	0
Waik 6 (bot)	0.33	0.46	0

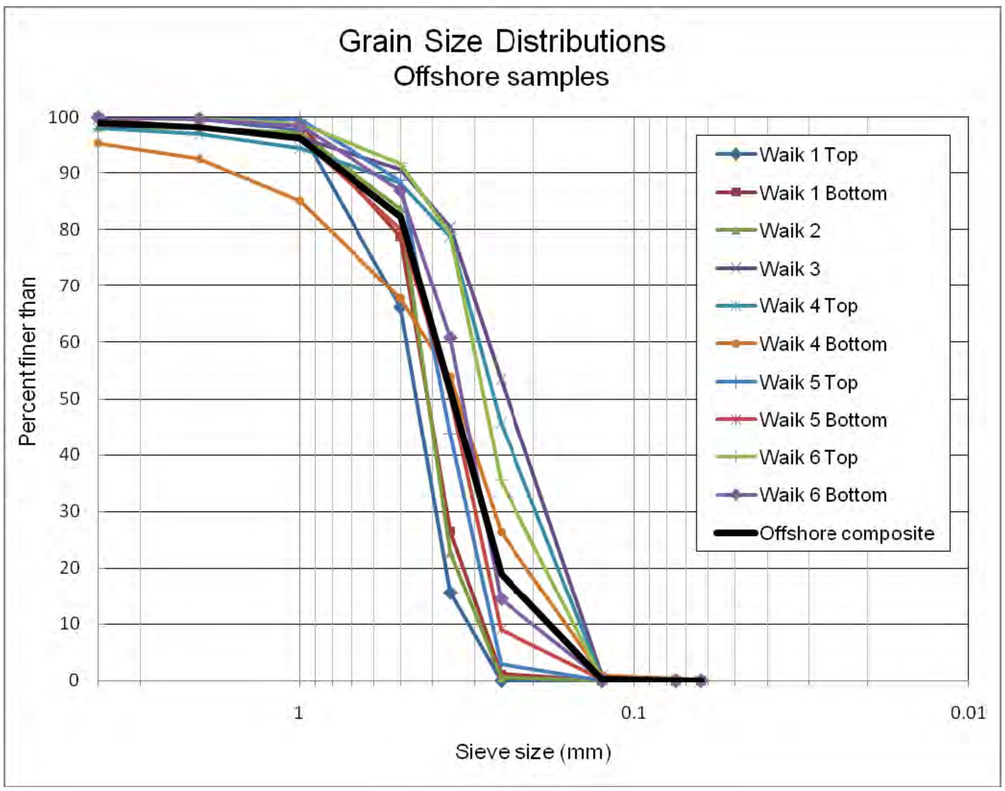

Figure 2-7 Grain size distributions, offshore samples

2.1.5 Comparison of Native and Borrow Sand

The composite beach sand distribution presented in Section 2.1.2 shows a median diameter of 0.34 mm. The composite distribution is shown in Figure 2-8, along with lines marking the +/- 20% grain size requirements presented in Section 2.1.1. The offshore composite distribution, also shown in Figure 2-8, has a median diameter D_{50} of 0.35 mm and falls very near the beach composite, well within the +/- 20% requirement. The offshore sand samples also have no coarse material and minimal fines.

In summary, the offshore borrow sand has the same characteristics as the existing native beach sand – the same grain size distribution, the same texture, a similar color – which is to be expected as the beach is the source of much of the offshore sand.

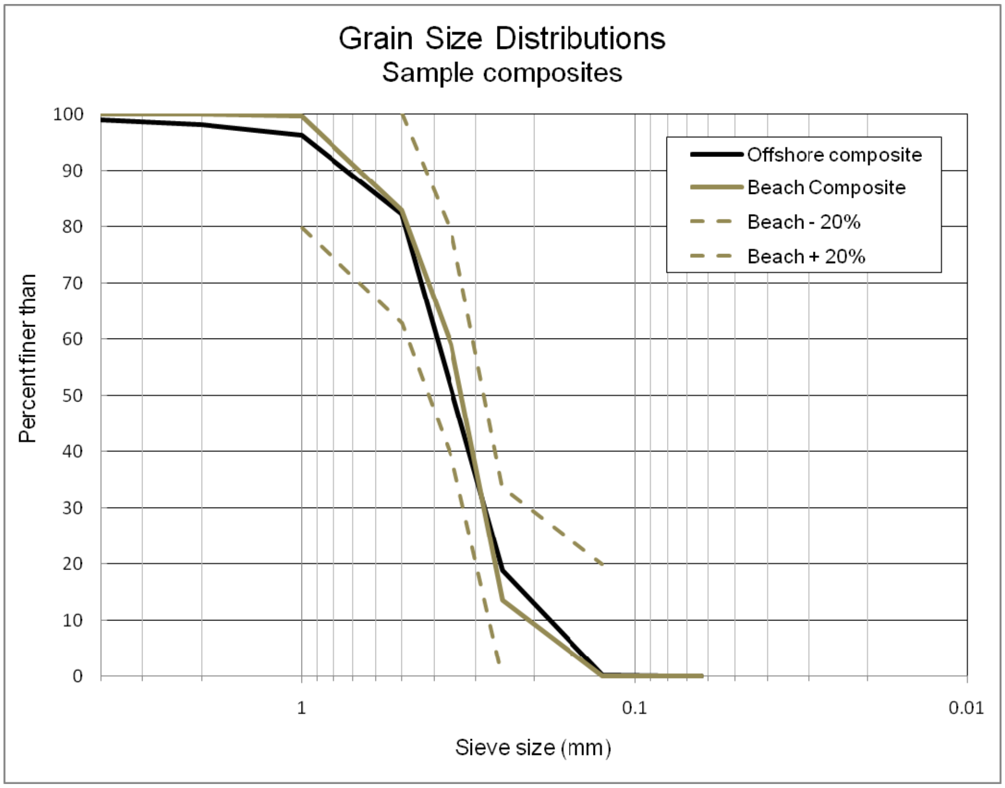

Figure 2-8 Grain size distributions, sample composites

2.1.6 Overfill Factor

A beach undergoes an adjustment period following nourishment. The beach equilibrium profile is achieved as sand moves cross shore and alongshore and there may be an accompanying decrease in beach volume. This loss of sand is compensated for through an overfill ratio, which describes the compatibility of the native beach and borrow sands and is dependent on the size distributions of the native and nourishment (borrow) sand.

The overfill ratio is determined based on the sand size characteristics of the two sands and represents the volume of fill necessary to yield the desired beach volumes calculated previously. Bodge (2004) compared overfill ratio methods and developed an expression that is believed to produce more accurate results than the previous methods.

The mean grain size, M, and sorting, σ, for the native and borrow sands are calculated as presented in the Coastal Engineering Manual (2006) as

$$M = \frac{(\phi_{16} + \phi_{50} + \phi_{84})}{3}$$

$$\sigma = \frac{(\phi_{84} - \phi_{16})}{4} + \frac{(\phi_{95} - \phi_{5})}{6}$$

The dimensionless grain size difference is calculated as

$$M_b' - M_n' = \frac{M_b - M_n}{\sigma_b}$$

where subscripts *n* and *b* refer to the native and borrow sand, and the overfill ratio is read from Figure 2-9.

The composite grain size distributions for the offshore sand ("borrow") and the beach sand ("native") were shown previously in Figure 2-8. The mean diameter M_b for the composite offshore sand is 1.49φ with a sorting σ_b of 0.75φ, while the mean diameter of the native beach sand M_n is found to be 1.51φ. These values produce a dimensionless grain size difference of -0.02, which is used along with Figure 2-9 to yield an overfill ratio of K = 1. An overfill ratio of 1.0 indicates that the native and borrow sand have the same grain size distribution, i.e. the borrow sand is not finer in size than the native beach sand, thus no significant loss of finer material is expected to rapidly occur after sand placement, and thus no over filling is necessary in order to achieve the desired increase in beach size.

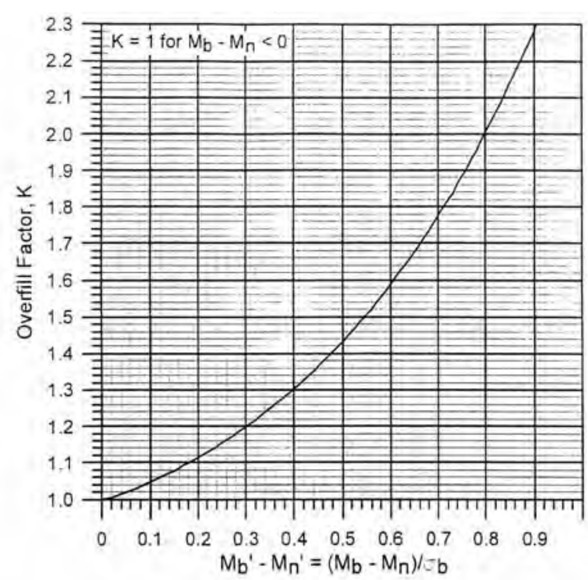

Figure 2-9 Dean's overfill ratio expressed as a single curve (Bodge, 2004).

2.2 Beach Maintenance Plan

2.2.1 Introduction

The beach maintenance plan is highly dependent on the volume of sand which can be recovered from the offshore deposits. While the sand source investigations indicate nearly 70,000 cy of sand are contained in areas A and B (see Figure 2-6), the sand thicknesses vary considerably, with a significant portion of the deposits being 1 to 3 feet thick, and the underlying reef platform is very irregular with high relief (see Figure 2-5). Thus, the volume of sand which can reasonably be expected to be recoverable using standard dredging equipment is likely significantly less than the total volume. As a general project objective it is desired to approximately double the beach width at the more narrow portions of the project area, e.g., fronting the Diamond Head Tower of the Moana Surfrider, and to restore the beach to a recent historical condition, i.e., the 1982 shoreline location.

2.2.2 Design Beach Shape and Volume

The proposed beach restoration layout and typical cross-section are shown on Figure 2-10. Assuming a 1V:7.5H beach slope, and a crest elevation of +6.5 feet and a toe at -3.5 feet, the required sand volume would be 24,000 cy. The beach slope and crest elevation is assumed to quickly reach an equilibrium shape similar to the existing beach.

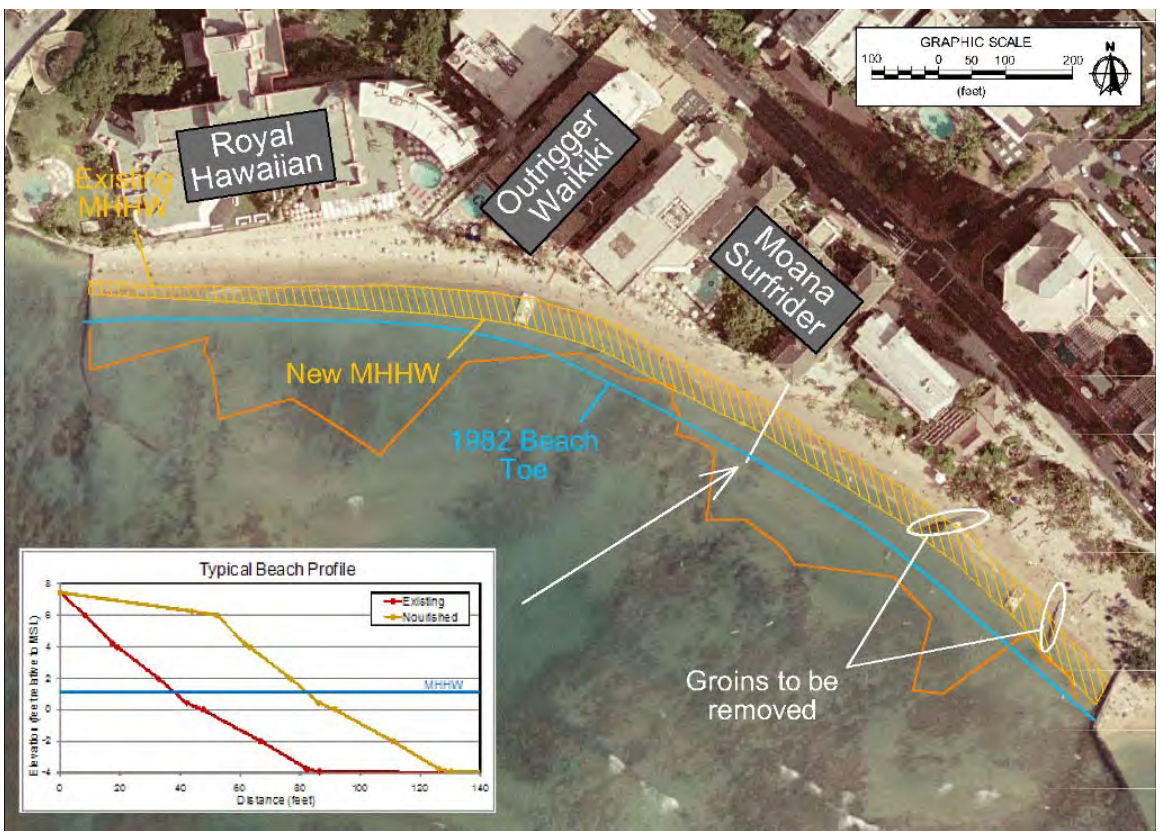

Figure 2-10 Beach Restoration layout and typical cross-section

2.2.3 Renourishment Interval

Given the project site's exposure to constant wave action, and its history of erosion, beach nourishment without stabilizing structures will not be a permanent improvement. While the groins at the ends of the project shoreline appear to prevent longshore transport out of the littoral cell, and the beach may sometimes show accretion seasonally, the net transport is considered to be primarily in the offshore direction. The average annual erosion rate in the project area has been about 2.3 feet per year (see Section 3.1.5.3). This equates to an estimated average annual loss of 1,400 cy. Thus, in approximately 10 years, a little more than half the nourishment sand will be lost and the beach will have receded to about half its desired width increase. The proposed maintenance plan includes re-nourishment after 10 years in order to maintain the desired beach width. Following the 2006 nourishment of Kuhio Beach, it was noted that the sand deposit rapidly returned to nearly its pre-dredging condition (i.e., the dredge depression filled in). In fact, an unseasonal south swell event occurred mid-way through the dredging, filling in the pit in the bottom that the dredging was creating, and permitting the dredge contractor to continue to recover sand from the same location and not have to move his equipment to continue sand recovery. Thus it can reasonably be expected that re-nourishment sand can periodically be obtained from the same offshore sand deposit.

2.3 Dredging System and Transport to Shore

Sand for this project will be obtained from deposits offshore of the project site as previously discussed. A number of options for recovery of this offshore sand exist. Each method has inherent strengths, limitations, and ranges of applicability. The three most common forms of dredging used in Hawaii include submersible slurry pumps operating from a barge or boat, self-contained hydraulic suction dredges, and crane with clamshell bucket operating from a barge.

2.3.1 Submersible Slurry Pump

Submersible slurry pumps, referred to as "Toyo Pumps" after the largest supplier of such, are distinguishable by the way that they are lowered from overhead and suspended above the seafloor. The pumps can be hydraulically or electrically driven, and are available in a range of sizes. Models are available with power ratings of up to 400 hp. A Toyo DP75B (75 hp) hydraulic pump was used successfully in the 2006 Kuhio Beach restoration project, where approximately 10,000 cubic yards of sand were pumped from offshore onto the beach within the crib walls.

Several equipment elements are required to successfully recover sand utilizing a submersible pump. A barge and crane are necessary to position the pump, which can be powered by hydraulics or an electric generator. The crane can move the pump across a small area, dependent on the crane size and length of its boom; however, beyond that area the barge must be entirely repositioned. The positioning of the barge would normally be controlled by a combination of moorings and spuds (vertical piles dropped down onto/into the seafloor). Additionally, depending on the distance from shore and the size of the pump, a booster pump may be required. The pipeline and hydraulic or electric lines are attached to the pump and must be maneuvered with each repositioning. An additional piece of equipment called a "jet ring" can be mounted on the pump to aid in entraining sand and increasing the proportion of sand in the slurry. This jet ring requires a water pump on deck and an additional 4-inch hose connected to the submersible pump. An illustration of this dredge system is shown on Figure 2-11 and Figure 2-12, taken from the Kuhio Beach project after-action report (American Marine, 2007).

The benefit of the submersible pump is its precise positioning and ability to reach into tight spaces. Using a crane-tip GPS unit to locate the pump, the operator can accurately position the pump to within a few feet of any location to effectively remove the sand from near the edge of the reef. Since many of the near-shore sand deposits off Waikiki are relatively small in area and bordered by hard reef-rock bottom, a smaller more precise methodology like the submersible pump is beneficial. American Marine (2007) reported consistent dredging volumes of 400 to 800 cy per day.

The primary drawback to the submersible pump is that it is labor intensive. It requires a crane operator and rigger, someone to maneuver the barge, and several people to handle the pumps, generators, and pipelines on deck. Additionally, the pump must be held at a relatively constant height above the seafloor. If the pump is lifted too high it will not entrain the sand, and if it is too low the slurry will become too concentrated and the pipeline will clog. Maintaining this balance is especially difficult for the crane operator in the presence of swells greater than one to two feet. However, the dredge equipment can be operated from an ocean-going barge, which provides reasonable seaworthiness. Given the relative success of this dredging methodology in the past it is considered to be the likely method to be employed for this project. However, construction bidders will be allowed to propose alternative methods, such as discussed in the next sections, provided they are in compliance with the project plans and specifications.

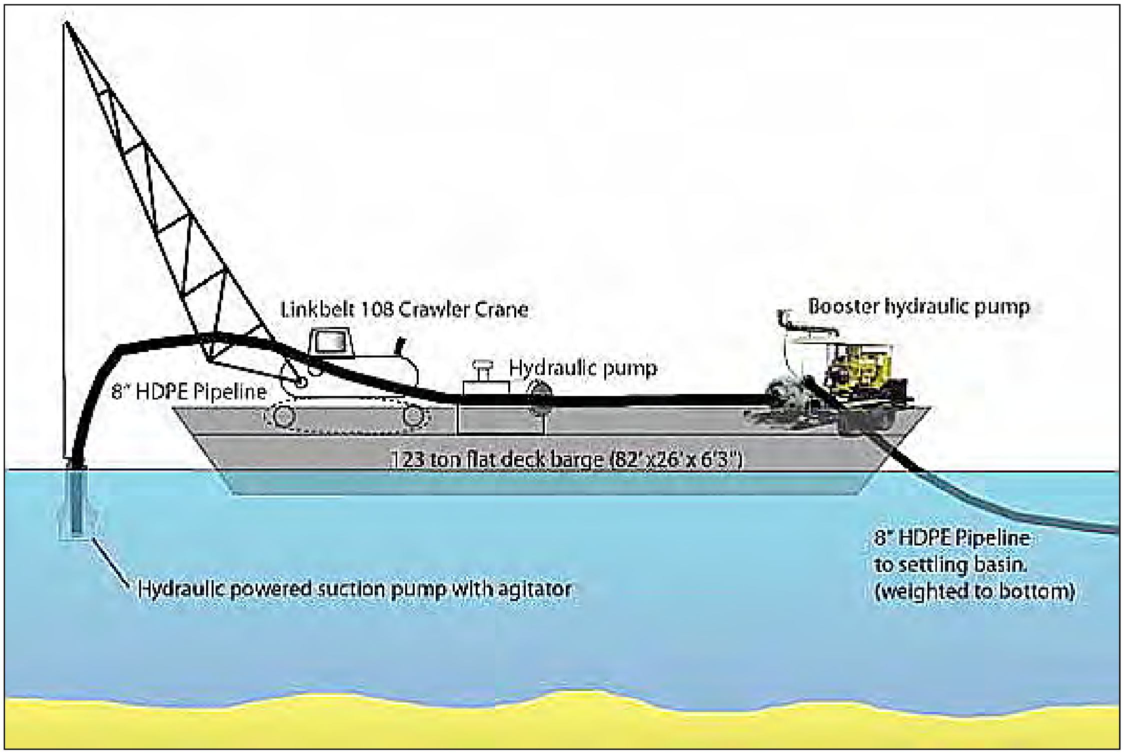

Figure 2-11 Schematic of sand pumping arrangement (American Marine, 2007)

Figure 2-12 American Service at the extraction site (American Marine, 2007)

2.3.2 Hydraulic Suction Dredge

The dredging alternative to a Toyo pump is a hydraulic suction dredge. A hydraulic dredge is a more traditional dredging technology that has been shown to be effective in beach nourishment. It is functionally similar to a submersible pump, except that in this case the pump is above water on a surface platform (e.g., a boat or barge), and a rigid suction pipe is lowered from the surface platform down to the seafloor. Dredged material is typically discharged through a pipeline to shore. Hydraulic dredges come in a wide range of sizes, from large ocean-going dredges for maintaining commercial ports and waterways, to small trailerable units used for lake and reservoir clearing or small marina maintenance. However, they all have the same basic components: a pump mounted on a boat or barge, a rigid suction pipe which can be lowered to the seafloor and a pipeline to shore for discharging the dredged material. A mechanical cutter head can be attached to the front of the suction head to loosen and stir up the sand for more efficient pickup by the suction head. A small hydraulic suction dredge (Mud Cat) was used in a small-scale sand pumping demonstration project conducted by the State of Hawaii Department of Land and Natural Resources in February 2000 (Noda, 2000). Approximately 1,400 cubic yards of sand was dredged from a deposit 1,500 feet offshore of Kuhio Beach, and pumped to a de-watering pit excavated into the dry beach area within the east crib wall basin. Some problems were encountered during the 2000 dredging project, primarily associated with difficulty keeping the dredge head on the bottom due to wave action which made pumping rates inefficient, and positioning/maneuvering difficulty around the sand recovery site. Recently, a small suction dredge (IMS Model 7012HP Versi-Dredge, see Figure 2-13) was used by Haseko (Hawaii) Inc. to remove fine sediment from the under-construction Ocean Point Marina at Ewa Beach, Oahu. The Versi-Dredge is self-propelled by paddle wheels at the stern, and these paddles can also be lowered to the sea floor on a ladder frame so the dredge can push itself along.

There are several disadvantages to the hydraulic suction dredge. The first is that its dredge depth capability is limited to the length of the suction head pipe, typically about 25 to 30 feet for smaller dredges. (Note – the proposed sand deposits to be dredged are in 10 to 20 feet of water.) A second disadvantage is the mobilization cost to bring in a dredge from the mainland, and this cost increases exponentially with dredge size. The Haseko Versi-Dredge, however, is reportedly still on-island. As with the Toyo pump dredge system, calm sea conditions are required to operate a small suction dredge. They are typically not designed as ocean going vessels, and provisions would have to be in place to secure the dredge should the surf come up.

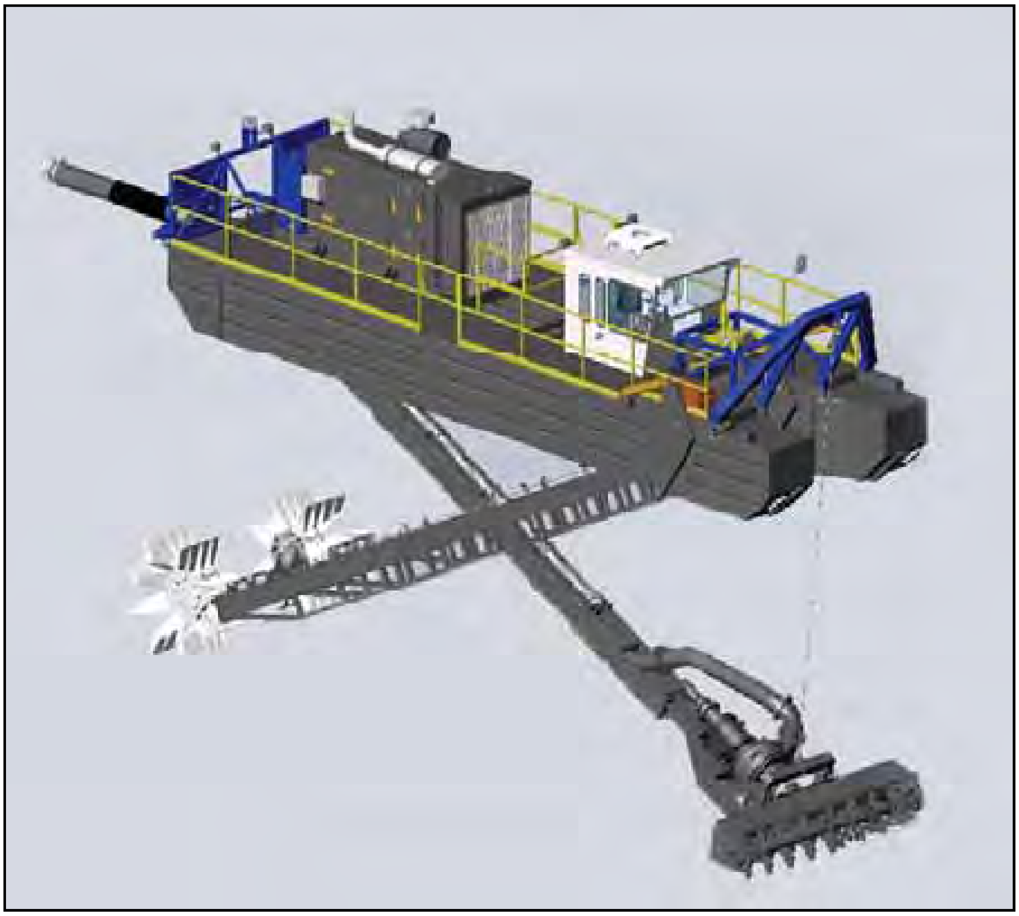

Figure 2-13 IMS 7012HP Versi-Dredge

2.3.3 Clamshell Dredging

Clamshell dredging describes the process of mechanically scooping and lifting the sediment, in this case sand, from the seafloor. The clamshell bucket is lowered with a crane in the open position, upon reaching the bottom, the crane operator closes the clamshell jaws and lifts the material out of the water, and finally the operator rotates the crane and opens the bucket over a waiting barge. Bucket sizes vary from as small as 1 cy to over 20 cy. Buckets are either sealed or open. A sealed bucket creates less turbidity at the dredge site; however, the recovered sand will include a large amount of water which then must be disposed of. A clamshell dredge is illustrated in Figure 2-14.

Figure 2-14 Clamshell dredging

Clamshell dredging is often used in association with a large barge on which the sediment is deposited. Once the sediment is deposited, transport is usually accomplished by moving the barge to a dock, which would likely have to be at Kalaeloa (Barber's Point) Harbor with subsequent transfer to land-based equipment for trucking back to Waikiki. This method would result in an involved and circuitous delivery to the project site,and the equipment size is restricted by the water depth at the sand recovery site, and thus it is not considered a viable alternative.

2.3.4 Pipeline Route and Anchoring System

Figure 2-15 depicts the proposed pipeline route. From the sand recovery vessel, the pipeline will be a combination of floating pipe in the vicinity of the sand source and dredge equipment to permit dredge mobility, and then submerged pipeline to shore. The submerged pipeline will be anchored in place to eliminate pipe dislocation and minimize impacts to the seafloor. The submerged pipeline will be placed upon sandy seafloor to the extent that it is practicable, in order to minimize damage to hard rock bottom habitat. As the pipeline nears shore, it will turn east and terminate at a dewatering area within the eastern Kuhio Beach crib. This is similar to the 2006 pipeline route which encountered no significant problems or conflicts with recreational activities.

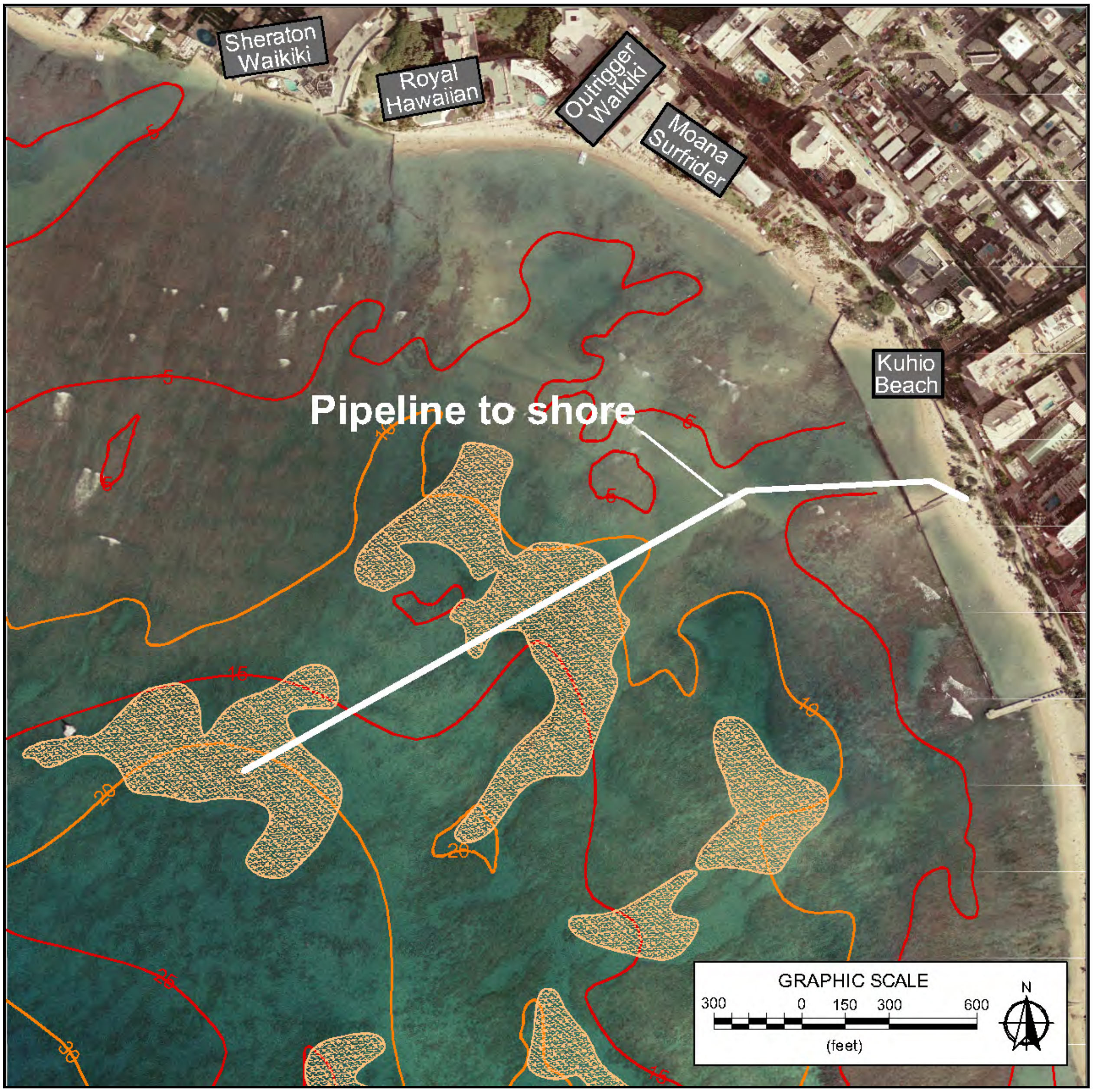

Figure 2-15 Pipeline route from sand deposits to shore

A number of options exist for anchoring the HDPE pipe onto the seafloor, depending on the composition of the bottom. Where the seafloor consists of a thick layer of sand, two commonly utilized anchors include helical screw piles and earth toggle anchors.

Helical screw piles are literally "screwed" into sediment, utilizing a rotary impact tool such as a pneumatic or hydraulic hammer drill.

Earth toggle anchors are driven into sediment using conventional pneumatic or hydraulic equipment such as a jackhammer. Once the specified depth is achieved, an attached tendon is pulled to rotate the anchor into place. Once the anchor fluke is in place, the anchor is pulled to set it at the desired holding capacity.

Shoreward of the sand recovery area, the bottom consists of a thin veneer of sand, cobbles, or hard substrate. In these areas, penetrating anchors such as helical screw piles and earth toggle anchors are not advised, and the use of precast concrete collar weights or pipe saddles is recommended.

Precast concrete collar anchors are made in half-circles, and are bolted together with stainless steel bolts. Pipelines using this type of anchor are typically assembled on land or at least out of the water, floated into position, and then sunk.

The contractor who bids on this project will ultimately determine the type of anchor system utilized. It is likely that the pipe anchor system will consist of a combination of anchor types due to the variation of the seafloor along the pipe route. The project construction plans will require that the pipeline be located in a specific, defined corridor along the sea bottom, selected to avoid and minimize potential impacts to benthic biota as far as practicable. The contractor will be required to remove all anchoring materials upon completion of the project.

2.4 Sand Slurry Dewatering

2.4.1 General Method

State of Hawaii Department of Health and U.S. Clean Water Act regulations require that the sand pumped to shore be dewatered at some point between dredging and final placement of the sand to reduce the occurrence of turbidity in the ocean water (i.e. release/suspension of fine sediment which reduces water clarity). Ideally, the dewatering should be accomplished with no direct dredge water flow back to coastal waters. The most common way to dewater a slurry mixture is to discharge it into an enclosed basin on the beach or backshore land, above the high water line, and let the water percolate into the ground. At the project site, however, there are two significant issues with this method – there is almost no undeveloped/unused backshore area where a basin of sufficient size could be constructed, and the backshore ground, below a relatively thin layer of loose sand, is very tightly packed sand and fine sediment through which water simply won't percolate in any reasonable time frame. To get around these obstacles the State's 2006 Kuhio Beach project constructed what was basically a two-stage dewatering system. The dredge slurry was pumped into a sand-bermed dewatering basin within the east crib, where the sand could settle out. This basin, at the opposite end from the slurry input, had an overflow discharge from the basin into the crib water, which was enclosed by a surface to bottom turbidity barrier which retained fine sediments and permitted non-turbid water to finally flow back into the coastal waters. This system reportedly worked adequately, so long as the initial basin berm walls were maintained so as to contain the sand water slurry.

2.4.2 Potential Dewatering Sites

During the 2006 Kuhio Beach nourishment, a 180 foot x 50 foot basin was constructed in this manner on the beach in the east Kuhio basin. This location was satisfactory for the 2006 project, since it was also the site of the nourishment. The present project to nourish Waikiki Beach would benefit from a dewatering site more convenient to distributing the sand in the Ewa direction. Development of a dewatering basin in front of the hotels is not practical, as there is too little area and would cause disruption to hotel operations and inconvenience to beach users. Two potential dewatering sites were initially considered. The first site is located in the open area between the Ewa groin of Kuhio Beach Park and the Moana Surfrider's Diamond Head Tower. However, much of this area is presently occupied by beach concessions, and it provides direct beach and water access from Kalakaua Avenue and is thus heavily used by visitors and residents alike. Use of this area would require temporary relocation of some of the concession activities, and possible removal/replacement of about 12 mature palm trees.

The second site is the Ewa basin of Kuhio Beach Park. A portion of the Ewa end of the basin could be separated to form a dewatering area, walled off by a stable containment berm. This location, however, is immediately adjacent to the Hula Mound, where nightly dance and music programs are held, and construction activities would have a significant impact on this. It is likely that construction work would have to cease each day in order to let the evening show proceed.

Given the issues associated with these two sites, it is recommended that the dewatering activities be primarily conducted within the eastern crib, at the same location as in the 2006 project. A stable containment berm placed inside the makai crib wall sill would be used to provide a stable containment berm on the ocean side, with a minimum elevation of about +5 feet to permit piling sand above sea level. Geotextile filter fabric would be used to line the inside of the dewatering area as necessary to prevent the escape of turbid water. The east end of the dewatering area would be bound by a heavy duty turbidity barrier, which would retain fine material and permit non-turbid water to pass. A secondary silt screen would be placed around the entire dewatering basin to contain any turbid water within the confines of the crib area. As the water drains from the basin, the dewatered sand can be removed and placed in a temporary holding site, and then the basin can be refilled with more sand slurry pumped from offshore. A schematic of the layout is shown in Figure 2-16.

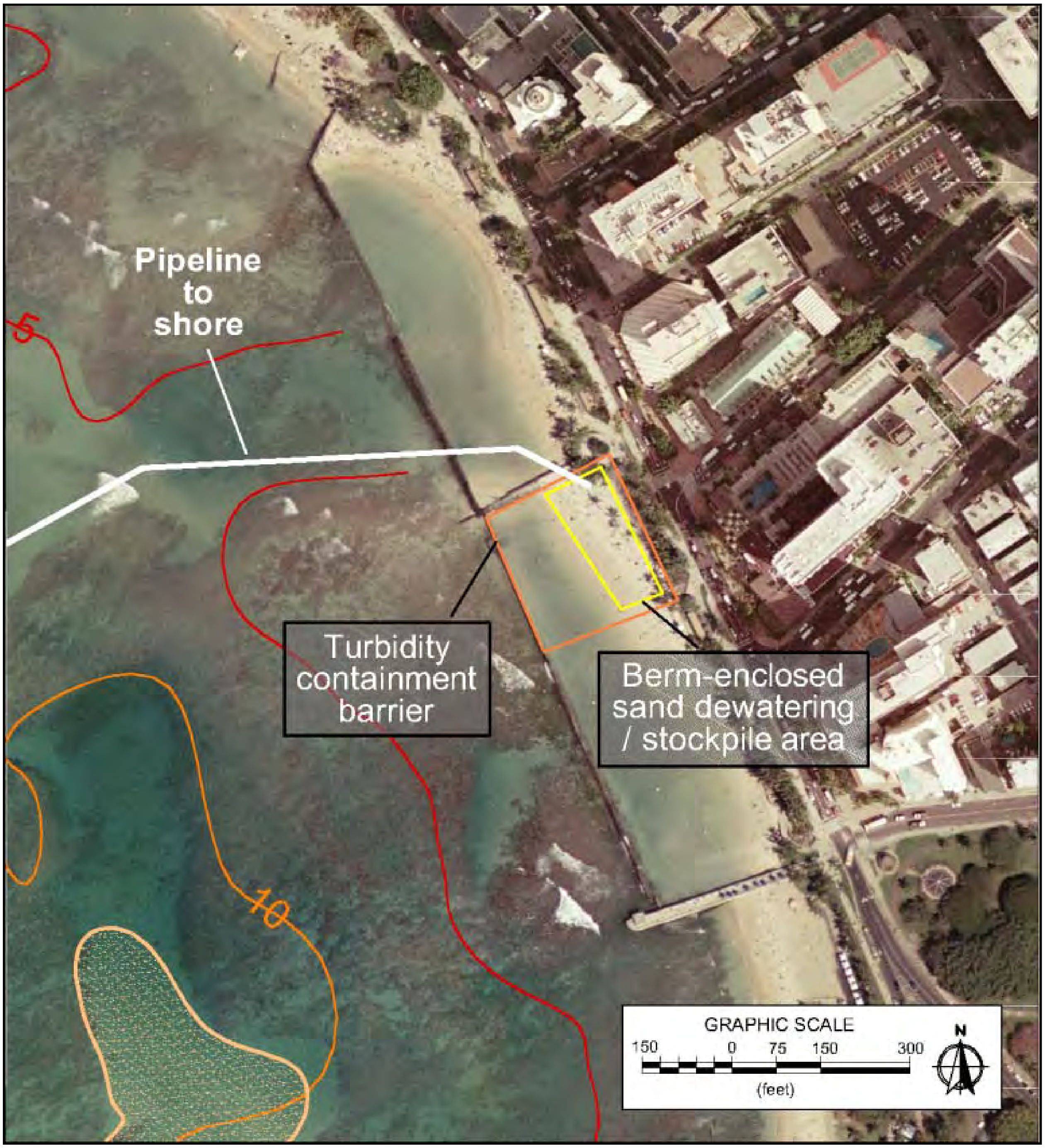

Figure 2-16 Dewatering site layout

2.5 Post-dewatering Sand Placement

Dewatered sand would initially be moved to a temporary above-water staging area along the west crib shore. The sand would then be moved and placed on the project area shoreline to the design cross-section and beach profile, starting at the east end and working west. A containment system/turbidity barrier would surround the area of active sand placement each evening to reduce the potential for turbidity impacts to coastal waters during sand placement in the water, consistent with requirements of the DOH.

Sand movement and placement during the 2006 Kuhio Beach project was accomplished using standard mechanical equipment, a front-end bucket loader and trucks. The same method could be used to accomplish the present project; however, as the sand has to be distributed along 1,700 linear feet of shoreline fronting three large hotels, the operation will be somewhat obtrusive. Some noise and smell from the equipment, and possibly some short-lived odor from the sand, will be unavoidable. The beach width will be increased beginning at the east end, adjacent to the Kuhio Beach dewatering site, thus the project will essentially build a truck travel way as it proceeds from east to west. This methodology would require that sand be primarily moved and placed in late afternoon and early evening when beach activity is reduced.

A new, recently-developed technology involves transport of sand by blowing it through a pipe with low-pressure air. The sand is initially loaded into a hopper at the upstream end of the pipe. A rotation is imparted upon the air/sand flow by the upstream pump. As a result, the sand tends to be centered within the pipe and is surrounded by a boundary layer of air. To date, this technology has not been applied in Hawaii; however, several demonstration projects are being considered at this time. The State of Hawaii and City and County of Honolulu have considered using this system to move sand at Kailua Beach from the stockpile adjacent to Kaelepulu Stream to the east end of the beach at the boat ramp. The Kaanapali Operator's Association is also considering a demonstration project to manage their beach by moving sand along the shore to counter periods of seasonal beach recession due to wave activity. This method of moving sand would eliminate the need for heavy equipment to move the sand and continually travel back and forth the length of the beach. Sand in Waikiki could be "blown" up the shore with the pipe being incrementally lengthened as placement proceeded from east to west. Smaller equipment would be used to move the blown sand into the design beach profile. This is the preferred method for moving and placing the sand. Advantages of this sand placement method include faster more efficient sand movement, elimination of heavy equipment operating on the beach and thus reduced air quality and noise impacts, and less disruption of recreational/commercial beach uses.

2.6 Groin Removal

Two old, deteriorated, remnant groins located at the east end of the project area, in the vicinity of the beach concessions (see Figure 2-10), would be removed prior to placement of the beach nourishment sand. The origin of these groins is unknown, and they appear to have been at least partially constructed of stacked concrete filled sand bags. They are in very poor condition, and are not sufficient in size or location on the beach to have a significant effect on littoral processes, or sand retention or transport. They do, however, present an obstacle for beach users to avoid, and as they would be partially or completely buried by the sand fill, it is considered prudent to remove them and the potential hazard to beach users that they pose.

2.7 Operational Considerations

The shallow depths and the wave environment present a challenge for the dredging contractor. In order to hold the dredge in a relatively stable manner, the operation must occur during low wave conditions. In Waikiki, the ocean is generally calmer in the winter. While high wave events in the winter are possible, they are infrequent and the likelihood of prolonged periods of calm water favorable for dredging is greater. The 2006 Kuhio Beach nourishment project was performed in December, and while the conditions were mostly favorable, there was a work delay due to the occurrence of an unusual south swell event.

WIS wave data for the project site is presented in Section 3.1.3.1. Figure 2-17 presents the monthly frequency of occurrence of southerly waves for the WIS data. The figure shows that the probability of southerly waves is significantly higher in the summer months than in the winter months. Thus ideally the in-water work should be accomplished during the December - March time frame.

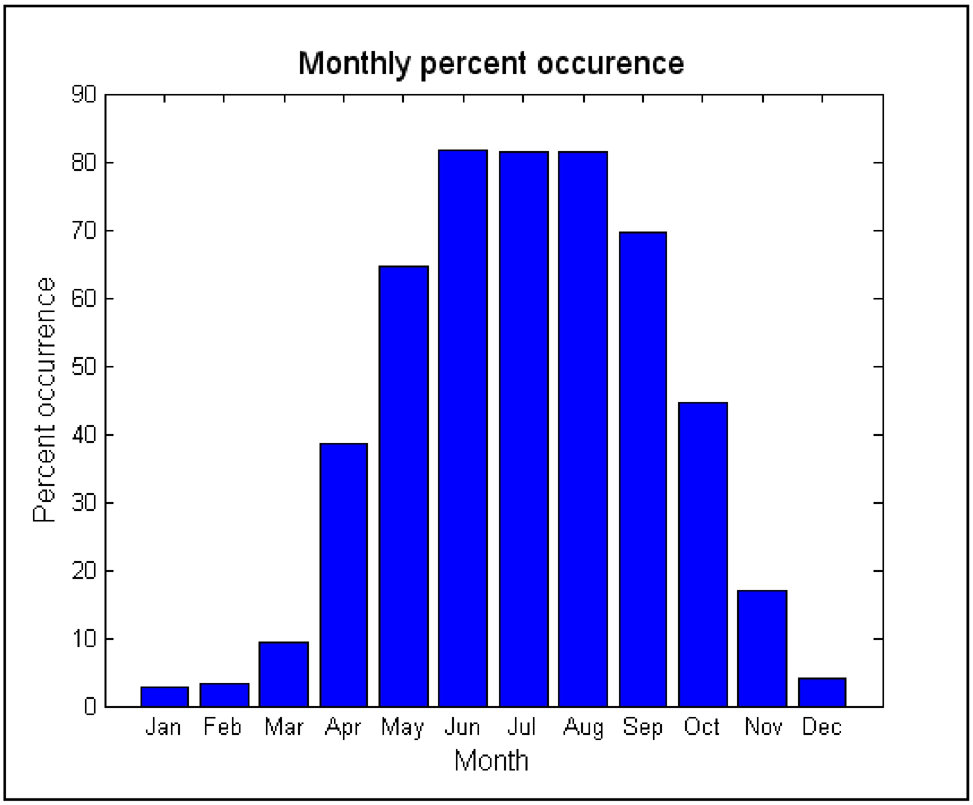

Figure 2-17 Monthly percent occurrence of southerly waves (southeast to west-southwest) at WIS station 114 for years 1981 to 2004

3. OVERVIEW OF THE EXISTING ENVIRONMENT

3.1 Physical Environment

3.1.1 Bathymetry and Nearshore Bottom Conditions

Waikiki is located on the south shore of Oahu, west of Diamond Head, along a pronounced embayment in the shoreline (Mamala Bay). This embayment is evident in the 18-foot depth contour, located approximately ½ mile offshore. Seaward of this, contours become straighter and bottom slope increases. A fringing fossil reef intersected by several relic stream channels extends approximately 1 mile offshore. Bottom slopes are generally mild inshore, consisting mainly of reefs and sand pockets. Bathymetry and surf sites in the project area are presented in Figure 3-1.

The shoreline is fronted by a shallow fossil limestone reef including channels and pockets filled with sand. This extends approximately 1,500 feet offshore, with depths generally 5 feet or less. Seaward of the surf zone (approximate 10-foot depth), to a depth of 40 feet, the average bottom slope is very gradual, 1V:100H. Between the 40 and 60-foot depth contours, bottom slopes increase to 1V:50H and further increase seaward of the 60-foot contour to 1V:15H. Detailed nearshore bathymetry information is available via the U.S. Army Corps of Engineers (USACE) Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) dataset.

The project area proposed for beach maintenance is approximately 93% sand bottom, with the remaining bottom being scattered fossil limestone rock outcrops. The patches of hard bottom show significant evidence of sand scour, and have little or no benthic biota on them. Given the predominance of sand these rock outcrops are likely buried some of the time.

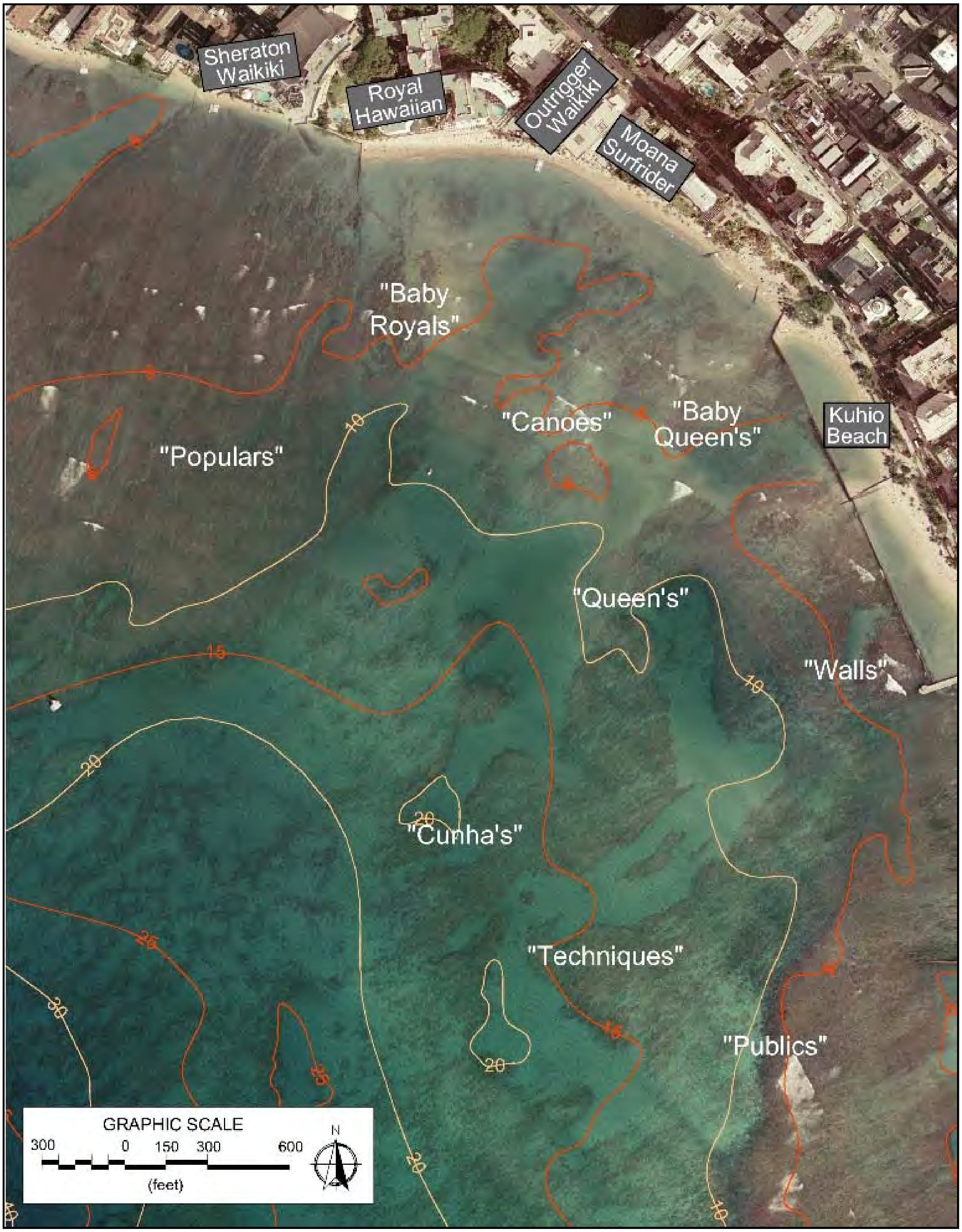

Figure 3-1 Project area bathymetry (contours in feet) and surf sites

3.1.2 Climate

The Hawaiian Island chain is situated south of the large Eastern Pacific semi-permanent high-pressure cell, the dominant feature affecting air circulation in the region. Over the Hawaiian Islands, this high-pressure cell produces very persistent northeasterly winds called the trade winds. During the winter months, cold fronts sweep across the north central Pacific Ocean, bringing rain to the Hawaiian Islands and intermittently modifying the trade wind regime. Thunderstorms, which are rare but most frequent in the mountains, also contribute to annual precipitation.

3.1.2.1 Temperature and Rainfall

Due to the tempering influence of the Pacific Ocean and their low-latitude location, the Hawaiian Islands experience extremely small diurnal and seasonal variations in ambient temperature. Average temperatures in the coolest and warmest months at Honolulu International Airport are 72.9˚ Fahrenheit (F) (January) and 81.4˚F (July), respectively. These temperature variations are quite modest compared to those that occur at inland continental locations. Additional temperature data from Honolulu International Airport are summarized in Table 3-1 and Table 3-2.

Table 3-1 Average Monthly Temperature, Rainfall, and Humidity

Month	Normal Ambient Temperature, ºFahrenheit		Average Monthly Rainfall (inches)		Average Relative Humidity (%)
	Daily Minimum	Daily Maximum	Monthly Minimum	Monthly Maximum	
January	65.7	80.4	0.18	14.74	71
February	65.4	80.7	0.06	13.68	69
March	66.9	81.7	0.01	20.79	65
April	68.2	83.1	0.01	8.92	62.5
May	69.6	84.9	0.03	7.23	60.5
June	72.1	86.9	T	2.46	59
July	73.8	87.8	0.03	2.33	60
August	74.7	88.9	T	3.08	60
September	74.2	88.9	0.05	2.74	61.5
October	73.2	87.2	0.07	11.15	63.5
November	71.1	84.3	0.03	18.79	67
December	67.8	81.7	0.04	17.29	74.75
Note: "T" signifies a trace amount of rainfall (i.e., less than 0.01 inch).					
Source: State of Hawaii Data Book 2003 (Data from Honolulu International Airport).					

Topography and the dominant northeast trade winds are the two primary factors that influence the amount of rainfall that falls on any given location on Oahu. Near the top of the Koolau Range on the windward side of Oahu that is fully exposed to the trade winds, rainfall averages nearly 250 inches per year. On the leeward side of the island, where the project is located, the rainfall is much lower, average annual rainfall in Waikiki is less than 20 inches per year. Although the project area is on the leeward side of the island, the humidity is still moderately high, ranging from mid-60 to mid-70 percent.

Table 3-2 Seasonal Rainfall and Temperature Patterns

<table>
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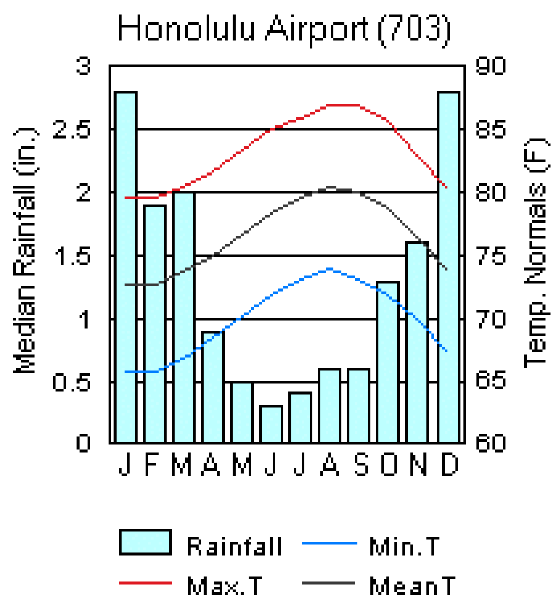
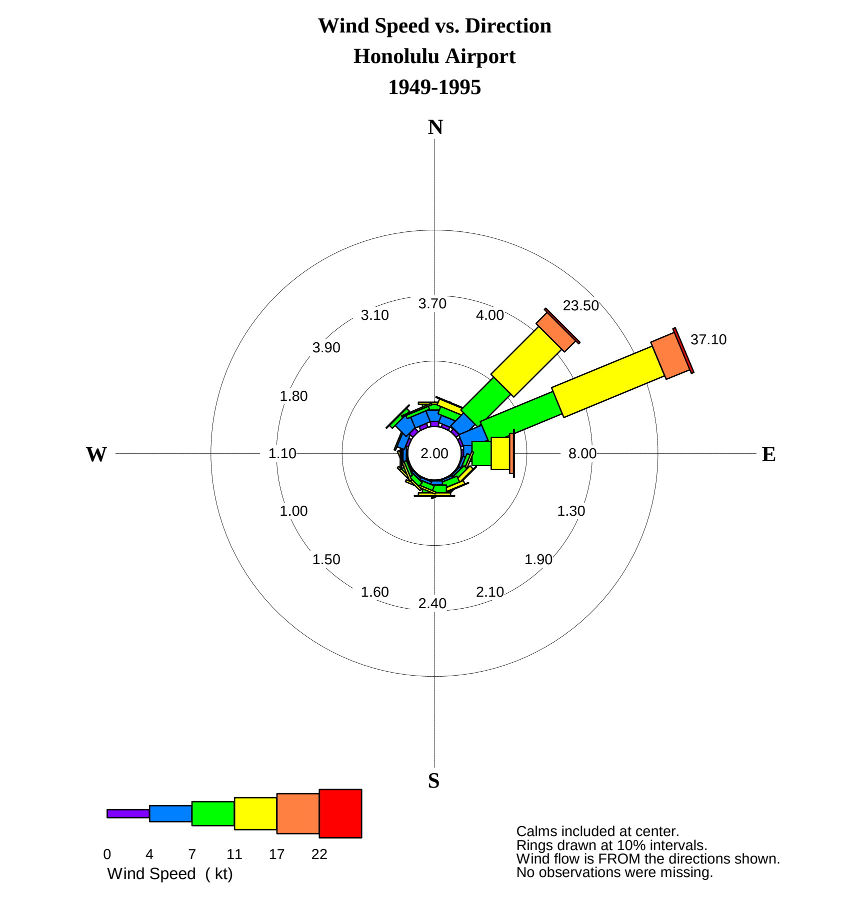
</td><td rowspan="2">
</td></tr>
<tr><td>Station Key: 703 (Honolulu Airport Station)
Coordinates: 21.33138°, 157.91862°
Elevation: 5 feet
Temperature Records: 30 years, 1941 to _____.
Rainfall Records: 29 years</td></tr>
<tr><td colspan="2">Source: http://hikawa.htohananet.com/climate-oahu/grids/whonolulu.html</td></tr>
</table>

3.1.2.2 Wind

The prevailing wind throughout the year is the northeasterly trade wind. Its average 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, generated by low pressure or cold fronts that typically move from west to east past the islands. Figure 3-2 shows a wind rose diagram applicable to the site based on wind data recorded at Honolulu International Airport between 1949 and 1995.

Tradewinds are produced by the outflow of air from the Pacific Anticyclone high pressure system, also known as the Pacific High. The center of this system is located well north and east of the Hawaiian chain and moves to the north and south seasonally. In the summer months, the center moves to the north, causing the tradewinds to be at their strongest from May through September. In the winter, the center moves to the south, resulting in decreasing tradewind frequency from October through April. 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 Airport, wind speeds resulting from these storms have on several occasions exceeded 60 mph. Kona winds are generally from a southerly to southwesterly direction, usually associated with slow moving low pressure systems known as Kona lows situated to the west of the island chain. These storms are often accompanied by heavy rains.



PERCENT OCCURRENCE: Wind Speed (kt)
LOWER BOUND OF CATEGORY

DIR	0	4	7	11	17	22
N	0.80	1.70	0.90	0.30	0.00	0.00
NNE	0.50	1.20	1.20	1.00	0.10	0.00
NE	0.60	2.80	7.10	10.30	2.40	0.30
ENE	0.40	3.80	12.00	16.60	3.90	0.40
E	0.30	1.30	2.90	2.80	0.60	0.10
ESE	0.10	0.40	0.50	0.30	0.00	0.00
SE	0.10	0.30	0.70	0.70	0.10	0.00
SSE	0.10	0.30	1.00	0.60	0.10	0.00

TOTAL OBS = 134736 MISSING OBS = 0

PERCENT OCCURRENCE: Wind Speed (kt)
LOWER BOUND OF CATEGORY

DIR	0	4	7	11	17	22
S	0.10	0.60	1.20	0.40	0.10	0.00
SSW	0.10	0.40	0.80	0.30	0.00	0.00
SW	0.10	0.30	0.80	0.30	0.00	0.00
WSW	0.10	0.20	0.40	0.30	0.00	0.00
W	0.20	0.50	0.20	0.20	0.00	0.00
WNW	0.40	1.20	0.20	0.00	0.00	0.00
NW	0.80	2.40	0.60	0.10	0.00	0.00
NNW	0.60	1.80	0.50	0.20	0.00	0.00

CALM OBS = 2695 PERCENT CALM = 2.00

Figure 3-2 Wind rose for Honolulu Airport (1949 to 1995)

3.1.2.3 Air Quality

The U.S. Environmental Protection Agency has set national ambient air quality standards (NAAQS) for ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide, 2.5-micron and 10-micron particulate matter ($PM_{2.5}$ and PM_{10}), and airborne lead. These ambient air quality standards establish the maximum concentrations of pollution considered acceptable, with an adequate margin of safety, to protect the public health and welfare. The State of Hawai‘i has also adopted ambient air quality standards for some pollutants. In some cases, these are more stringent than the Federal standards. At present, the State has set standards for five of the six criteria pollutants (excluding $PM_{2.5}$) in addition to hydrogen sulfide (DOH, 2003).

Generally, air quality in the area is excellent. The State of Hawaii Department of Health monitors ambient air quality on Oahu using a system of 9 monitoring sites. The primary purpose of the monitoring network is to measure ambient air concentrations of the six criteria NAAQS pollutants. DOH monitoring data for 2008 shows that air quality in the area during this year never exceeded the short-term or long-term State or National standards for the six pollutants measured [particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2) sulfur dioxide (SO_2), carbon monoxide, and hydrogen sulfide]. The Department of Health’s only ozone monitoring station on Oahu is located on Sand Island. Existing ozone concentrations at that location also meet State and Federal ambient air quality standards.

3.1.3 Wave Conditions

The wave climate in Hawaii is typically characterized by four general wave types. These include northeast tradewind waves, southern swell, North Pacific swell, and Kona wind waves. Tropical storms and hurricanes also generate waves that can approach the islands from virtually any direction. Unlike winds, any and all of these wave conditions may occur at the same time.

Tradewind waves occur throughout the year and are the most persistent April through September when they usually dominate the local wave climate. They result from the strong and steady tradewinds blowing from the northeast quadrant over long fetches of open ocean. Tradewind deepwater waves are typically between 3 to 8 feet high with periods of 5 to 10 seconds, depending upon the strength of the tradewinds and how far the fetch extends east of the Hawaiian Islands. 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 site is well sheltered from the direct approach of tradewind waves by the island itself, and only a portion of the tradewind wave energy refracting and diffracting around the southeast end of the island reaches Waikiki.

Southern swell is generated by storms in the southern hemisphere and is most prevalent during the summer months of April through September. Traveling distances of up to 5,000 miles, these waves arrive with relatively low deepwater wave heights of 1 to 4 feet and periods of 14 to 20 seconds. Depending on the positions and tracks of the southern hemisphere storms, southern swells approach between the southeasterly and southwesterly directions. The project site is directly exposed to swell from the southerly direction and these waves represent the greatest source of wave energy reaching the project site.

During the winter months in the northern hemisphere, strong storms are frequent in the North Pacific in the mid latitudes and near the Aleutian Islands. These storms generate large North Pacific swells that range in direction from west-northwest to northeast and arrive at the northern Hawaiian shores with little attenuation of wave energy. These are the waves that have made surfing beaches on the north shores of Oahu and Maui famous. Deepwater wave heights often reach 15 feet and in extreme cases can reach 30 feet. Periods vary between 12 and 20 seconds, depending on the location of the storm. The project site is sheltered by the island itself from swell approach from the north and northwest.

Kona storm waves also directly approach the project site; however these waves are fairly infrequent, occurring only about 10 percent of the time during a typical year. Kona waves typically range in period from 6 to 10 seconds with heights of 5 to 10 feet, and approach from the southwest. Deepwater wave heights during the severe Kona storm of January 1980 were about 17 feet. These waves had a significant impact on the south and west shores of Oahu.

Severe tropical storms and hurricanes obviously have the potential to generate extremely large waves, which in turn could potentially result in large waves at the project site. Recent hurricanes impacting the Hawaiian Islands include Hurricane Iwa in 1982 and Hurricane Iniki in 1992. Iniki directly hit the island of Kauai and resulted in large waves along the southern shores of all the Hawaiian islands. Damage from these hurricanes was extensive. Although not a frequent or even likely event, they should be considered in the project design, particularly with regard to shoreline structures, both in the water and on land near the shore.

3.1.3.1 Prevailing Deepwater Waves

Wave information is available in the form of hindcast data sets provided by the U.S. Army Corps of Engineers' Wave Information Studies (WIS). WIS results are generated by numerical simulation of past wind and wave conditions. WIS information produces records of wave conditions based on historical wind and wave conditions at numerous stations around the Hawaiian Islands. These hourly records of wave conditions are available for the years 1981 through 2004.

WIS Station 114, located 50 miles south of Lanai, was chosen as being representative, since it was exposed to the same waves that would affect the south shore of Oahu (e.g., exposed to southern swell and sheltered from prevailing tradewind waves by the island chain. Table 3-3 shows the frequency of occurrence of wave height and period for the WIS data. To make the data representative of wave conditions at the project site, this data has been filtered into 22.5-degree bins for directions southeast clockwise through west-southwest, as waves from other directions are blocked by the island of Oahu. The wave height and wave period distributions for the full WIS 114 data set are presented as roses in Figure 3-3 and Figure 3-4. Since the WIS station is located far from shore, the wave roses show the north swell, south swell, and tradewind waves.

The wave direction roses for WIS station 114 show that greater than 23% of all waves at that station are from the south-southwest direction. The filtered data shows that nearly 54% of the waves approaching the project site are from the south-southwest direction. Within that direction band, nearly all of the significant wave heights are between 2 and 6 feet with periods of primarily 12 to 15 sec. Based on this information, the most frequently occurring deepwater wave that can affect the project site is *Dir* = SSW (202.5°), H_s = 4 ft, T_p = 14 sec.

Table 3-3 WIS 114 Deepwater waves, 1981-2004, filtered to directions SE to WSW. Percent frequency of occurrence: significant wave height H_s (ft) vs. peak period T_p (sec).

Dir (°TN)	Hs\Tp	<6	6-8	8-10	10-12	12-14	14-16	16-18	>=18	Total%
SE	<1	-	-	-	-	-	-	-	-	0.0
123.75 -	1-2	-	-	-	-	-	-	-	-	0.0
146.25	2-3	-	-	0.97	0.08	-	-	-	-	1.0
	3-4	-	-	0.85	0.14	-	-	-	-	1.0
	4-5	-	-	0.10	0.02	-	-	-	-	0.1
	5-6	0.06	-	-	-	-	-	-	-	0.1
	Total%	0.1	0.0	1.9	0.2	0.0	0.0	0.0	0.0	**2.2**
Dir (°TN)	**Hs\Tp**	**<6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**>=18**	**Total%**
SSE	<1	-	-	-	-	-	-	-	-	0.0
146.25 -	1-2	-	-	-	-	-	-	-	-	0.0
168.75	2-3	-	-	0.83	0.75	-	-	-	-	1.6
	3-4	-	-	0.24	1.80	-	-	-	-	2.0
	4-5	-	-	0.45	0.28	-	-	-	-	0.7
	5-6	-	-	-	0.12	-	-	-	-	0.1
	Total%	0.0	0.0	1.5	2.9	0.0	0.0	0.0	0.0	**4.5**
Dir (°TN)	**Hs\Tp**	**<6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**>=18**	**Total%**
S	<1	-	-	-	-	-	-	-	-	0.0
168.75 -	1-2	-	-	-	-	-	-	-	-	0.0
191.25	2-3	-	-	0.99	2.07	0.32	0.22	0.14	-	3.7
	3-4	-	-	0.14	5.75	5.14	1.88	0.63	-	13.5
	4-5	-	-	-	1.09	3.02	2.01	0.41	-	6.5
	5-6	-	-	-	0.08	-	-	0.02	-	0.1
	6-7	-	-	-	-	-	-	-	-	0.0
	7-8	0.06	-	-	-	-	-	-	-	0.1
	8-9	-	0.18	-	-	-	-	-	-	0.2
	Total%	0.1	0.2	1.1	9.0	8.5	4.1	1.2	0.0	**24.1**
Dir (°TN)	**Hs\Tp**	**<6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**>=18**	**Total%**
SSW	<1	-	-	-	-	-	-	-	-	0.0
191.25 -	1-2	-	-	-	-	-	-	-	-	0.0
213.75	2-3	-	-	0.30	1.96	3.42	2.19	1.24	0.24	9.3
	3-4	-	-	0.36	3.73	11.63	7.53	3.79	0.36	27.4
	4-5	-	-	-	1.28	4.98	4.62	1.84	0.08	12.8
	5-6	-	-	-	0.04	0.41	1.96	0.59	0.16	3.2
	6-7	-	-	-	-	0.04	0.40	0.55	-	1.0
	7-8	-	-	-	-	-	-	-	-	0.0
	8-9	-	0.06	-	-	-	-	-	-	0.1
	9-10	-	0.02	-	-	-	-	-	-	0.0
	Total%	0.0	0.1	0.7	7.0	20.5	16.7	8.0	0.8	**53.7**
Dir (°TN)	**Hs\Tp**	**<6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**>=18**	**Total%**
SW	<1	-	-	-	-	-	-	-	-	0.0
213.75 -	1-2	-	-	-	0.02	-	-	-	-	0.0
236.25	2-3	-	-	0.41	1.19	0.93	0.18	-	-	2.7
	3-4	-	-	0.18	1.66	2.05	0.75	0.16	-	4.8
	4-5	-	-	-	0.63	1.07	0.14	0.02	-	1.9
	5-6	-	-	-	0.02	0.24	-	-	-	0.3
	6-7	-	-	-	-	0.04	-	-	-	0.0
	7-8	-	-	-	-	-	-	-	-	0.0
	8-9	-	-	-	-	-	-	-	-	0.0
	9-10	-	0.04	-	-	-	-	-	-	0.0
	Total%	0.0	0.0	0.6	3.5	4.3	1.1	0.2	0.0	**9.7**
Dir (°TN)	**Hs\Tp**	**<6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**>=18**	**Total%**
WSW	<1	-	-	-	-	-	-	-	-	0.0
236.25 -	1-2	-	-	-	-	-	-	-	-	0.0
258.75	2-3	-	-	0.32	0.38	0.04	-	-	-	0.7
	3-4	-	-	0.10	1.24	1.62	0.14	-	-	3.1
	4-5	-	-	-	0.87	0.65	0.06	-	-	1.6
	5-6	-	-	-	0.04	0.12	-	-	-	0.2
	6-7	-	-	-	-	0.02	-	-	-	0.0
	7-8	-	-	-	-	0.04	-	-	-	0.0
	8-9	-	-	-	-	0.08	-	-	-	0.1
	Total%	0.0	0.0	0.4	2.5	2.6	0.2	0.0	0.0	**5.7**
	All %	0.1	0.2	6.2	25.2	35.8	22.1	9.4	0.8	**100.0**

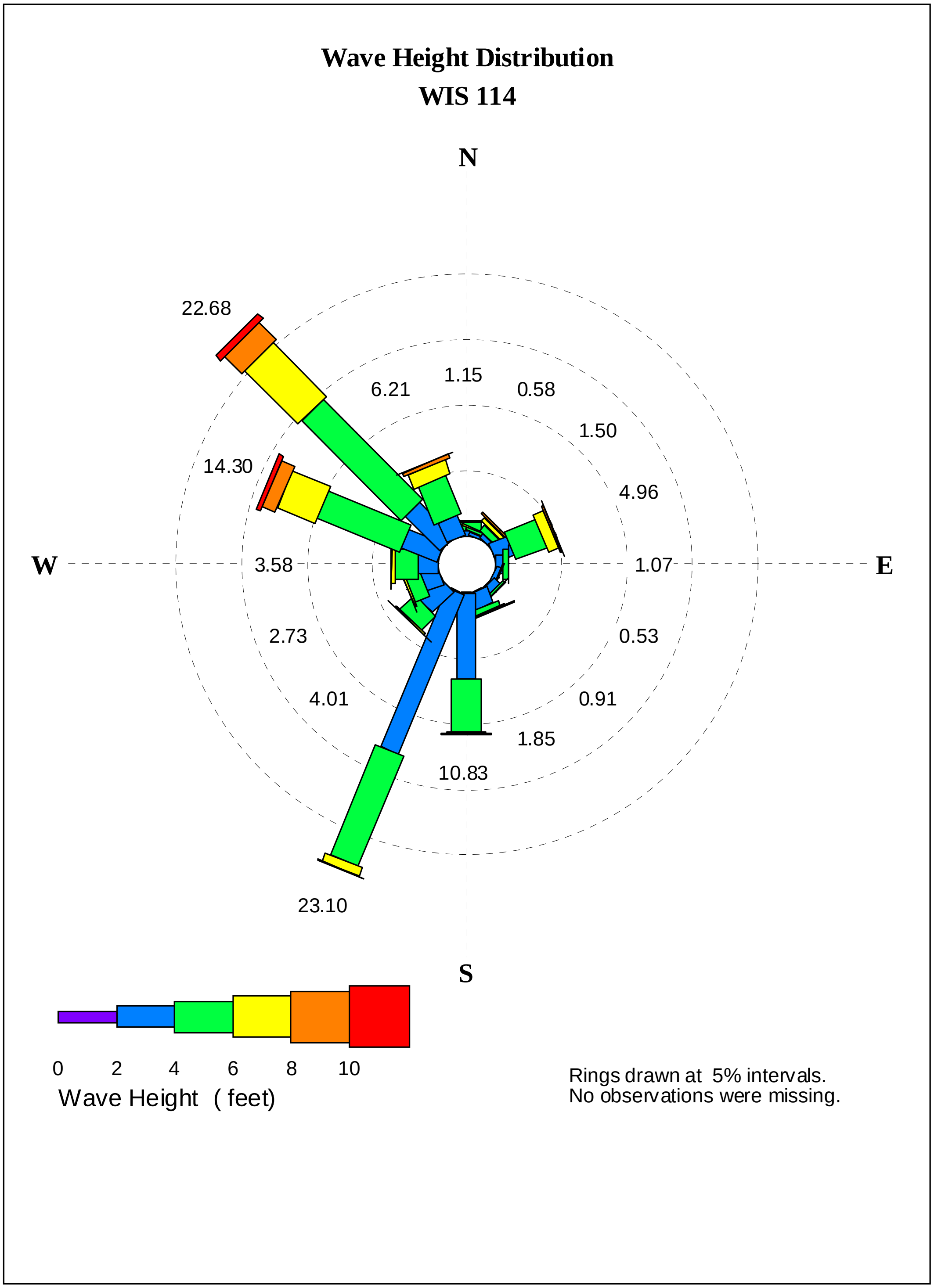


Figure 3-3 Wave Height Distribution: WIS Station 114

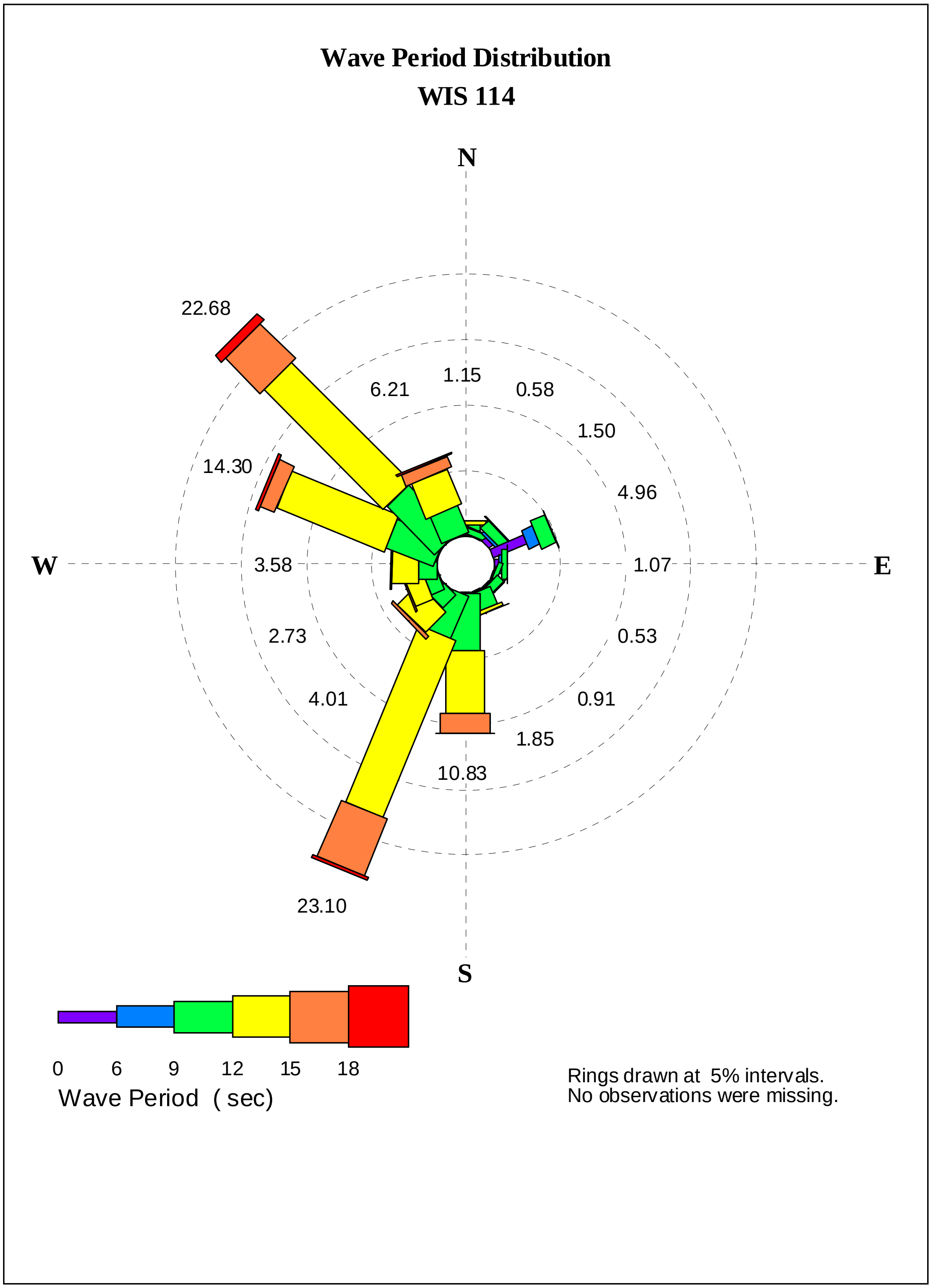


Figure 3-4 Wave Period Distribution: WIS Station 114

3.1.3.2 Extreme Wave Heights

The Hawaiian Islands are annually exposed to severe storms and storm waves generated by passing low pressure systems (Kona storms) and tropical cyclonic storms (hurricanes). Kona storms occur when the winter low pressure systems that travel across the North Pacific Ocean dip south and approach the islands. Strong southerly and southwesterly winds generated by these storms result in large waves on exposed shorelines, and often heavy rains. Hurricanes, the worst-case tropical cyclones, are caused by intense low pressure vortices that are usually spawned in the eastern tropical Pacific Ocean and travel westward. While they typically pass south of the Hawaiian Islands, their paths are unpredictable and they will occasionally pass near or over the islands. In recent years, Hurricane Iwa (1982) and Hurricane Iniki (1992) directly hit the island of Kauai, and resulted in large waves along southern shores of Oahu. Damage from these hurricanes was extensive, not only on Kauai, which was subject to both high winds and waves, but also along coastal areas of other islands exposed to the large waves.

The severe Kona storm of January 1980 is commonly used as a “design” Kona storm condition. The severity of this storm has been described as a “50-year” or even less frequent (i.e., more extreme) event. Hindcasts of the wave conditions by SEI following the storm indicated deepwater wave heights of 17 feet with a 9-second period approaching from 210°.

The report *Hurricanes in Hawaii* (Haraguchi, 1984) prepared for the USACE, Honolulu Engineer District (HED), presents hypothetical model and worst-case hurricane scenarios for the Hawaiian Islands. These scenario hurricanes have been used for detailed studies of hurricane storm wave inundation limits for the islands of Oahu and Kauai, prepared by Bretschneider and Noda (1985) and SEI (1986, 1993, and 2000) for the USACE-HED. The model hurricane is defined as the probable hurricane that will strike Hawaii in the future, based on the characteristics of storms previously approaching or striking the islands. The worst-case hurricane characteristics are based on subjective analysis of the data from 20 critical hurricanes in the Central Pacific and understanding of the basic atmospheric and oceanic conditions surrounding the Hawaiian Islands.

Bretschneider and Noda (1985) performed hurricane and wave modeling to determine the vulnerability of the south shore of Oahu to storm waves. Water level rise, wave runup elevation, and wave inundation limits were calculated at 71 locations between Koko Head and Barbers Point, including Profile 39, which was located at the Moana Surfrider shoreline. The findings of the report at that location are presented in Table 3-4 for southeast (SE) and southwest (SW) model and worst-case scenarios.

Table 3-4 Hurricane inundation at the Moana Surfrider shoreline

Hurricane		Still water level rise (feet)[1]	Runup elevation (feet)[1]	Inundation distance (feet)
SE	Model	6.5	8.3	206
	Worst	7.8	9.8	236
SW	Model	6.9	8.6	212
	Worst	9.3	----[2]	----[2]
[1] *Elevations relative to mean lower low water (MLLW)*				
[2] *Runup overtopped shoreline crest and inundated backshore*				

The calculated still water level rise in Table 3-4 includes inverse barometric tide (storm surge), wind setup, and +1.9 feet MLLW of astronomical tide.

3.1.3.3 Tides and Water Level Rise

Hawaii tides are semi-diurnal with pronounced diurnal inequalities (i.e., two high and low tides each 24-hour period with different elevations). Tidal predictions and historical extreme water levels are given by the Center for Operational Oceanographic Products and Services, NOS, NOAA, website. The nearest tide station to Waikiki is at Honolulu Harbor, where the water level data, based on the 1983-2001 tidal epoch, is:

Mean Higher High Water	1.9 ft.
Mean High Water	1.5 ft.
Mean Tide Level	0.8 ft.
Mean Low Water	0.2 ft.
Mean Lower Low Water	0.0 ft.

Hawaii is also subject to periodic extreme tide levels due to large scale oceanic eddies that propagate through the islands. These eddies produce tide levels up to 0.5 to 1-foot higher than normal for periods of up to several weeks.

During severe storm events a “super elevation” of the water level at the shore may occur. The rise in stillwater level along the shore during a hurricane or other storm event is due to a combination of the astronomical tide, oceanic eddies, wave setup, and storm surge due to reduced atmospheric pressure and wind stress.

During storm wave attack, the nearshore water level may be elevated above the tide level by the action of breaking waves offshore. This water level rise, termed wave setup, may be as much as 10 to 12% of the breaker height. Thus, the water level could be elevated an estimated 1 to 2 feet during severe storm wave conditions.

During hurricane conditions an additional water level rise due to wind stress and reduced atmospheric pressure can occur. This storm surge can potentially add another 1 to 2 feet to the stillwater level. For example, during the 1992 passage of Hurricane Iniki over Port Allen Harbor on the island of Kauai, a National Weather Service tide gauge recorded a water level rise of 4.9 feet above the predicted tide elevation.

The present rate of global mean sea-level rise (SLR) appears to be accelerating compared to the mean of the 20th Century, but the rate of rise is locally variable (Fletcher, 2009). Factors contributing to SLR include decreased global ice volume and warming of the ocean. Recent climate research by the Intergovernmental Panel on Climate Change (IPCC) predicts continued or accelerated global warming for the 21st Century and possibly beyond, which will cause a continued or accelerated rise in global mean sea level (USACE, 2009). It is estimated that global SLR may reach 1 meter (3.3 feet) by the end of this century, and the U.S. Army Corps of Engineers estimates possible SLR as high as 1.4 meters (4.6 feet). However, sea level is highly variable, and there is some indication that Hawaii's location in the middle of the Pacific Ocean may result in a somewhat delayed SLR here. However, it is inevitable that at some point Hawaii will feel the full effect of SLR, and this will obviously have a significant impact on the shorelines and low-lying coastal areas.

3.1.4 Currents and Circulation

Offshore tidal driven currents in Waikiki generally flow toward the north-northwest (Ewa) during high tide and south-southwest (Diamond Head) during low tide, generally flowing parallel with the bottom contours (Noda, 1991). Currents landward of the 30-foot bottom contour are weaker than the currents further offshore. Velocities are typically 0.15 to 0.5 feet/sec (0.1-0.3 knots). Wind speed and direction influences the surface (top 3 feet) current, creating eddies when opposed to the tide flow and enhancing it when blowing in the same direction.

Wave-induced currents predominate inside the breaker zone, generating both longshore (shore parallel) and onshore/offshore (rip) currents, which contribute significantly to sediment transport. From Gerritsen (1978): "In agreement with the dominant directions of the incoming waves, the longshore currents inside the surf zone flow from southeast to northwest most of the time. The wave-induced longshore current is a major cause for the direction and magnitude of the littoral drift. Along Waikiki Beach the littoral drift is therefore mostly in the westerly direction. Accumulations of sand east of the Queen's surf groin and east of the Royal Hawaiian Hotel groin are indications of a predominantly westerly littoral drift. Occasionally waves from opposite directions cause a reversal of the littoral drift pattern." During high wave conditions a rip current typically forms fronting the Royal Hawaiian Hotel, with current speeds sufficient to result in a significant movement of sand offshore. The result of this can be seen as a shoal or sandbar offshore, which is popular with beach users. A rip current is also typical in the deeper water channel fronting the Outrigger Waikiki and Moana Surfrider hotels used by beach catamarans. This current also carries sand offshore to the vicinity of the proposed sand recovery site.

3.1.5 Shoreline Characteristics and Coastal Processes

3.1.5.1 Waikiki Shoreline History

Waikiki was originally a wetland consisting of taro fields, fishponds, streams and narrow sand beaches. Until the late 1800's, the Waikiki shoreline consisted of a narrow barrier beach in front of a swamp and lagoon. In the late 1800's, the first tourist attractions to the area included bathhouses that offered towels, swimsuits, changing rooms, and the use of the beach for a fee. Development of beachfront hotels such as the Sans Souci, Moana Surfrider, and Honolulu Seaside soon followed, often necessitating construction of protective seawalls. In the early 1900's, the wetland areas were declared a hazard to public health, and the government decided to dredge a canal to drain the wetlands and use the dredge material to fill in the low-lying areas (Miller and Fletcher, 2003).

As early as 1910, seawalls became associated with beach loss. This resulted in the prohibition by the territorial government of additional seawall construction in 1917. This prohibition was generally ignored and by 1920, seawalls spanned the majority of the Waikiki shorefront (USACE, 2002). A 70-foot long concrete box culvert/groin was built northwest of the Halekulani channel in 1917. In 1927, the Board of Harbor Commissioners was allowed to rebuild the eroded Waikiki Beach and by 1930 they reported that eleven groins had been constructed including the Royal Hawaiian Groin which was built in 1927 and lengthened in 1930. Subsequently, the Waikiki area has undergone a succession of projects relating to dredging, sand replenishment, construction of groins, jetties, harbors and swimming areas, as well as removal of a number of piers that were declared unsafe (Wiegel, 2002).

"Beach Nourishment" as it is known today has probably been taking place in Waikiki since the early 1900's since it is likely that many if not all construction projects located near the beach included a component of sand relocation. Dredged material was commonly used as fill for adjacent projects or newly constructed beaches. Construction of groins often required grading of existing sand and addition of fill sand. An estimate, based on recorded volumes alone, indicates that nearly 400,000 cubic yards of sand has been placed on Waikiki beaches since 1929 (Wiegel, 2002). As a result of all this, there is very little, if any, "native" beach sand along Waikiki Beach. Miller and Fletcher (2003) used historical photogrammetry in combination with a model that relates beach width change to volumetric change in estimating that Waikiki beaches have gained less than 5,000 cubic yards since 1951 despite the fact that approximately 250,000 cubic yards of sand having been placed on it during that time. It can be deduced from this that at least 98% of the sand that government and private landowners have placed there has been lost.

3.1.5.2 Existing Beach Description

The project area is located along a slightly concave shoreline between the Kuhio Beach crib walls and the Royal Hawaiian Groin. Figure 3-5 presents an overview of the project site. The shoreline is fronted by a wide and shallow fringing reef extending over 4,000 feet from shore. The shallow nearshore water provides good natural protection from large storm waves; however, it also results in complex wave patterns as the incident waves propagate toward shore. The nearshore sea bottom is composed of calcareous limestone reef rock, with patches of sand and coral rubble. The beach is composed primarily of fine to medium calcareous sand.

Figure 3-5 Overview of project site

The project shoreline encompasses the 1,700-foot littoral cell that extends from the Royal Hawaiian groin on the west to the Ewa groin of Kuhio Beach Park on the east. There is some widening of the beach adjacent to the Royal Hawaiian groin, indicating net longshore transport to the west along this reach.

The Royal Hawaiian groin is the western boundary of the project site. The Royal Hawaiian groin was built in two sections; a straight section extends 165 feet perpendicular from shore where it transitions into a 190-foot long arcuate section that curves in the Diamond Head direction. The Royal Hawaiian Hotel is located in the backshore on the east side of the Royal Hawaiian groin, and is protected by a mostly buried concrete seawall. The beach on the east side of the Royal Hawaiian Groin, shown in Figure 3-6 is about 40 feet wide along the groin and has a foreshore slope of 1V:7.1H. The beach elevation at the seawall is +6.5 feet MSL and it is unknown how far the wall extends below the surface of the sand. The beach width in front of the hotel is as wide as about 85 feet opposite the east wing of the hotel, with a typical foreshore slope of 1V:7.6H and dry beach elevation of +6.5 feet MSL. This shoreline reach is popular with sunbathers, sightseers, and paddlers.

The shoreline curves slightly toward the south near the property line between the Royal Hawaiian Hotel and the adjacent Outrigger Waikiki hotel. Figure 3-7 shows a typical view of the backshore along this reach. The beach area fronting the Outrigger Waikiki Hotel typically contains beach umbrellas for the hotel guests. Several catamarans also launch from and land on the beach face throughout the day. There is no apparent shore protection between the sandy beach and the Outrigger.

The beach continues in front of the Moana Surfrider where dry beach width varies between about 35 and 55 feet and the beach foreshore slope was measured in two locations to be 1V:8.1H and 1V:7.7H (Figure 3-8). Beach berm elevation varies from +6 feet MSL on the west end of the hotel to more than +7 feet MSL near the Diamond Head Tower. The boundary between the sandy beach and the Diamond Head Tower appears to be a seawall with a splash guard on top. The 2.5-foot wide top is up to about one foot above the sand level and the depth of the wall is unknown. The top serves as a walkway along the beach. The beach continues in the southeast direction to the Ewa groin of Kuhio Beach Park (Figure 3-9). Two small deteriorated stub groins are located along this reach. The backshore contains the Hyatt beach concession, restroom facilities, and the police sub-station, all of which are housed in permanent structures. A variety of other concession stands are also located here, primarily surf board rentals. The backshore is more open than where the beach fronts the hotels. The beach foreshore slope near the Ewa Groin was measured to be 1V:7.7H.

In summary, the 1,700-foot long project shoreline is slightly concave with generally uniform beach characteristics along the project reach. The foreshore slope was found to be between 1V:7H and 1V:8H and beach berm elevations range from +6 feet to slightly more than +7 feet MSL. Dry beach widths, measured from the MHHL contour, were found to be 35 to 85 feet and are limited by the hotel facilities in the backshore.

Figure 3-6 Shoreline on east side of Royal Hawaiian groin

Figure 3-7 View of beach fronting the Outrigger Waikiki

Figure 3-8 View of beach fronting the Moana Surfrider and Outrigger Waikiki

Figure 3-9 Surfboard rental and other concessions between Moana Surfrider and Kuhio Beach

3.1.5.3 Shoreline Trends

A series of historical aerial photographs can be used to show shoreline trends. The University of Hawaii Coastal Geology Group (UH CGG) has undertaken historical analysis of Oahu's shoreline and is producing shoreline change maps based on survey data and aerial imagery from 1927 to 2005. Their analyses use the beach toe as the shoreline change reference feature. The analyses for the project shoreline are presented as transects 88 through 116 in Figure 3-10 and show that the project shoreline has accreted at historical rates of between about 0.5 ft/yr and 1 ft/yr over the full 78 years of data. Presumably this shoreline change primarily results from the considerable shoreline development and construction, including the placement of considerable quantities of fill and sand, which has occurred since the 1920s.

Sandy shorelines in general, however, are quite dynamic and change in response to incident wave conditions, such as high surf which can quickly alter the beach width. Additionally, beach nourishment projects were undertaken during this time period and were not factored into the analyses. This variability in the historical shoreline positions can therefore result in misleading conclusions about the beach. To better show the more recent trend, a shoreline change analysis was performed using the shoreline positions from 1982 to 2005 (shorelines determined by UH CGG). The year 1982 was chosen as the initial year since no significant non-natural alterations of the beach have occurred since then. The shoreline analysis for 1982 to 2005 is shown in Figure 3-11. From 1982 to 2005, the primary trend has been shoreline recession, with the shoreline retreating at rates of one to three plus feet per year, and an average annual rate of 2.3 feet. The highest recession rates were found in front of the Diamond Head Tower of the Moana Surfrider. The smallest erosion rates are adjacent to the Royal Hawaiian groin, indicating that the eroding sand has been moved west and is held by the groin.

The Royal Hawaiian groin and the Ewa groin at Kuhio Beach Park prevent longshore sediment transport into and out of the littoral cell; thus, sediment transport at the project site is accomplished primarily through onshore-offshore transport. There may, however, be a small amount of longshore transport within the cell, as discussed in Section 3.1.4, and as evidenced by the slight buildup of sand against the Royal Hawaiian groin. The bulk of the net sediment transport is therefore in the offshore direction. Observations of the nearshore waters in the vicinity of the project site indicate that there is sand available to naturally feed the beach and allow short-term and seasonal fluctuations in width. The longterm trend in Waikiki, however, is a net reduction in sand supply. For planning purposes, this trend should be given more weight than fluctuations in shoreline position.

The effectiveness of the Royal Hawaiian groin and the Kuhio Beach Ewa groin at preventing longshore transport opens up the possibility of beach nourishment along this shoreline reach, which can be considered as a single littoral cell. With no longshore transport out of the cell and by nourishing the beach along the full length of the cell, the project lifetime would likely increase. A total of 24,000 cubic yards of sand would be required to widen the 1,700-foot long reach by about 40 feet, approximately doubling the width of the narrow beach sections. Investigations by the University of Hawaii Coastal Geology Group, and confirmed by Sea Engineering, indicate that the offshore waters contain beach quality sand which could be recovered and used to nourish the beach.

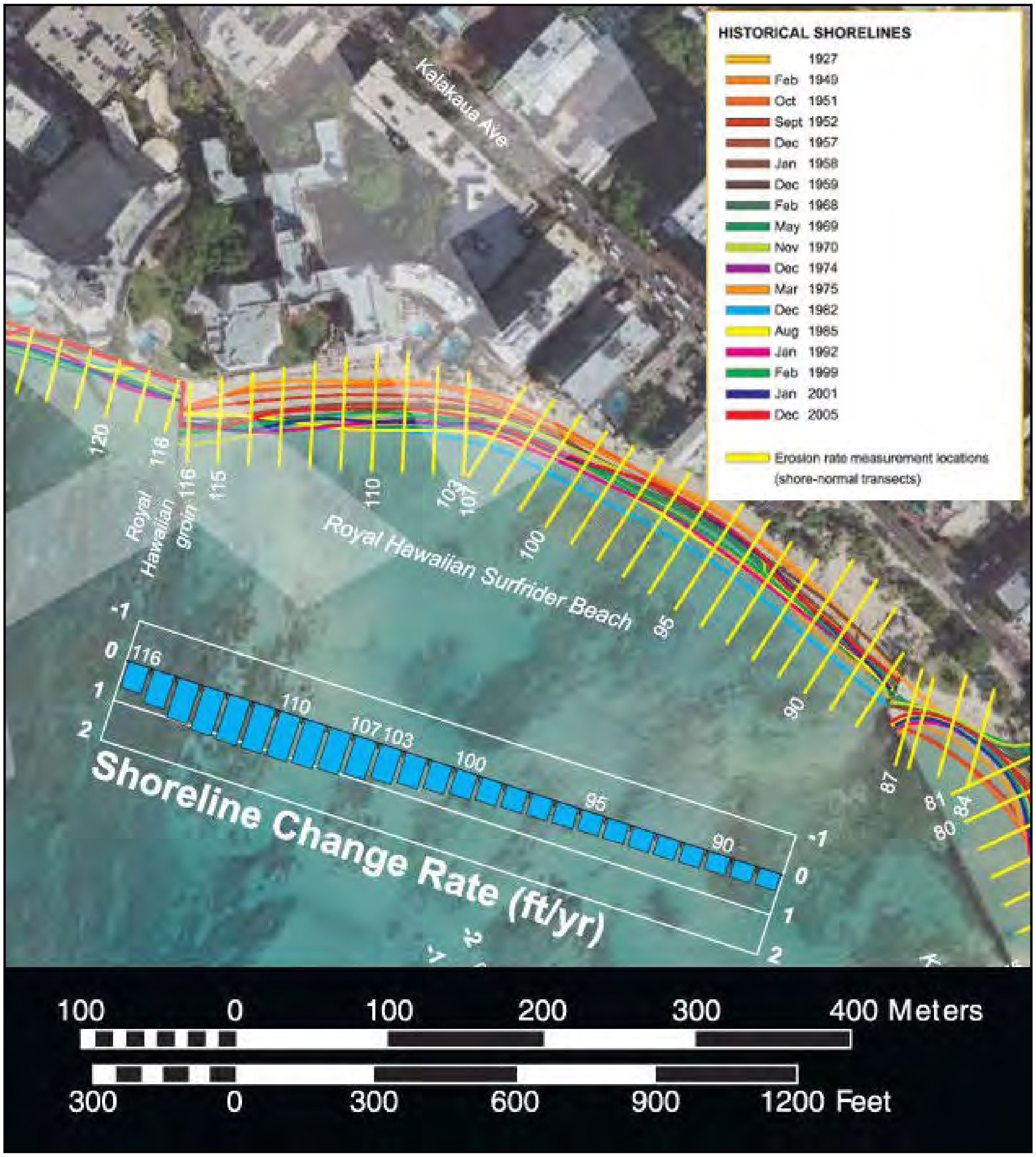


Figure 3-10 Historical shoreline change map (after Univ. of Hawaii Coastal Geology Group)

Figure 3-11 Historical shoreline positions, 1985-2005

3.1.6 Natural Hazards

3.1.6.1 Flooding

Flood hazards for the portion of Waikiki in which the project is located are depicted on Flood Insurance Rate Map (FIRM) Flood Sheet 15003C0370F. That map indicates that there are no threats of flooding from streams but that the shoreline is exposed to flooding caused by storm waves and tsunami. The area immediately inland of the shoreline is in Zone AE with a base flood elevation of 7 feet above mean sea level.

3.1.6.2 Tsunami

Tsunami are sea waves that result from large-scale seafloor displacements. They are most commonly caused by an earthquake (magnitude 7.0 or greater) adjacent to or under the ocean. If the earthquake involves a large segment of land that displaces a large volume of water, the water will travel outwards in a series of waves, each of which extends from the ocean surface to the sea floor where the earthquake originated. Tsunami waves are only a foot or so high at sea, but they can have wave lengths of hundreds of miles and travel at 500 miles per hour. When they approach shore, they too begin to feel bottom and slow down, but not into a surf-shaped wave. Instead the water increases greatly in height and pushes inland at considerable speed. The water then recedes, also at considerable speed, and the recession often causes as much damage as the original wave front itself.

Most tsunamis in Hawaii originate from the tectonically active areas located around the Pacific Rim (e.g., Alaska and Chile). Waves originating with earthquakes in these take hours to reach Hawaii, and the network of sensors that is part of the Pacific tsunami warning system are able to give Hawaii several hours advance warning of tsunami from these locations. Less commonly, tsunamis originate from seismic activity in the Hawaiian Islands, and there is much less advance warning for these. The 1975 Halape earthquake (magnitude 7.2) produced a wave that reached Oahu in less than a half hour, for example.

Fletcher, et al. (2002) report that 10 of the 26 tsunamis with flood elevations greater than 3.3 feet (1 m) that have made landfall in the Hawaiian Islands during recorded history have had "significant damaging effects on Oahu". This means that, on average, one damaging tsunami reaches Oahu every 19 years. The recent record (1946 to the present) has seen four tsunami cause damage on Oahu, a rate that is very close to the longer term average. In view of this, the U.S. Geological Survey (Fletcher, et al.) has given the Honolulu coastal zone a moderate to high (5) Overall Hazard Assessment (OHA). The report notes that while observations of tsunami flooding have not exceeded 8 feet, much of the Waikiki is below that elevation.

3.1.6.3 Storm Waves

The wave regime along the project shoreline is discussed in considerable detail in Section 3.1.3 of this report. The U.S. Geological Survey (Fletcher, et al., 2002) rates the threat from high waves along the shoreline as moderate to high because this region regularly receives nearshore breaking wave heights on the order of 6 feet from south swell.

3.1.7 Marine Biota

AECOS, Inc. has conducted several detailed investigations of marine biological resources in the general project area, including investigations specific to this project (see appendix A). The nearshore sea floor is a highly bio-eroded fossil limestone reef platform with sand filled pockets and channels. Corals are generally absent from the reef platform offshore of Waikiki, and coral colonies typically account for less than 1 percent of the bottom area. The predominant biotic attributes of the reef platform are a result of sand suspension and sand scour as a result of wave action. Reef fish are also relatively sparse throughout the area.

3.1.7.1 Benthos on the Limestone Platform

<u>Algae on the Limestone Platform</u>. The dominant species of benthic organisms on the reef platform are marine algae, also known as *limu* or seaweed, which cover virtually all exposed reef surfaces. The algae is primarily low growing or turf-like. *Acanthophora spicifera* and *Dictyota spp.* are the most abundant species. *Acanthophora spicifera* is one of two invasive red algal species (the other being *Gracilaria salicornia*) coming to dominate the benthic flora offshore of Waikiki. The occurrence of *G. salicornia* as a nuisance species in Waikiki has been well documented (Smith *et al*., 2004), and maps showing estimates of abundance throughout the Waikiki area reveal that the general project vicinity is one of the regions where it is most abundant. Other common macroalgae inhabiting the reef platform include *Avrainvillea amadelpha*, *Halimeda opuntia*, *Jania sp*., and *Amansia glomerata* (AECOS, 2008 and 2009a & b).

<u>Corals on the Limestone Platform</u>. Coral cover offshore of the project site is typically limited to less than 1 percent of the bottom, and is composed almost entirely of two species (*Porites lobata* and *Pocillopora meandrina*) (OI, 1990; MRC, 2007; and AECOS, 2008, 2009a & b). *P. lobata* occurs in a variety of growth forms, from flat encrustations flush with the reef surface to hemispherical lobed colonies that extend up to 2 feet in height. Many of the *P. lobata* colonies observed have areas of pink discoloration, a sign of disease or irritation (Rosenberg and Loya, 2004). *Pocillopora meandrina* occurs as short branching hemispherical colonies. Wave-induced scour from resuspended sand on the reef flat is probably responsible for the observed limited coral abundance.

Other coral species observed on the reef flat include *Cyphastrea ocellina* (Marine Research Consultants, 2007; AECOS, 2008, 2009a & b), *Montipora capitata*, *M. patula*, *P. evermanni*, *Psammocora sp*., *Leptastrea purpurea* and the soft coral *Anthelia edmondsoni* (AECOS, 2008, 2009a & b).

<u>Macroinvertebrates on the Limestone Platform.</u> The most common macroinvertebrates on the reef flat are the rock-boring urchin, *Echinometra mathaei*, and the black sea cucumber, *Holothuria atra*, which are responsible for much of the bioerosion and pitted nature of the reef platform. Also observed were various echinoderms and sponges such as *H. nobilis*, *Echinothrix diadema*, *Tripneustus gratilla*, *Echinostrephus aciculatus*, *Actinopyga mauritiana*, (OI, 1990); and an unidentified stomatopod.

3.1.7.2 Fishes

The fish community in the nearshore waters off Waikiki is largely structured by the local topography and composition of the reef; fishes are generally uncommon. A recent reconnaissance-level survey in the Waikiki vicinity found the most common species to be manini (*Acanthurus triostegus*) and reef triggerfish (*Rhinecanthus rectangulus*) and the survey also found various species of small juvenile fishes inhabiting the interstitial spaces in the reef (MRC, 2007).

Table 3-5 Invertebrate Abundance List in the Halekulani Sand Channel

Taxon	Halekulani 1	Halekulani 2	Control
Polychaeta	10	10	25
Platyhelminthes	17	0	0
Nemertea	10	5	0
Nematoda	134	281	461
Oligochaeta	24	54	3
Sipuncula	5	0	9
Arthropoda	48	22	29
Mollusca	1	2	0
Echinodermata	2	2	2
Total individuals per station	**251**	**376**	**742**
Total taxa per station	**17**	**15**	**31**

Source: Compiled by AECOS (2009) from data reported by Bailey-Brock and Krause (2008).

<u>*Fishes of the Nearshore Reef Platform.*</u> In 2007 and 2008, AECOS biologists conducted fish surveys of the nearshore reef platform between the Royal Hawaiian groin and Halekulani Channel from the shoreline out approximately 650 feet and in the Halekulani 1 and Halekulani 2 sand deposits. The purpose was to characterize the fish assemblages present in the project area. Fish surveys were conducted along ten 75-foot-long transects. The Halekulani Channel was represented by one inshore transect and one offshore transect. Inshore sand channel and reef flat transects were located approximately 250 feet from the shoreline while offshore transects averaged 460 feet from the shoreline.

Fifty fish species were identified in the project vicinity using an underwater visual survey technique. This survey does not accurately census seasonal, cryptic, nocturnal, and burrow-inhabiting fishes, although they may comprise half or more of the fish community (Willis, 2001). Analysis of the reef flat transect data reveals that within this environment, fish biomass is greater in offshore transects than inshore transects. The 57 kg/ha mean of all offshore reef flat transects is more than 2.5 times greater than the mean of 22 kg/ha for all inshore transects.

The reef flat is home to at least 38 different species of fishes. The saddle wrasse (*Thalassoma duperrey*) is the most abundant species and is nearly ubiquitous on the reef flat. Manini (*Acanthurus triostegus hawaiiensis*) is also abundant in small schools feeding on benthic algae, and the Christmas wrasse (*Thalassoma trilobatum*) is also abundant. The belted wrasse (*Stethojulis balteata*) and reef triggerfish (*Rhinecanthus rectangulus*) are common, solitarily scavenging for algae and benthic invertebrates. The elegant coris (*Coris venusta*) and kala (*Naso unicornis*) are encountered occasionally. Small schools of moana (*Parupeneus bifasciatus*) and omilu (*Caranx melampygus*) are uncommon on the reef flat. Tetradontids like the striped belly puffer (*Arothron hispidus*) and white spotted toby (*Canthigaster jactator*) are rarely encountered hovering in the water column or feeding on sponges. Bright-eyed damselfish (*Plectroglyphidodon imparipennis*) and Hawaiian gregory (*Stegastes marginatus*) are also rare, guarding territories on the substrate. Iridescent cardinalfish (*Pristiapogon kallopterus*), mamo (*Abudefdef abdominalis*), lizardfish (*Saurida sp*.), cigar wrasse (*Chelio inermis*), orangespine unicornfish (*Naso lituratus*), and the yellow-margin moray (*Gymnothorax flavimarginatus*) are also present on the reef flat.

3.1.7.3 Turtles

The most common sea turtle in the Hawaiian Islands is the green sea turtle or honu (*Chelonia mydas*) and is a common inhabitant of the shallow reefs off Waikiki. The green sea turtle population in Hawaii was in rapid decline in the early 1970s, mostly due to over-harvesting for turtle meat. In 1978, the *Chelonia mydas* was listed as a threatened species under the Endangered Species Act (ESA). Major threats to green sea turtles in Hawaii, listed in order from greatest to least threat, include: disease and parasites, accidental fishing take, and boat collisions. Other threats include: entanglement in marine debris, loss of foraging habitat to development, and ingestion of marine debris (NMFS-USFWS, 1998).

The National Marine Fisheries Service and Fish and Wildlife Service published a Recovery Plan for U.S. Pacific populations of the green sea turtle (NMFS-USFWS, 1998). Over the past 35-years that they have been protected, the nesting population of green turtles has steadily increased and at a rate much faster than anticipated (Balazs and Chaloupka, 2006). The outlook for the green sea turtle is considered to be favorable.

Hawaii has an estimated population of 35,000 adult and 250,000 juvenile green sea turtles (Leone, 2004). Nearly all green sea turtle nesting in the Hawaiian archipelago takes place in the remote Northwestern Hawaiian Islands at French Frigate Shoals where females converge annually to lay their eggs (Balazs and Chaloupka, 2006). Nesting is not known to occur off Waikiki. Upon hatching, young green sea turtles spend approximately the first six years of their lives foraging for plankton in the North Pacific Ocean (Zug, et al., 2002). They then migrate to the main Hawaiian Islands (MHI), their primary foraging grounds, to feed on the abundance of algae found there (Arthur and Balazs, 2008). Green sea turtles travel up to about 0.6 miles from resting areas to feeding areas (Balazs, 1980) and generally forage within an area of at least one square kilometer (Whiting, 1998). They are also known to exhibit high site fidelity to their foraging areas (Godley, et al., 2003).

The green sea turtle diet consists primarily of benthic macroalgae (Arthur and Balazs, 2008), which the shallow reefs of the MHI provide in abundance. Red macroalgae make up 78 percent of their diet while green macroalgae make up 12 percent (Arthur and Balazs, 2008). The single most consumed algal is prickly seaweed (*Acanthophora spicifera*), which is a non-native species introduced to Hawaii in 1950 (Huisman, et al., 2007). Recent surveys of the shallow reefs off Waikiki have found *A. spicifera* to be the most abundant species found there (AECOS, 2008). Numerous other microalgae species consumed by green turtles also occur off Waikiki (AECOS, 2008), including several other preferred algae as described in Russell and Balazs (2000).

Substantial foraging resources are available for sea turtles off Waikiki. The shallow reefs found along the south shore of Oahu are primarily made up of ancient limestone platforms covered by algae with very little coral cover, i.e., “live rock”. Algae generally cover more than 50 percent of the surface of the reef off Waikiki and up to 90 percent in some areas (AECOS, 2008).

Traditionally, sea turtles rest in deeper water during the day where they use reef features to shelter themselves (PACDIV, 1999) and come to shallow reef flats to feed at night (Balazs, et al., 1987). Before acquiring a status of threatened in Hawaiian waters under the Endangered Species Act, green sea turtles would flee on sight of humans (Balazs, 1996). In recent years, however, green sea turtles in Hawaii have become exceedingly tolerant of human presence and now regularly come to shallows to feed during the day as well as the night (Balazs, 1996).

High turbidity does not appear to deter green sea turtles from foraging and resting areas (Brock, 1998a and b). Previous construction projects on the south shore of Oahu at Hawaii Kai and off of Kapolei have found sea turtles adaptable and tolerant of construction-related disturbances (Brock, 1998a and b). The entrance channel into Pearl Harbor, which is periodically dredged and regularly trafficked by large ships and submarines, is home to a resident population of green sea turtles (PACDIV, 1999).

3.1.8 Water Quality

The waters offshore of Waikiki Beach are classified in the Hawaii Water Quality Standards (HDOH, 2004) as (a) marine waters, (b) open coastal, (c) reef flat, (d) Class A, and (e) Class II marine bottom ecosystem. It is the objective of Class A waters that their use for recreational purposes and aesthetic enjoyment be protected. Other uses are permitted so long as they are compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. Class A waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control.

Water quality in the project vicinity is summarized in Appendices A and C. The State Department of Health, Clean Water Branch (DOH/CWB) monitors water quality at four nearshore stations in the Waikiki Beach area: Fort DeRussy Beach, Gray’s Beach, Tavern’s Beach, and Kuhio Beach. HDOH also collects water quality samples at three popular surf sites offshore between Gray’s Beach and Kuhio Beach. Several nearshore areas in Waikiki are listed as impaired water bodies (HIDOH, 2008). These listings mean that the waters do not meet the Hawaii Water Quality Standards (HDOH, 2004). Two of the listed water bodies are in the project area: Kuhio Beach and Waikiki Beach Center. Kuhio Beach (HI681782) is listed as impaired for the wet season. The enterococci criterion is listed as "Not Attained," and the basis for listing the water body (decision code) for the remaining parameters—TN, NO3+NO2, TP, and turbidity—is unknown. Kuhio Beach is assigned "Category 3," meaning that "there is [sic] insufficient available data and/or information to make a use support determinations [sic]," and "Category 5," meaning that available data and/or information indicate that at least one designated use in [sic] not being supported or is threatened, and a TMDL is needed. Kuhio Beach is given a "Low" priority code for Total Maximum Daily Load (TMDL) development. Waikiki Beach Center (HI244505) is listed as impaired for the wet season, although the basis for listing the water body (decision code) is unknown for all of the listed parameters (TN, NO3+NO2, TP, and turbidity). Waikiki Beach Center is listed as a "Category 2," meaning available data and/or information indicate that some, but not all of the designated uses are supported and "Category 3." Waikiki Beach Center is not given a priority ranking for TMDL development.

AECOS has conducted detailed water quality investigations in the project area, including during and post the State's 2006 Kuhio Beach sand recovery and beach nourishment project (AECOS, 2008). Recent investigations for this project show that in general Waikiki water quality is consistent with that typically found in Hawaii's coastal waters, with temperature, salinity, dissolved oxygen and pH within normal limits (AECOS, 2009b). Total nitrogen and total phosphorus concentrations generally exceeded the State water quality criteria geometric mean values, but were generally within the 10% or 2% not to exceed values. Turbidity levels were elevated at all sampling stations, generally exceeding all State water quality values. The high turbidity levels were attributed to wave action stirring up and suspending fine bottom sediment.

The Hawaii State Water Quality Standards states that the enterococcus bacteria geometric mean of samples taken during any 30-day period should not exceed a level of 7 colony forming units (cfu)/100ml, and no single sample should exceed a level of 100 cfu/100ml. The DOH/CWB sampling for enterococcus shows that the 30-day geometric mean Standard is generally met both onshore and offshore. However, most of the onshore stations, though none of the offshore stations, show maxima that far exceed the single-sample Standard. Another indicator of human fecal contamination, that is particularly suited for tropical waters such as Hawaii, is *Clostridium perfringens*, although there is no State water quality standard for this bacteria. Measurements of this bacteria by DOH/CWB show that levels are generally low at the onshore beach stations, typically about 0.5 cfu/100ml, and virtually undetectable in the offshore stations.

3.2 Noise

3.2.1 Applicable Sound Limits

Hawaii Administrative Rules §11-46, "Community Noise Control" establishes maximum permissible sound levels (see Table 3.7) 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 some pre-determined distance from the sound source. The project site itself is in the Conservation District, but there are no noise-sensitive uses in that area at the present time. Because of that, the Class B limits applicable to land zoned for resort use appears the most applicable. HAR §11-46-7 grants the Director of the Department of Health the authority to issue permits to operate a noise source which emits sound in excess of the maximum permissible levels specified in Table 3-6 if it is in the public interest and subject to any reasonable conditions. Those conditions can include requirements to employ the best available noise control technology.

Table 3-6 Maximum Permissible Sound Levels in dBA

Zoning Districts	*Daytime (7 a.m. to 10 p.m.)*	*Nighttime (10 p.m. to 7 a.m.)*
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, apartment, 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 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: Hawaii Administrative Rules §11-46, "Community Noise Control"

3.2.2 Existing Sound Levels

Existing ambient noise levels vary considerably within the project area both spatially (i.e. from place to place) and temporally (i.e. from one time to another). In general, existing background sound levels along Waikiki Beach are relatively high, 55 to 60 dBA, due to surf, traffic, aircraft, and on-going maintenance and construction equipment. In the vicinity of significant construction activity noise levels can intermittently reach 80 dBA.

3.3 Historic, Cultural and Archaeological Resources

3.3.1 Hawaiian Habitation and Traditional Land Uses

In prehistoric and early historic periods, Waikiki was a place of great cultural significance for Hawaiians. It was important as an agricultural center, a site of royal residences and *heiau*, as well as being a center for traditional Hawaiian cultural practices including human sacrifice, surfing, gathering of *limu*, and the traditional healing ablutions in the waters of Kawehewehe. Waikiki was also the site of at least two important battles, the 1793 invasion of Oahu by the forces of the Moi of Maui, Kahekili and the 1795 invasion of Oahu by Kamehameha the Great which led up to the unification of the Hawaiian islands under his rule. The following general discussion of historical and cultural resources in the project vicinity is based on investigations accomplished by Cultural Surveys Hawaii, Inc. (Groza et al, 2009).

Habitation. Waikiki was a center of population and political power on Oahu beginning long before the Europeans arrived in the Hawaiian Islands during the late eighteenth century. Kanahele (1995:134) notes that Waikiki's ancient chiefs had located their residences there for hundreds of years and that Kamehameha V's residence was at Helumoa (near where the proposed project is located). Kanahele (1995:134-1345) goes on to explain that: "Three features were common to royal locations in Waikiki. They were situated 1) near the beach, 2) next to a stream or *'auwai* (canal) and 3) among a grove of coconut or *kou* trees."

Agriculture. Beginning in the fifteenth century, a extensive system of irrigated taro fields (*lo'i kalo*) was constructed across the littoral plain from Waikiki to lower Manoa and Palolo Valleys. This field system – thought to have been designed by the chief Kalamakua – took advantage of streams descending from Makiki, Manoa and Palolo valleys, which also provided ample fresh water for the people living in the ahupuaa. Water was also available from springs in nearby Moiliili and Punahou. Closer to the Waikiki shoreline, coconut groves and fishponds dotted the landscape. A sizeable population developed amidst this Hawaiian-engineered abundance.

Aquaculture. The area known as Fort DeRussy (Kalia) contained ten Hawaiian fishponds used for aquaculture. Hawaiian aquaculture is especially notable as it was not practiced elsewhere in the Pacific in the same form. The majority of fishponds most likely were constructed in the sixteenth century. There are four basic types of ponds:[1]

loko i'a kalo (fish and taro raised together in a pond),
loko wai (inland freshwater fishpond),
loko pu'uone (isolated shore fishpond formed by a barrier sand berm creating a single elongated ridge parallel to the coast), and
loko kuapā (seawall on a reef with sluice gates)

Davis (1989, 1991) classified the ten fishponds at Fort DeRussy as *loko pu'uone* with salt-water lens intrusion and fresh water entering from upland *'auwai* (canals). Kahawai Piinaio was this

[1] Note: the prefix *loko* in the name means "body of water" and the suffix describes the specific type.

type of stream. The 10 ponds are inland, swale-based ponds constructed between beach ridges that may have formed along the coast within the last millennium. Existing depressions in the sand were chosen to make the *loko pu'uone*, and brush was cleared out. During traditional times, the ponds were used to farm fish, usually for the Hawaiian *ali'i* (royalty). The *'ama'ama* (mullet) and the *awa* (milkfish) were the two types of fish traditionally raised in the ponds.

Marine and Freshwater Resources Gathering Practices. Kālia was once renowned for the fragrant *limu līpoa*, as well as several other varieties of seaweed such as *manauea*, *wāwae'iole*, *'ele'ele*, *kala* and some *kohu*. The area between the Royal Hawaiian and the Halekulani was the area where *limu līpoa* was traditionally gathered. Oral information passed down to Mr. Bob Paoa[2] confirmed the great fishing and the abundant *limu* in the Kalia area. The project area was valued for harvesting of *limu kala* in particular to make *lei* for offerings.

McDonald (1985:66) notes that the "*lei limu kala* was and is still offered at the *ku'ula* [stone god used to attract fish] by fishermen or anyone who wishes to be favored by or is grateful to the sea". It is also well-known as an area where Green Sea Turtles or *honu* foraged.

Green Sea Turtles (which are now listed as endangered and threatened) were once a food source for Native Hawaiians. The meat, viscera, and eggs supplemented the more common food sources like fish, birds, shellfish, coconuts, breadfruit and taro. Native Hawaiians valued the adult female turtle as a delicacy because of its high amount of green body fat (http://www.fws.gov/pacificislands/ fauna/honu.html). *Honu* were also incorporated into religious and traditional ceremonies and were (and are) considered by some Native Hawaiian families to be a personal family deity or *'aumakua*. The harvesting of turtles was often regulated according to *kapu* rules, reserved exclusively for the use of chiefs, priests or only men for special occasions such as a wedding, funeral, religious ceremony, building of a canoe, etc. Native Hawaiians used the green fat for medicinal purposes to treat burns and other skin disorders.

Interviews reported in Chiogioji *et al*. (2005) confirm that the Waikiki shoreline was abundant in many varieties of fish and *limu*, certain varieties of crab and lobster, as well as being good squid grounds. Fishermen who presently use the Waikiki coast confirm this is still true today. Where one chooses to fish depends on the crowds at the beach and time of day as well as the distribution of favored resources. In Waikiki, especially due to the high volume of people on the beaches, many fishermen these days go fishing at night. The more favorable fishing grounds are in front of the old Niumalu Hotel (Hilton Hawaiian Village), the Royal Hawaiian and Halekulani hotels, and the area fronting the Natatorium. Specifically, the area between Diamond Head and the Kapahulu Groin was considered better fishing grounds than the Outrigger Reef on the Beach/Fort DeRussy portion of the shoreline. Likewise, the squid grounds are located between the Kapahulu groin and Diamond Head.

Surfing and Other Sports. In pre- and early post-contact Waikiki, surfing was popular to both chiefs (*ali'i*) and commoners (*maka'āinana*). So important was surfing that there is a major

[2] Mr. Paoa is a community consultant who has participated in past cultural impact assessments by Cultural Surveys, Inc.

heiau dedicated to the *nalu* or surf, and its riders. Papaenaena, a terraced structure built at the foot of Diamond Head, is where surfers came to offer their sacrifices in order to obtain *mana* (supernatural and divine power) and knowledge of the surf. The site overlooked what surfers call today “First Break,” the start of the Kalehuawehe surfing course which extended to Kawewehi (the deep, dark surf) at Kālia. Although everyone, including women and children, surfed, it was the chiefs who dominated the sport. One of the best among Waikiki’s chiefs was Kalamakua; he came from a long ancestry of champion surfers whose knowledge, skill, and *mana* were handed down and passed on from generation to generation. The story of his romantic meeting with Keleanuinohoanaapiapi (“Great Kelea who flutters,”) has been preserved as a reminder of the role that surfing played in the history of Waikiki (Kanahele 1995:56-58). Kawehewehe, once the name of the surfing site off the project area, is called “Populars” today.

Wahi Pana (Storied Places). The proposed project area, and the Waikiki ahupuaa is a *wahi pana* (storied place), rich in *mo‘olelo* (legends, myths), such as stories about *mo‘o* (water spirits) associated with fishponds, springs and water resource areas that they guard and protect. Most noteworthy is Kawehewehe Pond, a place of spiritual healing. Kawehewehe is understood as the name of the beach on the Ewa side of the Royal Hawaiian Hotel (adjacent to Helumoa), just east of the Halekulani Hotel, Waikiki.

Kawehewehe takes its meaning from the root word, “*wehe*” which mean “to remove” (Pukui et al., 1974:383). Thus, as the name implies, Kawehewehe was a traditional place where people went to be cured of all types of illnesses – both physical and spiritual – by bathing in the healing waters of the ocean.[3] The patient might wear a seaweed (*limu kala*) lei and leave it in the water as a request that his sins be forgiven; hence the origin of the name *kala* (Lit., the removal; Pukui *et al*. 1974:99). After bathing in the ocean, the patient would duck under the water, releasing the lei from around his neck and letting the *lei kala* float out to sea. Upon turning around to return to shore, the custom is to never look back, symbolizing the ‘oki (to sever or end) and putting an end to the illness. Leaving the lei in the ocean also symbolizes forgiveness (*kala*) and the leaving of anything negative behind.

Hawaiian Trails. In *Fragments of Hawaiian History* John Papa ‘I‘i described the “Honolulu trails of about 1810” (1959: 89), including the trail from Honolulu to Waikiki. He said that: “Kawaiahao which led to lower Waikiki went along Kaananiau, into the coconut grove at Pawaa, the coconut grove of Kuakuaka, then down to Piinaio; along the upper side of Kahanaumaikai’s coconut grove, along the border of Kaihikapu pond, into Kawehewehe; then through the center of Helumoa of Puaaliilii, down to the mouth of the Apuakehau Stream. (‘I‘i 1959: 92).

Based on ‘I‘i’s description, the trail from Honolulu to Waikiki in 1810 coursed through the *makai* side of the present Fort DeRussy grounds in the vicinity of Kalia Road. It is likely that this trail was a long-established traditional route through Waikiki.

[3] It is uncertain if the tradition of Kawehewehe as a healing place originated hundreds of years ago in Hawaiian history or whether it began after the introduction of foreign diseases and epidemics that decimated thousands of Hawaiians.

Burials. The discovery of burials in the Waikiki area during recent construction projects has caused increasing concern over the last few years. There are approximately 14,500 records associated with LCA claims during the Mahele of 1847-1853. Of these records, 432 are for claims both awarded and unawarded in Waikiki. Among these 432 claims, there is only one mention of a graveyard or burial place, Claim 613 (to Kuluwailehua) which was not awarded (www.waihona.com). Although it is uncertain where the reported burial ground is located, based on the boundaries given in the testimony (Native Register, Vol. 2: 299-300) found in www.waihona.com, it is speculated that it might be adjacent to the old Waikiki Church near Kaiulani Avenue. If that is correct, it places the burials at least one-half mile from the closest point on the project site. The circumstances of the burials discovered closer to the project area are more mundane than battle deaths or human sacrifices, with the vast majority of the known deceased being the common people of Kalia. Withington (1953:16), probably referring to the *ʻokuʻu* (Lit., to squat on the haunches) or (possibly, cholera) plague (circa 1804), wrote: "…a few years of peace settled over the Islands. Kamehameha and other warring chiefs took this opportunity to re-establish their forces, which had been greatly reduced through war and disease. A terrible epidemic of measles had attacked the people of the islands. It is claimed that more than three hundred bodies were carried out to sea from Waikiki in one day." (Withington: 1953:16).

It is possible that some of the Kalia burials discovered to date reflect such early depopulation by introduced diseases. Hawaiians placed significance on the *iwi* (bones), which were regarded as a lasting physical manifestation of the departed person and spirit. "The bones of the dead were guarded, respected, treasured, venerated, loved or even deified by relatives; coveted and despoiled by enemies" (Pukui et al., 1974:107).

3.4 Recreation

John Clark, a locally recognized expert on ocean recreation and cultural activities in Hawaii, has completed an assessment of ocean recreation activities in the project vicinity (see Appendix B). His assessment included observation of ocean activities and ocean conditions in the project area, interviews with shoreline users, and evaluation of possible project effects and impacts on recreation activities. The project site, including the waters offshore, is the most heavily used section of Waikiki Beach, and is used for many different ocean recreation activities. These include sunbathing, swimming, surfing, standup paddling, bodyboarding, sand skimming, snorkeling, spear fishing, pole fishing, walking, wading and metal detecting. Annual recreation events such as canoe regattas and surf contests are held in the project area. Four beach concessions are located within the 1,700-foot-long project reach, providing beach umbrella and surfboard rentals, surfing lessons, and canoe rides. Four sailing catamarans are presently permitted to operate on Waikiki Beach. The beach concessions at the east end of the project site (Star Beach Boys and Hawaiian Oceans) lease their concession sites from the City and County of Honolulu. The sailing catamarans are permitted by the State DLNR/DOBOR.

Sunbathing. Sunbathing in the project site is possible from one end to the other, but the heaviest concentration of sunbathers is at the west end of the beach, where it is widest, fronting the Outrigger Waikiki and the Royal Hawaiian Hotels. The best time for sunbathing is at low tide during periods of little or no surf. At high tide at least half of the beach fronting the Moana

Hotel is covered with water, and if high surf combines with a high tide, waves may overrun the entire beach here and strike the retaining wall in the backshore, precluding all opportunities for sunbathing.

Swimming. Swimming in the project site occurs from one end to the other, but the greatest concentration of swimmers tends to be in the middle of the beach, fronting the Moana Hotel. With the surfboard rental, canoe ride, and catamaran ride concessions concentrated at both ends of the project site, the least amount of ocean craft traffic that might endanger swimmers is in the center of the beach.

Snorkeling. The reef fronting the project site is not known as a good site for snorkeling. The inner portions of the reef are largely covered with sand and do not attract the volume or variety of fish that other reefs do. For this reason snorkeling is a minor activity here. In addition, during periods of high surf, visibility over the reef is poor due to wave agitation of the ocean bottom. The channel between the surf spots Canoes and Sandbars, however, is a feeding site for green sea turtles. They may be seen at all times of the day eating the seaweed that grows on the reef flat.

During periods of low or no surf, some snorkeling for lost valuables such as rings, watches, and coins occurs at Canoes. This activity is an extension of the treasure hunting with metal detectors that takes place on the beach.

Surfing. Canoes is the name of the surf spot located directly off the Moana Hotel. It was known to native Hawaiian surfers as Kapuni, but its name was changed to Canoe Surf in the 1890s when commercial canoe rides were offered to visitors and then later shortened to Canoes. During especially large south swells, surf spots form seaward of Canoes. These spots, which are known as Blowholes and First Break, break and reform as they move towards shore into Canoes.

Canoes is the most highly used surf spot in Hawaii for commercial surfing activities, including surfboard rentals, surfing lessons, and outrigger canoe rides. Beginning surfers and surf instructors with beginners receiving lessons are concentrated on the smaller inside waves, which is known as Baby Canoes, while intermediate and advanced surfers ride the bigger waves outside.

Queen’s is the name of the surf spot located directly off the Duke Kahanamoku Statue. The waves at Queen’s are steeper than those at Canoes and are concentrated in a much smaller area, so beginning surfers and surf instructors with beginners receiving lessons generally do not surf here. Waves at Queen’s, however, reform near shore on the shallow reef at the east end of the project site. This surf spot is known as Baby Queen’s and attracts beginning surfers and surf instructors with lessons.

Canoes and Queen’s are located on the south shore of Oahu, which generally receives its biggest surf during the spring and summer months. However, there is almost always enough surf at both of these spots in the fall and winter to sustain the commercial surfing activities throughout the year. Four beach concessions are located in the project site, two on the east side of the Moana Hotel and two on the west side. The two on the east side are Star Beach Boys under Aaron

Rutledge and Hawaiian Oceans under Hubert Chang. The two on the west side are Aloha Beach Services under Didi Robello, and Waikiki Beach Services under Ted Bush.

The beach concessions position photographers on the beach inshore of their surf instructors while the surf instructors are giving surfing lessons. The photographers take digital pictures of the novice surfers receiving lessons with a telephoto lens and then the beach concessions offer the pictures for sale on a compact disc to the novice surfers when they come in.

Night surfing at Canoes is an occasional activity that usually happens under a full moon, but may also occur at other times of the month. Some surfers also bring in the New Year at Canoes by paddling out on New Year's Eve just before midnight to start their New Year by surfing.

Canoe Surfing. Catching waves with an outrigger canoe in Waikiki takes place at Canoes, the famous surf spot off the Moana Hotel that was named for this activity. The waves on the west edge of Canoes are ideal for this canoe surfing and often have enough momentum to carry the canoes all the way to shore.

All four of the beach concessions offer outrigger canoe rides. Use of the commercial canoes is controlled by the Division of Boating and Ocean Recreation (DOBOR), Department of Land and Natural Resources (DLNR), State of Hawaii. DOBOR controls boating in Waikiki shore waters and their administrative rules regarding commercial outrigger canoe operations may be accessed through their homepage under Title 13, Subtitle 11, Parts 2 and 3.

Canoe surfing is a feature in the Outrigger Canoe Club's annual Fourth of July canoe races in Waikiki. Known as the Walter J. MacFarlane Regatta, the race course begins on the beach fronting the Moana Hotel and then circles a buoy offshore which brings the canoes back to the beach through the waves of Canoes.

Catamaran Rides. Catamaran rides are a popular activity on Waikiki Beach. The catamarans park on the beach, where they load and unload passengers. They motor in and out of the beach, and sail up and down the Waikiki coast for specified periods of time.

Four catamarans are presently permitted to conduct catamaran ride operations on Waikiki Beach. From east to west, they are the Mana Kai, which is owned by William Brown, and operates at the east end of the project site; the Na Hoku and the Manu Kai, which are owned by John Savio, and the Kapoikai, which is owned by Sheila Lipton, all of which operate at the west end of the project site.

The Division of Boating and Ocean Recreation (DOBOR), Department of Land and Natural Resources (DLNR), State of Hawaii, controls boating in Waikiki shore waters. Administration of the beach landing areas for the catamarans in the project site comes under DOBOR's Oahu District Manager. DOBOR's administrative rules regarding commercial catamaran operations may be accessed through their homepage under Title 13, Subtitle 11, Parts 2 and 3.

Ocean Recreation Events. In addition to the annual Walter J. MacFarlane Regatta, which is held every July 4, a number of other ocean recreation events are held in the project site. These are primarily surf contests, which are run at the surf spot Queen's during the spring and summer months. Contest organizers set up their staging area on the beach at the east end of the project site between the Hula Mound and the Duke Statue. The staging area includes judging towers and a number of tents for t-shirt concessions, food concessions, and competitors. One of the best known of these contests is China Uemura's Longboard Surfing Classic, which celebrated its 25th anniversary this year.

The east end of the project site occasionally serves as the start and finish for rough water swims. These swims are generally held during the summer months, but may occur at any time of year.

Fishing and Gathering. Two types of fishing occur in the project site, spear fishing and pole fishing, but both are infrequent. During the field trips for this report, no spear fishers or pole fishers were observed, but one informant said that he goes spearing perhaps once a month for fish and octopus. The intensive use of the beach and the ocean in the project site by all of the other ocean users is a major deterrent to activities involving spears and fish hooks.

The project site was once known as a good place to gather edible seaweeds, or limu, especially *limu lipoa*, but little if any edible seaweed seems to remain in Waikiki today. No gathering activities of seaweed, shellfish, or other marine species were observed during the field trips or noted by the informants.

The Waikiki Marine Managed Areas (MMA) consists of two parts: the Waikiki Marine Life Conservation District (MLCD) and the Waikiki-Diamond Head Fisheries Management Area (FMA). The project site is not included in the Waikiki MMA.

Boating. The Division of Boating and Ocean Recreation (DOBOR), Department of Land and Natural Resources (DLNR), State of Hawaii, controls boating in Waikiki shore waters. DOBOR's administrative rules regarding commercial catamaran operations may be accessed through their homepage under Title 13, Subtitle 11, Parts 2 and 3.

DOBOR's administrative rules also regulate power boating in Waikiki shore waters. The catamarans and personal water crafts operated by the lifeguards are the only vessels under power that are permitted in the project site. Non-motorized boats such as surf skis (racing kayaks) and ocean kayaks (recreational kayaks) are permitted.

A large pocket of sand outside of the surf spot Queen's is called the Sand Spit. It is a popular anchorage for boats, especially in the evening and at night. On weekends and holidays, sometimes as many as 30 boats may be anchored there.

3.5 Economic Setting

Waikiki Beach is recognized as the State's primary tourist destination, attracting millions of visitors yearly. Waikiki contains approximately 44 percent of the rooms/lodging units available in the State. Quantifying the economic implications of the degraded beach condition is difficult.

However, the Waikiki Beach Erosion Control Reevaluation Report prepared by the U.S. Army Corps of Engineers contains an extensive economic analysis of the costs and benefits of beach restoration and erosion control along all of Waikiki beach (Lent, 2002, and USACE, 2002). Some of the findings of this analysis include the following.

Visitor surveys indicate that 12.6 percent of tourists who do not revisit cite crowding and congestion (considered to be of the beach) as reasons. This is equivalent to about 250,000 visitors, or 3.6 percent of the total visitors to the State in a year. These visitors, were they to come, would spend an estimated $181 million/year.

A benefit to cost ratio analysis was completed to determine Federal interest in restoring and improving Waikiki Beach, with a ratio greater than one indicating that benefits exceeded costs. The overall benefit to cost ratio for all of Waikiki was about 6. The total Waikiki Gross National Product (GNP) contribution to the annual Federal economy is an estimated $3.3 billion. This estimate excludes spending by mainland west coast visitors (USACE, 2002).

An economic analysis of the importance of Waikiki Beach accomplished by Hospitality Advisors LLC (2008) for the Waikiki Improvement Association showed that an overwhelming majority of all visitors consider beach availability to be very important. When presented with the possibility of the complete erosion of Waikiki, 58% of all westbound visitors said they would not consider staying in Waikiki without the beach.

3.6 Scenic and Aesthetic Resources

The gentle curve of the Waikiki shoreline, the wide expanse of water with multiple surf breaks, the changing colors resulting from the varying water depths and bottom types, and the backdrop of Diamond Head make the seaward and long-shore views from the shoreline spectacular. At the same time, the tall buildings that have been developed relatively close to the ocean along portions of the shore in the project area block the viewplane. As a result, views inland from this shoreline are not one of the “significant panoramic views” identified in the City and County of Honolulu’s Development Plan for the area.

The appearance of the beach is of significant interest to the shoreline hotels along the project area, the Royal Hawaiian, Outrigger Waikiki, and Moana Surfrider, as their guests represent the most numerous and closest viewers. However, it is also of considerable interest to those who own and/or use adjacent areas and the walkway along Kalakaua Avenue.

3.7 Public Infrastructure and Services

3.7.1 Transportation

Vehicular and Pedestrian Access. Pedestrian access is available from Kalakaua Avenue is available through public rights-of-way, and the large open space at the east end of the project area in the vicinity of the Duke Kahanamoku statue.

Harbors. The nearest harbor is the Ala Wai Harbor, which is owned and operated by the State of Hawaii. Commercial cargo arrives and departs through Honolulu Harbor.

Airports. Honolulu International Airport is approximately six miles west of the project site.

3.7.2 Water, Sewer and Communications Systems

Water Supply. The Honolulu Board of Water Supply (BWS) is responsible for the management, control and operation of Oahu's municipal water system that serves the entire Primary Urban Center Development Plan area. The BWS system is an integrated, island-wide system with interconnections between water sources and service areas. Water is exported from areas of available supply to areas of municipal demand.

None of the BWS facilities are present *makai* of the shoreline where the proposed beach maintenance would occur. Neither does it maintain nor operate any pipelines or other water supply facilities within the area that would be used by construction equipment.

Sanitary Wastewater Collection and Treatment Facilities. The City's Department of Environmental Services manages the municipal wastewater collection, treatment, and disposal system that serves the hotels surrounding the project site. The project site lies within the East Mamala Bay service area, with outflows processed through the Sand Island Wastewater Treatment Plant. The nearest City and County of Honolulu sanitary sewer line is located inland from the project area.

Telecommunication Facilities. There are no telecommunication lines within the shoreline area or in the area which would be used by construction equipment.

Electric Power. The Hawaiian Electric Company (HECO) provides electrical service to the project area. Most of the electrical power that is consumed in Waikiki comes from fossil fuel-fired generating units located at Waiau, Campbell Industrial Park, and Kahe. Power is delivered to customers by a system of underground and overhead transmission and distribution lines, none of which are in the project area.

3.7.3 Solid Waste Collection and Disposal

The City's Department of Environmental Services manages Honolulu's municipal solid waste system, including the H-POWER resource recovery facility and one sanitary landfill. A private company operates a construction debris landfill in Nanakuli, and private companies are responsible for solid waste collection from virtually all of the island's commercial organization.

3.7.4 Police, Fire and Emergency Medical Services

Police Protection. The Department of Land and Natural Resources Division of Conservation and Resources Enforcement (DOCARE) is responsible for enforcement activities in areas controlled by the Department of Land and Natural Resources, which includes the area seaward of the certified shoreline where the beach maintenance would take place. In addition, Honolulu Police Department officers patrol accessible areas of the beach on all-terrain vehicles (ATVs). Presently, officers only patrol as far as the Royal Hawaiian due to the limited shoreline access. The proposed project would facilitate police patrolling along the beach. The nearest police station is located at the Waikiki Beach Center (Police Sub-Station) on Kalakaua Avenue adjacent to the Moana Hotel. Police headquarters is located on Beretania Street near its intersection with Ward Avenue.

Fire Protection. The three nearest Fire Stations are on Makaloa Street, at the intersection of University and Date Streets, and at the intersection of Kapahulu Avenue and Ala Wai Boulevard. All are roughly 1.5 miles by road from the project site.

Emergency Medical Services. The three hospitals nearest to the project site are Kapiolani Women's and Children's Hospital on Punahou Street, Straub Hospital on King Street, and Queen's Hospital on Punchbowl Street. All three hospitals provide emergency medical services (EMS) to the area, as do the Fire Stations mentioned above.

4. POTENTIAL IMPACTS OF PROPOSED PROJECT

4.1 Effects on Seafloor and Shoreline Processes

The following criteria are considered in determining whether the effects that the proposed action would have on the physical characteristics of the seafloor and shoreline processes would be significant:

- Interfere with existing sand transport processes and beach stability/erosion;
- Affect the shape of the shoreline or the bottom in such a way as to interfere with existing recreational or commercial uses;
- Permanently alter a unique or recognized shoreline or bottom feature;
- Affect the bottom in such a way as to degrade the quality of waves used by surfers; and
- Conflict with existing federal, state or county statutes or regulations.

4.1.1 Impacts During Construction

Sand Recovery Sites. During sand recovery operations the sandy seafloor will be significantly altered in the immediate recovery area as a result of sand excavation. Pits, or depressions, will be formed in the sediment bed during actual dredging operations. Based on experience during the 2006 Kuhio Beach sand recovery activities wave action is anticipated to quickly move sand into and fill the depressions, returning the seafloor to nearly its pre-construction condition. During the 2006 sand recovery project the sand deposits were noted to return nearly to their pre-dredging elevations within 3 to 6 months post-construction, as evidenced by the disappearance of the emergent white limestone band around the edge of the sand deposit that appeared as sand was removed and the seafloor lowered during dredging (AECOS, 2007a, 2007b, 2008a, 2008b).

Sand Transport Pipeline. The small diameter (less than 1-foot) pipe will be mostly submerged and anchored to the sea floor. It will not reduce water depths sufficiently to affect navigation, and it is too small to affect nearby surfing sites such as Canoes and Queen's. The pipeline will pass between Queen's and Baby Queen's, and may impact activity at these sites during installation, maintenance, and removal of the pipe. As the pipeline nears shore and enters the east crib wall area it could pose a minor obstacle for swimmers and waders, however the pipeline will be marked and the nearshore and shoreline area to be used for dewatering of the sand will be closed to beach users during construction.

Sand Placement. Sand placement will alter the size of the beach, approximately doubling the dry beach width; however the shape of the shoreline will remain the same. Equipment operations on the beach will be minimized to the extent practicable. The sand placement activities may temporarily affect commercial activities, such as catamaran rides and surfboard rentals; however these impacts will be localized to the immediate area of sand placement activity. It is anticipated that the affected activities can temporarily relocate to help mitigate the impacts. In addition, sand placement will be primarily accomplished during the late afternoon and evening in order to reduce conflicts with beach use. No effects on shorelines adjacent to the project area are anticipated.

4.1.2 Long Term Effect on Shoreline Processes

The project will not alter or affect the presently on-going sand transport and shoreline processes in or outside of the project area. The beach width will be increased by approximately 40 feet; however, the beach will conform to the existing shape and configuration due to the dominate coastal processes, which will remain unchanged. The increased beach width is not expected to affect or alter the existing wave-driven longshore currents or circulation. The increased beach width will not affect surf sites located offshore. Offshore surf sites are primarily influenced by the hard limestone fossil reef formations that are at slightly higher elevation than the intermittent sand channels and pockets, and thus would not be significantly affected by either the recovery of sand from offshore or its migration back offshore over time. No new structures or other measures will be used to stabilize the sand fill. The beach is anticipated to continue eroding and the shoreline receding at the current average annual rate of 2.3 feet per year. Some of the new beach sand may be transported west and around the end of the existing Royal Hawaiian groin; however, the primary loss of sand is anticipated to be offshore as it has historically been. In essence, the project will recycle sand from offshore and back to the beach where it came from.

4.2 Water Quality Impacts

The following criteria are considered in the evaluation of whether the effects that the proposed action and the alternative of No Action on water quality would be significant:

- Consistency with the provisions of the Clean Water Act;
- The degree to which it would comply with applicable water quality standards or with other regulatory requirements related to protecting or managing water resources; and
- The extent to which it would degrade water quality in a manner that would reduce the existing or potential beneficial uses of the water.

4.2.1 Construction Period Impacts

4.2.1.1 Sand Recovery Operations

Sand will be pumped from offshore sand deposits using equipment and methodology similar to that used for the 2006 Kuhio Beach maintenance project. Monitoring that was conducted during that project indicates that the following temporary water quality impacts may occur:

- Slightly increased turbidity in the immediate vicinity of the suction head;
- Slightly decreased dissolved oxygen concentration as a result of the sand disturbance;
- Slightly increased nutrient levels (nitrogen and phosphorus) as a result of the sand disturbance; and
- Slight changes in pH.

The use of a suction dredge will result in the majority of bottom material disturbed being drawn into the dredge pipeline, with only a small amount of disturbed material escaping the dredge to affect adjacent areas or water quality. Careful placement of anchors, cables, and the sand transport pipe will insure that they do not move about and disturb/suspend bottom material.

These water quality impacts will be very temporary, lasting only during the actual dredging operations, and will be localized to the immediate vicinity of the dredging. Best Management Practices (BMPs) will be followed throughout the sand recovery work, consistent with the State Department of Health Water Quality Certification that will be required for the project.

4.2.1.2 Sand Transport Pipeline

The pipeline that will transport the sand from the recovery site to the dewatering area will be anchored to the bottom to minimize its movement and disturbance of bottom material along its route. Anchoring the pipeline will also reduce the likelihood of abrasion-related puncturing of the pipe which could result in the release of sand and turbidity.

4.2.1.3 Sand Dewatering and Placement

The greatest potential for project-related impacts to water quality will occur as the sand is dewatered and then placed on the beach. In order to minimize and avoid water quality impacts the sand will be dewatered in a two-stage system. Dewatering will be accomplished within the confines of the Kuhio Beach east crib, at the same location as was used for the 2006 beach maintenance project. A stable dewatering area containment berm will be placed inside the crib wall sill, with a minimum elevation of about +5 feet to permit piling sand above sea level. Geotextile filter fabric would be used to line the inside of the dewatering area as necessary to prevent the escape of turbid water. The east end of the dewatering area would be bound by a heavy duty turbidity barrier, which would retain fine material and permit non-turbid water to pass. The dewatering basin would also be surrounded by a secondary turbidity containment barrier to further insure that turbid water would not be introduced into nearshore waters. The general dewatering site layout is shown on Figure 2-17. As the water drains from the basin, the dewatered sand would be removed and placed on the beach, and then the basin can be refilled with more sand slurry pumped from offshore.

Dewatered sand would initially be moved to a temporary above-water staging area along the west crib shore. The sand would then be moved and placed on the project area shoreline to the design cross-section and beach profile, starting at the east end and working west. This sand movement and placement would be done in late afternoon and early evening when beach activity is less. A turbidity barrier would surround the area of active sand placement each evening to reduce the potential for turbidity impacts to coastal waters during sand placement in the water.

The best forecast of the effect that the sand dewatering and placement is likely to have on water quality can be made by examining the results of the extensive water quality monitoring that was conducted as part of the State's 2006 Kuhio Beach Nourishment Project, where sand recovered from offshore was also used to restore the beach. The sampling station locations for that project are shown in Figure 4-1 and the results are shown in Figure 4-2.

The results of the monitoring do not show any consistent relationship between work being carried out and fluctuations in the values of the various water quality parameters that were monitored at the offshore stations. Instead, they suggest that the fluctuations were due to natural factors unrelated to the beach nourishment project. Moreover, the variations of temperature, salinity, dissolved oxygen, and turbidity measured in this monitoring are all well within the natural ranges of these variables measured by the State Department of Health and discussed in Section 3.1.8, and summarized in Appendix A. Additional tests carried out for Fecal Coliform and Enterococcus in the pit and swimming area where active pumping was taking place indicated these did not exceed state standards and thus were not a problem.

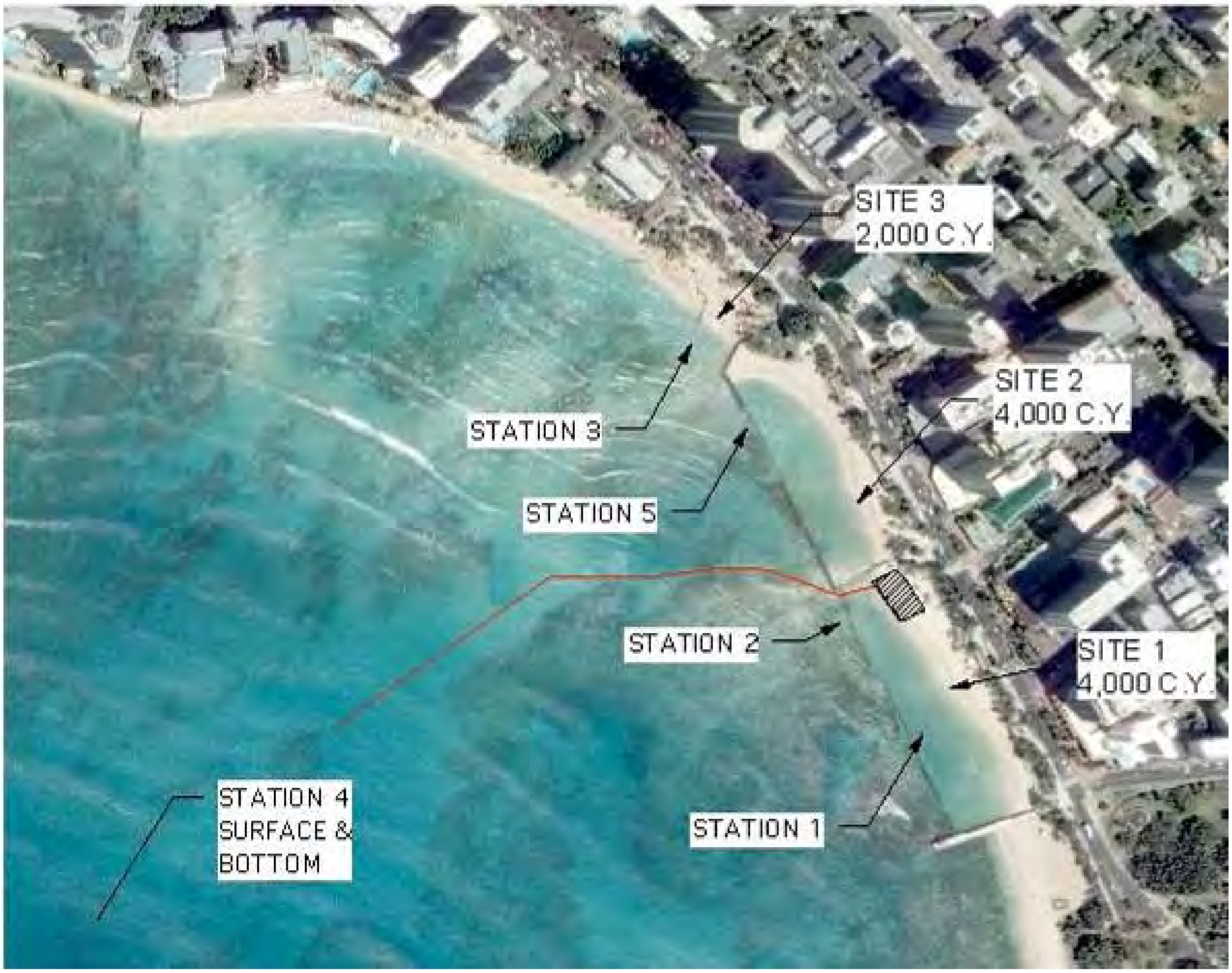
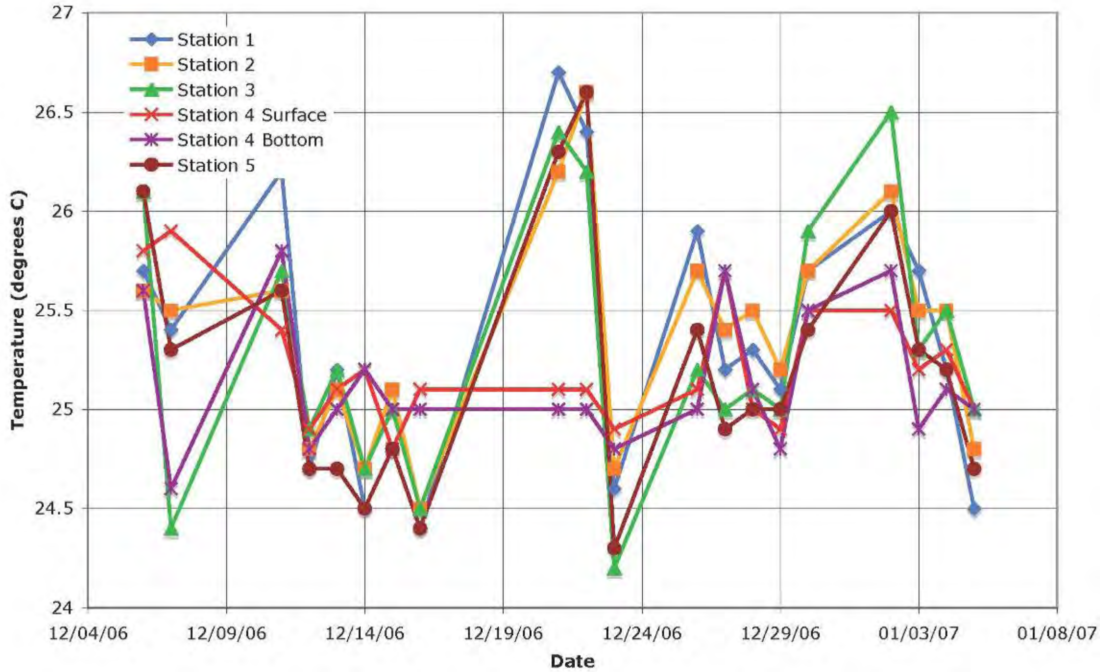
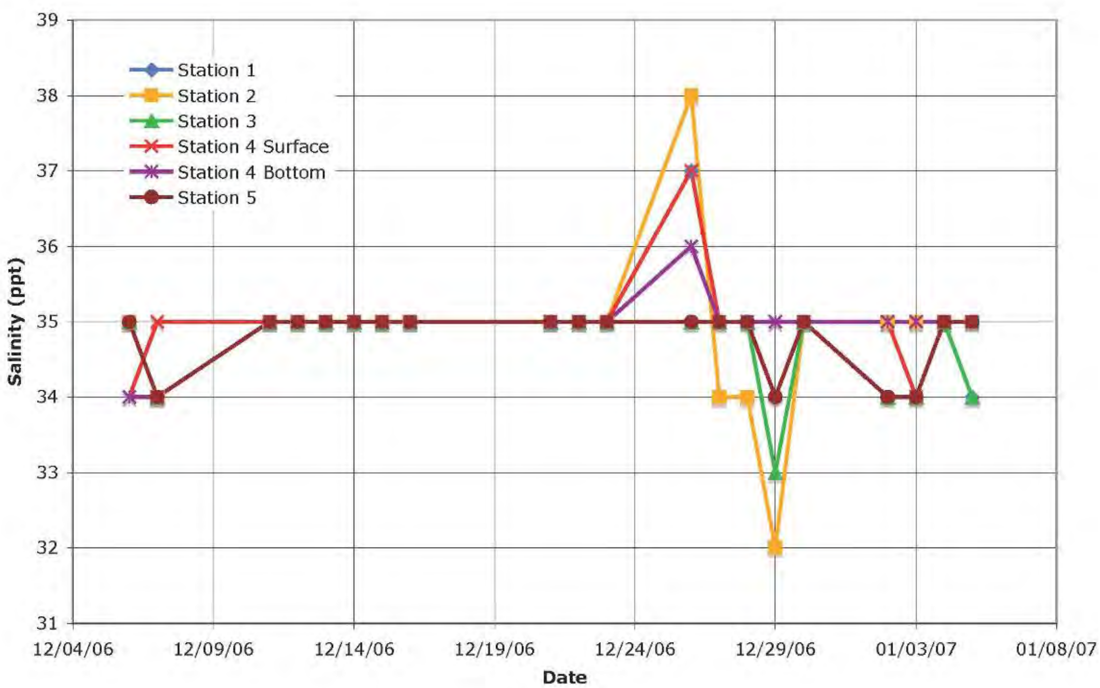


Figure 4-1 Kuhio Beach Small-Scale Sand Pumping Project Sampling Station Locations

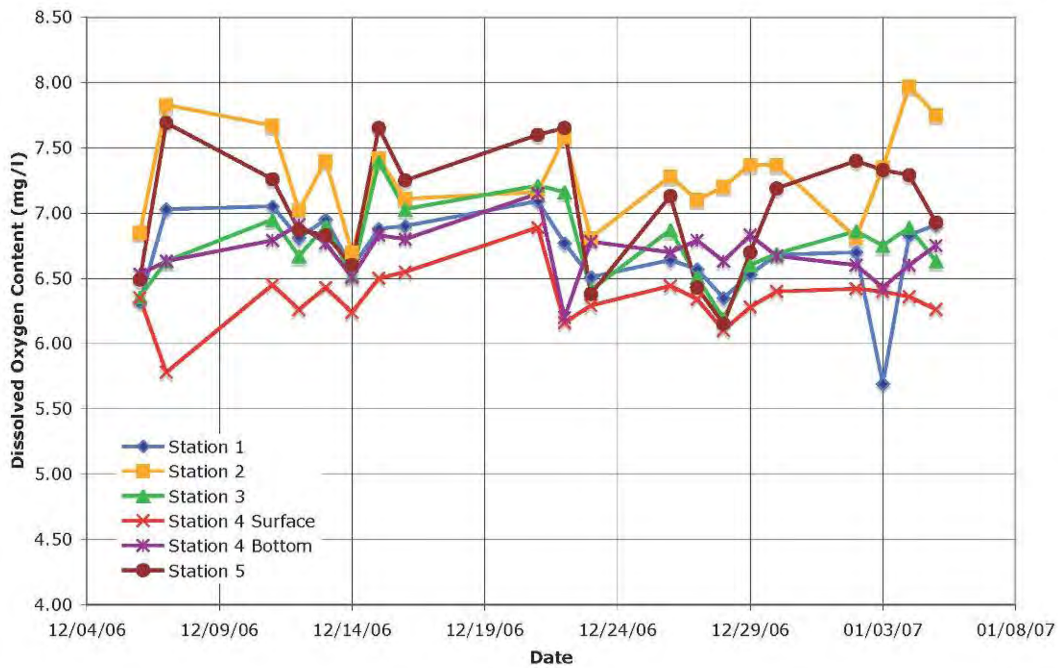


Source: American Marine Corporation (November 26, 2007), Figure 2.

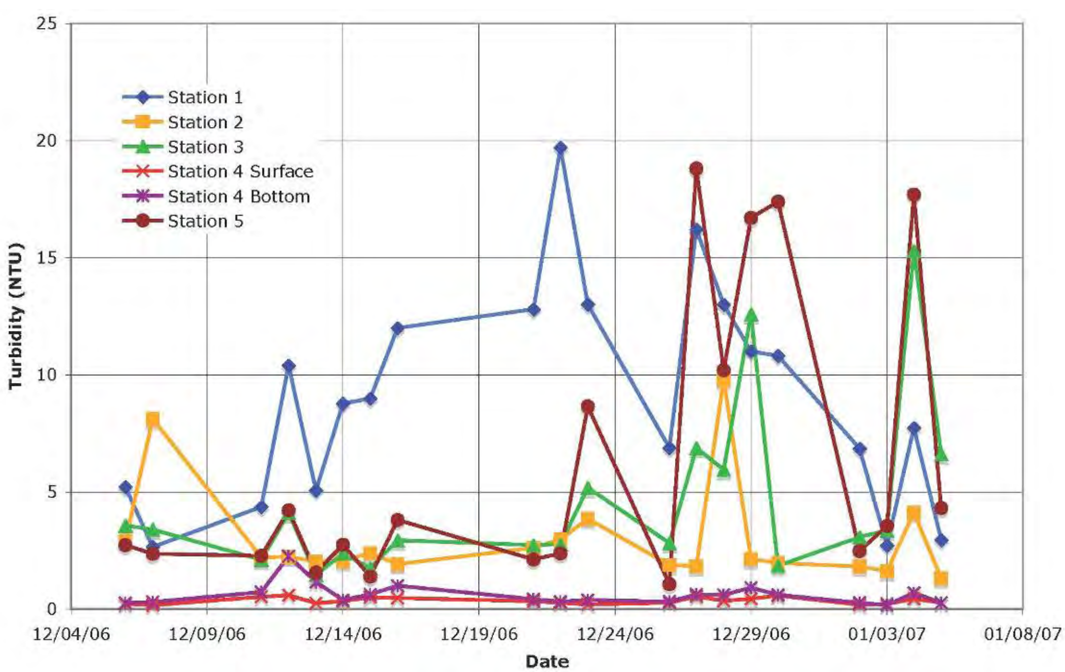


Source: American Marine Corporation (November 26, 2007), Figure 3.

Figure 4-2 Water Quality Effects: Kūhiō Beach Small-Scale Sand Pumping Project

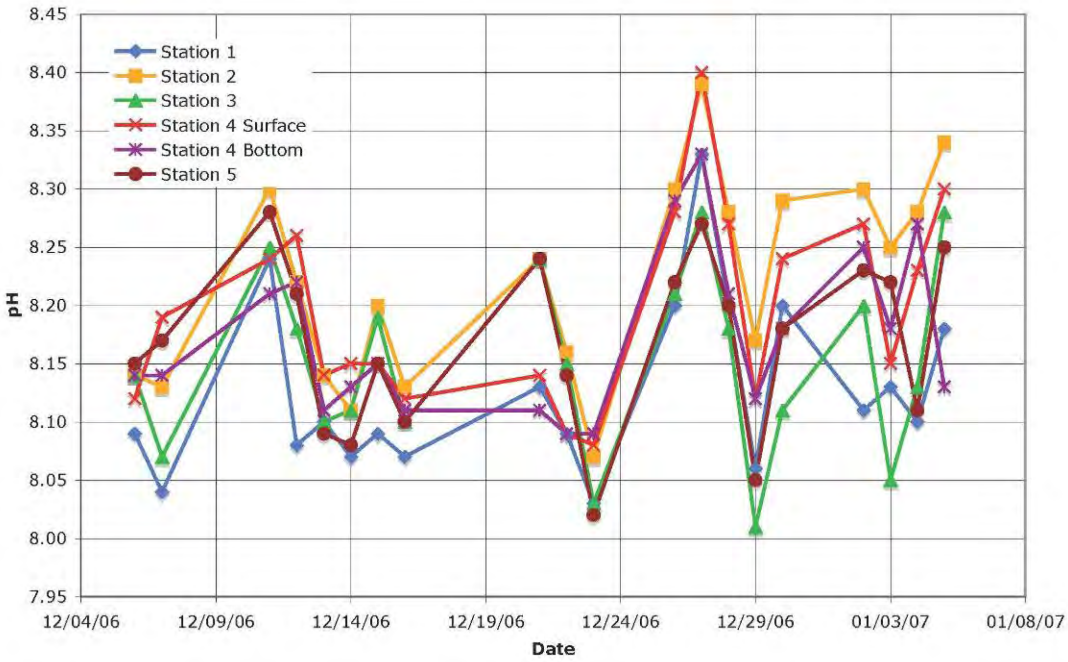


Source: American Marine Corporation (November 26, 2007), Figure 4.

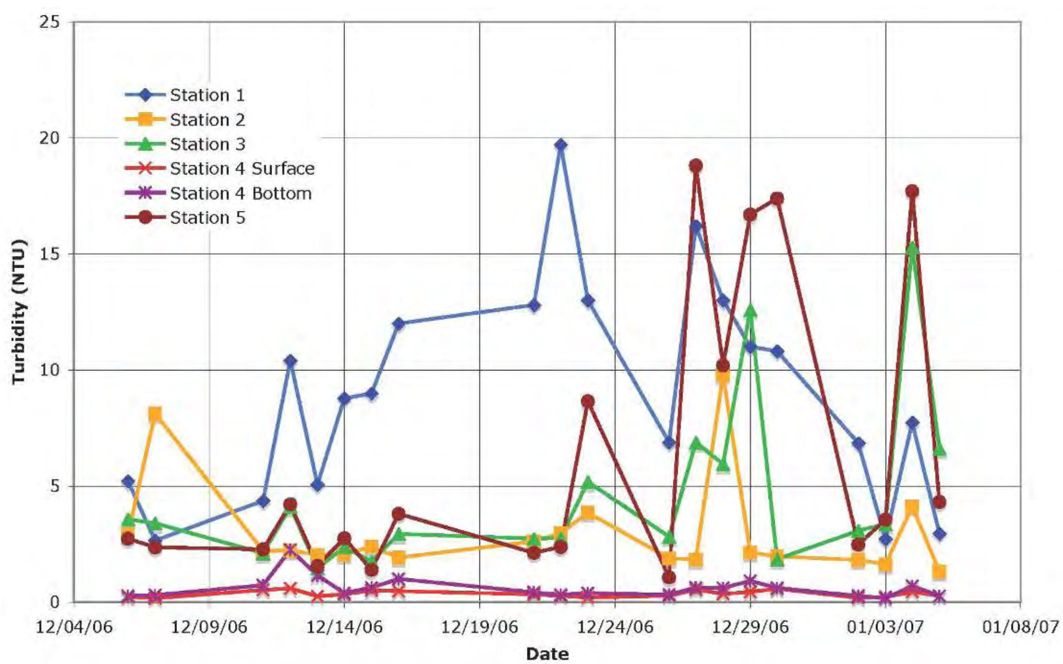


Source: American Marine Corporation (November 26, 2007), Figure 5.

Figure 4-2 cont'd



Source: American Marine Corporation (November 26, 2007), Figure 6.



Source: American Marine Corporation (November 26, 2007), Figure 7.

Figure 4-2 cont'd

4.2.2 Long Term Effect on Water Quality

The post-project report for the Kuhio Beach Nourishment Project concluded that no detrimental environmental impacts were observed and there were no complaints from beach users (American Marine Corporation (November 26, 2007: page 4)). Turbidity within the dewatering basin was high, but except for the occasions when the sand berms were breached, this did not affect State waters. The proposed action will require a more robust dewatering basin berm, thus eliminating the previous project's berm breaching problem.

In summary, impacts on water quality due to the recovery, transport, and placement of sand on the beach are predicted to be minor, temporary, and localized to the immediate vicinity of the recovery, dewatering and placement operations. Based on the monitoring of a similar sand recovery and emplacement project on nearby Kuhio Beach, no long-term impact on water quality is anticipated.

4.3 Biological Effects

Several aspects of the proposed project have the potential to affect marine biota. These include the following:

- Direct physical disturbance of the bottom during sand dredging and pumping, and sand placement on the beach.
- Direct physical disturbance of biota in the water column and the disturbed sand substrate as a result of project-related construction activities.
- Indirect effects associated with project related changes in water quality.
- Indirect effects related to re-colonization patterns as biota re-establishes itself in areas that were disturbed by temporary construction activities following the completion of construction.

This section of the report describes those potential biological effects. Effects are considered to be significant to the extent that they exceed the following criteria:

- Change environmental conditions (e.g., water quality, ambient noise level, wave energy, etc.) within a substantial part of the range of an important marine community.
- Involve work in a habitat believed to be used by known sensitive species (Federal or State listed endangered, essential fish habitat, etc.) or in a conservation district.
- Substantially affect the spawning area available to a marine species.

4.3.1 Construction Period Impacts

4.3.1.1 Sand Recovery Effects on Infauna

Investigation of infauna in the nearby Halekulani Channel sand deposits identified 31 species of infauna (Bailey-Brock and Krause, 2008). The most abundant taxa observed are the nematodes (round worms, phylum *Nematoda*; 62 percent), followed by oligochaete worms (earth worm relatives, phylum *Annelida*, subclass *Oligochaeta*, 12 percent) and copepods (tiny crustaceans, phylum *Arthropoda*; 8 percent). While the sand deposits may contain a diverse assemblage of infaunal invertebrates, none have been listed as threatened or endangered by Federal or State agencies and none of the infaunal species found are known to be preyed on by typical reef fish. Moreover, the types of organisms that are present have a relatively fast reproductive cycle and those organisms that survive the dredging typically repopulate areas within a relatively short period of time. Dredging will remove about 35 percent of the total estimated sand available from the recovery sites, and thus disturbance to infauna in the respective sand deposits will be substantial and significant. However, based on the recent Kuhio Beach experience, the sand deposits can be expected to fill back up with sand over time, and possibly quite rapidly, and infauna can be expected to rapidly repopulate the deposits.

4.3.1.2 Sand Recovery Effects on Corals

Studies conducted for the State's 2006 Kuhio Beach Restoration Project, which involved nearly identical activity in the same area, provide an excellent model understanding possible effects on coral and other marine biota (AECOS, 2007, 2008). The sand recovery sites are bordered by fossil limestone reef rock with less than one percent live coral cover. A survey conducted soon after the sand recovery work was completed identified some damage to individual coral colonies, with the condition of individual coral colonies varying greatly. Some corals were in pristine condition, others were mildly damaged (some branches broken, but colony mostly intact), and some were severely damaged or missing entirely. The majority of damage to corals appeared to be the result of equipment movement (pipeline, anchor lines), and much of this appeared to have occurred during an unseasonable south swell event mid-way during the dredging operations.

Biologists re-surveyed the sand extraction area approximately one year following the completion of the work and prepared a final post-construction survey report (Laing, February 22, 2008). Two divers snorkeled the area to inspect individual coral colonies for signs of previously existing damage and for signs of new damage. No recent coral damage was observed during the one-year survey. Previously damaged coral colonies and their cast off fragments experienced varying degrees of recovery success. They found that some coral colonies had succumbed to mechanical damage and died while others had responded with copious growth leading to a more robust growth form. A few previously damaged coral colonies with branches missing were revisited several times. The observations indicated illustrate that there was mixed success in coral fragment survival. Cast-off fragments either fell from the parent colony into a location that promoted growth or into a location that did not. Fragments that landed on sand died without having a stable place to become established. Fragments that landed on hard substrate sometimes survived initially, but later became overgrown with turf algae and died. Other live fragments observed in the 1-year survey were located in small shallow depressions in the reef that are protected during periods of elevated wave energy allowing them continued growth.

Measures proposed to be exercised to protect corals during construction activities include:

- Locating and marking significant corals in the vicinity of the areas to be dredged;
- Identifying a specific pipeline route corridor which minimizes the potential for damage to coral and other benthic fauna; and

- Transplanting corals as necessary and where practicable to relocate them from the construction site, particularly along the pipeline route.

4.3.1.3 Sand Recovery Effects on Fishes

The sand deposits are typically home to a relatively small and depauperate resident fish population. None of the fish species that have been observed is listed as rare or endangered. Neither are they considered particularly desirable by fishermen nor by those who conduct subsistence fishing along the shoreline. The Hawaii Coral Reef Assessment & Monitoring Program (CRAMP, 2008) ranked Waikiki low in mean number of species (55th) and fish biomass (51st) when compared to 56 other CRAMP sites throughout the main Hawaiian Islands. These fish are mobile. As evidenced by the fact that fish ingestion by a similar pump was not reported during the Kuhio Beach project, the vast majority of fishes are capable of avoiding the suction intake. Thus, the sand recovery operation will temporarily displace fish in the vicinity, but is unlikely to injure or kill a substantial portion of the population. Furthermore, because the resident fish population is small, the number of affected individuals will be small as well. Consequently, no significant effect is anticipated.

4.3.1.4 Sand Placement Effects

The beach maintenance sand placement to widen the beach will take place almost completely on existing sand bottom. Site investigations show that only about 5 percent of the project footprint may cover exposed limestone reef rock bottom, and even this nearshore hard bottom is regularly scoured and sometimes covered by sand. The new beach will replace in kind the sand bottom to be covered by the beach widening.

4.3.2 Long Term Impacts

The bottom composition in the nearshore environment of Waikiki and the project vicinity consists of a highly bioeroded fossil limestone reef platform with sand channels and deposits. The benthic community structure is heavily influenced by the scouring action of wave driven sand. The dominant taxa of benthic organisms are algae; corals and other macroinvertebrates are relatively rare. The greatest density and diversity of biota is found in areas where high vertical relief provides protection from sand scour. The Waikiki sea bottom is dominated by two introduced and invasive algal species: *Acanthophora spicifera* and *Gracileria salicornia*. Another invasive algal species, *Avrainvillea amadelha*, is also becoming more common.

AECOS (2007, 2008) conducted post-project marine monitoring for the 2006 Kuhio Beach nourishment project at intervals of 3, 6, 12 and 15 months. Four “impact” monitoring sites were located offshore of the Kuhio Beach crib walls, one site was located midway along the proposed project reach (offshore of the Moana), and control sites were located to the east in the Waikiki Marine Life Conservation District and to the west offshore of the Sheraton Waikiki Hotel. The post-construction monitoring showed a significant increase in the percent coverage of algae over the 15-month period, and other changes throughout the study area, however the changes were also evident at the control sites outside of the presumed influence of the project, thus it was concluded that the observed changes are due to factors other than the beach nourishment project.

Based on this past experience, no significant long term impacts are anticipated from the proposed action.

4.4 Effects on Endangered Species

As discussed in Section 3.1.7.3, the nearshore area off Waikiki is frequented by the threatened green sea turtle (*Chelonia mydas*), which feeds on the algae covered bottom. Hawaiian monk seals (*Monachus schauinslandi*) have been seen in Waikiki on rare occasions, but this is exceptional, and they have not been reported in the vicinity of the proposed project. No other listed species have been observed.

As discussed in Section 3.1.7.3, biologists have noted the regular presence of sea turtles in the project area. No obvious congregation or resting areas have been seen, but the turtles clearly forage on the algae that grows abundantly in the nearshore area. Turtle surveys in the general area indicate that turtle abundance is not negatively affected by the number of people in the water or all the water recreation activities which occur in Waikiki.

The operation of an underwater pump during dredging activities will produce an underwater sound that can be perceived by marine creatures. The ears of marine mammals and sea turtles are sensitive to changes in sound pressure which is produced by the amplitude, wavelength, and frequency of a sound wave. While audiograms are not available for whales and sea turtles, it is generally accepted that 120 dB causes disturbance to these sea creatures.

The underwater sound intensity level of a pump has not presently been determined; however, the level can be inferred based on the sound intensity level of the pump in air. The following relationship can be used to convert the source in-air sound level intensity to the source underwater sound level intensity:

$$dB\ (water) = dB(air) + 62$$

Pumps with power ratings of 75 Hp like the one used for the 2006 Kuhio Beach project are reported to generally produce in-air sound levels of about 90 dB; the corresponding source underwater sound level would be 152 dB. Propagation losses are primarily caused by spherical spreading and can be calculated using the following relationship:

$$\text{Propagation Losses} = 20\log(r)$$

where

r = radial distance from the source in meters

Using 152 dB as the source underwater sound level and using a threshold level of 120 dB for continuous noise for marine creature disturbance, the resulting operational clearance distance is found from:

$$20\log(r) = 152-120$$

which gives

$$r = 40 \text{ m } (131 \text{ ft}).$$

Thus, sea turtle disturbance would be limited to within about a 130-foot radius of the pumping operation. Turtles would be expected to move away from the disturbance, and as the impact area is relatively small and primarily in sandy bottom, it would not affect turtle foraging area.

The following Best Management Practices (BMPs) as typically recommended by the National Marine Fisheries Service (NMFS) will be adhered to during construction of the project to avoid impacts to the turtles:

1. Conduct a survey for marine protected species before any work in the water starts, and if a marine protected species is in the area, a 150-foot buffer must be observed between the protected species and the work zone.
2. Establish a safety zone around the project area whereby observers will visually monitor this zone for marine protected species 30 minutes prior to, during, and 30 minutes post project in-water activity. Record information on the species, numbers, behavior, time of observation, location, start and end times of project activity, sex or age class (when possible) and any other disturbances (visual or acoustic).
3. Conduct activities only if the safety zone is clear of turtles.
4. Upon sighting of a turtle within the safety zone during project activity, immediately halt the activity until the animal has left the zone. In the event a marine protected species enters the safety zone and the project activity cannot be halted, conduct observations and immediately contact NMFS staff in Honolulu to facilitate agency assessment of collected data.
5. For on-site project personnel that may interact with a protected species potentially present in the project area, provide education on the status of any listed species and the protections afforded to those species under Federal laws.

A summary of anticipated effects on endangered species is as follows:

- By using the above BMPs noise/physical disturbance to green sea turtles is expected to be temporary and insignificant and not result in adverse behavioral changes.
- Based on the in-water work being conducted in relatively shallow water with silt curtains confining the sediment, any exposure of marine protected species to turbidity and sedimentation would be temporary and not significant.
- The sand recovery site is not frequented by turtles or used as a foraging area due to a lack of algae on the sand bottom, the sand recovery equipment will be fitted with fences/barriers to prevent turtle entanglement or entrapment, and the above discussed BMPs will be implemented, thus physical disturbance to turtles is anticipated to be temporary and not significant during the sand recovery operations.

Given the extensive turtle foraging area in Waikiki, and the relatively small percent loss which would result from the project, the change in turtle foraging habits and habitats is not expected to be significant.

4.5 Noise Impacts

Noise from diesel powered equipment operating on the sand recovery vessel offshore can be expected to attenuate with distance such that it would be less than background levels along the shoreline. Equipment operation in the vicinity of the dewatering site and being used in the sand placement operations along the shoreline, however, would be audible and exceed current background noise levels. As the separation distance from the operating equipment decreases, very high noise levels (80+ dBA) can be expected to occur. Back up alarms which use beeping high frequency signals near 1,000 Hz can be relatively loud and tend to be intrusive because they occur in the high frequency band where the background ambient noise level tends to be lower.

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 beach users, hotel guests, etc. Some reduction is practical, however, and the following measures would be implemented.

- Equipment operation on the shoreline will be limited to the hours between 7am and 10pm.
- Broadband noise backup alarms in lieu of higher frequency beepers will 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 will specify 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 will be prohibited.
- Worker training on ways to minimize impact noise and banging will be required.
- A noise complaint hot line will be provided at the job site to allow for feedback from the hotel operators, which can be used to help develop modifications to construction operations whenever feasible.
- Construction operations will cease in the vicinity of scheduled performances, such as the nightly hula show at the west end of Kuhio Beach.

4.6 Effects on Historic, Cultural and Archaeological Resources

As discussed in Section 3.3 of this report the Waikiki area has a rich historical and cultural legacy. However, two aspects of the project make it unlikely that it would have a significant adverse effect on historic or archaeological sites.

1. Implementation of the project does not involve construction on or excavation of land areas that might contain physical remains. Work on land would take place in areas already transformed by Waikiki development.
2. The second is that the work to be undertaken seaward of the shoreline does not involve modification of soft deposits which could reasonably be expected to have the potential to hide archaeological materials or burials.

While the potential for adverse impact is low, close coordination with the State Historic Preservation Division and other concerned parties will be maintained. Care will also be taken when working on the beach to avoid disturbing previously undisturbed sandy sediments that might hide subsurface deposits.

There do not appear to be any known traditional Hawaiian cultural practices that would be adversely affected by the proposed project. Neither does it seem like the activities associated with the project will conflict with traditional cultural practices as expressed in legend. The proposed beach maintenance would be accomplished in an area which has been substantially altered over more than a century, which has recently eroded and receded landward, and is entirely makai of the shoreline where the existence of any cultural artifacts or remains are very unlikely. Based on the above, the proposed project is unlikely to have an adverse effect on rights customarily and traditionally exercised for subsistence, cultural and religious purposes.

4.7 Recreational Impacts

4.7.1 Construction Period Impacts

4.7.1.1 Impacts on Sunbathing and Swimming Opportunities

The proposed project would improve Waikiki Beach by restoring a recreational beach area approximately 1,700 feet long and averaging about 40 feet in width above the high tide line. This equates to approximately 65,000 square feet of additional beach area (1.5 acres), enough to accommodate about 600-800 beach users. It will also improve lateral access along the shore. The project will therefore have significant beneficial impact to primary recreational activities at Waikiki – sunbathing and walking. The increase in dry beach area will dramatically ease the present crowded conditions in the project area.

4.7.1.2 Impacts on Surfing

The sand recovery operations will occur near to, but seaward of, the typical surf zone. Thus they would not directly impact the surf sites. The work will be scheduled so as to try and avoid the summer larger surf season, as well as periods when surfing contests and other surf events are typically scheduled. The sand transport pipeline will be submerged and anchored to the bottom, thus should not interfere with surfers paddling out or riding waves. The anchor route will be marked with buoys. The construction activities will not result in significant interference with surfer access along the shore.

The removal of sand from the offshore deposits would not change the bottom topography over a large enough area or to a sufficient extent that it would alter the deep to shallow water transformation processes of incoming waves or their breaking characteristics. In addition, based on post-construction monitoring of the Kuhio Beach nourishment project, it is expected that the excavated sand deposits will relatively quickly fill in and return to near pre-dredging conditions (AECOS, 2008; American Marine, 2007; and Dolan Eversole, personal communication).

Offshore surf sites are primarily influenced by the hard limestone fossil reef formations that are at slightly higher elevation than the intermittent sand channels and pockets, and thus would not be significantly affected by either the recovery of sand from offshore or its migration back offshore over time. Given the predominant westerly transport of sand along the shore, and its offshore movement by rip currents acting in the deeper channel areas, the sand placement will not affect nearshore surf sites such as Baby Queens, Queens or Canoes by moving directly offshore and infilling beyond the initial placement profile.

4.7.1.3 Impacts on Beach Concessions and Catamaran Rides

The project may have some limited impact on the beach concessions; however, every effort will be made to minimize potential impacts. Beach concessions are primarily located in the large open area east of the Moana Surfrider, in the vicinity of the Duke Kahanamoku statue. The hotels also offer beach services located along the top of the beach. The dewatering site and construction staging area will be located in the Kuhio Beach crib wall area, away from the beach concessions, and will not significantly affect the concession operations during the majority of the project construction period. Sand will be moved and placed along the beach in late afternoon and early evening, when beach use is reduced and the concessions have ceased activity for the day. During the previous Kuhio Beach nourishment project it was noticed that the recovered sand emitted an unpleasant odor as it dried. This odor, and diesel smell and noise from equipment operation, may reduce the number of beach users in this area, and thus could have a small temporary impact on the beach concessions.

The sand recovery equipment will essentially be continuously moored offshore; however, it will be easy for the catamarans and other vessels to navigate around it. Sand placement on the beach will be accomplished in the late afternoon and early evening, when most beach catamaran activities have ceased, and the sand placement will be done at discrete localized areas each day and the catamarans can move slightly up or down the beach to avoid the daily work areas.

4.7.1.4 Impacts on Other Recreational Activities

Snorkeling. The shallow reef fronting the project area is not known as a particularly good site for snorkeling, and the surfing, canoes, catamarans and other recreational craft make snorkeling somewhat risky. The reef does not seem to attract the volume or variety of fish that other reefs do, and for this reason snorkeling is an infrequent activity here. In addition, during periods of high surf, visibility over the reef is poor due to wave agitation of the ocean bottom. The sand recovery operations will be well offshore, in water too deep for good snorkeling. Hence, the proposed project is not expected to have any negative impact on snorkeling activities. The additional beach area may increase the number of people who snorkel in the area. However, given the relatively poor quality of the reef flat environment, there is no evidence that the increase would be substantial or that the presence of additional people in the water would degrade the experience of other users.

Kayaking. Touring kayaks are not common in Waikiki. However, they are available for rent from the ocean activity desk at Fort DeRussy and are occasionally in the project area. The sand recovery area of operations and the equipment will be easy to avoid.

Fishing and Gathering. Two types of fishing occur in the project area, spear fishing and pole fishing, but both are infrequent. The offshore hard bottom was once noted octopus grounds, but they do not have that reputation today. Nonetheless, some spear fishermen still try their luck in these areas. Clark (2007) observed two divers looking for octopus during his reconnaissance survey. The reef fronting the project area is not known as a productive fishing area, so pole fishing is an infrequent activity. However, at certain times of the year, schools of *nehu*, small anchovy-sized fish, may congregate near shore. The *nehu* attract larger predators like *papio*, which are prized eating fish, which in turn attract pole fishermen. Pole fishermen whip for *papio*, which has the potential to create conflicts between them and swimmers. The proposed project will not affect fishing in the area during construction.

Many areas of Waikiki were once known as good places to gather edible seaweeds, or limu, but little if any edible seaweed seems to remain in Waikiki today. No gathering activities of seaweed, shellfish, or other marine species were observed during the field trips or noted by the informants. The recovered sand will be placed on existing nearshore sand bottom, where limu does not grow. Hence, no significant adverse effect on the limu resource is expected.

Waikiki Marine Managed Areas. The Waikiki Marine Managed Areas (MMA) consists of two parts: the Waikiki Marine Life Conservation District (MLCD) and the Waikiki -Diamond Head Fisheries Management Area (FMA). As the project area is not included in the Waikiki MMA, no effects are anticipated.

4.7.2 Long Term Impacts

The proposed project will result in a significant increase in recreational beach area, which, given the present rate of erosion and shoreline recession, is expected to last about 20 years. It is recommended however, that the project include a provision for future beach maintenance before the shoreline recedes back to its present location. The project proposes to conduct regular monitoring of the beach position, and initiate another sand recovery and placement project when half of the initial sand fill is lost. By doing this the beach recreational benefits can be constantly maintained in an improved condition over the long term

4.8 Changes in Susceptibility to Natural Hazards

The proposed project will extend the shoreline seaward, increasing the space between the water and the existing backshore infrastructure. This will greatly increase the wave energy dissipating properties of the beach, and will decrease wave runup and flooding of the backshore area. The presence of sandbags protecting existing hotel facilities and the foundation of the lifeguard stand indicate that wave runup is an existing problem along the project area shoreline. The increased energy dissipation of the widened beach will be a significant benefit with regard to reducing the susceptibility to natural ocean hazards.

The proposed beach restoration is located in an area that does not receive runoff from adjacent areas. It is not within the flood plain of a stream or canal. Hence, there is no potential for increased risk from this source, and the physical change in the shore that is proposed does not have the potential to alter storm runoff risks in adjacent areas.

4.9 Air Quality Impacts

Because most of the work that will take place will be in the water, or on the sandy shoreline, the proposed project differs from many construction projects in that it involves little or no on-site soil disturbance that could result in particulate emissions. Potential sources of air pollution as a result of the project are related to the construction phase.

During the actual construction process beach nourishment activities will create temporary degradation in air quality in the immediate vicinity of the project area. This negative impact to air quality will be limited to typical work hours, and will end once the sand is in place. The emissions from these internal combustion engines are far too small to have a significant or lasting effect on air quality. As part of the construction process, the contractor will observe all BMPs to keep construction related emissions to the lowest practicable levels.

Short-term degradation of air quality may occur due to emissions from construction equipment and would include carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOCs), directly-emitted particulate matter (PM_{10} and $PM_{2.5}$), and toxic air contaminants such as diesel exhaust particulate matter. Sulfur dioxide (SO_2) is generated by oxidation during combustion of organic sulfur compounds contained in diesel fuel. Off-road diesel fuel meeting Federal standards can contain up to 5,000 parts per million (ppm) of sulfur, whereas on-road diesel is restricted to less than 15 ppm of sulfur.

These construction impacts to air quality are short-term in duration and, therefore, will not result in adverse or long-term conditions. Implementation of the following measures will reduce any air quality impacts resulting from construction activities:

- Apply water or dust palliative to the site and equipment as frequently as necessary to control fugitive dust emissions.
- Properly tune and maintain construction equipment and vehicles.
- Locate equipment and materials storage sites as far away from hotels and commercial uses as practical. Keep construction areas clean and orderly.

During the previous Kuhio Beach nourishment project it was noted that the sand dewatering site emitted an unpleasant odor as the sand dried. It is likely that this odor will be present during the proposed project construction period; however, it ends quickly once the sand is exposed to the air. The sand to be recovered has a very low percentage of material smaller than sand size, and it will be wet, thus fugitive dust susceptible to airborne dispersion is expected to not be significant.

Once construction is completed the beach will have no long-term air emissions or impact on air quality.

4.10 Land Use and Socio-Economic Effects

The proposed project will restore and improve an existing public beach. The economic value of this beach to the commercial success of Waikiki is extremely significant. A study by Hospitality Advisors, LLC (2008) accomplished for the Waikiki Improvement Association showed that if

Waikiki Beach is not maintained and allowed to erode away it could result in a $2 billion annual loss in overall visitor expenditures, a $150 million annual loss in State tax revenue, and a loss of 6,350 jobs in the hotel industry alone. The project will not alter the existing land use pattern shoreward of the beach restoration. The improved beach is likely to attract beach users who do not presently use this area; however, this increased volume of visitors will be consistent with current, generally recreational usage in the area. This project could result in an increase in the level of commercial activity in the area, particularly for the beach concessionaires, and thus would have a significant long-term economic benefit. Some negative economic impact on commercial activities may result during construction; however, every effort will be made to minimize adverse impacts, particularly during the prime daytime beach use hours.

The direct socio-economic effects of the proposed project are limited principally to construction employment and related business activity. The direct construction employment and business expenditures are not large enough to affect the larger socio-economic context of the area.

Overall, the economic effect on existing land use is expected to be beneficial, and result in small gains for the general tourism industry. The improved beach would likely have a positive effect on property values in the immediate and extended area. While the economic gains expected to directly result from the proposed project to maintain the beach are modest, the loss which could result from not maintaining the beach and simply letting it continue to shrink and likely ultimately disappear would have a very significant effect on Waikiki and Hawaii tourism in general. Waikiki has 87% of the total hotel rooms on Oahu, and approximately 69% of all Oahu visitors participate in swimming/sunbathing/beach activities (Hospitality Advisors, LLC, 2008).

The State's 2006 Kuhio Beach Maintenance Project was the recipient of a national award for best restored beach by the American Shore and Beach Preservation Association. This award received international attention, and showcased the State's efforts to maintain the valuable Waikiki Beach shoreline.

4.11 Visual Impacts

Both residents and the tourist industry depend on Waikiki's scenic resources. The beauty of its coastline draws millions of tourists to its sights and beaches each year. Map A-1 of the City and County of Honolulu's *Primary Urban Center Development Plan* identifies all of Waikiki as being within a "Significant Panoramic View" zone. The *Waikiki Special Design Guideline*'s Urban Design Control Map also identifies the area within which the access right-of-way and construction staging area are located as being within the Waikiki Special Design district "Major View Corridor".

The City & County of Honolulu Land Use Ordinance (LUO) §9.80-3(a) designates some of the visual landmarks and significant vistas to be protected in the Waikiki area, as:

- Views of Diamond Head from many vantage points,
- Continuous views of the ocean along Kalakaua Avenue from Kuhio Beach to Kapahulu Avenue,

- Intermittent ocean views from Kalia Road across Fort DeRussy Park, Ala Wai Yacht Harbor, and the Ala Wai Bridge on Ala Moana Boulevard,
- *Mauka* views from streets *mauka* of Kuhio Avenue, and
- Views towards Ala Wai Yacht Harbor from Magic Island Park.

Due to its low elevation and profile, the proposed project does not have the potential to impact these views.

Construction equipment, material stockpiles, and construction activities will be present within the project area for several months during the construction of the project. Additionally, the dredging equipment will be visible for a period of about two months while it is moored about one-half mile offshore. All of these impacts are temporary and will not be present once the construction phase of the project is completed. But while present they will substantially alter the aesthetics of the shoreline.

4.12 Impacts on Public Infrastructure and Services

The proposed beach maintenance project has little potential to affect public infrastructure and services. Once in operation it will not require water or electrical power. In and of itself, it does not generate a need for additional sanitary wastewater collection and treatment facilities and it would not affect stormwater runoff that might impact the City's stormwater system. It is expected that most people visiting the beach would come by foot rather than in vehicles, and the improvements are not expected to increase the resident or visitor population of the island.

Prior to commencement of construction activities, the Police Department, Fire Department, and Emergency Medical Services will be informed of the project construction schedule and apprised of the emergency vehicle access routes to be used during construction. The contractor will be required to provide ample clearance for emergency vehicles at all times. The proposed project does not involve any activities that would permanently alter the need for, or ability to provide, emergency services.

Construction of the project will involve a relatively small construction crew, estimated to range between 10 and 15 workers onshore. During most of the construction these workers can park either in the construction staging area or existing public parking facilities. In addition to these workers, another 8 to 10 workers will operate the dredge equipment and pumping system that will transport sand from the offshore deposits to the shore. The work boat servicing the offshore operations will be based out of Honolulu Harbor, and the persons who work on it will park their vehicles at the harbor during the approximate 8 weeks the sand recover operation will require.

Mobilization and demobilization of the on-shore equipment and materials will involve some heavy truck traffic through Waikiki; however, this would be of limited duration. Because the project will retrieve sand from seaward of the project site and pump it ashore to nourish the beach, it eliminates the need for a large number of vehicle trips that would otherwise be required to import new sand to the project site.

Because of the very small number of vehicle-trips involved, construction worker and equipment/material delivery trips do not have the potential to substantially affect traffic volumes and/or the level of service on area roadways and do not require substantial mitigation efforts.

5. POTENTIAL IMPACTS OF NO ACTION

"No Action" consists of the Army Corps of Engineers or State of Hawaii agencies denying DLNR the necessary permits and approvals for the beach maintenance project. Without the project the existing shoreline processes will continue, with on-going erosion and the shoreline receding at the historical average rate of 2.3 feet per year. This will result in a continuing narrowing of the beach and decrease in usable dry beach area, and a resultant loss of shoreline recreation and commercial opportunity. At the current rate of erosion the narrower portions of the beach can be expected to be completely gone in 15 to 30 years. The majority of the backshore area, behind the beach, is protected by old seawalls, presently covered by the beach in front of them. Continuing erosion can be expected to begin to expose these seawalls, which will exacerbate the erosion problem, and could result in wall damage and the need for repairs in order to protect valuable backshore infrastructure. "No Action" is anticipated to result in no adverse impacts to adjacent shorelines, with the possible exception of damage to the west crib wall (east end of the project area), and the Royal Hawaiian groin at the west end due to foundation undermining or structure flanking.

The existing beach and offshore sand deposits do not affect coastal water quality. During periods of high surf there is typically a general increase in nearshore water turbidity due to the suspension of fine bottom material by wave action, and this can be expected to continue with or without the proposed project. Thus the "No Action" alternative will have no effect on existing water quality in the project area.

"No Action" will not affect the nearshore biological environment. Not implementing the project will simply result in the continuation of the deteriorated and relatively depauperate marine biota environment in Waikiki, and the continued growth of invasive algae. In the same way "No Action" will not affect endangered species, or historic, cultural and archaeological resources (with the exception of whatever historic/cultural significance the beach itself has).

"No Action" will ultimately have a very significant impact on beach related recreation resources. The diminishing beach area will severely limit sunbathing, will decrease the access for swimming, surfing and other water recreation activities, and will reduce the business opportunities for the beach concessions and catamaran rides.

The socio-economic impacts resulting from the loss of Waikiki Beach would be very extensive. In 2008 the Waikiki Improvement Association commissioned Hospitality Advisors, LLC to conduct an economic impact analysis of the effect of the complete erosion of Waikiki Beach (Hospitality Advisors, 2008). A summary of the study results are as follows.

- Waikiki Beach is recognized as a major tourism destination in Hawaii, as well as a popular recreational spot for visitors and residents. On average, there are 25,600 hotel rooms available in Waikiki on a daily basis, 87% of the total hotel supply on Oahu.

- According to a DBEDT Visitor Satisfaction Survey, approximately 69% of all Oahu visitors participate in swimming/sunbathing/beach activities. More than one-third of westbound (e.g. mainland) and Japanese visitors cited beach or swimming as their primary reason for staying in Waikiki. The top four planned activities for both westbound and Japanese visitors were swimming, sunbathing, surfing and snorkeling.

- An overwhelming majority, 76% to 79%, of all visitors consider beach availability to be very important. When presented with the possibility of the complete erosion of Waikiki Beach, 58% of all westbound visitors and 14% of Japanese visitors said they would not consider staying in Waikiki without the beach.

- There has been substantial recent capital investment in Waikiki in an effort to keep it competitive as a visitor destination; examples are the Outrigger Waikiki Beach Walk and Starwood property renovations/upgrades (Sheraton Waikiki Hotel, Royal Hawaiian Hotel and the Moana Surfrider Hotel).

- The estimated socio-economic loss to the State if Waikiki Beach is not maintained and allowed to erode away is very significant:

  - an estimated $661 million loss in annual hotel revenues,
  - a $2 billion loss in overall visitor expenditures,
  - a $150 million loss of State tax revenue, and
  - a hotel industry job loss of 6,350 people.

6. RELATIONSHIP TO RELEVANT PLANS, POLICIES & CONTROLS

This chapter discusses the compliance and compatibility of the proposed Waikiki Beach Maintenance Project with pertinent plans, policies, and regulations at county, state, and federal levels.

6.1 City and County of Honolulu

The proposed Waikiki Beach Maintenance Project is seaward of the certified shoreline and is therefore outside of the jurisdiction of the City and County of Honolulu. The only two land-based activities involved in the project are the dewatering of the sand in Kuhio Beach Park and the transport of sand to the Waikiki Beach shoreline. Thus, the project does not require any City-administered permits or approvals. The project does, however, relate to several of the goals and objectives set forth in the City and County's regional and island wide planning documents. The project is discussed in the context of each of the relevant documents in the following sections.

6.1.1 Oahu General Plan

The proposed Waikiki Beach Maintenance Project is relevant to four key objectives outlined in the Oahu General Plan. Each of these objectives and the relevant policies are listed below, followed by a discussion of the project's relationship to them.

> II. Economic Activity, Objective B: To maintain the viability of Oahu's visitor industry.
> Policy 2: Provide for a high quality and safe environment for visitors and residents in Waikiki
> Policy 3: Encourage private participation in improvements to facilities in Waikiki.
> Policy 8: Preserve the well-known and widely publicized beauty of Oahu for visitors as well as residents.

<u>Discussion</u>: According to the objectives listed in Section 1.2, the proposed project is intended to return sand to the beach between the Royal Hawaiian groin and Kuhio Beach Park. The action would help facilitate lateral access along the shore for both tourists and residents, thereby improving access to water-oriented recreational activities along the beach. Increasing the viability of Waikiki Beach, Oahu's top visitor destination, would help augment Oahu's visitor industry. The discussion in this DEA explains why we believe that the selected alternative best fulfills these objectives, and therefore why it is compatible with the vision of the Oahu General Plan.

> III. Natural Environment, Objective A: To protect and preserve the natural environment.
> Policy 1: Protect Oahu'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 3: Retain the Island's streams as scenic, aquatic, and recreation resources.

Policy 4: Require development projects to give due consideration to natural features such as slope, flood and erosion hazards, water-recharge areas, distinctive land forms, and existing vegetation.
Policy 5: Require sufficient setbacks of improvements in unstable shoreline areas to avoid the future need for protective structures.
Objective B: To preserve and enhance the natural monuments and scenic views of Oahu for the benefit of both residents and visitors.
Policy 1: Protect the Island's well-known resources: its mountains and craters; forests and watershed areas; marshes, rivers, and streams; shoreline, fishponds, and bays; and reefs and offshore islands.

Discussion: The proposed project would restore and maintain the beach, while widening the buffer between the ocean and the hotels. It would help to protect the backshore properties from coastal flooding and property damage that could occur as a result of waves overtopping a narrow beach or impacting the presently buried seawalls. The scenic views of the beach would also be improved.

X. Culture and Recreation, Objective D: To provide a wide range of recreational facilities and services that are readily available to all residents of Oahu.
Policy 5: Encourage the State to develop and maintain a system of natural resource-based parks, such as beach, shoreline, and mountain parks.
Policy 6: Provide convenient access to all beaches and inland recreation areas.
Policy 8: Encourage ocean and water-oriented recreation activities that do not adversely impact on the natural environment.
Policy 10: Encourage the private provision of recreation and leisure-time facilities and services.

Discussion: As discussed in Section 4.7, a wider expanse of sandy beach will increase the recreational opportunities for visitor and resident beachgoers. The beach is heavily used for recreational purposes, and a wider beach will improve the recreational aspect for the users. Allowing for future maintenance would help keep the value of the beach at its highest.

6.2 State of Hawaii Laws and Regulations

6.2.1 Hawaii State Planning Act

The Hawaii State Planning Act (Chapter 226, Hawaii Revised Statutes, as amended) outlines themes, goals, guidelines, and policies for statewide planning. The proposed Waikiki Beach Maintenance Project relates to the following objectives stated in §226-11: "*Objectives and policies for the physical environment--land-based, shoreline, and marine resources*":

1. Exercise an overall conservation ethic in the use of Hawaii's natural resources.
2. Ensure compatibility between land-based and water-based activities and natural resources and ecological systems.
3. Take into account the physical attributes of areas when planning and designing activities and facilities.

4. Manage natural resources and environs to encourage their beneficial and multiple uses without generating costly or irreparable environmental damage.
5. Pursue compatible relationships among activities, facilities, and natural resources.
6. Promote increased accessibility and prudent use of inland and shoreline areas for public recreational, educational, and scientific purposes. [L 1978, c 100, pt of §2; am L 1986, c 276, §10]

Discussion: The proposed beach maintenance project is intended to restore the beach to its 1982 position to help conserve and provide accessibility of this valuable shoreline. The project would increase the recreational value of an area that is already heavily-used by locals and tourists and supports multiple recreational uses. Thus, it is consistent with the above objectives.

6.2.2 State Land Use Laws

The Board of Land and Natural Resources (BLNR) regulates uses of the State Conservation District by issuing Conservation District Use Permits for approved activities. The criteria that the OCCL will use in evaluating the project are outlined in Hawaii Administrative Rules §13-5-30. Each criterion is listed below, followed by a discussion of how the proposed project complies with it.

1. The proposed land use is consistent with the purpose of the conservation district;

Discussion: The purpose of the Conservation District is to conserve, protect, and preserve the important natural resources of the State through appropriate management and use to promote their long-term sustainability and the public's health, safety, and welfare (HAR §13-5-1). As discussed throughout this EA, the proposed project is expected to improve and increase the variety of and access to water-oriented recreational activities while protecting other valuable coastal resources. Thus, it is in keeping with the purpose of the Conservation District. The project is consistent with the Coastal Erosion Management Plan (COEMAP), adopted by the Board of Land and Natural Resources, and which identifies beach restoration as a long-term strategy where applicable for maintaining the shoreline.

2. The proposed land use is consistent with the objectives of the subzone of the land on which the use will occur;

Discussion: The proposed project is in the Resource Subzone of the Conservation District, and consists of land use activities consistent with uses R-6 Marine Construction and R-7 Mining and Extraction (HAR §13-5-25). As specified in HAR §13-5-24(c)(4), these uses are permitted in this Subzone with the acquisition of a Land Board-approved Conservation District Use Permit. The applicant is seeking this permit coverage for the project.

3. The proposed land use complies with provisions and guidelines contained in chapter 205A, HRS, entitled "Coastal Zone Management," where applicable;

Discussion: The Hawaii Coastal Zone Management Program Consistency Review confirms the consistency of the project with the Coastal Zone Management Act and the objectives outlined in Chapter 205A, HRS (see Section 6.3.6).

4. The proposed land use will not cause substantial adverse impact to existing natural resources within the surrounding area, community or region;

Discussion: The proposed project involves emplacement of sand on a small portion of existing fossil limestone reef rock ("live rock") that is used as habitat for marine biota. At the same time, the project will be removing sand from offshore, exposing live rock in an area less exposed to human impacts and more suitable as marine biota habitat.

5. The proposed land use, including buildings, structures and facilities, shall be compatible with the locality and surrounding areas, appropriate to the physical conditions and capabilities of the specific parcel or parcels;

Discussion: The proposed project will widen the beach to approximately its 1982 position. There will be no permanent structures constructed. From the nearby hotels or vessels on the ocean, the wider beach would be essentially unobtrusive, and would keep this shoreline reach looking natural.

6. The existing physical and environmental aspects of the land, such as natural beauty and open space characteristics, will be preserved or improved upon, whichever is applicable;

Discussion: The proposed beach maintenance project will create an area of sandy beach that would be nearly identical in appearance to the existing adjacent sandy beaches. This action would improve the continuity of Waikiki's beachfront appearance.

7. Subdivision of land will not be utilized to increase the intensity of land uses in the conservation district;

Discussion: No property subdivision is needed for the proposed project.

8. The proposed land use will not be materially detrimental to the public health, safety and welfare.

Discussion: Once the proposed maintenance has been completed, there will be no regular sources of emissions or waste that could prove detrimental to public health. All offshore uses have inherent safety risks to users (e.g., inclement weather, rough seas, potentially dangerous marine life). However, as discussed in Section 4.1.2, the project will not create a significant hazard to public safety and welfare.

6.3 Federal Acts and Legislation

6.3.1 Archaeological and Historic Preservation Acts

Consultation with the State Historic Preservation Division will be accomplished to ensure that the project complies with the provisions of the Archaeological and Historic Preservation Act (16 U.S.C. § 469a-1) and the National Historic Preservation Act (16 U.S.C. § 470(f)).

6.3.2 Clean Air Act (42 U.S.C. § 7506(c))

As discussed in Section 4.9, the only emissions associated with the project would be during construction. Once the sand is emplaced the proposed project will not produce any emissions. It is consistent with the provisions of the Clean Air Act.

6.3.3 Clean Water Act (CWA) of 1977, as amended (33 USC §§1251-1387)

The Clean Water Act (CWA) is the key legislation governing surface water quality protection in the United States. Sections 401, 402, and 404 of the Act require permits for actions that involve wastewater discharges or discharge of dredged or fill material into waters of the United States. The discharge of the sand that would maintain the beach constitutes fill as defined in the CWA and is subject to regulations implementing the CWA. In Hawaii, the U.S. Environmental Protection Agency has delegated responsibility for implementing the Act to the State. A Section 401 Water Quality Certification Application for this project will be submitted to the State Department of Health.

6.3.4 Rivers and Harbors Act (33 USC §403)

Section 10 of the Rivers and Harbors Act, 33 USC §403, requires a Department of the Army (DA) permit for any activity that obstructs or alters navigable waters of the U.S., or the course, location, condition, or capacity of any port, harbor, refuge, or enclosure within the limits of any breakwater, or of the channel of any navigable water. The proposed beach maintenance project would extend into navigable water; hence the project requires a Section 10 permit from the Army Corps of Engineers.

6.3.5 Coastal Zone Management Act (16 U.S.C. § 1456(c) (1))

Enacted as Chapter 205A, HRS, the Hawaii Coastal Zone Management (CZM) Program was promulgated in 1977 in response to the Federal Coastal Zone Management Act of 1972. The CZM area encompasses the entire state, including all marine waters seaward to the extent of the state’s police power and management authority, as well as the 12-mile U.S. territorial sea and all archipelagic waters.

6.3.5.1 Recreational Resources

Objective: Provide coastal recreational opportunities accessible to the public.

Policies:

- Improve coordination and funding of coastal recreational planning and management; and
- Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:
- Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;
- 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;
- Providing and managing adequate public access, consistent with conservation of natural resources, to and along shorelines with recreational value;
- Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;
- 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;
- Adopting water quality standards and regulating point and nonpoint sources of pollution to protect, and where feasible, restore the recreational value of coastal waters;
- Developing new shoreline recreational opportunities, where appropriate, such as artificial lagoons, artificial beaches, and artificial reefs for surfing and fishing; and
- 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.

Discussion: The primary purpose of the project is to maintain a public recreational beach and increase coastal recreational opportunity.

6.3.5.2 Historic Resources

Objective: 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.

Policies:

- Identify and analyze significant archaeological resources;
- Maximize information retention through preservation of remains and artifacts or salvage operations; and
- Support state goals for protection, restoration, interpretation, and display of historic resources.

Discussion: No historic or archaeological sites or resources are known or likely to exist at the site and which would be affected by the project. The construction specifications will contain provisions to protect any historic resources and alert the proper agencies should any be found during the construction activities.

6.3.5.3 Scenic and Open Space Resources

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

Policies:

- Identify valued scenic resources in the coastal zone management area;
- 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;
- Preserve, maintain, and, where desirable, improve and restore shoreline open space and scenic resources; and
- Encourage those developments that are not coastal dependent to locate in inland areas.

Discussion: The proposed project will enhance and preserve the quality of coastal scenic and open space resources by maintaining the sandy beach area.

6.3.5.4 Coastal Ecosystems

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

Policies:

- Exercise an overall conservation ethic, and practice stewardship in the protection, use, and development of marine and coastal resources;
- Improve the technical basis for natural resource management;
- Preserve valuable coastal ecosystems, including reefs, of significant biological or economic importance;
- 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
- 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.

Discussion: The proposed project will have no significant long-term impacts on the coastal ecosystem. The project construction specifications will include requirements which will reduce, minimize and avoid the potential for adverse impacts during construction to the maximum extent practicable.

6.3.5.5 Economic Uses

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

Policies:
- Concentrate coastal dependent development in appropriate areas;
- Ensure that coastal dependent development such as harbors and ports, and coastal related development such as visitor industry facilities and energy generating facilities, are located, designed, and constructed to minimize adverse social, visual, and environmental impacts in the coastal zone management area; and
- Direct the location and expansion of coastal dependent developments to areas presently designated and used for such developments and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:
- Use of presently designated locations is not feasible;
- Adverse environmental effects are minimized; and
- The development is important to the State's economy.

Discussion: The proposed beach restoration and maintenance project will provide significant economic benefit to the visitor industry and the State.

6.3.5.6 Coastal Hazards

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

Policies:
- Develop and communicate adequate information about storm wave, tsunami, flood, erosion, subsidence, and point and nonpoint source pollution hazards;
- Control development in areas subject to storm wave, tsunami, flood, erosion, hurricane, wind, subsidence, and point and nonpoint source pollution hazards;
- Ensure that developments comply with requirements of the Federal Flood Insurance Program; and
- Prevent coastal flooding from inland projects.

Discussion: The proposed project will extend the shoreline seaward, increasing the space between the water and land-side development. This will increase the ability of the beach to dissipate wave energy and reduce runup, and thus protect backshore infrastructure. It will not have a significant effect on tsunami run-up.

6.3.5.7 Managing Development

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

Policies:

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

Discussion: The proposed project permitting and approval process will provide an opportunity for public participation in the plan formulation process.

6.3.5.8 Public Participation

Objective: Stimulate public awareness, education, and participation in coastal management.

Policies:

- Promote public involvement in coastal zone management processes;
- Disseminate information on coastal management issues by means of educational materials, published reports, staff contact, and public workshops for persons and organizations concerned with coastal issues, developments, and government activities; and
- Organize workshops, policy dialogues, and site-specific mediations to respond to coastal issues and conflicts.

Discussion: The public will have an opportunity to review and comment on this EA as part of the public review process.

6.3.6 Beach Protection

Objective: Protect beaches for public use and recreation.

Policies:

- 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;
- Prohibit construction of private erosion-protection structures seaward of the shoreline, except when they result in improved aesthetic and engineering solutions to erosion at the sites and do not interfere with existing recreational and waterline activities; and
- Minimize the construction of public erosion-protection structures seaward of the shoreline.

Discussion: As discussed in Section 4.7, the proposed beach restoration project will help restore and maintain an existing public beach, and increase beach related recreation opportunity.

6.3.6.1 Marine Resources

Objective: Promote the protection, use, and development of marine and coastal resources to assure their sustainability.

Policies:

- Ensure that the use and development of marine and coastal resources are ecologically and environmentally sound and economically beneficial;
- Coordinate the management of marine and coastal resources and activities to improve effectiveness and efficiency;
- Assert and articulate the interests of the State as a partner with federal agencies in the sound management of ocean resources within the United States exclusive economic zone;
- Promote research, study, and understanding of ocean processes, marine life, and other ocean resources in order to acquire and inventory information necessary to understand how ocean development activities relate to and impact upon ocean and coastal resources; and
- Encourage research and development of new, innovative technologies for exploring, using, or protecting marine and coastal resources.

Discussion: The proposed project will not significantly affect marine and coastal resources. The project plan will be fully coordinated with federal and state marine resource agencies, including NOAA/NMFS, USFWS, USEPA and DLNR/DAR.

6.3.7 Endangered Species Act (16 U.S.C. 1536(a)(2) and (4))

The Endangered Species Act (16 U.S.C. §§ 1531-1544, December 28, 1973, as amended 1976-1982, 1984 and 1988) provides broad protection for species of fish, wildlife, and plants that are listed as threatened or endangered in the U.S. or elsewhere. The Act mandates that federal agencies seek to conserve endangered and threatened species and use their authorities in furtherance of the Act's purposes. It provides for listing species, as well as for recovery plans and the designation of critical habitat for listed species. The Act outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species, and contains exceptions and exemptions.

Existing biota on and near the project site and potential impacts of the proposed project are discussed in Sections 3.1.7, 4.3, and 4.4 of this EA including endangered species. The endangered green sea turtle is known to frequent the project area; however, no significant impacts to turtles are anticipated to occur as a result of the project.

6.3.8 Fish and Wildlife Coordination Act (FWCA) of 1934, as amended (16 USC §§661-666[c] et seq.)

The FWCA provides for consultation with the USFWS and other relevant Federal and State agencies when a Federal action proposes to modify or control U.S. waters for any purpose. The Applicant has already initiated this consultation, and both it and the COE will continue to seek advice as it continues the environmental assessment and permitting processes.

6.3.9 Magnuson-Stevens Fishery Conservation and Management Act (16 USC §1801 et seq.)

The Magnuson-Stevens Act (16 USC §1801 et seq.), as amended by the Sustainable Fisheries Act, PL 104-297, calls for action to stop or reverse the loss of marine fish habitat. The waters out to 200 miles (mi) around the Hawaiian Islands are under the jurisdiction of the Western Pacific Regional Fishery Management Council (WPRFMC). The WPRFMC has approved a Fisheries Management Plans (FMP) for Hawaii that designates all the ocean waters surrounding Oahu, from the shore to depths of over 100 feet, including the area that would be affected by the proposed project as "Essential Fish Habitat" (EFH).

The WPRFMC has also identified "Habitat Areas of Particular Concern" (HAPC). As defined in the 1996 amendments to the Act, these habitats are a subset of EFH that are "rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area." The area that would be affected by the proposed project is not within a HAPC.

6.3.10 Marine Mammal Protection Act (MMPA) of 1972, as amended (16 USC §§1361-1421(h) et seq.)

Reauthorized in 1994, the MMPA establishes a moratorium, with certain exceptions, on the taking of marine mammals in U.S. waters and by U.S. citizens on the high seas and on importing of marine mammals and marine mammal products into the U.S. The applicant's preliminary consultation for this project indicates that it will comply with the MMPA.

6.3.10.1 Migratory Bird Treaty Act (MBTA) of 1918, as amended (16 USC §§703 712 et seq.)

The MBTA is a bilateral migratory bird treaty with Canada, Mexico, Japan, and Russia. Sections 703 to 712 of the Act prohibit the taking of migratory birds in the absence of a permit. The actions involved in nourishing and maintaining the beach are not anticipated to have the potential to affect migratory birds.

6.3.11 National Historic Preservation Act (NHPA) of 1966 (16 USC §470 et seq.)

Section 106 of the NHPA of 1966, 16 USC §470(f), as amended, requires Federal agencies having direct or indirect jurisdiction over a Federal undertaking to take into account effects on any district, site, building, structure, or object that is included or is eligible for inclusion in the National Register of Historic Places (NRHP) prior to the approval of expenditure of any funds or issuance of any license or permit. The applicant's informal consultation with the Historic Preservation Division of the State of Hawaii Department of Land and Natural Resources indicates that the proposed project will not adversely affect historic properties. Formal consultation with the Hawaii State Historic Preservation Officer (SHPO) will be made to confirm this.

6.3.11.1 Native American Graves Protection and Repatriation Act (NAGPRA) of 1990 (25 USC §3001)

NAGPRA provides for the protection and repatriation of Native American and Native Hawaiian human remains and cultural items discovered on Federal lands. The Proposed Action does not involve the use of Federal land and is not, therefore, subject to the Act.

6.3.11.2 EO 13089, Coral Reef Protection (63 FR 32701)

EO 13089, dated June 11, 1998, directs all Federal agencies whose actions may affect U.S. coral reef ecosystems to:

- Identify their actions that may affect U.S. coral reef ecosystems;
- Utilize programs and authorities to protect and enhance the condition of such ecosystems; and
- Ensure that any actions they authorize, fund, or carry out will not degrade the conditions of such ecosystems.

Marine biological consultants are inventorying the coral resources in and around the areas that could be affected by the proposed project. The results of these surveys will be used to confirm the extent to which the proposed action is likely to affect coral reefs and to identify measures that will be undertaken to mitigate these unavoidable effects.

6.3.11.3 EO 13186, Responsibilities of Federal Agencies to Protect Migratory Birds (16 USC §§ 703-711) (66 FR 3853)

Under EO 13186, dated January 10, 2001, all Federal agencies taking actions that have, or are likely to have, a measurable negative impact on migratory bird populations are directed to develop and implement a Memorandum of Understanding (MOU) with USFWS that promotes the conservation of migratory bird populations. The applicant's preliminary assessment indicates that the proposed project would not affect habitat used by migratory bird populations. The USFWS will be consulted to confirm this determination.

6.3.11.4 EO 12898, Environmental Justice

Under EO 12898, dated February 11, 1994, Federal agencies are required to address the potential for disproportionately high and adverse environmental effects of their actions on minority and low-income populations. Agencies are required to ensure that their programs and activities that affect human health or the environment do not directly or indirectly use criteria, methods, or practices that discriminate on the basis of race, color, or national origin. NEPA documents are specifically required to analyze effects of Federal actions on minority and low-income populations and, whenever feasible, to develop mitigation measures to address significant and adverse effects on such communities. The EO states that the public, including minority and low-income communities, should have adequate access to public information relating to human health or environmental planning, regulation, and enforcement.

The proposed project would expand the amount of sandy beach available to the general public in Waikiki, including members of low-income and minority groups. Unless information to the contrary arises out of the environmental review process, there does not appear to be any mechanism through which the proposed project could impose disproportionately high adverse effects on minority or low-income populations.

6.3.11.5 EO 13123, Greening the Government through Efficient Energy Management (65 FR 24595)

E0 13123, Part 2, Section 204, dated April 21, 2000, states "each agency shall strive to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects and by purchasing electricity from renewable energy sources." Construction and maintenance of the proposed beach improvements do not involve the ongoing use of electricity. The applicant's general policy is to promote energy efficiency throughout its operations, and it will include a statement to that effect in its construction contract for the proposed beach restoration and maintenance project.

6.4 Project Relationship With Waikiki Beach

6.4.1 Waikiki Beach Development

There is little evidence to suggest that Waikiki Beach, generally considered to extend from the Elks Club on the east to the Ala Wai Boat Harbor to the west, is or ever was "master planned". What exists today is a series of individual actions by property owners and government agencies along various segments of the beach and then reactions to problems that ensued, beginning more than 100 years ago. At present, Waikiki Beach is entirely man-made; there is no natural shoreline between Honolulu Harbor and Diamond Head. However, there have been general overall improvement plans suggested by various investigators over the years. In the early 1960s investigations by the U.S. Army Corps of Engineers (USACE) led to a congressionally authorized improvement plan, which was de-authorized in the mid-1970s as a result of public concerns and opposition. In 1979, the report *Beach and Surf Parameters in Hawaii* (Gerritsen, 1979) was published by the University of Hawaii Sea Grant Program, and included a section on "Measures for Improvement" of Waikiki Beach. In the 1990s, the State DLNR contracted with the engineering firm of Edward K. Noda and Associates, Inc. for extensive study of Waikiki Beach and possible improvements. This work is summarized in the *Final Environmental Assessment, Kuhio Beach Improvements* (Noda, 1999). The report *Independent Evaluation Study of Proposed Kuhio Beach Improvements* (Bodge, 2000) prepared for the State DLNR included a chapter on overall "Waikiki Beach Improvements".

<u>USACE (1965)</u> – The USACE plan consisted of:

- Widening the average dry beach width to 180 feet from Duke Kahanamoku Beach (Hilton Hotel) to the Natatorium, and 75 feet from the Natatorium to the Elks Club.
- Constructing or modifying the following structures:

- Extension of the existing box culvert/groin at the east end of Fort DeRussy Beach to 350 feet.
- Construction of a new 350-foot groin between the Sheraton Waikiki and the Royal Hawaiian hotels.
- Construction of a new 350-foot groin at the north end of Kuhio Beach.
- Extension of the existing Kapahulu Avenue storm drain by 130 feet.
- Raising the 190-foot long shoreward crest elevation of the Queen's Surf groin from 4.5 feet to 8 feet.
- Construction of a new 350-foot groin near the Aquarium.
- Construction of a 100-foot stub groin extension from the southwest corner of the Natatorium.
- Construction of up to four additional groins if required.

The USACE did not construct any of the authorized improvements. In 1969 Fort DeRussy beach was improved by the Army. Work included beach fill and the construction of a box culvert and rock groin on the eastern boundary adjacent to the Outrigger East hotel. The State of Hawaii completed improvements to Kuhio Beach in 1972, however they departed extensively from the USACE plan.

Gerritsen (1978) – Dr. Gerritsen identified many issues and concerns regarding improvements to Waikiki Beach, and presented his suggestions from a purely technical standpoint. Suggested improvements were generally as follows:

- Fort DeRussy – no improvement necessary

- Fort DeRussy to Royal Hawaiian Hotel
  - Beach nourishment
  - Extend the Fort DeRussy culvert/groin and add a spur on the east side of the head
  - Construct a new T-head groin in the vicinity of the Halekulani Hotel
  - Replace the existing Royal Hawaiian groin with a new T-head groin

- Royal Hawaiian Hotel to Kapahulu Storm Drain/Groin
  - Beach nourishment
  - Construct a new offshore breakwater fronting the Moana Hotel
  - Construct a new groin at the north end of Kuhio Beach
  - Improve the effectiveness of the Kuhio Beach Crib Wall

- Kapahulu Storm Drain to the Elks Club: Beach nourishment stabilized by T-head groins, the number and configuration of which would depend on whether or not the Natatorium is removed.

DLNR (1999) – The Kuhio Beach improvement plan proposed by DLNR/DOBOR consisted of reconstruction of the offshore crib wall system and restoration and improvement of the beach. The plan proposed replacing the concrete and stone crib walls with new rock groins at each end and a segmented breakwater in the middle. The proposed improvements to Kuhio Beach have not yet been implemented by the State.

Bodge (2000) – The DLNR Land Division contracted with Dr. Kevin Bodge of Olsen Associates, Inc. to conduct a review of the proposed Kuhio Beach improvements. Dr. Bodge and his firm have considerable experience with the design and construction of beach projects similar to the Kuhio Beach plan, i.e. beach fill stabilized by T-head groins. Dr. Bodge presented some general design considerations and improvement suggestions for the entire beach. He suggested that the beach is already "compartmentalized", both by existing structures and backshore usage/facilities, and that this compartmentalizing readily allows for beach improvements to be made in a step-by-step or piece-wise approach. He further suggested that "it is not necessary to address, design or construct, all of the Waikiki improvements at one time", and that different sponsorship and funding could be utilized for different areas. For the Royal Hawaiian beach segment Dr. Bodge recommends "*Periodic beach nourishment between the Royal Hawaiian Hotel and Kuhio Beach, without stabilizing structures, or, the possible use of three or four T-head groins to stabilize the beach and eliminate the need for periodic re-nourishment*."

The proposed beach improvement plans outlined above were all also discussed in terms of discrete beach segments or compartments, generally defined by existing structures and backshore usage. Beach improvements were discussed in terms of each reach being a separate project, capable of being implemented incrementally as stand-alone improvements. The beach segments are generally defined from east to west as follows (Gerritsen, 1978; Fletcher and Miller, 2003).

1. Sans Souci (Kaimana) Beach: Kaimana Hotel/Elks Club to the Natatorium
2. Queens Beach: Natatorium to the Queen's groin
3. Kapiolani Beach: Queen's groin to the Kapahulu storm drain
4. Kuhio Beach: Kapahulu storm drain to the Duke Kahanamoku statue
5. Royal Hawaiian Beach: Duke Kahanamoku statue to the Royal Hawaiian groin
6. Halekulani Beach: Royal Hawaiian groin to the Ft. DeRussy groin/drain culvert
7. Ft. DeRussy Beach: Ft. DeRussy groin to the Hilton pier
8. Duke Kahanamoku Beach: Hilton pier to the Ala Wai Boat Harbor

The proposed Waikiki Beach Maintenance project is located in the Royal Hawaiian beach segment, fronting the Royal Hawaiian, Outrigger Waikiki, and Moana Surfrider hotels. Thus the proposed project is consistent with existing planning studies for Waikiki Beach improvements, and capable of being implemented as a stand-alone project. It would also integrate well with future beach improvement projects should they be implemented.

6.4.2 Recent Waikiki Beach Maintenance

In 2006 the State DLNR performed beach maintenance in the Kuhio Beach segment of Waikiki. The project consisted of the recovery of 10,000 cubic yards of sand from deposits immediately offshore of Kuhio Beach, pumping it to shore for dewatering, and placing it on the beach to nourish and widen the beach. The sand was primarily placed within the confines of the crib walls, however approximately 20% was placed on the beach west of the crib wall, fronting the Duke Kahanamoku statue.

6.4.3 Possible Future Waikiki Projects

Several Waikiki Beach improvement projects for beach segments other than the project area are presently being considered.
Gray's Beach. Kyo-ya Hotels & Resorts, LP are proposing to restore the beach fronting the Sheraton Waikiki Hotel, at the east end of the Halekulani Beach segment. This 500-foot-long reach currently has no sand beach, and the shoreline is comprised of a vertical concrete seawall. The proposed project would use offshore sand from the Halekulani Channel to restore a beach, and construct three T-head rock groins to stabilize the beach and prevent erosion and loss of sand. An EIS Preparation Notice has been published, and a Draft EIS for the project is in preparation.

Natatorium. The City & County of Honolulu is exploring alternatives for the aging and deteriorated Waikiki Natatorium (between the Sans Souci and Queens beach segments). Alternatives include replacing the natatorium with a beach, possibly including rock groin stabilizing structures.

As these would be accomplished in separate discrete beach segments it is reasonable to consider them as stand-alone projects.

7. MITIGATION

7.1 Mitigation During Construction

7.1.1 Protection of Endangered Species

The following Best Management Practices (BMPs) as typically recommended by the National Marine Fisheries Service (NMFS) will be adhered to during construction of the project to avoid impacts to the turtles.

1. Conduct a survey for marine protected species before any work in the water starts, and if a marine protected species is in the area a 150-foot buffer must be observed between the protected species and the work zone.
2. Establish a safety zone around the project area whereby observers will visually monitor this zone for marine protected species 30 minutes prior to, during, and 30 minutes post project in-water activity. Record information on the species, numbers, behavior, time of observation, location, start and end times of project activity, sex or age class (when possible) and any other disturbances (visual or acoustic).
3. Conduct activities only if the safety zone is clear of turtles.
4. Upon sighting of a turtle within the safety zone during project activity, immediately halt the activity until the animal has left the zone. In the event a marine protected species enters the safety zone and the project activity cannot be halted, conduct observations and immediately contact NMFS staff in Honolulu to facilitate agency assessment of collected data.
5. For on-site project personnel that may interact with a protected species potentially present in the project area, provide education on the status of any listed species and the protections afforded to those species under Federal laws.

7.1.2 Best Management Practices During Construction

Best Management Practices (BMPs) for construction operations will be developed to help minimize adverse impacts to coastal water quality and the marine ecosystem. The project specifications will require the Construction Contractor to adhere to environmental protection measures, including, but not limited to, the following:

- The Contractor shall perform the work in a manner that minimizes environmental pollution and damage as a result of construction operations. The environmental resources within the project boundaries and those affected outside the limits of permanent work shall be protected during the entire duration of the construction period.

- Any construction related debris that may pose an entanglement hazard to marine protected species must be removed from the project site if not actively being used and/or at the conclusion of the construction work.

- The Contractor shall submit a Best Management/Environmental Protection Plan for approval prior to initiation of construction. The plan shall include, but not be limited to:

1. Protection of Land Resources
2. Protection of Water Resources
3. Disposal of Solid Waste
4. Disposal of Sanitary Waste
5. Disposal of Hazardous Waste
6. Dust Control
7. Noise Control

- The construction contractor shall be required to employ standard BMPs for construction in coastal waters, such as daily inspection of equipment for conditions that could cause spills or leaks; cleaning of equipment prior to operation near the water; proper location of storage, refueling, and servicing sites; and implementation of adequate spill response procedures, stormy weather preparation plans, and the use of silt curtains and other containment devices.

- No contamination (trash or debris disposal, alien species introductions, etc.) of marine (reef flats, lagoons, open oceans, etc.) environments adjacent to the project site shall result from project related activities.

- The Contractor shall confine all construction activities to areas defined by the drawings and specifications. No construction materials shall be stockpiled in the marine environment outside of the immediate area of construction.

- The Contractor shall keep construction activities under surveillance, management and control to avoid pollution of surface or marine waters. Construction related turbidity at the project site shall be controlled so as to meet water quality standards. All water areas affected by construction activities shall be monitored by the Contractor. If monitoring indicates that the turbidity standards are being exceeded due to construction activities, the Contractor shall suspend the operations causing excessive turbidity levels until the condition is corrected. Effective silt containment devices shall be deployed where practicable to isolate the construction activity, and to avoid degradation of marine water quality and impacts to the marine ecosystem. In-water construction shall be curtailed during sea conditions that are sufficiently adverse to render the silt containment devices ineffective.

- Waste materials and waste waters directly derived from construction activities shall not be allowed to leak, leach or otherwise enter marine waters.

- Fueling of project related vehicles and equipment should take place away from the water. A contingency plan to control the accidental spills of petroleum products at the construction site should be developed. Absorbent pads, containment booms and skimmers will be stored on site to facilitate the cleanup of petroleum spills.

- The project shall be completed in accordance with all applicable State and County health and safety regulations.

- The sand shall be of beach-compatible quality, moderately well sorted with rounded and polished grains composed of primarily calcareous material. The sand shall be dominantly composed of naturally occurring carbonate beach or dune sand. Crushed limestone or other man-made or non-carbonate sands are not allowable.

- All construction material including sand shall be free of contaminants of any kind including: excessive silt, sludge, anoxic or decaying organic matter, turbidity, temperature or abnormal water chemistry, clay, dirt, organic material, oil, floating debris, grease or foam or any other pollutant that would produce an undesirable condition to the beach or water quality.

- Sand fill placement shall not be done during storms or periods of high surf.

- Any spills or other contaminations shall be immediately reported to the DOH Clean Water Branch (808-586-4309).

- Best management practices shall be utilized to minimize adverse effects to air quality and noise levels, including the use of emission control devices and noise attenuating devices.

- A dust control program shall be implemented and windblown sand and dust shall be prevented from blowing offsite by watering when necessary.

- Public safety best practices shall be implemented, possibly including posted signs, areas cordoned off, and on-site safety personnel.

- Public access along the shoreline during construction shall be maintained so far as practicable and within the limitations necessary to ensure safety.

- The Contractor shall review all best management practices with the project applicant/representative prior to the commencement of beach nourishment activities.

7.2 Water Quality Monitoring Plan

The intent of the water quality monitoring plan (WQMP) is to conduct water quality sampling and analysis to monitor potential impacts caused by in-water work of the project, including dredging, dewatering, and sand placement work. The WQMP includes baseline (preconstruction), during construction, and post-construction monitoring. Data collected as part of the WQMP will be used to assess the adequacy of BMPs applied during construction and will facilitate assessing the impacts of the project on water quality of the nearshore waters in the project vicinity. If shown to be necessary by the monitoring data, BMPs will be modified during construction to better protect water quality. The WQMP is presented in detail in Appendix C.

The monitoring program largely follows the General Monitoring Guidelines for Section 401 Water Quality Certification Projects (HDOH, 2000). Receiving water quality parameters to be measured are: pH, turbidity, total suspended solids (TSS), dissolved oxygen (DO), salinity, temperature, enterococcus, and clostridium. Six sampling stations will be established: one nearshore control station, two offshore control stations (one surface and one bottom), and three nearshore impact stations. One of the impact stations will be located near the dewatering area and the other two will be located at either end of the nourished beach. The samples will all be collected from a depth of 0.3 m (1 ft) below the surface of the water, except the bottom sample at the offshore control station, which will be collected 1 m (3 ft) above the bottom. The locations of the stations will be finalized after the construction design documents are completed.

In-water work is expected to be completed within approximately two months. BMPs will be installed and will remain until completion of the Project. HDOH-CWB will be notified if any modifications to the schedule or BMPs are proposed. Prior to construction, samples will be collected once a month for ten months (or more frequently if there is less time available) at all of the control stations for a total of ten sampling events. Collecting preconstruction samples over this longer time period will provide a representative baseline covering temporal and seasonal differences. During construction samples will be collected from the three controls stations and three impact stations every day dredging, dewatering, and sand placement is performed throughout the duration of the project. Enterococcus and clostridium will be measured once a week. Post construction sampling at the three control station will occur one time per week for three weeks once the project is completed.

7.3 Marine Environment Monitoring Plan

A marine ecosystems monitoring plan has been designed to quantify positive and negative impacts of beach nourishment on the nearshore reef flat. The two primary goals of the monitoring program are: 1) to assess changes in specific biotic and physical variables due to the project and 2) to test for correlations between variables. A “Before-After, Control-Impact” (BACI) monitoring design and analysis will be employed. The BACI monitoring design accounts for natural spatial and temporal variation that occurs in ecosystems, which can mask project–related changes to the resident biotic community. The BACI monitoring program has been recommended by critical reviews of historical beach nourishment monitoring programs.

The monitoring program will assess the following reef flat variables: percent benthic cover (biotic and abiotic), coral colony abundance, coral colony size, and rugosity. These variables will be monitored in the project and reference (control) areas before and after project construction: one time before construction and four times after construction (immediately after construction, and one, three, and five years post-construction).

In addition to monitoring responses to beach nourishment on the reef flat, coral colonies growing in proximity to dredging operations at the sand deposits and the pipeline corridor will be monitored, and the sand deposits will be monitored for benthic infauna.

The complete marine environmental monitoring plan is presented in Appendix D.

7.4 Beach Monitoring Plan

Post-construction monitoring of the beach would also be done to evaluate project performance.

Post-construction project performance and beach stability will be monitored by periodically surveying beach profiles and documenting the characteristics of the shoreline with photographs. Beach profiles are a common measurement technique used to investigate coastal processes and shoreline change. The profiles are performed by measuring the land along a transect perpendicular to the shoreline, and may extend as far shoreward or seaward as necessary to capture specific project features. For this project the profiles will extend from the backshore seaward to a point past the intersection of the beach slope with the existing natural sea bottom. Profile locations would be at approximate 200-foot intervals along the project reach, a total of ten profiles. Recoverable benchmarks will be established at each profile location to insure that all profiles are measured at the same location, azimuth, and with the same elevation control. The profiles would be measured using standard survey equipment and techniques. The profiles will be plotted and a summary and discussion of the results will be prepared following each survey. The schedule for beach monitoring profiles will be as follows.

1. Immediately (within 72 hours) after placement of the sand fill to the design beach shape at each profile location.
2. A complete set of profiles at all locations will be accomplished 30 days, 6 months and 12 months post-construction.
3. After the first year post-construction profiles will be measured annually for 10 years.

Additional profile locations or measurement times may be added as deemed warranted by the project coastal engineer in order to more fully measure the performance of the project, e.g., should an atypical or unusual shoreline formation or change occur or should changes occur more rapidly than anticipated.

The beach monitoring program will provide information to determine the performance and impacts of the project, if any, as well as helping to establish a timetable for possible future beach maintenance activities.

8. DETERMINATION

8.1 Determination Criteria

Chapter 343, Hawaii Revised Statutes (HRS), and Hawaii Administrative rules (HAR) §11-200, establish certain categories of action that require the agency processing an applicant's request for approval to prepare an environmental assessment. HAR §11-200-11.2 established procedures for determining if an environmental assessment (EA) is sufficient or if an environmental impact statement (EIS) should be prepared for actions that may have a significant effect on the environment. HAR §11-200-12 lists the following criteria to be used in making such a determination.

1. *Involves an irrevocable commitment to loss or destruction of any natural or cultural resource.*

Nourishment and maintenance of the existing sandy beach resource will contribute to the preservation and continuation of this very valuable natural resource. The offshore sand to be used to nourish the beach is essentially a sustainable resource in the context of the scope and scale of the proposed project. The offshore sand in large part is believed to have come from the shore through natural processes of offshore sand transport by waves and currents, and these processes are expected to continue. The proposed project would simply periodically manually recycle the sand from offshore back onto the beach.

Implementation of the project does not involve construction on or excavation of land that might contain physical historic or archaeological remains. The work on land will take place in an area which has already been substantially altered over more than a century, which has recently eroded and receded landward, and is entirely makai of the shoreline where the existence of any cultural artifacts or remains is very unlikely. The proposed project is unlikely to have any significant adverse effect on known practices customarily and traditionally exercised for subsistence, cultural and religious purposes.

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

The proposed project would improve Waikiki Beach by restoring a valuable and heavily utilized recreational beach, and will have significant beneficial impact to recreational activities consistent with the purposes of the environment in the project area. No adverse long term impacts to the environment are anticipated to result from this project. There may be temporary short-term impacts during construction, however these are not anticipated to be significant, and will be mitigated to the maximum extent practicable by the use of BMPs and monitoring procedures.

3. *Conflicts with the State's long-term environmental policies or goals and guidelines as expressed in Chapter 343, HRS, and any revisions thereof and amendments thereto, court decisions, or executive orders.*

The proposed project is consistent with Hawaii's State Environmental Policy as established in Chapter 343(4)(A), HRS, to establish, preserve, and maintain recreation areas, including the shoreline, for public recreational use.

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

The economic value of Waikiki Beach to Hawaii's visitor industry and the economic success of Waikiki as a visitor destination is extremely significant. The estimated socio-economic loss to the State would be quite high if Waikiki Beach is not maintained and is allowed to erode away – a $2 billion loss in overall visitor expenditures, a $150 million loss in tax revenue, and a job loss of 6,350 people. The proposed project will help maintain this very valuable socio-economic resource.

5. *Substantially affects public health.*

The proposed project will have some impact on air, noise and water quality during construction, however these will be mitigated to the maximum extent practicable by BMPs and monitoring procedures. The project will not result in any post-construction or long-term effects on public health.

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

The project will not alter the existing land use pattern shoreward of the beach restoration area. The improved beach is likely to attract beach users who do not presently use this area, however this increase will be consistent with the current recreational use of the area. The project could result in an increase in the general level of commercial activity in the area, and thus would have a long-term benefit. The proposed project has little or no potential to affect public infrastructure and services. Once completed it will require no water, power, sanitary wastewater collection, or additional emergency services.

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

Other than temporary, short-term environmental impacts during construction, and which are generally not considered significant, the proposed project would not result in impacts which can be expected to degrade the environmental quality in the project area. In fact, the opposite would be true - the project would restore and maintain a valuable coastal resource.

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

The proposed project simply restores and maintains an existing sand beach resource. It does not enlarge the beach beyond its recent (1982) historical position, or add any new structures to the shoreline. Although a regular periodic maintenance program for the beach is recommended and proposed, the proposed project does require or commit to future larger actions.

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

The nearshore area off Waikiki is frequented by the threatened green sea turtle, which feeds on the algae covered hard fossil limestone bottom areas. Hawaiian monk seals have been infrequently seen in Waikiki. The project will not affect turtle food sources, as algae does not grow on the offshore sand deposits or the beach, and turtle foraging and abundance is not adversely affected by people and water recreation activities. Turtle protection procedures as recommended by the National Marine Fisheries Service will be in place during construction.

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

There will be some temporary, short-term impacts to air and water quality, and noise levels, during construction. However, these impacts will be limited to the construction period and will not be significant. BMP's, water turbidity controls, and a water quality monitoring program will be in effect to help minimize the construction impacts. The contractor will be required to submit an Environmental Protection Plan for approval prior to the start of construction, which will include provisions for reducing air, water, and noise impacts. Once construction is complete and the sand is placed on the beach there would be no activity or mechanism for further air, water or noise impacts.

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.

The proposed project will provide a beneficial impact by extending the shoreline seaward, increasing the space between the water and the backshore infrastructure. This will increase the wave energy dissipating properties of the beach, decrease wave runup and flooding of the backshore area, and thus reduce susceptibility to natural ocean hazards. The proposed project will not change the shoreline elevation, and will not change the existing tsunami flood hazard. The beach is subject to long-term chronic erosion, and this is expected to continue. Therefore regular periodic nourishment will be necessary to maintain the project benefits over the long term.

12. Substantially affects scenic vista and view planes identified in county or state plans or studies.

The proposed project is relevant to objectives of the Oahu General Plan, including protecting and improving the natural environment, restoring natural resources, retaining scenic resources, and enhancing scenic views. The restored beach would not alter the scenic Waikiki shoreline, and a wider beach would be visually and aesthetically more attractive.

13. Requires substantial energy consumption.

Other than energy expended during construction operations, the project would require no additional energy consumption.

8.2 Determination

In accordance with the potential impacts outlined in Section 4 of this DEA, the provisions of Chapter 343 HRS, and the significance criteria discussed above, the Office of Conservation and Coastal Lands of the State of Hawaii Department of Land and Natural Resources expects the determination for this project to be a Finding of No Significant Impact (FONSI).

9. CONSULTATION

9.1 Parties Consulted

The consultation activities and coordination with agencies, organizations, and individuals undertaken by DLNR/OCCL are summarized in Table 9.1 below. The names of individuals and organizations invited to attend the scoping meetings who actually attended or sent representatives are indicated by asterisks.

Table 9-1 Agencies and individuals consulted with during EA preparation

EA Scoping Meeting December 2, 2009

Federal

- U.S. Army Corps of Engineers, Honolulu District, Regulatory Branch*
- U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office
- NOAA, National Marine Fisheries Service, Pacific Islands Regional Office
    - Pacific Islands Environmental Coordinator
    - Habitat Conservation Division*
    - Protected Resources Division*
- U.S. Environmental Protection Agency, Region IX, Honolulu Branch

State

- Office of Environmental Quality Control
- Department of Land and Natural Resources
    - Aquatic Resources Division*
    - Historic Preservation Division*
    - Office of Conservation and Coastal Lands*
    - Engineering Division*
- Department of Health, Clean Water Branch
- DBEDT, Office of Planning, Coastal Zone Management Program

City & County of Honolulu
Department of Planning and Permitting
Department of Design and Construction*
Waikiki Neighborhood Board*

Other consultation
NOAA, National Marine Fisheries Service, Pacific Islands Regional Office, Habitat Conservation Division
State Department of Health, Environmental Management Division, Clean Water Branch
Waikiki Neighborhood Board[1]
Waikiki Improvement Association
University of Hawaii Sea Grant Program

[1] At their February 9, 2010 meeting the Waikiki Neighborhood Board voted unanimously in favor of a motion to support the project.

Ocean activities consultation (see Appendix B)
Brunetti, Vince. Manager of the food concession in the HPD Waikiki Substation building.
Bush, Ted. Owner, Waikiki Beach Services.
Carvalho, David. Manager, Hawaiian Oceans beach concession.
Chang, Hubert. Owner, Hawaiian Oceans beach concession.
Couch, Tom. Staff, Hawaiian Oceans beach concession.
Downing, George. Save Our Surf.
Goto, Ralph. Director, Ocean Safety Division, Honolulu Emergency Services.
Harada, Ivan. Waikiki Lifeguard, retired.
Howe, Jim. Operations Chief, Ocean Safety Division, Honolulu, Emergency Services.
Iaukea, Rocky. Manager, Mana Kai catamaran.
Lipton, Sheila. Owner, Kapoikai catamaran.
Merino, Paul. Waikiki District Lifeguard Captain, Ocean Safety Division, Honolulu Emergency Services.
Oahu District Manager, DOBOR.
Quintal, Sidney. Director, Department of Environmental Services.
Robello, Didi. Owner, Aloha Beach Services.
Santiago, Jay. Captain, Kapoikai catamaran.
Savio, John. Owner, Na Hoku and Manu Kai catamarans.
Shipley, Jack. Waikiki surf contest judge.
Star Beachboys.
Wright, Chalian. Concession Specialist, Department of Environmental Services.

9.2 EA Preparers

The Waikiki Beach Maintenance DEA was prepared by Sea Engineering, Inc. The respective contributions of individuals are as follows:

Scott P. Sullivan M.S. Ocean Engineering	Principal-in-Charge
David A. Smith Ph.D Ocean Engineering P.E. Civil Engineering	Contributing Author

Technical consultants included the firm of AECOS, Inc. (marine biology and water quality) and John Clark (water and beach recreation).

9.3 DEA Distribution

DLNR will distribute this DEA to the organizations and individuals listed in Table 9-2, and request their comments on the project.

Table 9-2 Draft EA Distribution List

City and County of Honolulu
Department of Design and Construction
Department of Environmental Services
Department of Facility Maintenance
Department of Parks and Recreation
Department of Planning and Permitting
Department of Transportation Services
Department of Emergency Services, Ocean Safety

State Agencies
Department of Accounting and General Services
Department of Business, Economic Development & Tourism
DBEDT – Office of Planning, CZM Program
Department of Hawaiian Home Lands
Department of Health, Clean Water Branch
Department of Land and Natural Resources
DLNR – Historic Preservation Division
DLNR – Division of Aquatic Resources
Office of Hawaiian Affairs
UH Environmental Center

Federal Agencies
U.S. Army Corps of Engineers, Honolulu District
U. S. Fish and Wildlife Service
NOAA/NMFS, Pacific Islands Regional Office
U.S. EPA, Region IX, Honolulu Branch

Libraries
Waikiki-Kapahulu Public Library
Legislative Reference Bureau

Elected Officials
U.S. Senator Daniel K. Inouye
U.S. Senator Daniel Akaka
U.S. Congressman Neil Abercrombie
U.S. Congresswoman Mazie Hirono
State Senator Less Ihara, Jr.
State Senator Brickwood Galuteria
State Representative Tom Brower
State Representative Scott Nishimoto
County Councilmember Charles Djou
Waikiki Neighborhood Board No. 9 Chair Robert Finley

Citizen Groups, Individuals and Consulted Parties
Ala Wai Watershed Association
Outrigger Waikiki Hotel
Kyo-ya Hotels & Resorts
Kamehameha Schools
Surfrider Foundation, Oahu Chapter
George Downing, Save Our Surf
Sierra Club
The Nature Conservancy of Hawaii
Waikiki Improvement Association
Waikiki Business Improvement District Association
Hawaii Hotel & Lodging Association
Waikiki Residents Association
Clyde Aikau, beach concessionaire
Aloha Beach Services, beach concessionaire
Waikiki Beach Services, beach concessionaire
Hawaiian Oceans, beach concessionaire
Star Beachboys, beach concessionaire
Mana Kai, beach catamaran
Kapoikai, beach catamaran

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APPENDIX A:
MARINE BIOLOGICAL AND WATER QUALITY RESOURCES AT WAIKĪKĪ BEACH, O‘AHU

AECOS, INC.

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AECOS No. 1205

Marine biological and water quality resources at Waikīkī Beach, O‘ahu

Prepared by:

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September 29, 2009

Marine biological and water quality resources at Waikīkī Beach, Oʻahu[1]

September 29, 2009 | ***DRAFT*** | *AECOS* No. 1205

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Introduction

The Department of Land and Natural Resources, Office of Coastal and Conservation Lands (DLNR-OCCL) is proposing to nourish the sand beach at Waikīkī, Oʻahu between the Royal Hawaiian groin and the west end of the Kūhiō Beach crib wall (Fig. 1). The proposed Waikīkī Beach restoration project involves the recovery of sand from offshore and placement of this sand on the beach. The project will be undertaken and monitored based upon experiences gained from the December 2006 project to nourish Kūhiō Beach (*AECOS*, 2008), which is located adjacent to the east.

The Waikīkī Beach restoration project has the potential to affect marine resources and water quality in the project area. This report describes existing marine biological resources and water quality off of Waikīkī Beach. This information will be used to assess the potential effects of constructing and maintaining the proposed nourished beach.

[1] Report prepared for Sea Engineering, Inc. for use in the preparation of an Environmental Assessment.

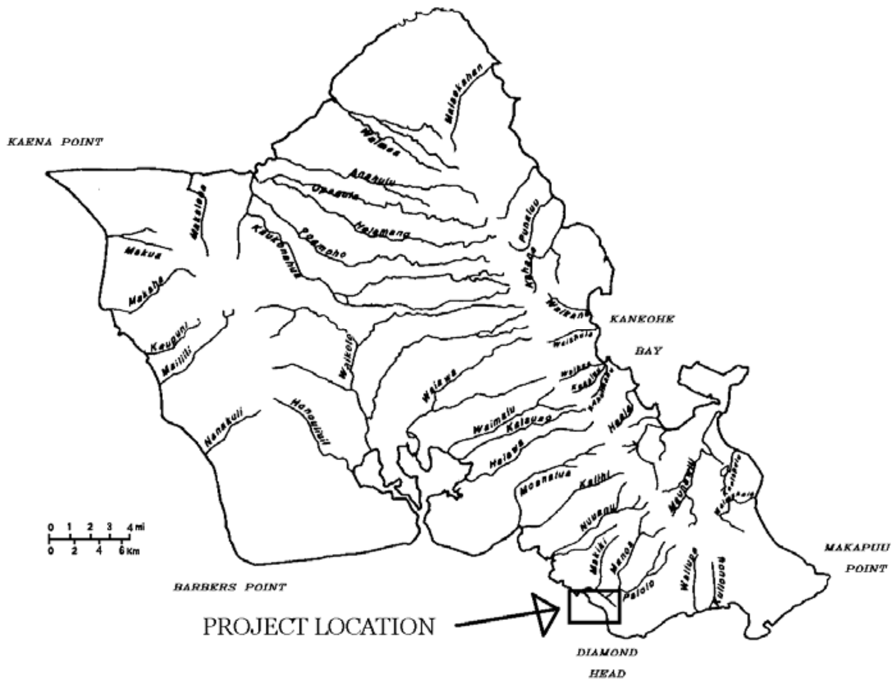

Figure 1. Island of Oʻahu showing location of Waikīkī Beach.

Project Area Description

The entire shoreline from Kahanamoku Beach on the west to Sans Souci Beach on the east is highly altered by seawalls, groins, and jetties in an effort to stabilize the shoreline. Over 500,000 cubic yards of sand have been placed on the beach at Waikīkī since 1928. However, only two percent of that sand remains on the beach today (Fletcher and Miller, 2003).

Waikīkī reef is an open coastal, coral reef environment with biotic attributes largely influenced by sand suspension and scour caused by impinging waves (*AECOS*, 1979). The fringing reef consists of a highly-eroded fossil limestone platform with scattered, sand-filled pockets and supporting turf-forming algae. Coral colonies in the nearshore waters off Waikīkī are sparse and account for less than one percent of the bottom (OI, 1991; MRC, 2007; *AECOS*, 2007a, 2008, 2009a). Other reef macroinvertebrates, such as sea urchins and sea cucumbers, are conspicuous but relatively uncommon (OI, 1991; MRC, 2007; *AECOS*, 2009a). Fish biomass and diversity are low in this area of low bottom complexity (Williams et al., 2006; MRC, 2007; *AECOS*, 2009a). Green sea turtles or *honu* (*Chelonia mydas*) are regularly observed over the shallow reef of Waikīkī, as many of their preferred algal food species are abundant or common on the reef flat (*AECOS*, 2009a). A diverse assemblage of sediment-dwelling invertebrates lives in the sand patches of Waikīkī reef (Bailey-Brock and Krause, 2008). In general, the water quality off Waikīkī is good, although waves and the shallow bottom often result in elevated turbidity levels as sediments are constantly re-suspended (*AECOS*, 2009b; USEPA, 2009).

Methods

Marine Biology

A reconnaissance marine biological survey was conducted on July 29, 2009 by *AECOS* biologists. Biologists snorkeled the waters between the west end of the Kūhiō crib wall and the west end of the project area near the Royal Hawaiian groin, out to the proposed offshore sand extraction area. The purpose was to identify marine flora and fauna, and to note biological resources that might be of special concern. Observations and data collected from this survey are combined with data *AECOS* recently collected from adjacent beaches for the Kūhiō Beach small-scale nourishment project (*AECOS*, 2007a, 2008) and the proposed Gray's Beach nourishment project (*AECOS*, 2009a, 2009b). The resources offshore of these adjacent beaches are similar and interconnected to those offshore of Waikīkī Beach. Fig. 2 shows the location of the proposed Waikīkī Beach nourishment project, survey area for the proposed project, and areas surveyed for the Kūhiō Beach and Gray's Beach projects.

A comprehensive quantitative survey was planned to determine percent cover of various reef bottom types, and to quantify macroalgae, macroinvertebrates, coral colonies, and fishes in the project area. However, the biologists were unable to implement the planned survey due to high surf conditions experienced throughout the mid-summer months. The actual survey implemented consisted of a qualitative snorkeling survey of the entire project area; one 25-m transect survey for bottom composition, two 25-m transect surveys for macro-invertebrates and corals, and two 10-minute fish counts.

Biologists swam a U-shaped path from the eastern side of the project area to the proposed primary sand source, and then back to the shoreline at the western side of the project area, avoiding areas actively utilized by board surfers. Biologists conducted a qualitative observational survey of the project area and made a species list with abundance categories for fishes, algae, and macro-invertebrates as observed, coral colonies encountered were measured, and substratum types were recorded. The swim path (grey line) with locations of significant substratum changes and other observations are shown in Fig. 3. The survey path was chosen to best address areas where corals were anticipated to be found and where potential for direct impacts associated with pipeline placement might occur. The majority of the bottom offshore of the project area is sand in shallow water. Waves coming in across the sand bottom attract numerous board surfers.

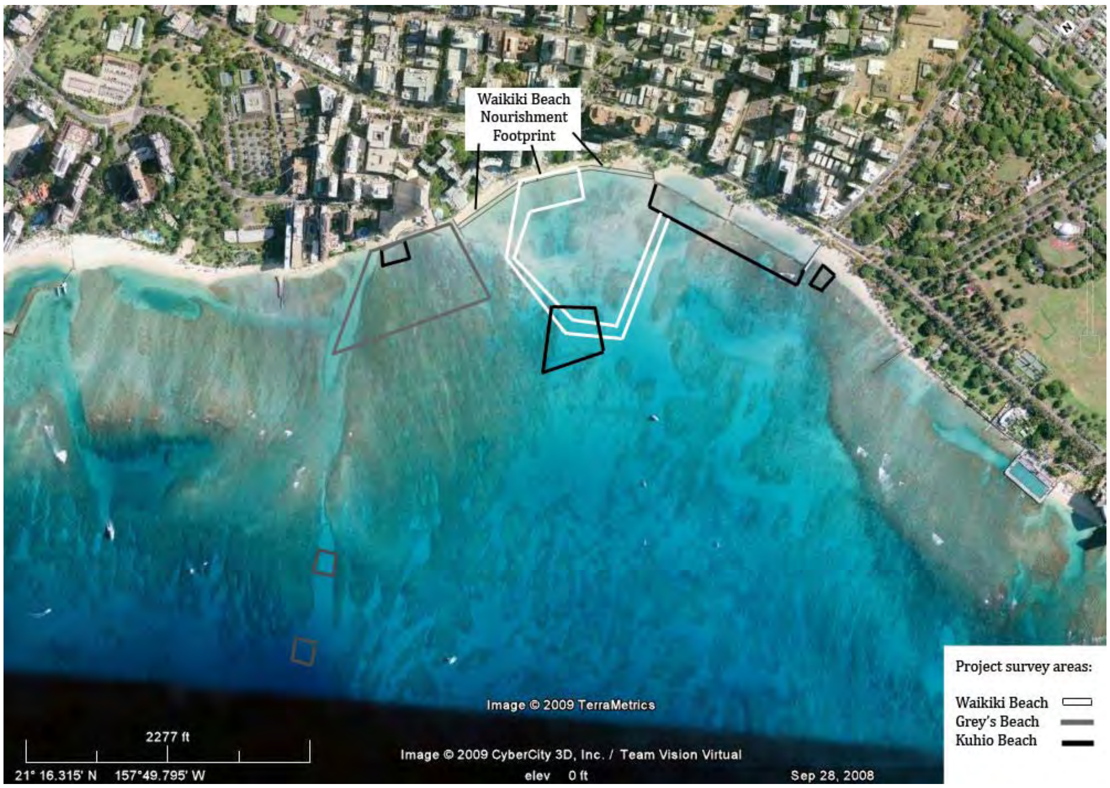

Figure 2. Proposed project location and survey areas for present project, Kūhiō Beach nourishment project, and proposed Gray's Beach nourishment project, Waikīkī, Oʻahu.

In the nearshore waters fronting the Prince Kūhiō Hotel, a small area of hard bottom within the area of direct impacts was surveyed for benthic organisms. A 25-m (82-ft) transect line was laid in a westerly direction, starting at a randomly determined point that was located by GPS (see Fig. 3). Benthic composition along the transect was determined as percent cover using a point-intercept quadrat method. A 0.5 x 0.5 m (0.25 m^2) polyvinyl chloride (PVC) quadrat frame was placed at every other meter mark along the 25-m transect line for a total of 10 quadrat frame placements. The frame was strung with a 10 cm grid of five rows and five columns, producing 25 point-intercepts. Once laid in place and weighted down by 2-lb weights against moving with the wave surge, the item under each of the 25 cross points (from among the choices of hard substrate, live coral, coralline alga, fleshy alga, and sand) was recorded. Hard substrata included limestone reef pavement, basalt boulder, or rubble without algal growth; fleshy algae included turf-forming and macro or foliose species. From these counts, percent cover was determined by category.

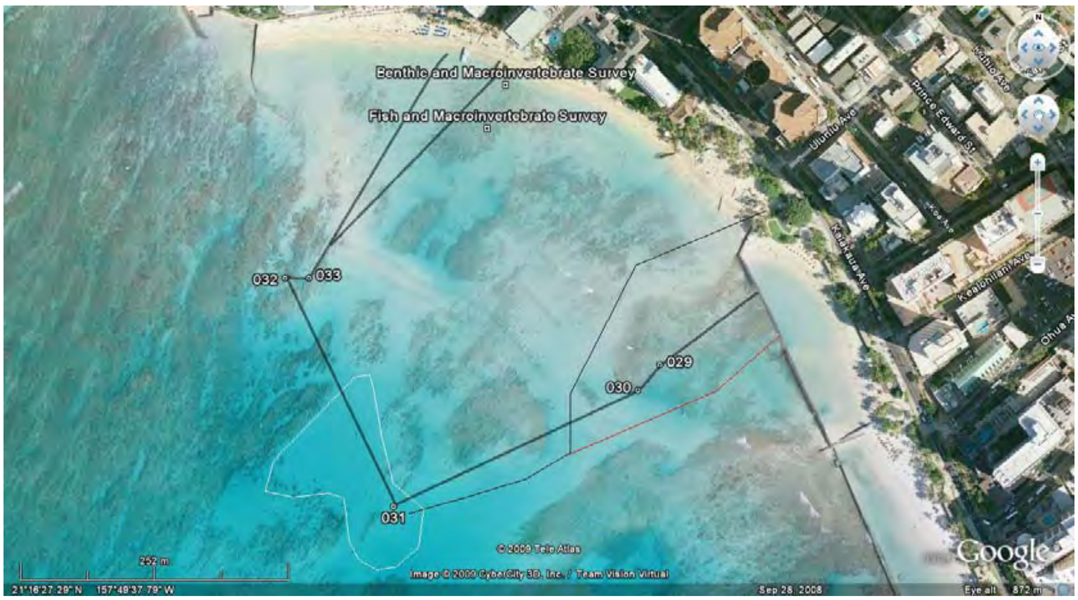

Figure 3. Project area with locations of benthic survey, macroinvertebrate/coral surveys, fish survey, swim survey path (thick, grey line) with selected numbered waypoints. Potential pipeline corridors are shown as thin black and red lines.

Two belt transect surveys to count macroinvertebrates and corals were conducted: one on the same 25-m transect line as was used for the benthic composition survey and one that was laid in an easterly direction from the starting point of the timed fish survey (see Fig. 3, above). All macroinvertebrates and corals observed within a 2 m (6 ft) wide swath centered along the transect line were identified and counted and all individual coral colonies were identified and measured.

A quantitative fish survey was conducted using a timed swim, belt transect method, where biologists swam slowly for 10 minutes and recorded all fish species and their approximate lengths observed within 2 m (7 ft) of the transect path. Biologists swam off in opposite directions, east and west, from a randomly determined point that was located by GPS on the reef fronting the Prince Kūhiō hotel (see Fig. 3, above).

Water Quality

To characterize the water quality off Waikīkī Beach and to contribute to establishing baseline water quality conditions in the project area, five sampling stations were established (Fig. 4) and two sampling events completed on July 21, 2009, in the middle of the dry season. The morning sample event took place during a predicted lower low water (LLW) of -0.4 ft at 0837 and the afternoon sampling event took place during a predicted higher high water (HHW) of 2.7 ft at 1604 (NOAA, 2009). Samples were analyzed for salinity, DO, temperature, pH, turbidity, total suspended solids, chlorophyll α, nitrate + nitrite, ammonia, total nitrogen, and total phosphorus. Table 1 lists the field instruments and analytical methods used to evaluate these samples. Sta. W4 was a control site, located on the west side of the Royal Hawaiian Groin. Sta. W3 was located just off the beach near Duke's Restaurant. Sta. W2 was located on the northwest side of the northern groin of the Kūhiō Beach crib. Sta. W1 was located just *makai* (seaward) of the center of the Kūhiō Beach crib seawall. Sta. W5 was located approximately 400 m (1312 ft) offshore, near the pit proposed for sand recovery.

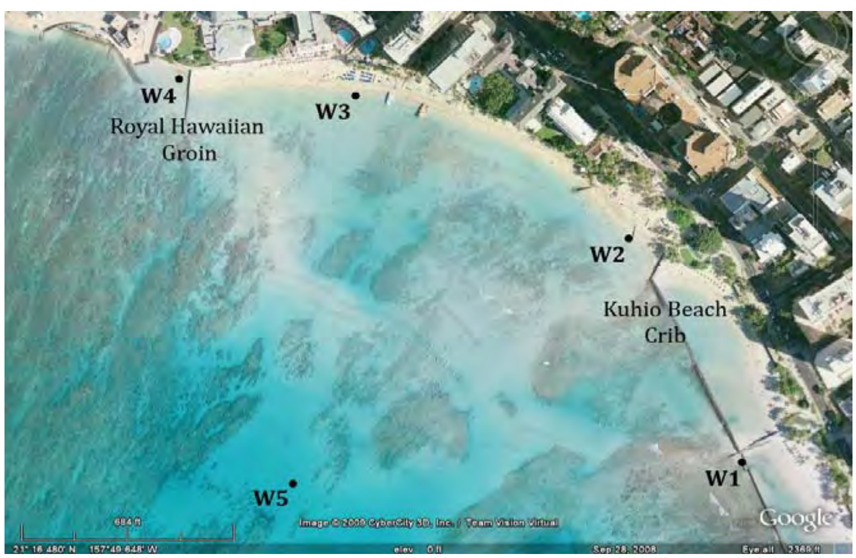

Figure 4. Waikīkī Beach restoration project water quality sampling stations, Waikīkī, Oʻahu.

Table 1. Analytical methods and instruments used for analysis of water quality off Waikīkī Beach, Oʻahu.

Analysis	**Method**	**Reference**	**Instrument**
Ammonia	EPA 350M	Karloeff in Grasshoff et al. (1986)	Technicon AutoAnalyzer II
Chlorophyll α	10200 H	Standard Methods, 20th Edition (1998)	Turner Model 112 fluorometer
Dissolved Oxygen	EPA 360.1	EPA (1979)	YSI Model 85 DO meter
Nitrate + Nitrite	EPA 353.2	EPA (1993)	Technicon AutoAnalyzer II
pH	EPA 150.1	EPA (1979)	Hannah pocket pH meter
Salinity	bench salinometer	Grasshoff in Grasshoff et al. (1986)	AGE Model 2100 salinometer
Temperature	Thermister calib. to NBS certified thermometer / EPA 170.1	EPA (1979)	YSI Model 550A DO meter
Total Nitrogen	persulfate d igestion EPA 353.2	D'Elia et al. (1977) / EPA (1993)	Technicon AutoAnalyzer II
Total Phosphorus	persulfate digestion/EPA 365.1	Koroleff in Grasshoff et al. (1986)/EPA 1993)	Technicon AutoAnalyzer II
Total Phosphorus	persulfate digestion/EPA 365.1	Koroleff in Grasshoff et al. (1986)/EPA (1993)	Technicon AutoAnalyzer II
Total Suspended Solids	Method 2540D (EPA 160.2)	Standard Methods 20th Edition (1998); EPA(1979)	Mettler H31 balance
Turbidity	Method 2130B (EPA 180.1)	Standard Methods 20th Edition (1998); EPA (1993)	Hach 2100N Turbidimeter

D'Elia, C.F., P.A. Stendler, & N. Corwin. 1977. *Limnol. Oceanogr.* 22(4): 760-764.

EPA. 1979. Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, EPA 600/4-79-020.

EPA. 1993. Methods for the Determination of Inorganic Substances in Environmental Samples. EPA 600/R-93/100. U.S.

EPA. 1983. Test Methods for the Chemical Analysis of Water and Wastes

Grasshoff, K., M. Ehrhardt, & K. Kremling (eds). 1986. Methods of Seawater Analysis (2nd ed). Verlag Chemie, GmbH, Weinheim.

Standard Methods. 1998. Standard Methods for the Examination of Water and Wastewater. 20th Edition. 1998. (Greenberg, Clesceri, and Eaton, eds.). APHA, AWWA, & WEF. 1220 pp.

Water samples were collected from just below the sea surface at each station. Temperature, dissolved oxygen (DO), field salinity, and pH measurements were taken in the field. Water samples for all other analytes were collected in appropriate containers, preserved on ice, and taken to *AECOS* in Kāneʻohe, Oʻahu (Log Nos. 25482 and 25483) for laboratory analyses.

Results

The reef flat adjacent to the proposed eastern pipeline corridor within 50 m (164 ft) of shore has low relief with a veneer of sand and scattered shallow sand pockets. This area has an abundance of spiny seaweed (*Acanthophora spicifera*) and P*adina* sp., and patches of *Sargassum obtusifolium*. Gorilla *ogo* (*Gracilaria salicornia*) is common throughout the area. Corals are absent within the first 50 m (164 ft) offshore the crib wall. Offshore of waypoint 029, approximately 50 m (164 ft) from shore, coral rubble is found on a bottom with cover of sea lettuce (*Ulva fasciata*), *Halimeda* sp., and various turf-forming algae. Lobe coral (*Porites lobata*) and cauliflower coral (*Pocillopora meandrina*) colonies are conspicuously scattered across the bottom. Within approximately 3 m (9 ft) of the swim path, 13 *P. lobata* colonies, ranging in size from 5 to 20 cm (2 to 8 in) in diameter, and 3 colonies of *Poc. meandrina*, ranging in size from 15 to 25 cm (6 to 10 in) in diameter, were observed. Adjacent to the edge of the reef flat, a field of *Padina* sp. and tufts of *Dictyota acutiloba* are present. Between the outer edge of the shallow reef flat (waypoint 030) and the proposed primary sand source (waypoint 031), the bottom is all sand with no macroinvertebrates or fishes encountered during the survey.

At the primary sand source area, high surf conditions resulted in clouds of suspended sand sweeping past emergent limestone outcrops. The limestone outcrops here vary considerably in size, with larger, more elevated outcrops supporting scattered *Poc. meandrina* colonies ranging in size from 5 to 10 cm (2 to 4 in) in diameter. Rock-boring urchin (*Echinometra mathaei*) and collector urchin (*Tripneustes gratilla*), and patches of the fleshy algae, *Asparagopsis taxiformis* and *Dictyopteris australis*, are present. Low lying outcrops and lower reaches of taller outcrops are generally devoid of algal growth and macroinvertebrates. Few fishes were observed.

Between the primary sand source and the western side of the project area, emergent limestone outcrops were encountered with minimal algal cover and no corals. However, at the far western end of the project area, a shoaling area with water depths of 1 to 1.25 m (3 to 4 ft; waypoint 032) has high topographic complexity with overhangs, holes, and depressions and about 1 m (3 ft) of vertical relief. Here, coral rubble accumulates in depressions and *E. mathaei* occur in small holes in the limestone. *Poc. meandrina* colonies were conspicuous, ranging in size from 5 to 40 cm (2 to 16 in; only one was less than 15 cm or 6 in); *P. lobata* colonies, ranging in size from 5 to 20 cm (2 to 8 in), are present but less prevalent. *G. salicornia* and *A. spicifera* dominate the fleshy algal assemblage with sparse *Ulva* and *Dictyosphaeria versluysii* present. Urchins (banded urchin or *Echinothrix calamaris* and *E. mathaei*) and fishes are present amongst the limestone reef structures, including: doublebar goatfish (*Parupeneus bifasciatus*), saddle wrasse (*Thalassoma duperrey*), raccoon butterflyfish (*Chaetodon lunula*) juvenile belted wrasse (*Stethojulis balteata*), and juvenile convict tang or *manini* (*Acanthurus triostegus*).

Waypoint 033 is at the intersection of the eroded limestone reef platform and a broad sand bar that appears to be a build-up of sand that has drifted offshore of the beach. The eastern side of this sand bar is interspersed by a low relief and sand-swept, algae-dominated platform with *Padina*, *Sargassum obtusifolium*, *S. polyphyllum*, and occasional dense patches of *G. salicornia*. Dozens of people wade, swim, and play in this shallow surf zone of mixed sand and hard bottom.

Benthic Reef Community

<u>Algae</u> — The dominant benthic organisms on the reef platform off Waikīkī Beach are marine macroalgae, also known as *limu* or seaweed, which cover virtually all exposed hard surfaces that are not scoured or buried by shifting sands. The growth form of these algae is universally low growing or turf-like. Up to 87 different species of algae have been reported from the Waikīkī reef since 1969 (Doty, 1969; Chave et al., 1973; OI, 1991, Huisman et al., 2007; MRC, 2007; and *AECOS*, 2007a, 2008, 2009a).

Although today the flora of Waikīkī reef remains relatively diverse, two invasive red algae (Rhodophyta) species, *Acanthophora spicifera* and *Gracilaria salicornia*, dominate the benthic flora and now cover most hard substrata (Smith et al., 2004; Huisman et al., 2007; MRC, 2007; *AECOS*, 2007a, 2008, 2009a). Algae cover between 75 and 100% (based on visual estimations) of all hard surfaces on the reef flat except along the margins of channels or low relief limestone outcrops where they cover less than 25% of the hard bottom. Table 2 provides a checklist of algae observed on the reef off Waikīkī Beach in the present survey and observed previously in surveys off Gray's Beach and Kūhiō Beach (*AECOS*, 2006, 2007a, and 2008).

Table 2. List of algae observed on reef offshore Waikīkī Beach (July 2009), Gray's Beach (2006 to 2008), and Kūhiō Beach (2006 to 2008).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	**Common name**	**Location of reef** Gray's	Kūhiō	Waikīkī	**QC Code**
CYANOPHYTA	BLUE-GREEN ALGAE				
Leptolyngbya crosbyana		R			05
Lyngbya sp.		P			07
Lyngbya majuscule			R	R	05, 10
Symploca hydnoides		R	R	O	05, 10
CHLOROPHYTA	GREEN ALGAE				
indet.		R	R		05
Avrainvillea amadelpha		C, C	U	R	05, 07
Bornetella sp.		P			07
Bornetella sphaerica			R		05
Bryopsis sp.		O	R		05
Caulerpa racemosa			R		05
Caulerpa sertularioides			U	O	05, 10
Chaetomorpha antennina			R		05
?*Cladophoropsis luxurians*		R			05
Chlorodesmis cf. *plagiogramma*			R		05
Cladophora sp.		R			07
Cladophora fascicularis			R		05
Cladophora luxurians			R		05
Cladophora sericea				R	10
Cladophoropsis luxurians		R			05
Codium arabicum		O	R	R	05, 10
Codium edule		C	O	R	05, 10
Dictyosphaeria cavernosa			U		05
Dictyosphaeria versluysii		P	R	R	07, 05, 10
Enteromorpha sp.		U	R		05
Halimeda sp.				U	10
Halimeda opuntia		R	O		05
Halimeda discoidea		O			07
Microdictyon cf *setchellianum*			R		05
Microdictyon umbilicatum			U		05
Neomeris annulata		R	R	R	07, 05, 10
Spyridea filamentosa			R		05
Ulva fasciata	sea lettuce	U	O	C	07, 05, 10
Ulva reticulata			U		05
PHAEOPHYTA	BROWN ALGAE				
Asteronema breviarticulata			U		05
Chnoospora sp.			R		05
Colpomenia sinuosa			R		05
Colpomenia tuberculata			R		05
Dictyopteris australis			R	R	05, 10
Dictyopteris ceylanica			R		05
Dictyopteris cf. *plagiogramma*			R		05
Dictyota sp.				C	10

Table 2 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	**Common name**	**Location of reef** Gray's	Kūhiō	Waikīkī	**QC Code**
Dictyota acutiloba		O	O	O	05, 10
Dictyota bartayresiana	*alani*	R	O		05
Dictyota ceylanica		P			07
Dictyota friabilis		R	R		05
Dictyota sanwichensis			R		05
Dictyota spp.		A, C, A	U		05, 06, 07
Distromium flabellatum			R		05
Lobophora variegata		R	R		05
Padina spp.		C, P	U	A	06, 07, 05, 10
Padina australis		O	O		05
Padina cf. *japonica*		O	O		05
Sargassum spp.		C			06
Sargassum echinocarpum		C, C	C	A	05, 07, 10
Sargassum obtusifolium				A	10
Sargassum polyphyllum				R	10
Sphacelaria furcigera			R		05
Stypopodium hawaiiensis			U		05
Turbinaria ornata		U, C, A	R	R	05, 06, 07, 10
RHODOPHYTA	RED ALGAE				
indet.		R	R		05
Acanthophora spicifera	spiny seaweed	A, A, A	C	A	05, 06, 07, 10
Asparagopsis taxiformis		R, C, P	U	U	05, 06, 07, 10
Botryocladia skottsbergii		R			05
?Centroceras clavulatum		C	R		05
Coelothrix irregularis			R		05
Dasya sp.		P	R		07, 05
Dichotomaria marginata			R		05
Dichotomaria obtusata			O		05
Dictyopterus australis				O	10
Galaxaura spp.		O, C, O	R		05, 06, 07
Galaxaura fastigiata		O	R		05
Galaxaura rugosa			R		05
Gelidiella pusillum			R		05
Gelidiopsis scoparia			R		045
Gracilaria sp.			R		05
Gracilaria bursapastoris			R		05
Gracilaria coronopifolia		O	R	R	05, 10
Gracilaria rugosa			R		05
Gracilaria salicornia		A, A, O	C	C	05, 06, 07, 10
Hydrolithon breviclavium			O		05
Hydrolithon gardineri		R	C		05

Table 2 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	**Common name**	**Location of reef** Gray's	Kūhiō	Waikīkī	**QC Code**
Hydrolithon onkodes		R	C		05
Hydrolithon reinboldii			O	O	05, 10
Hypnea sp.			R	R	05, 10
Hypnea cervicornis			U		05
Hypnea chordacea			R		05
Jania sp.		C	C	O	05, 10
Laurencia sp.		R	O		05
Laurencia mcdermidiae		R	R		05
Laurencia nidifica		R	U		05
Liagora spp.		P	R	R	07, 05, 10
Liagora f. *ceranoides*			U		05
Martensia fragilis		U	O		05
Martensia sp.		P			07
Melanamansia glomerata		U	C		05
Peyssonnelia rubra		R	R		05
Plocamium sandvicense		R, P	R		05, 07
Pneophyllum conicum			R		05
Portieria hornemannii		R	R	R	05, 10
Pterocladiella spp.		C			06
Pterocladiella caerulescens		R	R		05
Sporolithon sp.		P	R		07, 05
Tricleocarpa cylindrica		R	R		05
Trichogloea spp.		C			06
Trichogloea lubrica		R			05
Wrangelia sp.		R			05
Wrangelia elegantissima			O		05

KEY TO SYMBOLS USED IN TABLE 2:

Abundance categories:

R - Rare - Only one or two individuals or specimens observed in area.

U - Uncommon - Three to no more than a dozen individuals or specimens observed in area.

O - Occasional – Seen irregularly and always in small numbers;

C - Common – Seen regularly, although generally in small numbers.

A - Abundant - Found in large numbers and widely distributed.

QC Code:

05 - Reported previously by aquatic biologists from reef offshore Gray's Beach or Kūhiō Beach on March 15 – April 3, 2006, March 22 - 23, 2007, and March 3 - 7, 2008 (*AECOS*, 2008).

06 - Reported previously by aquatic biologists from reef offshore Gray's Beach in March 2007 (MRC, 2007).

07 - Reported previously by aquatic biologists from reef offshore Gray's Beach on November 30, 2007, December 10 - 11, 2007, December 13, 2007, December 17, 2007, December 29, 2007, January 18, 2008, and April 21, 2008 (*AECOS*, 2009a).

10 - Observed in the field by aquatic biologists on July 29, 2009, or collected for identification in the laboratory. None was saved as voucher specimens.

From our present survey, *A. spicifera* is abundant on the reef flat off Waikīkī Beach and *G. salicornia* has a patchy distribution but can be dominant where present. In addition to these two invasive species, *Dictyota sandvicensis*, *Padina australis*, and *Sargassum obtusifolium* are common on hard surfaces of the reef. Another invasive species, *Avrainvillea amadelpha*, is present on this reef flat. At least two of the species of algae preferred by green sea turtle (*Chelonia mydas*; NMFS-USFWS, 1998) are present on the reef platform off Waikīkī Beach: *Acanthophora spicifera* is abundant and *Ulva fasciata* is common. Several native algal species of interest (C. Smith, Univ. of Hawaiʻi, pers. comm.) are present on this reef platform: *Sargassum echinocarpum* and *S. obtusifolium* are abundant, and *S. polyphyllum* and *Gracilaria coronopifolia* are rare.

<u>Macroinvertebrates</u> — Surveys on the reef flat off Waikīkī have observed common macroinvertebrates, including *Holothuria atra*, *H. nobilis*, *Echinothrix diadema*, *Tripneustus gratilla*, *Echinometra mathaei*, *Echinostrephus aciculatus*, and various sponges (OI, 1991); *E. matheai*, *E. aciculatus*, and *H. atra* (MRC, 2007); and an unidentified stomatopod, *E. diadema*, E. *mathaei*, *T. gratilla*, *Actinopyga mauritiana*, *H. atra*, and *H. cinerascens* (*AECOS*, 2007a, 2008, 2009a).

Table 3 provides a checklist of macroinvertebrates (other than coral) observed on the reef off Waikīkī Beach in the present survey and observed previously in surveys off Gray's Beach and Kūhiō Beach (2006, 2007a, and 2008). Sea urchins are the most conspicuous animals on the reef, particularly *Echinometra mathaei*, which have burrowed into the limestone reef. *Holothuria atra*, the black sea cucumber or *loli*, is the most common sea cucumber encountered on the reef.

Table 3. List of macroinvertebrates (other than coral) observed on the reef off Waikīkī Beach, (July 2009), Gray's Beach (2006 to 2008), and Kūhiō Beach (2006 to 2008).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	**Common name**	**Location of reef** Gray's	Kūhiō	Waikīkī	**QC Code**
PORIFERA, DEMOSPONGIAE	SPONGES				
CHONDRILLIDAE					
Chondrosia chucalla	meandering sponge			R	10
MOLLUSCA, GASTROPODA	MOLLUSKS				
CONIDAE					
Conus imperialis	imperial cone			R	10
CYPRAEIDAE					
Cyrpaea caputserpentis	serpent's-head cowry			R	10
Cyrpaea tigris†	tiger cowrie			R	10

Table 3 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	Common name	Location of reef Gray's	Kūhiō	Waikīkī	QC Code
MURICIDAE					
Morula granulata	drupe			R	10
Morula uva	grape drupe	P			07
MOLLUSCA, CEPHALOPODA, TEUTHOIDEA					
SEPIOLIDAE					
Sepioteuthis lessoniana	big fin squid, *muheʻe*	R			05
ARTHOPODA, CRUSTACEA, STOMATOPODA					
indet	mantis shrimp	R			05
ARTHOPODA, CRUSTACEA, DECAPODA					
STENOPODIDAE					
ALPHEIDAE					
Alpheus deuteropus	petroglyph shrimp	P			07
ECHINODERMATA, OPHIUROIDEA	BRITTLE STARS				
OPHIOCOMIDAE					
Ophiocoma erinaceus	spiny brittle star	P			07
ECHINODERMATA, ECHINOIDAE	SEA URCHINS				
DIADEMATIDAE					
Diadema paucispinum	long-spined urchin	O, U			06, 07
Echinothrix diadema	blue-black urchin	O, R	R		05, 06
Echinothrix calamaris	banded urchin	C	R	U	07, 05, 10
ECHINOMETRIDAE					
Echinometra mathaei	rock-boring urchin	O, P, C	C	O	05, 06, 07, 10
Echinometra oblonga	oblong urchin		R		05
Echinostrephus aciculatus		P			06
Heterocentrotus mammillatus	red-pencil urchin	U	O	R	07, 05, 10
TOXOPNEUSTIDAE					
Tripneustes gratilla	collector urchin	R, O	U	U	05, 07, 10
ECHINODERMATA, HOLOTHUROIDAE	SEA CUCUMBERS				
HOLOTHURIIDAE					
Actinopyga mauritiana	white-spotted sea cucumber, *loli*	R, P	R		05, 07
Holothuria atra	black sea cucumber, *loli okuhi kuhi*	C, O, C	U	R	05, 06, 07, 10
Holothuria cinerascens		U	U		05
Holothuria whitmaei				R	10

KEY TO SYMBOLS USED IN TABLE 3:

Abundance categories:

R - Rare - Only one or two individuals or specimens observed in area.

U - Uncommon - Three to no more than a dozen individuals or specimens observed in area.

O - Occasional – Seen irregularly and always in small numbers;

Table 3 (continued).

C - Common – Seen regularly, although generally in small numbers.
A - Abundant - Found in large numbers and widely distributed.
Other symbols and categories:
† - identified by shell or carapace only.
QC Code:
05 - Reported previously by aquatic biologists from reef offshore Gray's Beach or Kūhiō Beach on March 15 – April 3, 2006, March 22 - 23, 2007, and March 3 - 7, 2008 (*AECOS*, 2008).
06 - Reported previously by aquatic biologists from reef offshore Gray's Beach in March 2007 (MRC, 2007).
07 - Reported previously by aquatic biologists from reef offshore Gray's Beach on November 30, 2007, December 10 - 11, 2007, December 13, 2007, December 17, 2007, December 29, 2007, January 18, 2008, and April 21, 2008 (*AECOS*, 2009a).
10 - Observed in the field by aquatic biologists on July 29, 2009.

Two belt transects consisting of 2 m (6 ft) wide swaths centered along the 25-m transect lines were used to estimate macroinvertebrate density and community composition in the area likely to be affected by the nourished beach (Table 4). All macroinvertebrates observed within the swaths were identified and counted and all individual coral colonies were to be identified and measured (no coral colonies were observed in the survey area).

Table 4. Results of macroinvertebrate and coral surveys on the reef off Waikīkī Beach.

Transect	Species	Count
S1	*Tripneustes gratilla*	1
S1	*Holothuria whitmaei*	1
M2	*Echinometra mathaei*	7
M2	*Echinothrix calamaris*	5
M2	*Holothuria atra*	1
M2	*Cyrpaea caputserpentis*	1

Echinometra mathaei, the rock boring urchin, is the most common macroinvertebrate in the project area with an estimated density of 0.07 m^{-2} and *Echinothrix calamaris*, the banded urchin, is the second most common with an estimated density of 0.05 m^{-2}. The remaining macroinvertebrates observed, *Tripneustes gratilla*, *Holothuria whitmaei*, *H. atra*, and *Cyrpaea caputserpentis*, have an estimated density of 0.1 m^{-2} in the project area. No coral colonies were observed in the 100 m^2 of reef flat surveyed in these two transects.

Hermatypic corals — The most common (although total cover comprising less than one percent of the bottom) hermatypic corals found on the reef flat off Waikīkī Beach are *Porites lobata* and *Pocillopora meandrina,* the most commonly reported species on this reef (OI, 1991; MRC, 2007; and *AECOS*, 2007a, 2008, 2009a). In addition, *Cyphastrea ocellina* (MRC, 2007; *AECOS,* 2007a, 2008, 2009a), *Montipora capitata*, *M. patula*, *P. evermanni*, *Psammocora* sp., and *Leptastrea purpurea* (*AECOS,* 2007a, 2008, 2009a) have been observed off Waikīkī. Table 5 provides a checklist of corals observed on the reef off Waikīkī Beach in the present survey and observed previously in surveys off Gray's Beach and Kūhiō Beach (2006, 2007, and 2008).

Table 5. List of corals observed on the reef offshore Waikīkī Beach, (July 2009), Gray's Beach (2006 to 2008), and Kūhiō Beach (2006 to 2008).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	Common name	Location Gray's	 Kūhiō	 Waikīkī	QC Code
CNIDARIA, ANTHOZOA					
ALCYONACEA					
ALCYONIIDAE					
Anthelia edmondsoni	*ʻokole*, blue soft coral	<1%			07
TELESTACEA, ZOANTHINARIA, ZOANTHIDAE SCLERACTINIA,					
ACROPORIDAE					
Montipora capitata	rice coral	<1%			05, 06, 07
Montipora patula	spreading coral	<1%			05, 06, 07
FAVIIDAE					
Leptastrea purpurea	crust coral	<1%			05
Cyphastrea ocellina	ocellated coral	<1%			05, 06
POCILLOPORIDAE					
Pocillopora damicornis		<1%			10
Pocillopora meandrina	cauliflower coral	<1%		<1%	05, 06, 07, 10
PORITIDAE					
Porites evermanni		<1%			05
Porites lobata	lobe coral	<1%		<1%	05, 06, 07, 10
Porites lutea	mound coral				07
SIDERASTREADAE					
Psammocora sp.		<1%			05
Psammocora stellata		<1%			07

Coral abundances are given in percent coverage.

Table 5 (continued).

KEY TO SYMBOLS USED IN TABLE 5:
QC Code:

05 - Reported previously by aquatic biologists from reef offshore Gray's Beach or Kūhiō Beach on March 15 – April 3, 2006, March 22 - 23, 2007, and March 3 - 7, 2008 (*AECOS*, 2008).

06 - Reported previously by aquatic biologists from reef offshore Gray's Beach in March 2007 (MRC, 2007).

07 - Reported previously by aquatic biologists from reef offshore Gray's Beach on November 30, 2007, December 10 - 11, 2007, December 13, 2007, December 17, 2007, December 29, 2007, January 18, 2008, and April 21, 2008 (*AECOS*, 2009a).

10 - Observed in the field by aquatic biologists on July 29, 2009.

Detailed observations of corals were limited to three locations in the survey area: 1) the shallow reef at the far west side of the project area with large *Poc. meandrina* colonies, 2) the far east side of the project area adjacent to a potential pipeline corridor with various small *Poc. meandrina* and *P. lobata* coral colonies present, and 3) the sand extraction area with coral colonies lining the western perimeter of the sand source area as well as on limestone outcrops within the sand source area. No coral growth was observed on the limestone outcrops directly off the beach area proposed for sand nourishment. No large, (>50 cm or 20 in diameter) mound-forming corals were observed anywhere in the survey area.

The western portion of the project area has the most topographic complexity of the survey area, although it is not very elevated in comparison to the adjacent sand area. GPS waypoints and coral colonies associated with those locations can be seen in Table 6. Fig. 3 is a map of these locations. Fig. 5 provides size class distribution of the corals observed, it should be noted that small colonies were likely overlooked.

Table 6. Locations and measured diameters of corals observed in project area offshore Waikīkī Beach.

Species	General location and GPS waypoint (WPT)	Max diameter (cm)
Porites lobata	Pipeline - WPT 029	15
Porites lobata	Pipeline - WPT 029	5
Porites lobata	Pipeline - WPT 029	5
Porites lobata	Pipeline - WPT 029	10
Porites lobata	Pipeline - WPT 029	5
Porites lobata	Pipeline - WPT 029	5
Porites lobata	Pipeline - WPT 029	5

Table 6 (continued).

Species	General location and GPS waypoint (WPT)	Max diameter (cm)
Porites lobata	Pipeline - WPT 029	10
Porites lobata	Pipeline - WPT 029	15
Porites lobata	Pipeline - WPT 029	10
Porites lobata	Pipeline - WPT 029	10
Porites lobata	Pipeline - WPT 029	5
Porites lobata	Pipeline - WPT 029	20
Pocillopora meandrina	Pipeline - WPT 029	20
Pocillopora meandrina	Pipeline - WPT 029	25
Pocillopora meandrina	Pipeline - WPT 029	15
Pocillopora meandrina	Sand Extraction - WPT 031	5
Pocillopora meandrina	Sand Extraction - WPT 031	10
Pocillopora meandrina	Sand Extraction - WPT 031	10
Pocillopora meandrina	Sand Extraction - WPT 031	5
Pocillopora meandrina	Sand Extraction - WPT 031	5
Pocillopora meandrina	Sand Extraction - WPT 031	10
Pocillopora meandrina	Sand Extraction - WPT 031	10
Pocillopora meandrina	West side - WPT 032	5
Pocillopora meandrina	West side - WPT 032	40
Porites lobata	West side - WPT 032	10
Porites lobata	West side - WPT 032	10
Porites lobata	West side - WPT 032	20
Pocillopora meandrina	West side - WPT 032	15
Pocillopora meandrina	West side - WPT 032	20
Pocillopora meandrina	West side - WPT 032	25
Pocillopora meandrina	West side - WPT 032	35
Pocillopora meandrina	West side - WPT 032	20
Porites lobata	West side - WPT 032	5

Benthic Community Composition — One transect consisting of ten quadrats was used to calculate benthic community composition in the area likely to be affected by the nourished beach (Table 7). The majority of the substratum is sand followed by algal-turf covered limestone (Fig. 6). A moderate amount of macroalgae, and very little crustose coralline algae or bare limestone is present. Percent coral cover measured in the transect survey was zero.

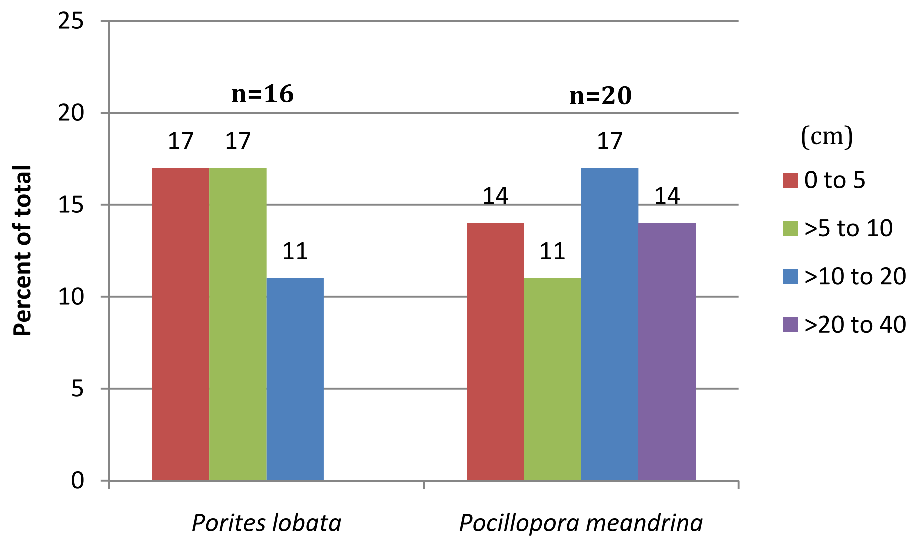

Figure 5. Coral colonies observed within project area divided among size classes as measured at the widest width.

Table 7. Summary statistics of percent benthic cover for reef offshore Waikīkī Beach.

	Sand	Turf algae	Macro-algae	Crustose coralline algae	Lime-stone	Coral	Macro-invertebrates
Mean	62	26	10	1	1	0	0
Median	68	24	6	0	0	0	0
Range	4-100	0-68	0-28	0-4	0-4	0	0
Std. dev.	33	24	12	2	2	0	0

Fish Community

The fish community in the nearshore waters off Waikīkī is largely structured by the local topography and composition on the reef flat; however, fishes are generally uncommon in this area. Recent surveys off Waikīkī (MRC, 2007; *AECOS*, 2009a) found the most common species to be wrasses (*Thalassoma duperrey*, *T. trilobatum*, *Stethojulis balteata*), *manini* (*Acanthurus triostegus*) and reef triggerfish (*Rhinecanthus rectangulus*). The surveys also found several species of small juvenile fishes inhabiting small holes and spaces in the reef structure. These previous surveys off of Gray's Beach and the present survey off of Waikīkī Beach identified 58 fish species in the project area (Table 8). The underwater visual survey technique, typically used for these surveys, does not accurately census seasonal, cryptic, nocturnal, and burrow-inhabiting fishes, although they may comprise half or more of the fish biomass (Willis, 2001).

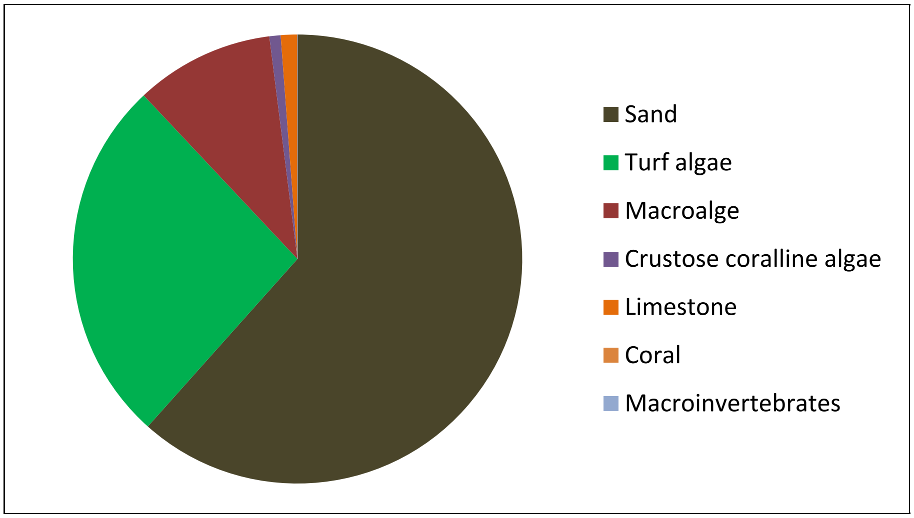

Figure 6. Percent benthic cover on reef flat off Waikīkī Beach.

The saddle wrasse (*Thalassoma duperrey*) is the most common species over the reef flat off Waikīkī Beach. *Manini* (*Acanthurus triostegus hawaiiensis*) is also commonly seen in small schools feeding on benthic algae, and the Christmas wrasse (*Thalassoma trilobatum*), belted wrasse (*Stethojulis balteata*), and reef triggerfish (*Rhinecanthus rectangulus*) are commonly seen solitarily scavenging for algae and benthic invertebrates. *Kala* (*Naso unicornis*) and *oʻopu hue* (*Arothron hispidus*) are encountered occasionally farther offshore.

Table 8. List of fishes observed on the reef flat off Waikīkī Beach (July 2009) and Gray's Beach (2007 to 2008).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	Common name	Location of reef: Gray's	Location of reef: Waikīkī	QC Code
VERTEBRATA, ACTINOPTERYGII	BONY FISHES			
MURAENIDAE				
Echidna nebulosa	snowflake moray *puhi kāpā*	R		07

Table 8 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	Common name	Location of reef Gray's	Waikīkī	QC Code
Gymnothorax flavimarginatus	yellowmargin moray *puhi paka*	R		07
OPHICHTHIDAE				
Callechelys lutea (E)	freckled snake eel, puhi	R		07
SYNODONTIDAE				
Saurida sp.	unid. lizardfish, *ʻulae*	R		07
Synodus dermatogenys	clearfin lizardfish, *ʻulae*		R	10
FISTULARIDAE				
Fistularia commersonii	cornetfish, *nūnū peke*	R		07
SCORPAENIDAE				
Sebastapistes coniorta	speckled scorpionfish	R		07
CIRRHITIDAE				
Cirrhitus pinnulatus	stocky hawkfish *poʻopaʻa*	R		07
Paracirrhites forsteri	blackside hawkfish *hilu pilikoʻa*	R		07
APOGONIDAE				
Pristiapogon kallopterus	iridescent cardinalfish *ʻupāpalu*	R		07
MALACANTHIDAE				
Malacanthus brevirostris	flagtail tilefish, *makaʻā*	R		07
CARANGIDAE				
Caranx melampygus	bluefin trevally, *omilu*	U		07
Decapterus macarellus	mackerel scad, ō*pelu*	R		07
MUGILIDAE				
Mugil cephalus	mullet *ʻamaʻama*	R		07
MULLIDAE				
Mulloidichthys vanicolensis	yellowfin goatfish *wekeʻā*	R		07
Parupeneus insularis	double bar goatfish, *munu*	U		07
Parupeneus bifasciatus	twobar goatfish *moana*		R	10
Parupeneus multifasciatus	manybar goatfish *moana*	R	R	07, 10
Upeneus arge	bandtail goatfish *weke pueo*	R		07
CHAETODONTIDAE				
Chaetodon auriga	threadfin butterflyfish *kikākapu*	R		07
Chaetodon fremblii (E)	bluestripe butterflyfish *kikākapu*	R		07
Chaetodon lunula	raccoon butterflyfish *kikākapu*	R	U	07, 10
Heniochus diphreutes	pennant butterflyfish	R		07
BLENNIIDAE				
Cirripectes vanderbilti	scarface blenny		R	10

Table 8 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	**Common name**	**Location of reef** Gray's	Waikīkī	**QC Code**
POMOCENTRIDAE				
Abudefduf abdominalis (E)	Hawaiian sergeant, *mamo*	R		07
Dascyllus albisella (E)	Hawaiian domino damselfish *ʻaloʻiloʻi*	R		07
Plectroglyphidodon imparipennis	bright-eye damselfish	R		07
Stegastes marginatus	Hawaiian gregory	R		07
LABRIDAE				
indet. Labridae	juvenile wrasse	R	R	07, 10
Cheilio inermis	cigar wrasse, *kupou*	R		07
Coris venusta(E)	elegant coris	O		07
Stethojulis balteata (E)	belted wrasse, *ōmaka*	C	U	07, 10
Thalassoma duperrey (E)	saddle wrasse *hinālea lauwili*	A	O	07, 10
Thalassoma trilobatum	Christmas wrasse, *ʻāwela*	A	R	07, 10
Xyrichtys sp.	razorfish, *laenihi*	R		07
SCARIDAE				
indet. Scaridae	juvenile parrotfish, *uhu*	R	R	07, 10
PINGUIPEDIDAE				
Parapercis schauinslandii	redspotted sandperch	R		07
BLENNIIDAE				
Cirripectes vanderbilti (E)	scarface blenny, *pāoʻo*	R		07
Parablennius thysanius	tassled blenny		U	10
GOBIIDAE				
Gnatholepsis anjerensis	eyebar goby	R		07
indet. Gobiidae	indet. goby, *oʻopu*	R		07
ZANCLIDAE				
Zanclus cornutus	Moorish idol *kihikihi*	R	U	07, 10
ACANTHURIDAE				
indet. Acanthuridae	surgeonfish		R	10
Acanthurus blochii	ringtail surgeonfish *pualu*	R		07
Acanthurus dussumieri	eyestripe surgeonfish		U	10
Acanthurus nigrofuscus	brown surgeonfish *māʻiʻiʻi*	R	U	07, 10
Acanthurus triostegus (E)	convict tang, *manini*	A	O	07, 10
Acanthurus xanthopterus	yellowfin surgeonfish *pualu*	R		07
Naso lituratus	orangespine unicornfish *umauma lei*	R		07
Naso unicornis	unicornfish, *kala*	O	O	07, 10
BOTHIDAE				
indet. Bothidae	indet. flounder, *pākiʻi*	R		07
BALISTIDAE				
Melichthys niger	black durgon *humuhumu ʻeleʻele*	R		07

Table 8 (continued).

PHYLUM, CLASS, ORDER, FAMILY *Genus species*	**Common name**	**Location of reef** Gray's	Waikīkī	**QC Code**
Rhinecanthus rectangulus	reef triggerfish *humuhumu nukunuku apuaʻa*	C	U	07, 10
Sufflamen bursa	lei triggerfish *humuhumu lei*	R		07
OSTRACIIDAE				
Lactoria diaphana	spiny cowfish, *pahu*	R		07
Ostracion meleagris camurum (E)	spotted boxfish, *moa*	R	U	07, 10
TETRAODONTIDAE				
Arothron hispidus	stripebelly puffer *oʻopu hue*	R	O	07, 10
Canthigaster jactator (E)	Hawaiian whitespotted toby	R		07

KEY TO SYMBOLS USED IN TABLE 8:

Abundance categories:

R - Rare - Only one or two individuals or specimens observed in area.

U - Uncommon - Three to no more than a dozen individuals or specimens observed in area.

O - Occasional – Seen irregularly and always in small numbers;

C - Common – Seen regularly, although generally in small numbers.

A - Abundant - Found in large numbers and widely distributed.

Other symbols and categories:

E – Endemic – Found in Hawaiʻi and nowhere else.

QC Code:

06 - Reported previously by aquatic biologists from reef offshore Gray's Beach in March 2007 (MRC, 2007).

07 - Reported previously by aquatic biologists from reef offshore Gray's Beach on November 30, 2007, December 10 - 11, 2007, December 13, 2007, December 17, 2007, December 29, 2007, January 18, 2008, and April 21, 2008 (*AECOS*, 2009a).

10 - Observed in the field by aquatic biologists on July 29, 2009.

The 2007 surveys of Gray's Beach off Waikīkī found mean fish biomass for nearshore reef flat transects to be 39 kg/ha (*AECOS*, 2009a). That survey described five trophic guilds as present, the most common fishes being mobile invertebrate feeders. However, herbivores accounted for most of the fish biomass.

Very few fishes were encountered during the present survey as evidenced by the timed fish swim survey (Table 9). The location of this survey is shown in Fig. 3. More than half of the transect running to the east was over sand bottom where no fishes were observed; only 6 common nearshore reef fishes were seen over hard bottom areas. The transect that ran west was primarily over the eroded limestone reef platform with one area of modest topographic complexity where numerous fishes were observed. About half of the 32 fish recorded during the two timed fish swims were seeking refuge among four sunken, approximately 30-cm (12 in) square, concrete blocks, which provide the only topographic shelter in the survey area. The surgeonfish family (Acanthuridae) was most represented with at least four species: *Acanthurus dussumieri*, *Acanthurus nigrofuscus, Acanthurus triostegus*, and *Naso unicornis*. The wrasse family (Labridae) was represented by at least two species: *S. balteata* and *T. duperrey*. The most numerous fish was *manini* (*A. triostegus*) with 10 individuals counted.

Table 9. Results of 10-minute time fish surveys on the reef off Waikīkī Beach at Transect M2.

Direction from starting point	Species	Size (cm)	Count
East	*Zanclus cornutus*	25	1
East	Juvenile Scaridae	10	2
East	*Rhinecanthus rectangulus*	20	1
East	Unidentified Acanthuridae	20	1
East	*Ostracion meleagris*	10	1
East	Juvenile Labridae	5	1
West	*Chaetodon lunula*	10	1*
West	*Acanthurus dussumieri*	5	1*
West	*Acanthurus nigrofuscus*	5	1*
West	*Acanthurus triostegus*	10	1
West	*Acanthurus triostegus*	5	1
West	*Acanthurus triostegus*	5	8*
West	*Naso unicornis*	15	1
West	*Zanclus cornutus*	8	1
West	*Stethojulis balteata*	5	1
West	*Stethojulis balteata*	3	1
West	*Thalassoma duperrey*	5	2*
West	*Thalassoma duperrey*	15	1*
West	*Parablennius thysanius*	5	1
West	*Ostracion meleagris*	10	1
West	*Arothron hispidus*	5	1

*observed near a pile of sunken concrete blocks

Water Quality

Background information — This section of the report is taken largely from a report on water quality prepared by *AECOS* for the nearby proposed Gray's Beach nourishment project (*AECOS*, 2009b).

The waters offshore Waikīkī Beach are classified in the Hawaiʻi Water Quality Standards (HDOH, 2004) as (a) marine waters, (b) open coastal, (c) reef flat, (d) Class A, and (e) Class II marine bottom ecosystem. It is the objective of Class A waters that their use for recreational purposes and aesthetic enjoyment be protected. Other uses are permitted so long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. Class A waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control.

The Hawaiʻi Department of Health (HDOH) monitors water quality at four nearshore stations in the Waikīkī Beach area: Ft. DeRussy Beach, Gray's Beach, Tavern's Beach, and Kūhiō Beach (Fig. 7; USEPA, 2009). Water quality samples were collected irregularly at these stations and data are available as follows: Ft. DeRussy – May 1990 to December 2008, Gray's Beach – June 1983 to December 2008, Tavern's Beach – November 1982 to December 2008, and Kūhiō Beach – June 1990 to December 2008. Table 10 summarizes the results of these tests. The stations in this table have been arranged from west (Ft. DeRussy) to east (Kūhiō Beach). Mean salinity tends to increase west to east, possibly due to fresh water inputs from the Ala Wai Canal west of the Ft. DeRussy station. Mean temperatures are highest at the two central stations (Gray's Beach and Tavern's Beach) and may represent slower circulation at these stations. No trend is apparent in mean pH values among these stations. A trend of decreasing geometric mean turbidity levels from west to east is apparent. Because these water quality samples are collected close to shore, this may represent a difference in wave exposure, which certainly influences turbidity levels in these nearshore waters.

HDOH also collected water quality samples at three popular surfing locations offshore between Gray's Beach and Kūhiō Beach (see Fig. 7) in July and August 2007. These data are summarized in Table 11. Mean salinity values and temperatures at these three stations are very similar. The mean pH level at Canoe's is somewhat elevated compared with Popular's and Three's located further off the shore, as are mean DO saturation and mean turbidity.

Figure 7. Satellite image showing location of HDOH water quality sampling stations off Waikīkī.

In the 2007/2008 wet season, *AECOS* collected water samples at five stations off Gray's Beach to characterize the water quality and establish baseline water quality conditions for the proposed Gray's Beach nourishment and stabilization project (Fig. 8); results of this sampling effort are presented in Tables 12 and 13.

HDOH also collected water quality samples in deeper water far offshore in Mamala Bay (Table 14). The mean pH and DO saturation levels at the Mamala Bay station are representative of open coastal and oceanic water, as is the low geometric mean turbidity level. Mean salinities and temperatures at this offshore station are somewhat lower compared with the nearshore and mid-reef means (Tables 10 and 11). The differences may reflect an effect of solar radiation in shallow water (reef flat) locations resulting in heating effects and higher evaporation rates (leading to higher salinities). However, for variable parameters like salinity and temperature in nearshore waters, six data points do not provide much confidence in the representativeness of the means.

Table 10. A summary of selected water quality parameters for the nearshore waters off Waikīkī (data collected by HDOH; USEPA, 2009).

Station		Salinity (ppt)	Temp. (ºC)	pH	DO sat. (%)	Turbidity (NTU)
Ft. DeRussy						
	mean	**34.1**	**24.8**	**8.08**	**85**	**6.75**†
	range	24.0 – 36.0	21.9 - 26.8	7.59 - 8.35	67 - 96	0.8 - 56.2
	count	*231*	*65*	*55*	*77*	*55*
Gray's Beach						
	mean	**34.4**	**24.8**	**8.06**	**82**	**4.37**†
	range	29.0 - 36.2	21.0 - 30.0	7.54 - 8.80	53 - 122	0.2 - 29.0
	count	*529*	*256*	*183*	*263*	*195*
Tavern's Beach						
	mean	**34.3**	**25.2**	**8.08**	**88**	**5.11**†
	range	28.0 - 36.0	22.1 - 27.4	7.49 - 8.29	63 - 102	1.8 - 13.9
	count	*225*	*64*	*54*	*53*	*54*
Kūhiō Beach						
	mean	**34.8**	**24.8**	**8.02**	**84**	**3.05**†
	range	29.0 - 36.8	21.2 - 29.9	7.31 - 8.24	74 - 95	0.9 - 21.8
	count	*1019*	*693*	*481*	*468*	*469*

† geometric mean

Table 11. Summary of selected water quality parameters in the mid-reef waters of Mamala Bay near Waikīkī Beach (data collected by HDOH; USEPA, 2009).

Station		Salinity (ppt)	Temp. (ºC)	pH	DO sat. (%)	Turbidity (NTU)
Three's						
	mean	35.34	26.6	7.84	77	0.96†
	range	34.78 - 35.63	26.3 - 27.1	7.76 - 7.89	61 - 95	0.42 - 2.04
	count	*11*	*11*	*11*	*11*	*11*
Popular's						
	mean	35.37	26.6	7.95	75	0.93†
	range	34.78 - 35.62	26.3 - 27.1	7.85 - 8.04	60 -93	0.53 - 1.74
	count	*11*	*11*	*11*	*11*	*11*
Canoe's						
	mean	35.35	26.6	8.05	85	1.09†
	range	34.78 - 35.63	26.3 - 26.9	7.93 - 8.17	76 - 96	0.54 - 2.11
	count	*10*	*10*	*10*	*10*	*10*

† geometric mean

Figure 8. Gray's Beach restoration project water quality sampling stations off Waikīkī.

Table 12. Summary of physical water quality measurements made between September 11 and December 12, 2007 at five stations off Gray's Beach.

Station	Temp. (ºC)	Salinity (PSU)	DO sat. (%)	pH	Turbidity (NTU)	TSS (mg/L)
West						
Geo. Mean	27.0	34.9	91	8.12	5.92*	21*
Range	25.3 - 29.1	34.3 - 35.5	84 - 111	8.04 - 8.30	3.72 - 10.0	16 - 28
Count	6	6	6	6	6	6
Center (nearshore)						
Geo. Mean	26.9	34.9	95	8.08	5.85	21
Range	25.0 - 29.1	34.3 - 35.5	84 - 107	7.95 - 8.30	3.23 - 9.7	16 - 28
Count	6	6	6	6	6	6
Center (offshore)						
Geo, Mean	26.8	34.8	100	8.14	3.26	15
Range	24.9 - 28.8	34.0 - 35.3	75 - 122	8.05 - 8.30	1.98 - 5.40	8.4 - 23
Count	6	6	6	6	6	6

Table 12 (continued).

Station	Temp. (ºC)	Salinity (PSU)	DO sat. (%)	pH	Turbidity (NTU)	TSS (mg/L)
East						
Geo. Mean	27.2	34.7	97	8.07	5.03	16
Range	25.4 - 29.0	33.9 - 35.3	84 - 114	7.80 - 8.20	4.11 - 7.00	10 - 26
Count	6	6	6	6	6	6
Extraction						
Geo. Mean	26.5	34.9	92	8.15	0.58	11
Range	25.1 - 27.9	34.5 - 35.4	83 - 101	8.04 - 8.20	0.34 - 0.90	3.6 - 23
Count	6	6	6	6	6	6

Table 13. Summary of selected water quality measurements made between September 11 and December 12, 2007at five stations off Gray's Beach.

Station	Ammonia (µg N/L)	Nitrate + Nitrite (µg N/L)	Total N (µg N/L)	Total P (µg P/L)	Chl. α (µg/L)
West					
Geo. Mean	<1*	9*	177*	24*	0.86*
Range	*<1*	*3 – 56*	*148 - 200*	*16 - 51*	*0.48 - 1..83*
Count	6	6	6	6	6
Center (nearshore)					
Geo. Mean	<1	9	196	27	0.68
Range	*<1*	*5 – 17*	*172 - 257*	*19 - 32*	*0.26 - 1.37*
Count	6	6	6	6	6
Center (offshore)					
Geo. Mean	<1	7	187	24	0.64
Range	*<1*	*4 – 11*	*149 - 220*	*17 - 37*	*0.30 - 1.4*
Count	6	6	6	6	6
East					
Geo. Mean	<1	3	170	20	0.57
Range	*<1*	*1 – 7*	*142 - 232*	*15 - 29*	*0.36 - 1.28*
Count	6	6	6	6	6
Extraction					
Geo. Mean	<1	2	143	14	0.25
Range	*<1*	*<1 - 4*	*125 - 185*	*11 - 18*	*0.11 - 0.34*
Count	6	6	6	6	6

Table 14. Summary of selected water quality parameters in offshore waters of Mamala Bay (data collected by HDOH; USEPA, 2009).

Station	Salinity (ppt)	Temp. (ºC)	pH	DO sat. (%)	Turbidity (NTU)
Mamala Bay					
mean	**33.9**	**24.5**	**8.18**	**103**	**0.34**†
min	30.0 – 35.2	20.0 – 27.7	7.10 - 8.60	87 - 128	0.05 – 10.0
count	362	286	344	229	359

† geometric mean

Water quality conditions for the three areas described (nearshore, mid-reef, and offshore) are summarized in Table 15. The higher temperature and salinity for the mid-reef environment, compared with both the nearshore and offshore environments, is likely due to the fact that the mid-reef samples were limited to a one-month period in the middle of summer, whereas data from both the nearshore and offshore stations were collected over a number of years in summer and in winter. The increase in turbidity levels from offshore to reef stations demonstrates the effect of waves moving over a shallow bottom.

Table 15. A comparison of average water quality conditions in the nearshore, mid-reef, and offshore waters of Mamala Bay near Waikīkī (data collected by HDOH; USEPA, 2008 and AECOS; AECOS, 2009b).

Location	Salinity (ppt)	Temp. (ºC)	pH	DO sat. (%)	Turbidity (NTU)
Nearshore					
mean	**34.5**	**24.8**	**8.08**	**84**	**3.22**†
range	24.0 - 35.9	21.0 - 30.0	7.49 - 8.64	53 - 126	nd - 56.2
count	1725	785	368	803	481
Outer reef					
mean	**35.4**	**26.6**	**7.94**	**79**	**1.00**†
range	34.8 - 35.6	26.3 - 27.1	7.76 - 8.17	60 - 96	0.42 - 2.11
count	32	32	32	32	32
Offshore					
mean	**34.0**	**24.5**	**8.18**	**103**	**0.34**†
range	30.0 - 35.2	20.0 - 27.7	7.10 - 8.18	87 - 128	nd - 10.0
count	362	359	344	229	359

nd – not detected
† geometric mean

The results for basic water quality parameters for the July 21, 2009 sampling event are given in Table 16. Water temperature was higher at all stations during the afternoon sampling event. Water temperature ranged from a low of 25.2°C at Sta. W4 during the morning sampling event to a high of 28.9°C at Sta. W2 during the late afternoon sampling event. The rise in water temperature from morning to late afternoon results from the cumulative response to solar radiation in these nearshore shallow waters. These same waters cool during the night, resulting a diurnal cycle for water temperature.

The salinities measured in the project area show no evidence of freshwater inputs at any station and are normal for seawater. Salinity was somewhat lower during the afternoon high tide sampling event, except at Sta. W4 where the reverse was true. Salinity ranged from a low of 34.28 PSU at Sta. W4 during the morning sampling event to a high of 35.28 PSU at Sta. W5 in the offshore waters during the morning sampling event.

Dissolved oxygen (DO) saturation levels ranged from a low of 83% at Sta. W2 during the morning sampling event to a high 115% at Sta. W4 during the afternoon sampling event. DO saturation levels were highest at all stations during the afternoon sampling event. DO saturation levels in these nearshore waters are directly affected by both benthic algal and phytoplankton photosynthesis. Thus, as solar radiation and temperature increase during the daylight hours, oxygen-producing photosynthesis increases as well resulting in high DO levels.

Table 16. Summary of physical water quality conditions during two sampling events on July 21, 2009 at five stations off Waikīkī Beach.

Station	Time	Temp. (ºC)	Salinity (PSU)	DO sat. (%)	pH	Turbidity (NTU)	TSS (mg/L)
W1	0907	26.1	35.28	111	8.14	1.38	11.9
W1	1740	27.4	34.87	99	8.28	3.92	14.1
W2	0826	25.7	35.17	90	8.12	3.54	13.6
W2	1703	28.9	34.87	98	8.28	8.48	12.2
W3	0815	25.7	34.98	91	8.02	3.42	8.9
W3	1652	28.5	34.87	104	8.21	7.90	12.5
W4	0805	25.2	34.28	87	7.93	3.34	8.5
W4	1641	28.7	34.97	115	8.07	3.40	16.2
W5	0820	25.6	35.01	83	8.10	1.65	11.5
W5	1635	26.9	34.87	93	8.09	1.70	10.6

pH ranged from a low of 7.93 during the morning sampling event to a high of 8.28 at Stas. W1 and W5 during the afternoon sampling event. Most of the pH levels appear lower than would be expected in seawater. pH increased at all stations, except Sta. W2, between the morning and afternoon sampling events. An increase in pH in these waters during daylight hours follows as a response to the uptake of carbon dioxide due to photosynthesis in the water column.

Turbidity and total suspended solids (TSS) levels were generally elevated at all stations—wave action is the likely cause. Turbidity levels ranged from a low of 1.38 NTU at Sta. W5 during the morning sampling event to a high of 7.90 NTU at Sta. W3 during the afternoon sampling event. Turbidity levels were highest at all stations during the afternoon sampling event. Total suspended solids (TSS) ranged from a low of 8.5 mg/L at Sta. W4 during the morning sampling event to a high of 16.2 mg/L also at Sta. W4 during the afternoon sampling event. TSS values are higher than expected for the turbidity recorded, a result that comes from the way these two measurements of suspended matter are made. TSS is sensitive to fine sand in the water column because it is a dry weight of all solid matter in a collected water sample. Turbidity, on the other hand, is a measure of the light-scattering property of particles finer than sand; sand particles settle out of the light beam before a stable reading can be taken. Field conditions that re-suspend sand off the bottom will result in high TSS without a corresponding increase in turbidity.

The results for the nutrient and biological water quality parameters are given in Table 17. Ammonia (NH_3) was not detected at four of the stations and was found at a low concentration (2 µg N/L) during the morning sampling event only at Sta. W4. NH_3 is typically present in undetectable to very low concentrations in coastal waters of Hawaiʻi, as NH_3 is rapidly oxidized to nitrate + nitrite (NO_3 + NO_2) in these waters. NO_3 + NO_2 concentrations were quite variable, ranging from a low of 2 µgN/L at Sta. W2 to a high of 62 µgN/L at Sta. W3, both during the afternoon sampling event. NO_3 + NO_2 concentrations were highest during the morning sampling event at all stations, except Station W5. NO_3 + NO_2 is a form of inorganic nitrogen that is most commonly utilized in benthic algal and phytoplankton production in marine waters.

Most of the total nitrogen (Total N) measured at all five stations is organic nitrogen, rather than inorganic moities. Total N concentrations ranged from a low of 180 µgN/L at Sta. W2 to a high of 297 µgN/L at Sta. W3, both during the afternoon sampling event. Total nitrogen represents the total reservoir of nitrogen that theoretically can be used in benthic algal and phytoplankton productivity. Total nitrogen consists of both particulate and soluble components, each containing refractile portions that are not available as a nutrient source.

Table 17. Summary of selected chemical and biological water quality conditions during two sampling events on July 21, 2009 at five stations off Waikīkī Beach.

Station	Time	Ammonia (µg N/L)	Nitrate + Nitrite (µg N/L)	Total N (µg N/L)	Total P (µg P/L)	Chl. α (µg/L)
W1	0907	<1	3	172	18	0.51
W1	1740	<1	4	199	21	0.62
W2	0826	<1	39	243	25	0.39
W2	1703	<1	13	290	28	0.50
W3	0815	<1	62	251	31	0.42
W3	1652	<1	14	297	30	0.38
W4	0805	2	28	268	25	1.42
W4	1641	<1	8	276	20	0.75
W5	0820	<1	4	194	19	0.45
W5	1635	<1	2	180	13	0.50

Total phosphorus (Total P) concentrations ranged from a low of 13 µgP/L during afternoon sampling event at Sta. W2 to a high of 31 µgP/L at Sta. W3 during the morning sampling period. Total P, like Total N, represents the total reservoir of phosphorus available for primary productivity in these coastal waters. It also has refractile components that will not be oxidized to soluble organic phosphorus forms that can be utilized in the photosynthetic process.

Chlorophyll α concentrations ranged from a low of 0.27 µg/L at Sta. W2 during the afternoon sampling event to a high of 1.42 µg/L at Sta. W4 during the morning sampling event. Chlorophyll α levels in the water column give a indication of the amount of phytoplankton biomass present.

Conclusions

The community structure of the benthos located offshore of the central Waikīkī Beach proposed to be nourished is largely dictated by the scouring action of wave-driven sand. Potentially, the daily use by hundreds of beachgoers also influences the reef biotic community. The richest biotic assemblages occur in the areas where vertical structural relief affords protection from continually shifting sands and corals living in these areas should be capable of withstanding the pulse of additional sands from the replenishment project. The areas with little or no vertical relief could suffer a greater impact, although they already tend to have less algal diversity and few or no coral colonies present.

Both direct and indirect impacts to the biological community and water quality of Waikīkī reef are likely to be fairly minimal, but construction best management practices (BMPs) must be implemented, particularly during dredging, laying of the pipeline, and dewatering. Our survey did not find any corals located within the footprint of the proposed beach and it appears as if the pipeline can be laid along sand channels to avoid coral growth. Corals are present on limestone outcrops near the sand pit proposed for dredging; these corals should be marked, avoided, and monitored. Relatively few fishes are present on the reef, as they typically associate with areas of greater topographic relief and less human disturbance. Fishes will not be adversely affected by the project.

Afternoon winds and waves increase the suspended sediment load in the nearshore waters. A water quality monitoring plan should be developed and implemented to ensure project activities do not further degrade the water quality.

We propose that a monitoring program be developed that focuses on the specific components of particular interest to the resource and permitting agencies: water quality, large (> 50 cm in diameter) mound-forming corals, and the abundance of feeding resources for green sea turtles, a protected species.

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APPENDIX B:
OCEAN ACTIVITIES REPORT FOR THE
WAIKIKI BEACH SAND MAINTENANCE PROJECT
AT WAIKIKI, HONOLULU, HAWAII

JOHN CLARK

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Ocean Activities Report

for the

Waikiki Beach Sand Maintenance Project

at

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October 2009

1.0 OCEAN ACTIVITIES REPORT

1.1 Purpose

This ocean activities report is intended to provide background information to Sea Engineering, Inc., for a planned sand replenishment project on Waikiki Beach. Sea Engineering, Inc. is developing an environmental assessment, which includes a concept plan, for the proposed project.

1.2 Project Location

The project location is the shoreline of Waikiki Beach from the west end of Kuhio Beach Park near the Duke Kahanamoku Statue to the low retaining wall at the common boundary of the Royal Hawaiian and Sheraton Waikiki Hotels. The wall extends offshore and curves east, where it is submerged. From east to west the project fronts the Duke Kahanamoku Statue, the Honolulu Police Department substation, the Sheraton Moana Surfrider Hotel, the Outrigger Waikiki Hotel, and the Royal Hawaiian Hotel. This section of shoreline is considered to be the center of Waikiki Beach.

1.3 Project Description

The Waikiki Beach sand replenishment project will be similar to the Kuhio Beach sand replenishment project that was undertaken in 2006. The Waikiki Beach project will bring approximately 25,000 cubic yards of sand to the beach from an off shore sand reservoir. The sand will be pumped ashore from a barge anchored over the sand reservoir through a pipeline anchored to the ocean bottom. The pipeline will lie on the ocean bottom in the channel between the surf spots known as Queen's and Canoes. Onshore, the sand will be stockpiled at a dewatering site and then spread along the beach. The project does not include building or removing any structures and is estimated to take 30 to 45 days.

1.4 Scope

The scope of work included:

1. Observing ocean activities and ocean conditions in the project site.

2. Identifying ocean recreation activities in the project site and determining whether the proposed project affects these activities.

3. Interviewing shoreline users, including staff of the surfboard/canoe ride/catamaran beach service concessions and City and County of Honolulu lifeguard staff.

4. Identifying potential impacts of the sand replenishment project on the ocean recreation activities in the project site.

1.5 Survey Methodology

Information for this survey was gathered from site visits and from interviews with people familiar with the shoreline of the project site. Site visits and interviews were conducted during August, September, and October 2009.

2.0 Physical Conditions

2.1 Historic Site Description

The shoreline of Waikiki Beach between the Duke Statue and the Royal Hawaiian Hotel was historically the center of Waikiki Beach, a distinction it still holds today. Before the name Waikiki Beach was introduced, Hawaiians called this section of shoreline Kahaloa. The backshore of Kahaloa was known as Ulukou, which is now occupied by the Sheration Moana Surfrider Hotel. The Moana, which opened in 1901, is the oldest hotel in Waikiki. The original owner of the hotel chose the center of Waikiki Beach for its location. The Royal Hawaiian Hotel at the west end of the project site is also one of the oldest hotels in Waikiki. It opened in 1927.

Waikiki Beach was a favorite bodysurfing, surfing and canoe surfing site among native Hawaiians for hundreds of years before it became an international visitor destination. Two of Waikiki's most famous surf spots, Queen's and Canoes, lie directly off the project site.

2.2 Present Site Description

A narrow sand beach runs the length of the project site, widening slightly at its west end where it fronts the Outrigger Waikiki and Royal Hawaiian Hotels. The section of beach fronting the Moana Hotel is the narrowest, where it is emergent at low tide and mostly submerged at high tide. When periods of high surf occur during high tides, waves may wash across the entire beach and strike the base of the low seawall fronting the Moana Hotel.

2.3 Ocean Bottom

The ocean bottom fronting the project site is shallow and sandy nearshore and transitions into a coral reef flat with small pockets of sand as it extends seaward. At the east end of the project site, the coral reef is shallow and creates a beginners' surf spot known as Baby Queen's. At the west end of the project site, the coral reef is completely covered with sand, forming a shallow sandbar. Surf breaking on the sandbar is called Sandbars or Baby Royals.

Further offshore the reef creates the surf spots called Queen's and Canoes. Queen's is in line with the Duke Statue, and Canoe's is in front of the Moana Hotel. The inside section of Canoes, which is known as Baby Canoes, is a beginners' surf spot. A channel separates Queen's and Canoes, and another channel separates Canoes and Sandbars.

The nearshore ocean bottom in the east end of the project site includes remnants of several former seawalls, some of which are partially submerged.

2.4 Boat Channel

The channel that separates the two surf spots of Canoes and Sandbars was created by fresh water intrusion from the former Apuakehau Stream. Apuakehau Stream crossed Waikiki Beach approximately between the Moana and the Outrigger Waikiki Hotels, but its stream waters were cut off during the 1920s by construction of the Ala Wai Canal. Its streambed was filled during the same project. The channel created by the stream passes between the two surf spots and further offshore passes the surf spot called Populars on its west margin.

This channel is used by all of the boats that are authorized to access Waikiki Beach, including four catamarans, outrigger canoes, and various rescue craft.

3.0 Ocean Recreation Activities

The project site, including the waters offshore, is the most heavily used section of Waikiki Beach and is used for many different ocean recreation activities. These include sunbathing, swimming, surfing, standup surfing, bodyboarding, skimming, canoe surfing, snorkeling, spear fishing, pole fishing, strolling, wading, and metal detecting.

Commercial ocean recreation activities include bodyboard and surfboard rentals, surfing lessons, surfing lesson photography, canoe rides, and catamaran rides.

3.1 Sunbathing

Sunbathing in the project site is possible from one end to the other, but the heaviest concentration of sunbathers is at the west end of the beach, where it is widest, fronting the Outrigger Waikiki and the Royal Hawaiian Hotels. The best time for sunbathing is at low tide during periods of little or no surf. At high tide at least half of the beach fronting the Moana Hotel is covered with water, and if high surf combines with a high tide, waves may overrun the entire beach here and strike the retaining wall in the backshore, precluding all opportunities for sunbathing.

3.2 Swimming

Swimming in the project site occurs from one end to the other, but the greatest concentration of swimmers tends to be in the middle of the beach, fronting the Moana Hotel. With the surfboard rental, canoe ride, and catamaran ride concessions concentrated at both ends of the project site, the least amount of ocean craft traffic that might endanger swimmers is in the center of the beach.

3.3 Snorkeling

The reef fronting the project site is not known as good site for snorkeling. The inner portions of the reef are largely covered with sand and do not attract the volume or variety of fish that other reefs do. For this reason snorkeling is a minor activity here. In addition, during periods of high surf, visibility over the reef is poor due to wave agitation of the ocean bottom. The channel between the surf spots Canoes and Sandbars, however, is a feeding site for green sea turtles. They may be seen at all times of the day eating the seaweed that grows on the reef flat.

During periods of low or no surf, some snorkeling for lost valuables such as rings, watches, and coins occurs at Canoes. This activity is an extension of the treasure hunting with metal detectors that takes place on the beach.

3.4 Surfing

Canoes is the name of the surf spot located directly off the Moana Hotel. It was known to native Hawaiian surfers as Kapuni, but its name was changed to Canoe Surf in the 1890s when commercial canoe rides were offered to visitors and then later shortened to Canoes. During especially large south swells, surf spots form seaward of Canoes. These spots, which are known as Blowholes and First Break, break and reform as they move towards shore into Canoes.

Canoes is the most highly used surf spot in Hawaii for commercial surfing activities, including surfboard rentals, surfing lessons, and outrigger canoe rides. Beginning surfers and surf instructors with beginners receiving lessons are concentrated on the smaller inside waves, which is known as Baby Canoes, while intermediate and advanced surfers ride the bigger waves outside.

Queen’s is the name of the surf spot located directly off the Duke Kahanamoku Statue. The waves at Queen’s are steeper than those at Canoes and are concentrated in a much smaller area, so beginning surfers and surf instructors with beginners receiving lessons generally do not surf here. Waves at Queen’s, however, reform near shore on the shallow reef at the east end of the project site. This surf spot is known as Baby Queen’s and attracts beginning surfers and surf instructors with lessons.

Canoes and Queen’s are located on the south shore of Oahu, which generally receives its biggest surf during the spring and summer months. However, there is almost always enough surf at both of these spots in the fall and winter to sustain the commercial surfing activities throughout the year. Four beach concessions are located in the project site, two on the east side of the Moana Hotel and two on the west side. The two on the east side are Star Beach Boys under Aaron Rutledge and Hawaiian Oceans under Hubert Chang. The two on the west side are Aloha Beach Services under Didi Robello, and Waikiki Beach Services under Ted Bush.

The beach concessions position photographers on the beach inshore of their surf instructors while the surf instructors are giving surfing lessons. The photographers take digital pictures of the novice surfers receiving lessons with a telephoto lens and then the beach concessions offer the pictures for sale on a compact disk to the novice surfers when they come in.

Night surfing at Canoes is an occasional activity that usually happens under a full moon, but may also occur at other times of the month. Some surfers also bring in the New Year at Canoes by paddling out on New Year’s Eve just before midnight to start their New Year by surfing.

3.5 Canoe Surfing

Catching waves with an outrigger canoe in Waikiki takes place at Canoes, the famous surf spot off the Moana Hotel that was named for this activity. The waves on the west edge of Canoes are ideal for this canoe surfing and often have enough momentum to carry the canoes all the way to shore.

All four of the beach concessions offer outrigger canoe rides. Use of the commercial canoes is controlled by the Division of Boating and Ocean Recreation (DOBOR), Department of Land and Natural Resources (DLNR), State of Hawaii. DOBOR controls boating in Waikiki shore waters and their administrative rules regarding commercial outrigger canoe operations may be accessed through their homepage under Title 13, Subtitle 11, Parts 2 and 3.

Canoe surfing is a feature in the Outrigger Canoe Club’s annual Fourth of July canoe races in Waikiki. Known as the Walter J. Macfarlane Regatta, the race course begins on the beach fronting the Moana Hotel and then circles a buoy offshore which brings the canoes back to the beach through the waves of Canoes.

3.6 Catamaran Rides

Catamaran rides are a popular activity on Waikiki Beach. The catamarans park on the beach, where they load and unload passengers. They motor in and out of the beach, and sail up and down the Waikiki coast for specified periods of time.

Four catamarans are presently permitted to conduct catamaran ride operations on Waikiki Beach. From east to west, they are the Mana Kai, which is owned by William Brown, and operates at the east end of the project site; the Na Hoku and the Manu Kai, which are owned by John Savio, and the Kapoikai, which is owned by Sheila Lipton, all of which operate at the west end of the project site.

The Division of Boating and Ocean Recreation (DOBOR), Department of Land and Natural Resources (DLNR), State of Hawaii, controls boating in Waikiki shore waters. Administration of the beach landing areas for the catamarans in the project site comes under DOBOR’s Oahu District Manager. DOBOR's administrative rules regarding commercial catamaran operations may be accessed through their homepage under Title 13, Subtitle 11, Parts 2 and 3.

3.7 Ocean Recreation Events

In addition to the annual Walter J. Macfarlane Regatta, which is held every July 4 (see 3.5), a number of other ocean recreation events are held in the project site. These are primarily surf contests, which are run at the surf spot Queen’s during the spring and summer months. Contest organizers set up their staging area on the beach at the east end of the project site between the Hula Mound and the Duke Statue. The staging area includes judging towers and a number of tents for t-shirt concessions, food concessions, and competitors. One of the best known of these contests is China Uemura’s Longboard Surfing Classic, which celebrated its 25^{th} anniversary this year.

The east end of the project site occasionally serves as the start and finish for rough water swims. These swims are generally held during the summer months, but may occur at any time of year.

3.8 Fishing and Gathering

Two types of fishing occur in the project site, spear fishing and pole fishing, but both are infrequent. During the field trips for this report, no spear fishers or pole fishers were observed, but one informant said that he goes spearing perhaps once a month for fish and octopus. The intensive use of the beach and the ocean in the project site by all of the other ocean users is a major deterrent to activities involving spears and fish hooks.

The project site was once known as a good place to gather edible seaweeds, or limu, especially limu lipoa, but little if any edible seaweed seems to remain in Waikiki today. No gathering activities of seaweed, shellfish, or other marine species were observed during the field trips or noted by the informants.

The Waikiki Marine Managed Areas (MMA) consists of two parts: the Waikiki Marine Life Conservation District (MLCD) and the Waikiki-Diamond Head Fisheries Management Area (FMA). The project site is not included in the Waikiki MMA.

3.9 Boating

The Division of Boating and Ocean Recreation (DOBOR), Department of Land and Natural Resources (DLNR), State of Hawaii, controls boating in Waikiki shore waters. DOBOR's administrative rules regarding commercial catamaran operations may be accessed through their homepage under Title 13, Subtitle 11, Parts 2 and 3.

DOBOR's administrative rules also regulate power boating in Waikiki shore waters. The catamarans and personal water crafts operated by the lifeguards are the only vessels under power that are permitted in the project site. Non-motorized boats such as surf skis (racing kayaks) and ocean kayaks (recreational kayaks) are permitted.

A large pocket of sand outside of the surf spot Queen’s is called the Sand Spit. It is a popular anchorage for boats, especially in the evening and at night. On weekends and holidays, sometimes as many as 30 boats may be anchored there.

4.0 Impacts on Ocean Recreation Activities

The sand replenishment plan proposes to add approximately 25,000 cubic yards of sand to the existing beach in the project site. The following are some of the impacts that the project might have.

4.1 Short Term Impacts

The location of the dewatering site for the sand that is pumped ashore, which includes a heavy equipment staging area, will impact the ocean recreation activities at the east end of the project site. It may eliminate use of that particular section of beach for all commercial and non-commercial users for the duration of the project. In addition, as sand is moved and spread to the west of the dewatering site, all commercial and non-commercial users in the project site will be temporarily impacted at some point during the process.

a. The location of the dewatering site will directly impact the operations of one or both of the beach concessions at the east end of the project site for the duration of the project. Star Beachboys and Hawaiian Oceans are the two beach concessions here. Both of them lease their concession sites from the City and County of Honolulu's Department of Environmental Services (DES). The Director of DES is Sidney Quintal, and his Concession Specialist is Charlian Wright.

   According to Ms. Wright, there are provisions in the beach concession contracts that provide for impacts on the beach concession businesses due to City or State construction projects. The City has the ability to make adjustments to the monthly lease rents, which are otherwise fixed. The City also has the ability to permit the lessees to relocate their operations from their present sites, which are also fixed. However, even with these adjustments, work opportunities for the concessions' staff and surf instructors may be considerably reduced or eliminated.

   Ms. Wright also handles the food concession in the Honolulu Police Department's substation in the project site. The food concession is leased to the Hyatt Waikiki, which is the hotel across Kalakaua Avenue from the Duke Statue. The contact for the Hyatt is Vince Brunetti, who believes the project will reduce the foot traffic to his concession. According to Ms.Wright, there are provisions in the food concession contract that provide for impacts on the food concession business due to City or State construction projects.

b. The location of the dewatering site will displace beach goers for the duration of the project. These beach users are among the potential customers for the beach concessions who do remain in operation.

c. The location of the dewatering site may impact the operations of the catamaran concession at the east end of the project site. This catamaran landing area comes under the jurisdiction of the State of Hawaii's Division of Boating and Ocean Recreation (DOBOR), Oahu District Manager.

d. The location of the dewatering site may impact the staging area for surfing contests, which set up their towers and tents at the east end of the project site. Surfing contests are held in Waikiki during the spring and summer months, so this impact will only occur if the project takes place at that time of year.

e. The location of the dewatering site may impact cultural and entertainment activities at the Hula Mound, which is makai of the banyan tree at the east end of the project site.

f. Informants familiar with the Kuhio Beach sand replenishment project noted that sand at the dewatering site emits a strong, offensive odor as it dries. The constant odor and the diesel smell from the heavy equipment may reduce the number of beach users in the project site, and, therefore, customers for the beach concessions and the food concession at the makai end of the HPD substation.

g. The ocean outside of Queen's and Canoes has been a traditional site to scatter the ashes of beach boys, surfers, and many others who have requested to have their ashes scattered off Waikiki. Two informants noted that removing sand from that area is like disturbing a graveyard.

h. Noise from the sand-spreading operations in the evening may intrude on open air cultural and entertainment events, shoreline restaurants, and hotel rooms.

i. Sand-spreading operations will displace people strolling on the beach in the evenings.

j. Safety concerns from the lifeguards:

   Sand hill at the dewatering site may reduce their visibility of the beach.
   Sand hill and equipment staging area may reduce their response time to certain areas of the beach.
   Lifeguards are on duty until 5:30 pm. They recommend spreading sand after their personnel are off-duty.
   Lifeguard towers cannot be moved. Project will have to work around them.
   Towers cannot be closed for any reason.
   Certain places in the project site are used by the lifeguards and other first responders as access points from Kalakaua Avenue to the beach. When operations during the project block these access points, the lifeguards and other first responders should be notified.

k. Project timeline.
   All of the informants except one recommended scheduling the project during the fall, from mid-September to the end of November. This is the slowest time of year for commercial ocean recreation activities on Waikiki Beach, and the least likely time of year for south shore surf and kona storms. In addition, no surfing contests are held in Waikiki after September. Several informants noted that April and May are also slow, but that they would not want to see the project start in the spring. If there were delays, there would be a possibility that the project would run into summer, which is their busiest time of year.

4.2 Long Term Impacts

a. All informants stated that currents, high tides, and surf, especially during the spring and summer months, will immediately erode the imported sand as soon as it is put in place. They believe the sand will move west and accumulate on the shallow sandbar in front of the Royal Hawaiian, which is the surf spot called Sandbars.

b. A number of informants believe that the sandbar has increased in size in recent years because all of the sand from the Kuhio Beach project has accumulated there. Other informants believe the increase in size is a result of normal sand movement in the Waikiki area. Whatever the cause, the sandbar's increase in size has had two impacts. Sand has extended into the channel between the sandbar and Canoes, making it more difficult for the catamarans at the west end of the project site to come in and out at low tide, and the expanded sandbar has created some water safety issues for the lifeguards.

c. An increase in the size of the sandbar may also close off more of the channel, which for the catamarans at the west end of the project site will further impact their entry and exit operations. Catamarans may have to reduce their passenger loads and may not even be able to get in or out during low tides, especially during the minus tides of spring. In addition, during periods of high surf when waves at Canoes encroach on the east side of the channel, catamarans may be forced into the surf zone, if the west side of the channel is filled in.

d. Several informants stated that the project will be a waste of time and money because they believe the imported sand will be eroded as soon as it is put in place.

e. Other informants stated that the sand dredged offshore is dirty sand with a lot of black sediment in it, which is not appropriate for Waikiki Beach.

f. One informant suggested importing sand from dune deposits elsewhere on Oahu, especially denser, larger-grained sand, which may help to slow the erosion process.

g. One informant suggested removing the groin in front of the Royal Hawaiian and letting the sand erode and accrete naturally. This might eliminate the sandbar and the safety issues that go with it, and it might create a beach in front of the Sheraton Waikiki without the proposed construction of the three T-groins.

h. Canoes is the single most important commercial surf spot in Hawaii, and there is concern that the sand may not only accumulate on the sandbar in front of the Royal Hawaiian, but that it may accumulate on the reef that creates Canoes. Some informants believe that Canoes is shallower now because of the sand from the Kuhio Beach project and that the surf does not break like it used to. Additional sand may impact the way the waves break, which are now ideal for beginners and canoe surfing.

i. If the pipeline is left in place for additional sand replenishments, ensure that it can withstand high surf and that no one can get stuck under it.

j. The pipeline will act as a fish aggregation device, which may attract more spear and pole fishers to Waikiki Beach.

k. Turtles are common in the channel on the west side of Canoes, where they feed on seaweed in small patches of reef. Migrating sand may fill these patches and eliminate some of these nearshore feeding areas.

l. All informants stated that if the imported sand remains in place, the improved beach will be more attractive to visitors and encourage more use of the beach, especially by providing more sunbathing areas. Additional beach users will mean more commercial opportunities for the beach concessions and catamaran operators.

m. Safety Concerns.
Beach users like to walk out on the sandbar, especially at low tide. There are dropoffs and several deep holes near the outer edge of the sandbar where poor and non-swimmers get into trouble and need to be rescued. Further expansion of the sandbar with two and one-half times the amount of sand as the Kuhio Beach project will move it farther offshore and closer to the surfers at Canoes, creating additional safety concerns if waders are able to walk into the surf zone.

4.3 Summary

While some informants were against the sand replenishment project and consider it to be a waste of money, most agreed that is a good idea. When it is completed, they think it will enhance the image of Waikiki Beach, that visitors will enjoy it, and that it will stimulate business for the beach and catamaran concessions.

All of the informants believe, however, that the imported sand will erode quickly and accrete in the channel and on the existing sandbar at the west end of the project. Some informants are concerned that the eroding sand will also cover the reef that creates the surf spot Canoes.

APPENDIX C:

WATER QUALITY MONITORING AND ASSESSMENT
PROGRAM FOR CLEAN WATER ACT (CWA)
SECTION 401WATER QUALITY CERTIFICATION,
WAIKIKI BEACH MAINTENANCE PROJECT,
WAIKIKI, OAHU, HAWAII

AECOS, INC.

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Water Quality Monitoring and Assessment Program for Clean Water Act (CWA) Section 401 Water Quality Certification, Waikīkī Beach Maintenance Project, Waikīkī, Oʻahu, Hawaiʻi[1]

December 23, 2009 ***DRAFT*** *AECOS* No. 1205B

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Introduction

This water quality monitoring and assessment program (WQMP) accompanies the Environmental Assessment (EA) for the proposed Waikīkī Beach Maintenance Project on the southern coast of Oʻahu (Fig. 1). This WQMP is to serve as a template during the environmental review process and will be revised once a construction contractor has been selected and Best Management Practices (BMPs) have been developed. Data Quality Objectives (DQOs) will be developed after BMPs have been developed and the WQMP will be revised and submitted by the construction contractor for the Clean Water Act (CWA) Section 401 Water Quality Certification (WQC).

This WQMP describes the monitoring requirements to be met during water quality monitoring efforts for the 401 WQC. The intent of the WQMP is to conduct water quality sampling and analysis to monitor potential impacts caused by in-water work of the project, including dredging, dewatering, and sand placement work. The WQMP includes baseline (preconstruction), during-construction, and post-construction monitoring. Data collected as part of the WQMP will be used to assess the adequacy of BMPs applied during construction and will facilitate assessing the impacts of the project on the water quality of the

[1] This WQMP has been prepared to be submitted with the Environmental Assessment. It is not site-specific and includes neither construction Best Management Practices nor Data Quality Objectives.

nearshore waters of the Pacific Ocean. If shown to be necessary by the monitoring data, BMPs will be modified during construction to protect water quality.

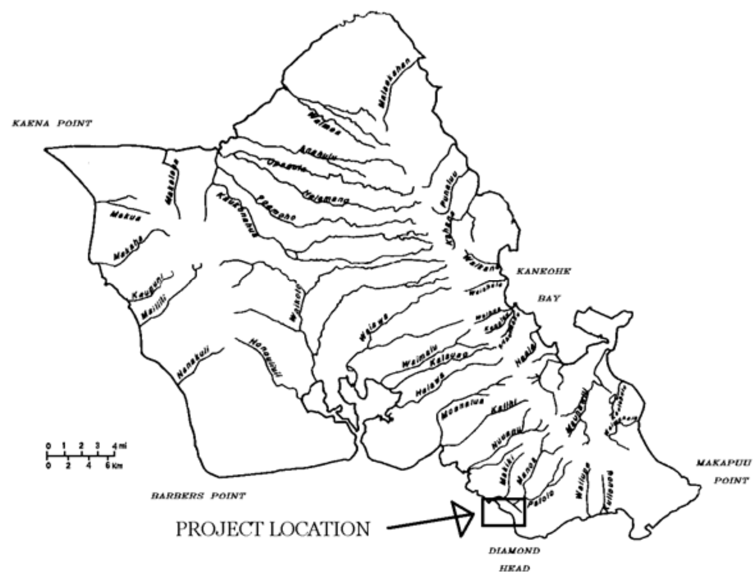

Figure 1. Island of Oʻahu showing location of Waikīkī Beach.

Background Information

The State of Hawaiʻi proposes to conduct periodic beach nourishment and restoration of Waikīkī Beach for a 15-year period using offshore sand. The proposed project includes the following primary components:

- The recovery of approximately 18,349 cubic meters (24,000 cubic yards) of sand from deposits located 457 to 914 m (1,500 to 3,000 ft) offshore of the project area in a water depth of about 3 to 6 m (10 to 20 ft).
- Pumping the sand to an onshore dewatering site to be located in an enclosed basin within the eastern Kūhiō Beach crib walls.
- Transport of the sand along the shore in the project area and placement to the design beach profile.
- The proposed project consists of the initial maintenance plan and up to two future maintenance projects at 7 to 8 year intervals recovering approximately 9,175 cubic meters (12,000 cubic yards).

The dredging system and methods for delivery of sand to shore will be determined by the construction contractor. Once onshore, the sand will be dewatered to reduce turbidity in the ocean. It is recommended that the dewatering activities be primarily conducted within the eastern Kūhiō crib, at the same location as in the 2006 project. As the water drains from the basin, the dewatered sand can be removed and placed in a temporary holding site. The sand would then be moved and placed on the project area shoreline to the design cross-section and beach profile, starting at the east end and working west.

Several nearshore areas in Waikīkī are listed as impaired water bodies (HIDOH, 2008). These listings mean that the waters do not meet the Hawaiʻi Water Quality Standards (HDOH, 2004). Two of the listed water bodies are in the project area: Kūhiō Beach and Waikīkī Beach Center. Kūhiō Beach (HI681782) is listed as impaired for the wet season. The enterococci criterion is listed as "Not Attained," and the basis for listing the water body (decision code) for the remaining parameters—TN, NO_3+NO_2, TP, and turbidity— is unknown. Kūhiō Beach is assigned "Category 3," meaning that "there is [sic] insufficient available data and/or information to make a use support determinations [sic]," and "Category 5," meaning that available data and/or information indicate that at least one designated use in [sic] not being supported or is threatened, and a TMDL is needed. Kūhiō Beach is given a "Low" priority code for Total Maximum Daily Load (TMDL) development. Waikiki Beach Center (HI244505) is listed as impaired for the wet season, although the basis for listing the water body (decision code) is unknown for all of the listed parameters (TN, NO_3+NO_2, TP, and turbidity). Waikīkī Beach Center is listed as a "Category 2," meaning available data and/or information indicate that some, but not all of the designated uses are supported and "Category 3." Waikīkī Beach Center is not given a priority ranking for TMDL development.

As a result of these impaired listings, studies will be conducted to determine the total maximum daily load (TMDL) of pollutants that the nearshore waters can accommodate without violating Hawaiʻi's Water Quality Standards. Because TMDLs have not yet been established at either of the listed water bodies, only those parameters listed in the General Monitoring Guidelines (HDOH, 2000) will be measured as part of this WQMP. Monitoring is not proposed to determine operational impacts of the nourishment project.

Monitoring Program

The monitoring program largely follows the General Monitoring Guidelines for Section 401 Water Quality Certification Projects (HDOH, 2000).

Organization and Responsibilities

The water sampling and field testing will be performed by personnel trained to perform these tasks. Samples for turbidity, total suspended solids, enterococcus, and clostridium will be collected and delivered to a qualified laboratory for analyses.

The construction contractor's assigned representative will perform daily visual inspections of the construction site to ensure that the construction activities do not result in adverse impacts to the nearshore waters of Waikīkī Beach. Sampling personnel will perform visual inspections while sampling. Information recorded by the contractor's representative and the samplers will include at a minimum: description of the construction activity, date, time, weather conditions, and any other observed activities not related to construction activities that may affect water quality. A copy of the contractor's daily observations will be available for use in preparing the final report. Sampler observations will be included with the individual sampling reports. Contractor observations will be available on-site while the project is on-going. Upon project completion all observations and field books will be available for inspection by HDOH-authorized personnel.

Table 1 provides responsibilities and necessary qualifications of the personnel to be involved with this monitoring program.

Parameters to be measured

Receiving water quality parameters to be measured are: pH, turbidity, total suspended solids (TSS), dissolved oxygen (DO), salinity, temperature, enterococcus, and clostridium.

Table 1. Summary of responsibilities and qualifications.

Name	Responsibility	Qualification
	Project Manager	Project management, laboratory, and field experience
	Collect samples and perform field measurements	Trained in collecting water samples and performing field measurements
	Notify samplers and laboratory when in-water construction will start with enough time to collect 401 WQC preconstruction samples prior to starting work.	Knowledgeable of construction activities as they relate to 401 WQC requirements. Familiar with nearshore waters. Knowledgeable of WQC monitoring requirements for this project.
	Make daily visual observations of BMPs and construction activity to be logged in a notebook to be used as part of the assessment process.	

Sampling Locations

Six sampling stations will be established: one nearshore control station, two offshore control stations (one surface and one bottom), and three nearshore impact stations. One of the impact stations will be located near the dewatering area and the other two will be located at either end of the nourished beach. The samples will all be collected from a depth of 0.3 m (1 ft) below the surface of the water, except the bottom sample at the offshore control station, which will be collected 1 m (3 ft) above the bottom. The locations of the stations will be determined after the construction design and best management practices (BMPs) have been developed.

Once the monitoring program begins, Global Positioning System (GPS) coordinates of the sampling site locations will be recorded during sampling and provided to HDOH-CWB with the field notes. The sampling locations may change due to natural environmental conditions.

Sampling Frequency

In-water work is expected to be completed within two months. BMPs will be installed and remain until completion of the Project. HDOH-CWB will be notified if any modifications to the schedule or BMPs are proposed.

Preconstruction Sampling—Prior to construction, samples will be collected once a month for ten months (or more frequently if there is less time) at all of the control stations for a total of ten sampling events. Collecting preconstruction samples over this longer time period will provide a representative baseline covering temporal and seasonal differences.

During-Construction Sampling—Samples will be collected from the three controls stations and three impact stations every day dredging, dewatering, and sand placement is performed throughout the duration of the project. Enterococcus and clostridium will be measured once a week.

Post-Construction Sampling—Post-construction sampling will occur one time per week for three weeks once the project is completed and all in-water BMPs are removed. The three control stations will be sampled.

Sample Collection

The field samplers will record their initials, the date, time of sample collection and time of field measurements, location, and field measurement for each sample. They will note construction activity, unusual site conditions, and condition of any treatment device or facility at the time of sample collection. Samplers will note any non-construction related activity that might impact water quality. Field personnel will record weather conditions.

Turbidity, TSS, enterococcus, and clostridium will be measured from grab samples collected by the field samplers. Temperature, salinity, and DO will be measured *in situ.* pH may be measured *in situ* or from a collected sample, but must be measured within 15 minutes of sample collection. Table 2 lists the analyses to be measured, hold times, and preservation.

Samples will be collected at each monitoring station. A one-liter plastic bottle will be used for turbidity and TSS analysis and two 250-mL sterile bottles will be used for enterococcus and clostridium. Prior to collecting a sample, each plastic bottle will be pre-rinsed with the water to be sampled. The ocean samples will be collected just below the surface in 1-m (3-ft) of water by facing the bottle upcurrent of the sampler. The offshore bottom sample will be collected 1 m (3 ft) above the bottom using a Nisken sampler. Once collected, sample bottles will be tightly capped and placed in a cooler on ice until they are received by the laboratory. pH may be measured out of a bottle or beaker (used only for pH measurement) within 15 minutes of collection if it is not measured *in situ.*

Table 2. Analytical hold times and preservatives for the WQMP.

Analysis	Hold time	Preservation
Temperature	immediate	none
Salinity	immediate	none
Dissolved Oxygen	immediate	none
pH	15 minutes	none
Turbidity	48 hrs	chill on ice* to 4ºC
Total Suspended Solids	7 days	chill on ice to 4ºC
Enterococcus	6 hours	chill on ice to 4ºC
Clostridium	6 hours	chill on ice to 4ºC

*wet ice will be used in the field to chill the samples quickly.

Field Analysis

pH, temperature, salinity, and DO will be measured in the field. Meter calibration procedures are outlined in the standard operating procedures (SOP) specifically written for the pH and DO meters used. Temperature will be measured with the DO meter. The DO meter thermister will be calibrated, at a minimum annually, against a National Institute of Standards and Technology-certified thermometer. Salinity will be measured using a handheld refractometer or a DO meter that also measures salinity. The pH and DO meters will be maintained and calibrated according to manufacturer instructions and the SOP. Operation and calibration will only be performed by personnel who have been properly trained in these procedures. Documentation of calibration and any maintenance information will be maintained in appropriate field or log books. All calibrations will be made prior to analyzing the samples. Analysis of pH must be undertaken within 15 minutes of sample collection. Temperature and DO should be made *in situ*, if conditions allow. Salinity and pH may be measured from a sample collected specifically for those analyses. Table 3 provides information on the methods and instruments to be used.

Table 3. Analytical methods and instruments to be used in the field for the WQMP.

Analysis	**Units**	**Method**	**Reference**	**Instrument***
Temperature	ºC	SM 2550B	SM (1998), YSI manual	YSI DO thermister
Salinity	psu	Refractive index or conductivity	Refractometer instructions, YSI manual	Hand held refractometer or YSI 85
Dissolved Oxygen	mg/L	SM 4500-O G / membrane electrode	SM (1998), YSI manual	YSI Do meter 550 or 85
pH	standard units	SM4500-H^+	SM (1998)	Hanna pHEP 5 pocket pH meter

*A typical instrument is listed; other manufacturers may be substituted.

Any field equipment that has been shown by calibration or otherwise to be defective, is to be taken out of service until it has been repaired. The equipment is placed back in service only after verifying by calibration that the equipment performs satisfactorily. If at any time calibration and maintenance is beyond the capability of the trained personnel, the Project Manager will be notified. An attempt will be made to solve the problem. If the equipment or instrument still cannot be repaired, the equipment will be taken out of service and sent for repair and replacement equipment will be obtained from the laboratory.

Chain of Custody Procedures

Once samples have been obtained and site conditions and field measurements have been properly documented in the field notebook, a written record of the chain of custody of the samples must be made for the turbidity and total suspended solids analyses. A chain of custody (COC) form will be filled out and accompany the samples to the laboratory; information on the form will state which analyses are to be performed. The form will identify the samples, so the laboratory can report the analytical results by sample ID. When transferring possession of samples, the sampler will sign and record the date and time on the COC record. Each person who takes custody will fill in the appropriate section of the COC record.

Laboratory Analysis

The laboratory will document the analytical procedures used and any relevant Quality Assurance/Quality Control (QA/QC) and instrument calibration information pertaining to the specific analyses. All analytical results and field notes will be entered into a notebook or file established for this purpose, and will be provided in a final report prepared for the monitoring program. This file, including relevant QA/QC results, will be retained in the laboratory records and will be available for inspection by HDOH-authorized personnel during normal business hours.

The laboratory will participate annually in US Environmental Protection Agency (USEPA)-certified provider water studies for water pollution and water supply for turbidity and total suspended solids determination.

TSS, turbidity, eneterococcus, and clostridium will be analyzed at the laboratory. Table 4 provides information on laboratory methods and instruments to be used.

Table 4. Analytical methods and instruments to be used in the laboratory for the WQMP.

Analysis	**Units**	**Method**	**Reference**	**Instrument***
Turbidity	ntu	EPA 180.1, rev. 2.0	USEPA (1993)	2100N Hach Turbidimeter
Total Suspended Solids	mg/l	SM 2540D	SM (1998)	Mettler H31
Enterococcus	CFU per 100 mL or MPN per 100 mL	JDEXX enterolert or SM 9230	SM (1998)	Incubators
Clostridium	CFU per 100 mL	Bisson and Cabelli	Bisson and Cabelli (1980)	Incubators

* Typical instruments are listed; other manufacturers may be substituted.

Reports and Assessment

A preconstruction monitoring report will assess water quality and compare baseline data to applicable Hawaiʻi Water Quality Standards. This report will be prepared within 45 days of completion of preconstruction monitoring and analysis.

During construction, results will be sent by facsimile to HDOH-CWB within 24 hours or the first business day after they become available. *In situ* sampling results will be submitted by facsimile within 24 hours or by the next business day. Depending on sample load in the laboratory, turbidity, eneterococcus, and clostridium will be submitted within 72 hours and TSS within 8 days. Within two weeks of completing all analyses, a typed report of results will be mailed to the Hawaii Department of Land and Natural Resources-OCCL. The report will also be sent to HDOH-CWB via facsimile (808)586-4352 or email at cleanwaterbranch@doh.hawaii.gov. These reports will have a running statistical summary (provided there are sufficient data for statistical analysis) for each phase of the project. These reports will also include field notes.

A final report and water quality assessment will be prepared upon completion of the monitoring program. This report will be submitted to HDOH-CWB within 60 days following completion of post-construction monitoring and analysis. The final report will identify the methods and procedures for analytical measurements and include all data collected as well as statistical summaries of results by station and activity phase (preconstruction, during-construction, and post-construction). This report will also assess whether water quality was impacted by the construction activity. Upon completion of the monitoring program, the contract laboratory will retain the original data and field notebook for a minimum of five years.

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APPENDIX D

MARINE ENVIRONMENTAL MONITORING PLAN
FOR THE WAIKIKI BEACH MAINTENANCE PROJECT,
WAIKIKI, OAHU, HAWAII

AECOS, INC.

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Marine environmental monitoring plan for the Waikīkī Beach maintenance project, Waikīkī, Oʻahu, Hawaiʻi[1]

December 29, 2009 | *DRAFT* | *AECOS* No. 1205C

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Introduction

The State of Hawaiʻi Department of Land and Natural Resources, Office of Coastal and Conservation Lands (DLNR-OCCL) is proposing to nourish the sand beach at Waikīkī, Oʻahu between the Royal Hawaiian groin and the west end of the Kūhiō Beach crib wall (Fig. 1). The entire shore from Honolulu Harbor to Diamond Head, including that of Waikīkī Beach, is essentially man-made, with seawalls, groins, and jetties constructed to stabilize the shoreline. Over 500,000 cubic yards of sand have been placed on Waikīkī Beach since 1928; however, only two percent of that sand remains on the beach today (Fletcher and Miller, 2003).

DLNR-OCCL proposes to nourish Waikīkī Beach with sand recovered from offshore Waikīkī sand deposits. The goal of the current project is to restore and maintain Waikīkī Beach, fronting Waikīkī's historic landmark hotels, to enhance recreational and aesthetic enjoyment of the area, protect the backshore area, and facilitate lateral access along the shoreline. This report considers existing marine biological resources and the potential effects of restoring and maintaining Waikīkī Beach. The monitoring plan draws upon experiences gained from the December 2006 project to nourish Kūhiō Beach (*AECOS*, 2008), which is located adjacent to Waikīkī Beach in the east.

[1] Report prepared for Sea Engineering, Inc. for use in the preparation of an Environmental Assessment and various environmental permits. This report will become part of the public record for the State of Hawaiʻi Department of Land and Natural Resources, Office of Coastal and Conservation Lands beach maintenance project.

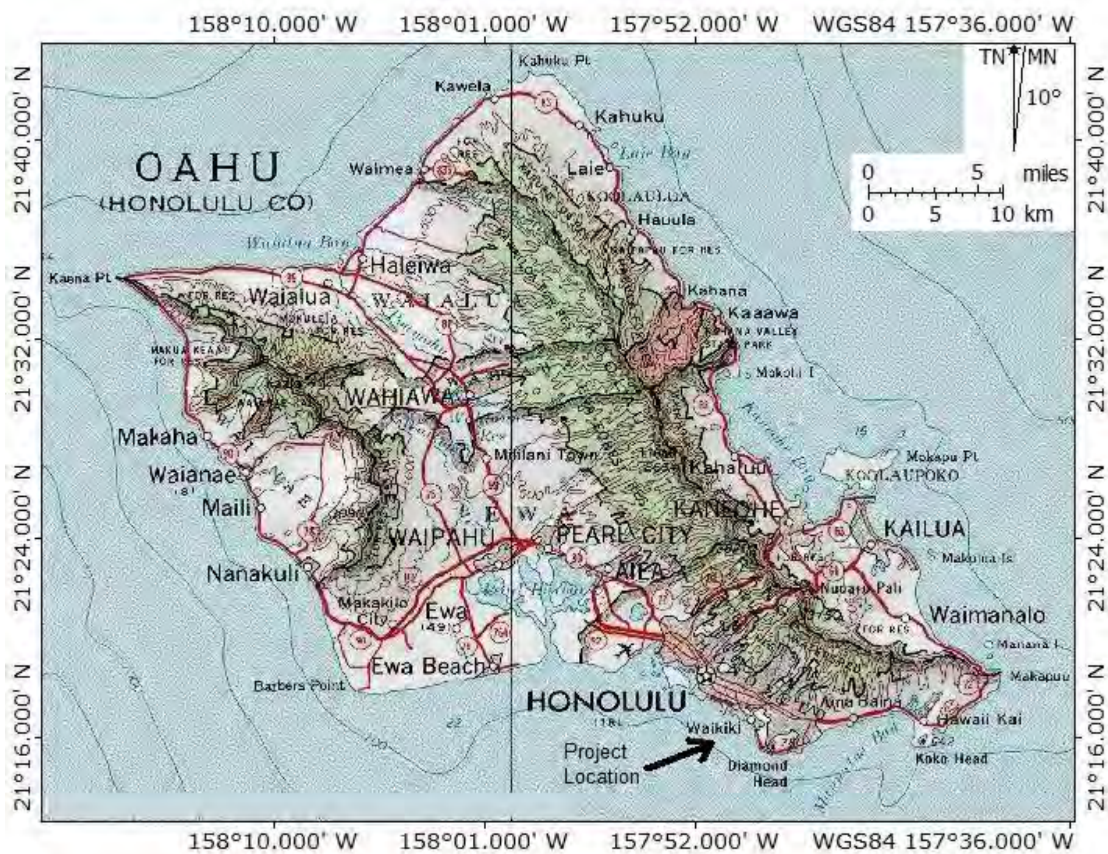

Figure 1. Island of Oʻahu showing location of Waikīkī Beach.

The marine environment fronting Waikīkī Beach is an open coastal environment with a sand and limestone reef bottom (Fig. 2). The fringing reef located in the project area consists of a fossil limestone platform with scattered, sand-filled pockets, high benthic algal cover, and very little live coral (<1% of the area). The most conspicuous life forms are fleshy algae. Reef macroinvertebrates, such as sea urchins and sea cucumbers, are present, but in low numbers. Fish biomass and diversity are low in this area of low bottom complexity. Green sea turtles or *honu* (*Chelonia mydas*) are regularly observed over the shallow reefs off Waikīkī, as many of their preferred algal food species are abundant or common on the reef flat. A diverse assemblage of sediment-dwelling invertebrates lives in the sand patches off Waikīkī, with lower abundances observed closer to shore (Bailey-Brock and Krause, 2008). In general, the water quality off Waikīkī is good, although waves and the shallow bottom often result in elevated turbidity levels as sediments are constantly resuspended.

Figure 2. Waikīkī Beach nourishment proposed footprint, sand deposit area, and pipeline corridor, Waikīkī, Oʻahu.

Project Description

The proposed project plan includes the following major components:

- The recovery of approximately 24,000 cubic yards (18,250 m^3) of sand from an offshore sand deposit (Fig. 2) located 1,500 to 3,000 ft (457 to 914 m) offshore of the project area in a water depth of about 10 to 20 ft (3 to 6 m).
- Pumping sand to an onshore dewatering site via a pipeline (Fig. 2) to be located in an enclosed basin within the eastern Kūhiō Beach crib walls.
- Transport of the sand along the shore in the project area and placement to the design beach profile.

The initial nourishment project would require 24,000 cubic yards (cy) of sand to effectively double the approximately 40-foot (12 m) existing beach width. A second nourishment is also proposed after about 10 years, when approximately half of the restored beach is expected to have been lost due to continuing erosion. The second nourishment would involve an estimated 14,000 cy.

Marine ecosystems background information

The bottom within the immediate project area is sand with a small area of hard bottom fronting the Prince Kūhiō Hotel. The reef flat seaward of the project area is mostly sand with patches of emergent limestone. To either side of the project area are extensive algae-dominated, limestone outcrops. To the west is the reef flat off Gray's Beach (Fig. 2) and the Halekūlani Channel. To the east, is the Kūhiō Beach crib wall structure.

The dominant taxa of benthic organisms on the reef platform off Waikīkī are marine fleshy algae, also known as *limu* or seaweed, which cover most exposed reef rock surfaces that are not scoured or buried by shifting sands. The growth form of much this *limu* is short stature or turf-forming. Although today the flora of Waikīkī reef remains relatively diverse, two invasive red algae (Rhodophyta), *Acanthophora spicifera* or spiny seaweed and *Gracilaria salicornia* or gorilla *ogo*, dominate the benthic flora and now cover much of the hard substrata (Smith et al., 2004; Huisman et al., 2007; MRC, 2007; *AECOS*, 2007, 2008, 2009a). In addition to these two non-native species, *Dictyota sandvicensis*, *Padina australis*, and *Sargassum obtusifolium* are common on hard surfaces of the reef. Another invasive species, *Avrainvillea amadelpha*, is present on this reef flat. At least two algal species preferred by green sea turtles (*Chelonia mydas*; NMFS-USFWS, 1998) are present: *Acanthophora spicifera* is abundant and *Ulva fasciata* is common. Native algal species of interest (C. Smith, UH, pers. communication) are present on this reef flat: *Sargassum echinocarpum* and *S. obtusifolium* which are abundant, and *S. polyphyllum* and *Gracilaria coronopifolia* which are rare.

Surveys on the reef off Waikīkī have observed common macroinvertebrates including various echinoderms and sponges such as *Holothuria atra*, *H. nobilis*, *Echinothrix diadema*, *Tripneustus gratilla*, *Echinometra mathaei*, *Echinostrephus aciculatus*, and miscellaneous sponges (OI, 1990); *E. mathaei*, *E. aciculatus*, and *H. atra* (MRC, 2007); and an unidentified stomatopod, *E. diadema*, *E. mathaei*, *T. gratilla*, *Actinopyga mauritiana*, *H. atra*, and *H. cinerascens* (*AECOS*, 2007, 2008). The boring urchin, *E. mathaei*, and the black sea cucumber, *H. atra* or *loli*, are the most conspicuous animals on the reef fronting Waikīkī Beach (*AECOS*, 2009b), but have relatively low numbers.

Corals are largely absent on the reef platform offshore of Waikīkī (Chave, et al., 1973; *AECOS*, 1979, 1987, 1995, 2009a, 2009b; OI, 1991); colonies are sparse and account for less than one percent of the nearshore bottom (*AECOS*, 2007, 2008; MRC, 2007). At nearby Gray's Beach reef, to the west, coral cover is <1% and colonies are small, with an average coral head being 7 cm (2.8 in) in diameter. In the recent *AECOS* (2009b) survey for this project, no coral growth was observed on the limestone outcrops directly off the beach area proposed for sand nourishment. No large, (>50 cm or 20 in diameter) mound-forming corals were observed anywhere in the survey area. Coral sightings were limited to three locations: 1) the shallow reef at the far west side of the project area with large cauliflower coral (*Pocillopora meandrina*) colonies, 2) the far east side of the project area fronting the west end of the crib wall and adjacent to a potential pipeline corridor with various small *Poc. meandrina* and lobe coral (*Porites lobata*) colonies present, and 3) the sand extraction area with coral colonies on limestone outcrops around the western perimeter of the sand source basin as well as on outcrops within the basin.

"Benthic infauna" are aquatic animals that live within the bottom substratum (sand in this case) rather than on its surface. Infauna have been documented from sand deposits in the Halekūlani Channel, to the west of the source sand deposit (Bailey-Brock and Krause, 2008). Most of the diverse species observed are less than 1 mm (0.04 in) in size and have relatively low abundances. Various types of worms are most abundant, making up 85% of the total fauna, followed by arthropods, echinoderms, and mollusks. The furthest offshore of three stations surveyed in 2008, near the reef margin, had the highest taxonomic diversity and the highest overall number of individuals, while the site closest to shore (0.7 km or 0.5 mi from shore) and in the shallowest water had the fewest individuals with about one third the number found at the offshore site. The sand deposit for use in the Waikīkī Beach project is between 0.3 and 0.5 km (0.2 and 0.3 mi) from shore.

Approximately 2,270 m^2 (24,400 ft^2) of intertidal sand habitat and 3,200 m^2 (34,700 ft^2) of subtidal sand habitat will be created by the project. The beach will be widened by approximately 40 ft (12 m). This sand will provide habitat for small infaunal organisms such as small worms, crustaceans, and mollusks. The time it will take for infauna to recover is unknown, but is anticipated to be rapid due to the small size and rapid regeneration time of most infaunal animals (Bailey-Brock and Krause, 2008).

The fish community in the nearshore waters off Waikīkī is largely structured by the minimal topography with fishes being generally uncommon. Recent surveys off Waikīkī (MRC, 2007; *AECOS*, 2009a and 2009b) found the most common species to be wrasses (*Thalassoma duperrey*, *Thalassoma trilobatum*, and *Stethojulis balteata*), *manini* (*Acanthurus triostegus*), and reef triggerfish (*Rhinecanthus rectangulus*). These surveys off of Gray's Beach and Waikīkī Beach have identified 58 species in the project area. The underwater visual survey technique, typically used for these surveys, does not accurately census seasonal, cryptic, nocturnal, and burrow-inhabiting fishes, although they could comprise half or more of the fish biomass (Willis, 2001). The temporary disturbance of sand deposit food resources on the ecosystem is not expected to have significant impacts on the fish populations because of the abundance and availability of the resource in nearby sand areas.

Marine ecosystems monitoring program

Program design

This monitoring program has been designed to quantify positive and negative impacts of beach nourishment on the nearshore reef flat. In designing the program, we assume the following "no effect" null hypotheses:

a. Physical complexity or rugosity on the reef flat will remain unchanged from preconstruction values.
b. The number of coral colonies and percent cover of coral will not change significantly in the nearshore waters off Waikīkī Beach from pre-construction values.
c. The percent cover of crustose, coralline algae will not change significantly in the in the nearshore waters off Waikīkī Beach from pre-construction values.
d. The percent cover of algae will not change significantly in the nearshore waters off Waikīkī Beach from preconstruction values.

The two primary goals of the Waikīkī Beach monitoring program are: 1) to assess changes in specific biotic and physical variables due to the project and 2) to test for correlations between variables. A "Before-After, Control-Impact" (BACI) monitoring design and analysis (Smith, 2003) will be employed. The BACI monitoring design accounts for natural spatial and temporal variation that occurs in ecosystems, which can mask project–related changes to the resident biotic community. The BACI monitoring program has been recommended by critical reviews of historical beach nourishment monitoring programs (Peterson and Bishop, 2005; Hart et al., 2006).

The Waikīkī Beach monitoring program will assess the following reef flat variables: percent benthic cover (biotic and abiotic), coral colony abundance, coral colony size, and rugosity. These variables will be monitored in the project and reference (control) areas before and after project construction: one time before construction and four times after construction (immediately after construction, and one, three, and five years post-construction).

In addition to monitoring responses to beach nourishment on the reef flat, coral colonies growing in proximity to dredging operations at the sand deposits and the pipeline corridor will be monitored, and the sand deposits will be monitored for benthic infauna.

Qualitative survey of marine biota

During each scheduled monitoring event, a survey of marine biota for compilation of a species list with DACOR (Dominant, Abundant, Common, Occasional, and Rare) abundance categories will be conducted for project area substrata.

Quantitative surveys of benthic cover

Three distinct areas will be monitored using benthic transect surveys: the reef flat fronting Waikīkī Beach and two adjacent reference (control) areas (east and west of the project area). Substrate type and benthic biota will be surveyed quantitatively along each transect. The benthic transect surveys will be conducted prior to commencement of project construction, immediately after all construction has been completed, and one, three and five-years post-construction, for a total of five survey events.

<u>Reef flat</u> – Four reef flat areas surrounding the project area (i.e. off Waikīkī Beach and near the breached areas of the crib wall) will be delineated and surveyed using a quantitative photoquadrat transect method to estimate project

effects on reef flat biota. Within each area, two 25-m transects will be laid parallel to shore and surveyed. Several areas surveyed during the Kūhiō nourishment project (AECOS, 2008) are proposed to serve as survey locations for the present monitoring plan: Site No. 2, Site No. 5, and Site No. 6 (Fig. 3).

Photographs to estimate substrate composition (biotic and abiotic) will be taken of a 0.383 m^2 quadrat (or similar) with an Olympus 5050 digital camera and underwater housing (or similar) mounted on a support frame. Photographs will be taken at each meter mark along the 25-m transects. Between 10 and 25 photoquadrats per transect will be analyzed. The quadrats will be analyzed using the Coral Point Count with Excel Extension (CPCe) computer program (Kohler and Gill, 2006), quality of the photographs permitting. Between 20 and 50 randomly placed points will be analyzed from each photoquadrat and assigned to one of the following categories: live coral, other macroinvertebrate (identified if possible), crustose coralline algae (CCA), turf algae, fleshy macroalgae, sand, rubble, or bare limestone outcrop. If water clarity is not suitable for photoquadrats then the point-intercept quadrat method will be used in its place. Percent coverage will be calculated by dividing the number of points intercepted by each biota type by the total number of points occurring in each of the sampling grids. An attempt will be made to identify organisms to the species level, although the clarity of the water (and size of organism) at the time of sampling will influence the extent of the taxonomic determination that can be made. For each benthic category, an overall percent cover value will be determined and this figure will be used for before-after and control-impact comparisons.

Reference reef flat – A reference area will be located at each end of the project area, with as similar habitat characteristics as possible. These areas will be surveyed as described above for the reef flat survey. Two reference (control) areas surveyed during the Kūhiō nourishment project (AECOS, 2008) are proposed to serve as survey areas for the present monitoring plan. These are designated "Control East" and "Control West" (Fig. 3). Control West is located within an area of potential direct impacts associated with a proposed beach restoration project for the adjacent shoreline. Therefore, the western control area may be moved further west to the reef flat fronting the Hawaii Army Museum and Ft. Derussy Park.

Statistical analysis - An *a priori* power analysis will be conducted after the first sampling event to determine the adequacy of the number of transects. The desired outcome of the power analysis is to achieve adequate power to detect effects of importance, defined as the ability to detect, with 80 percent probability, a decline of approximately 50 percent or an increase of approximately 100 percent (Peterson and Bishop, 2005). Quadrats or transects will be added to the monitoring design, if required, to achieve this minimum power. A *post hoc* power analysis will be conducted to quantify the magnitude of the effect that could be detected. Statistical analyses will be conducted to determine if changes occurred to the substrate composition. Pair-wise differences for each category and for total coverage for each area and sampling event will be used in Student's paired *t*-tests.

For each event, a total of 12 transects are anticipated to be surveyed: 8 project reef flat transects and 4 reference reef flat transects. Along each transect, between 10 and 25 quadrats will analyzed for a total of between 120 and 300 quadrats overall. Within each photoquadrat, between 20 and 50 points will be analyzed for a total of between 2,400 and 15,000 points overall. Post-construction conditions will be compared to preconstruction conditions with respect to influences of sand movement on benthic substrata.

Quantitative survey of corals

Coral cover is exceedingly low at the project site and the already described survey methods may not adequately sample rare biota. Therefore, in addition to the photoquadrat or point-intercept survey methods, all corals within 0.5 m of either side of each 25-m transect line will be identified to species (where possible) and the size class to which the maximum diameter of the colony belongs recorded (1 to 5 cm; >5 to 10 cm; >10 to 20 cm; >20 to 40cm; >40 to 80 cm; >80 to 160 cm; or >160 cm; NOAA, 2008). Size class distribution will be determined for each species of coral for project reef flat and reference reef flat sites. The total survey area will be 300 m^2 (3,230 ft^2).

Physical Habitat Complexity

Physical habitat complexity will be determined along the first 10-m of each reef flat transect. These will be surveyed once before and once after project completion. The chain-link method will be used to measure rugosity, a measure of the physical complexity of the bottom used as an indicator of the physical habitat structure available for marine organisms. Rugosity will be calculated from the relationship between two field measurements: the distance of a transect (straight-line distance; in this case 10 meters) and the length of fine metal chain draped over the bottom (and into holes, depressions, and crevices) between the two transect ends (McCormick, 1994). An index of rugosity for each transect is derived by dividing the length of the chain needed to cover the distance between transect ends by the length of the transect line. The chain is a light-weight brass chain marked at 1-m intervals. Rugosity can be used to test correlations among overall coral cover, coral species diversity, fish abundance, and fish biomass. All 12 transects will be surveyed for rugosity.

Figure 3. Proposed four reef flat survey areas and east and west control areas (white boxes). Survey areas surveyed during Kūhiō Beach sand nourishment (yellow boxes).

Sand source site infauna

Re-colonization rate by infaunal invertebrates is not known for this environment in Hawaiʻi and previous sand community studies lack data from subsequent samplings over time. To survey for potential impacts to sand infauna, a total of 9 sand samples will be collected: 3 within each of the 2 proposed sand extraction sites (WAIK-4 and WAIK-6) and 3 within a nearby control sand deposit (WAIK-2; Fig. 4). Infaunal organisms will be identified and the diversity and density of taxa determined for each sample. Samples will be collected on four occasions: preconstruction, immediately after dredging has been completed, 3-months after, and 1-year after.

Sand deposit perimeter corals

To survey for potential impacts to coral colonies bordering the sand deposits, a transect photoquadrat survey will be conducted. A 50-m transect will be laid adjacent to the sand deposit on the reef top where corals are present. Photographs of a 1-m^2 quadrat will be taken along the entire length of the transect and all corals within a half meter of either side identified and measured. Perimeter corals will be surveyed on two occasions: pre-construction and immediately after dredging has been completed.

Pipeline corridor corals

Although, the pipeline corridor will be chosen based on a pathway that would least likely cause impact to coral colonies, there is potential for damage to coral heads. To survey for potential impacts to coral colonies along the pipeline corridor, a transect survey will be conducted. In areas where corals fall within 10-m to either side of the proposed pipeline corridor, a 50-m transect will be laid and corals identified and measured. Pipeline corridor corals will be surveyed on two occasions: preconstruction and immediately after dredging has been completed.

Reports

Reports will be prepared for each benthic biological monitoring event. Each report will describe the methods and results, and provide a discussion of the results.

Figure 4. Sand deposit infauna sampling stations (WAIK-2, WAIK-4, and WAIK-6) Waikīkī Beach, Oʻahu, Hawaiʻi (SEI image).

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