Technical Memorandum, Treatability Study Work Plan for Under-Pier Activated Carbon Amendment Treatment of Contaminated Sediments at Sierra 1B Pier, Pearl Harbor

JOINT BASE PEARL HARBOR-HICKAM, OAHU, HAWAII

PHNC National Priorities List Site

April 2014

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

Comprehensive Long-Term Environmental Action Navy
Contract Number N62742-12-D-1829, CTO 0015

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Prepared for:

NAVFAC
Naval Facilities Engineering Command
NAVFAC PACIFIC

Department of the Navy
Naval Facilities Engineering Command, Pacific
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Prepared under:

Comprehensive Long-Term Environmental Action Navy
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ACRONYMS AND ABBREVIATIONS

µg/kg	microgram per kilogram
µm	micrometer
AC	activated carbon
ARAR	applicable or relevant and appropriate requirement
BAZ	biologically active zone
bswi	below sediment–water interface
cm	centimeter
cm/y	centimeter per year
COC	chemical of concern
COC_D	concentration of dissolved chemical of concern in porewater
COC_{SPME}	chemical of concern concentration measured in a passive sampler
DGT	diffuse gradients in thin film
D_p	peak wave direction
DU	decision unit
ENR	enhanced natural recovery
EPA	Environmental Protection Agency, United States
FS	feasibility study
ft	foot/feet
ft^2	square foot/feet
g/cm^3	gram per cubic centimeter
GAC	granular activated carbon
H_s	significant wave height
ID	identification
in/y	inch per year
$K_{SPME,D}$	solid-phase micro-extraction–dissolved phase partition coefficient
lb/ft^3	pound per cubic foot
m/s	meter per second
mg/kg	milligram per kilogram
MLLW	mean lower low water
MNR	monitored natural recovery
NAVFAC	Naval Facilities Engineering Command
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
Pa	pascal
PAC	powdered activated carbon
PCB	polychlorinated biphenyl
PDMS	polydimethylsiloxane
PRG	preliminary remediation goal
PSD	particle size distribution
RAL	remedial action level
RCM	reactive core mat
RI	remedial investigation
SPI	sediment profile imaging
SPME	solid-phase micro-extraction
SWAC	surface area–weighted average concentration
TBC	to be considered
TOC	total organic carbon

T_p	peak wave period
TS	treatability study
U.S.	United States
WBD	wet bulk density
WP	work plan

1. Introduction

This technical memorandum presents the work plan (WP) for a treatability study (TS) to evaluate the feasibility of under-pier activated carbon (AC) amendment treatment of contaminated sediment at the Pearl Harbor Sediment site, located within Joint Base Pearl Harbor-Hickam, Oahu, Hawaii (Figure 1-1).

The Draft Final Pearl Harbor Sediment Feasibility Study (FS) report (AECOM 2014) identified the presence of contaminated sediments with concentrations of mercury and polychlorinated biphenyls (PCBs) above the remedial action levels (RALs) that may require remediation. The Draft Final FS report evaluated potential remedial alternatives and recommended amendment treatment as potentially the most feasible remedial technology to address contaminated sediments under the piers in Pearl Harbor, due to the limited access encountered from the pier structures.

The TS objectives are to evaluate the feasibility of applying amendment materials in selected under-pier areas, and to assess the effectiveness of the approach in reducing the risks posed to human and ecological receptors from contaminated under-pier sediments. The TS results will be used in the FS to provide further support for evaluating remedial alternatives specific to the under-pier areas, and (if the treatment approach is successful) will form part of the rationale used to select the final remedy for the Pearl Harbor Sediment site in the record of decision. The TS will be conducted at Sierra 1B Pier located within Quarry Loch, Pearl Harbor (Figure 1-1).

This WP has been prepared for the United States (U.S.) Department of the Navy, Naval Facilities Engineering Command (NAVFAC), Pacific, in accordance with contract task order number 0015 of the Comprehensive Long-Term Environmental Action Navy IV program.

This TS WP was prepared based on the Draft Final Pearl Harbor Sediment FS report (AECOM 2014) and the following regulatory and Navy guidance:

- *Guidance for Conducting Treatability Studies under CERCLA* (EPA 1992)
- *Guidance for Quality Assurance Project Plans, EPA QA/G-5* (EPA 2002)
- *Project Procedures Manual, U.S. Navy Environmental Restoration Program, NAVFAC Pacific* (DON 2007)
- *Department of the Navy Environmental Restoration Program Manual* (DON 2006)
- *Use of Amendments for In Situ Remediation at Superfund Sediment Sites* (EPA 2013)

1.1 Physical Setting

Pearl Harbor is a delta-shaped natural estuary located on the south-central coast of the island of Oahu, Hawaii (Figure 1-1). Current and historical activities around Pearl Harbor include Navy industrial and operational activities; private industrial operations; municipal, commercial, and urban activities; and agriculture. Chemicals used for these activities impact surface water runoff discharged to Pearl Harbor. Sediments in open water and under-pier areas of Pearl Harbor are the ultimate sink or repository for some of these chemicals; they also serve as the natural habitat for a wide variety of estuarine and marine species.

The site selected for the TS is Sierra 1B Pier, an active submarine berthing area along the northern shoreline of Quarry Loch, within Southeast Loch (Figure 1-1). Sierra 1B is the western section of Sierra 1 Pier, which covers the entire northern shoreline of Quarry Loch. Sierra 1B is approximately

550 feet long and 46 feet wide, representing an area of approximately 25,000 square feet (ft^2) (0.6 acre). As discussed in the Draft Final FS report (AECOM 2014), remedial action may be required to address mercury and total PCB concentrations exceeding the RALs in soft sediments that have accumulated in areas where the slope is relatively moderate under this pier; therefore, the Sierra 1B site is considered a suitable site to evaluate the constructability and effectiveness of amendment application as a remedial alternative for under-pier sediments in Pearl Harbor.

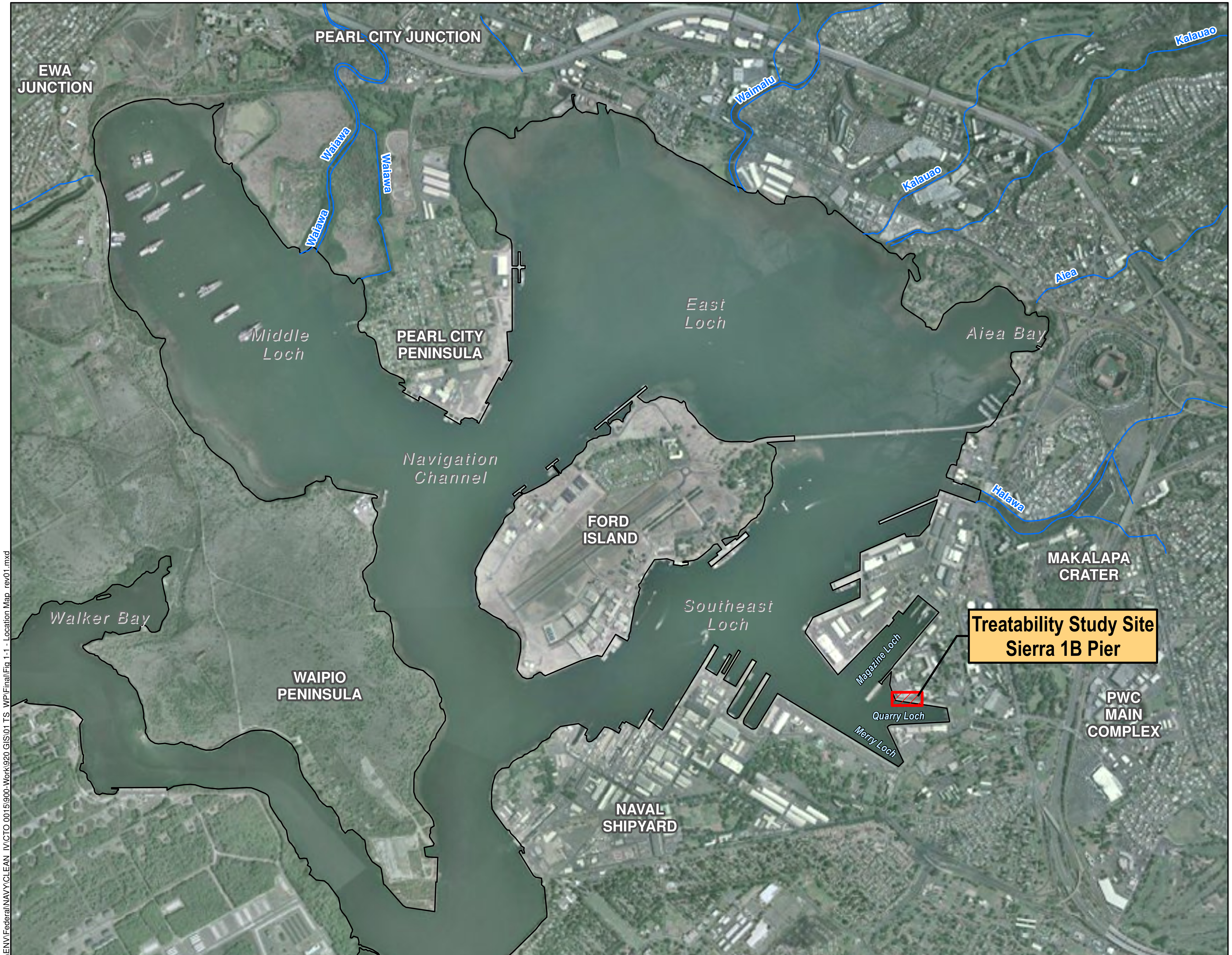
1.1.1 Geology

A generalized geologic map of the area around Pearl Harbor is presented on Figure 1-2. Hard, consolidated volcanic tuff deposits from the Honolulu Volcanics dominate the area immediately east of the harbor where the majority of the shorelines with piers are located. Approximately 90 percent of the Pearl Harbor seafloor is classified as unconsolidated sediment, primarily terrigenous mud (silt and clay), and calcareous sand. The unconsolidated sediment layer in the inner portions of the harbor is believed to be more than several meters thick. A submerged limestone/fossilized reef platform covered by a relatively thin layer of mud and sand surrounds much of the shoreline. Visual survey results of under-pier areas conducted as part of the FS field investigation (AECOM 2014) showed the presence of a thin layer of unconsolidated sediment of silt, clay, and calcareous sand overlying hard substrate of limestone/fossilized reef. The survey also indicated the presence of rubble, large fragments of coral, and anthropogenic debris such as concrete blocks and metal.

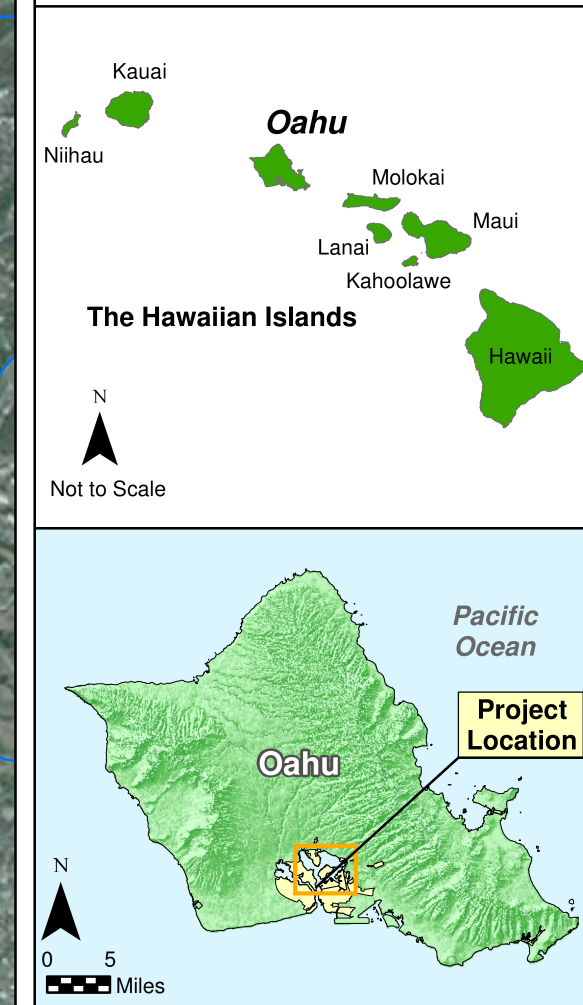
1.1.2 Sediment Transport

Hydrodynamic and sediment transport modeling of Pearl Harbor conducted as part of the Pearl Harbor Sediment Remedial Investigation (RI) Addendum (AECOM 2013, Appendix C.2) concluded that all of Pearl Harbor is a depositional environment. The depositional nature of the harbor is further supported by radioisotope measurements taken in locations throughout the harbor (AECOM 2013, 2014), which showed net deposition at all locations. The harbor-wide hydrodynamics are driven by tides and freshwater flows from five major streams that flow from the surrounding watersheds into the harbor, and virtually the entire sediment load discharged to the harbor, approximately 578 tons/day, is attributable to the stream flows. Analysis of suspended stream sediments collected for the FS field investigation indicate clean incoming sediments from the major streams in Pearl Harbor (AECOM 2014). The study results showed that the potentially significant erosion mechanisms in the open water areas are resuspension by vessel propeller wash in the main channels (rate of approximately 52 tons/day) and hurricane events (75,600 tons of resuspension per event). A recent study of resuspension from propeller wash in Pearl Harbor indicated that tugboats running at maximum power at Bravo Pier resulted in erosion of 4 centimeters (cm) of the sediment bed at 48 feet water depth and 15 cm at 31 feet (Wang 2013).

Net deposition was also observed for under-pier areas based on radioisotope measurements taken from sediments under the piers. Wave and current velocity measurements taken from under-pier areas indicated very little wave activity and very low current velocity (AECOM 2014). The low-energy net depositional environment, the isolated nature of under-pier areas, and limited sediment transport suggest that potentially significant erosion by propeller wash and hurricane events is unlikely to remobilize and transport sediments from under-pier areas to other locations within the harbor.



LOCATION MAP



LEGEND

- Site Boundary
- Stream

NOTES

1. Map projection: Hawaii State Plane Zone 3, NAD83.
2. Aerial photo source: USGS Earth Data, Hawaii Data Clearing House.

N

0 0.25 0.5 1 Mile

Figure 1-1
Site Location Map
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

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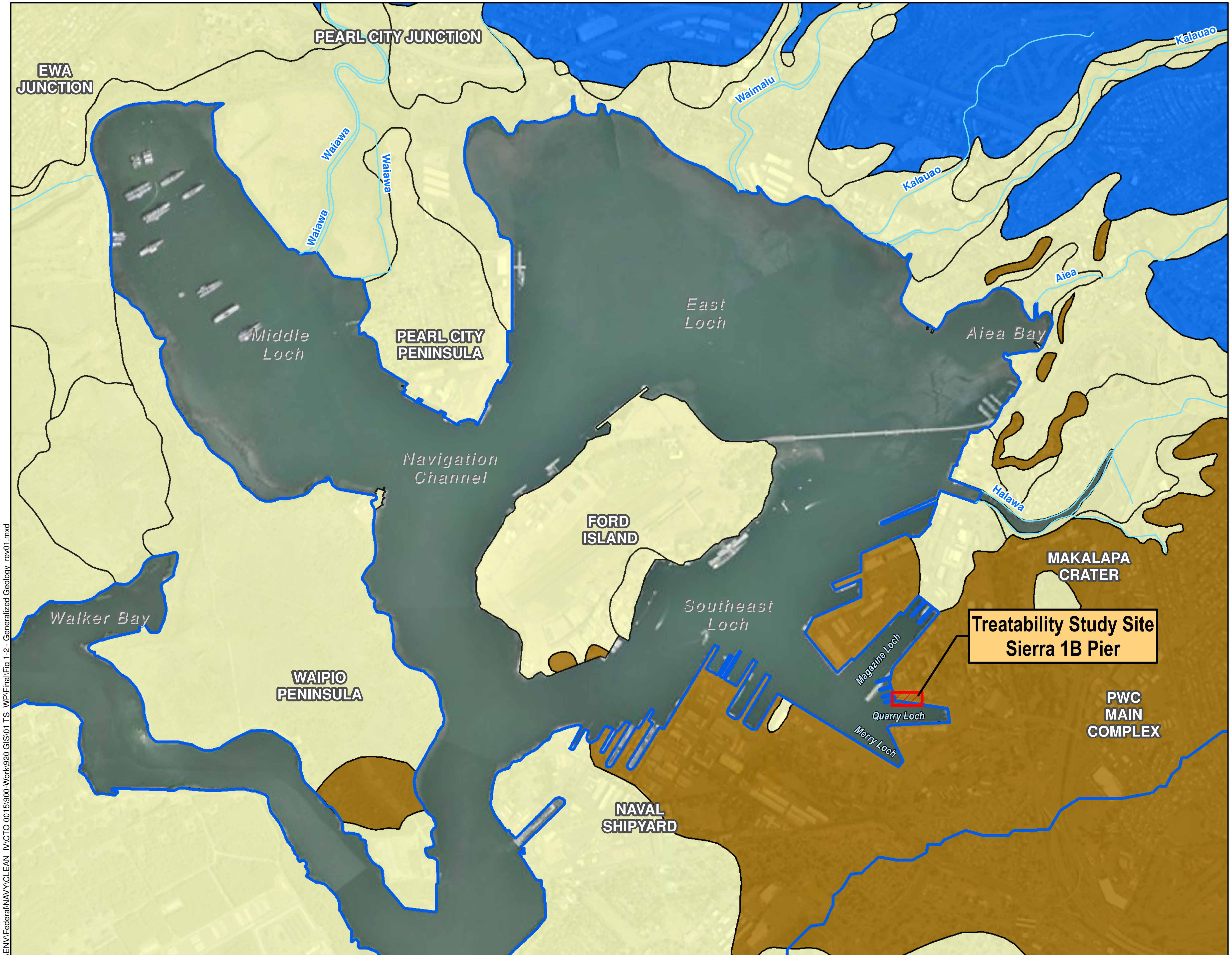

LEGEND

- Site Boundary
- Pearl Harbor Watershed Boundary
- Honolulu Volcanics
- Koolau Basalt
- Sedimentary Deposit
- Stream

NOTES

1. Map projection: Hawaii State Plane Zone 3, NAD83.
2. Aerial photo source: USGS Earth Data, Hawaii Data Clearing House.

N

0 0.25 0.5 1 Mile

Figure 1-2
Generalized Geology of the Pearl Harbor Watershed
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

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1.1.3 Ecological Habitat

The waters of Pearl Harbor contain two primary ecological zones based on substrate type: a soft bottom zone composed of unconsolidated sediment, and a hard substrate zone composed of fossilized reef material or anthropogenic items such as steel sheet piles, concrete piers, wooden piles, and sunken items (NAVFAC Pacific and HHF 2011, Appendix B2). The Draft Final FS report (AECOM 2014) indicated that both substrate types are also present under the piers. A Smith et al. (2006) survey of the marine community in Pearl Harbor and the entrance channel reported that piers and sunken derelict items provide important habitat for fish, corals, and green sea turtles, and that these items should not be removed unless they create a navigational hazard. Visual observations of under-pier areas during the FS investigation (AECOM 2014) indicated the presence of large debris consisting of coral and concrete rubble that provides habitable environment for fish, corals and green sea turtles; removal of these debris items as part of a remedial action can therefore reduce the extent of available habitat for marine organisms in Pearl Harbor.

1.2 Summary of the Pearl Harbor Sediment RI and FS Investigations

The RI Addendum report (AECOM 2013) recommended further consideration to address potentially unacceptable risks associated with exposure to sediments in seven specific areas where chemical of potential concern concentrations exceeded the preliminary remediation goals (PRGs). These seven areas were designated as decision units (DUs) in the RI Addendum report, and further refined to six DUs in the FS WP (AECOM 2012). Additional investigation conducted in the FS phase of the project refined the boundaries of the six DUs and narrowed the list of chemicals of concern (COCs) for the FS remedial alternative analysis. The DU locations and DU-specific COCs are identified on Figure 1-3. The surface area–weighted average concentration (SWAC) of each COC was calculated for sediment within each DU and compared to the appropriate PRG. The FS then developed RALs for the COCs with SWACs greater than the PRGs, and evaluated alternatives for remedial action to reduce the SWACs as necessary to achieve the PRGs.

The Draft Final FS report also identified the presence of sediments with COC concentrations above the PRGs under the piers in two DUs (DU SE-1: Southeast Loch and DU N-2: Off Oscar 1 and 2 Piers Shoreline), described as follows:

- For DU SE-1, under-pier COCs with both point concentrations and SWACs exceeding the PRGs include copper, lead, mercury, and total PCBs. The SWACs for copper and lead only slightly exceed the PRGs, and any remedial action to address the more widespread mercury and total PCBs will also address copper and lead. The RALs developed for DU SE-1 are 1.3 milligrams per kilogram (mg/kg) for mercury and 420 micrograms per kilogram (µg/kg) for total PCBs.
- For DU N-2, under-pier COCs with point concentrations exceeding the PRGs include cadmium, copper, lead, mercury, zinc, and total PCBs. Under-pier COCs with SWACs exceeding the PRGs are mercury and total PCBs. The RALs developed for DU N-2 are 1.4 mg/kg for mercury and 380 µg/kg for total PCBs.

The Draft Final FS report evaluated remedial actions only for under-pier areas with surface sediment concentrations of mercury and total PCBs exceeding the RALs.

The Draft Final FS report recommended thin-layer capping or amendment treatment as potentially the most feasible remedial action for under-pier areas within these DUs due to the pier structures and foundations limiting accessibility to the sediments for more conventional remedial technologies. The stream and storm drain outfall results from the FS field investigation confirmed that the streams are sources of clean sediments, but that sediments discharged from the storm drains may be an ongoing source of contamination that should be further evaluated before remedy implementation (AECOM 2013). Continuing sources from outfalls may potentially affect this TS by depositing contaminated sediment on top of the amendment layer. However, the AC amendment treatment proposed in this TS has the potential to treat a limited amount of newly deposited contaminated sediment.

1.3 UNDER-PIER AREAS IDENTIFIED FOR REMEDIATION OF SEDIMENTS

The overview of under-pier areas and sediments within DU SE-1 and DU N-2 presented below is based on available data and information collected during the FS field investigation (AECOM 2013). The data and information are provided as background on under-pier conditions and also to present the physical and chemical characteristics used to evaluate and ultimately chose a treatability study area.

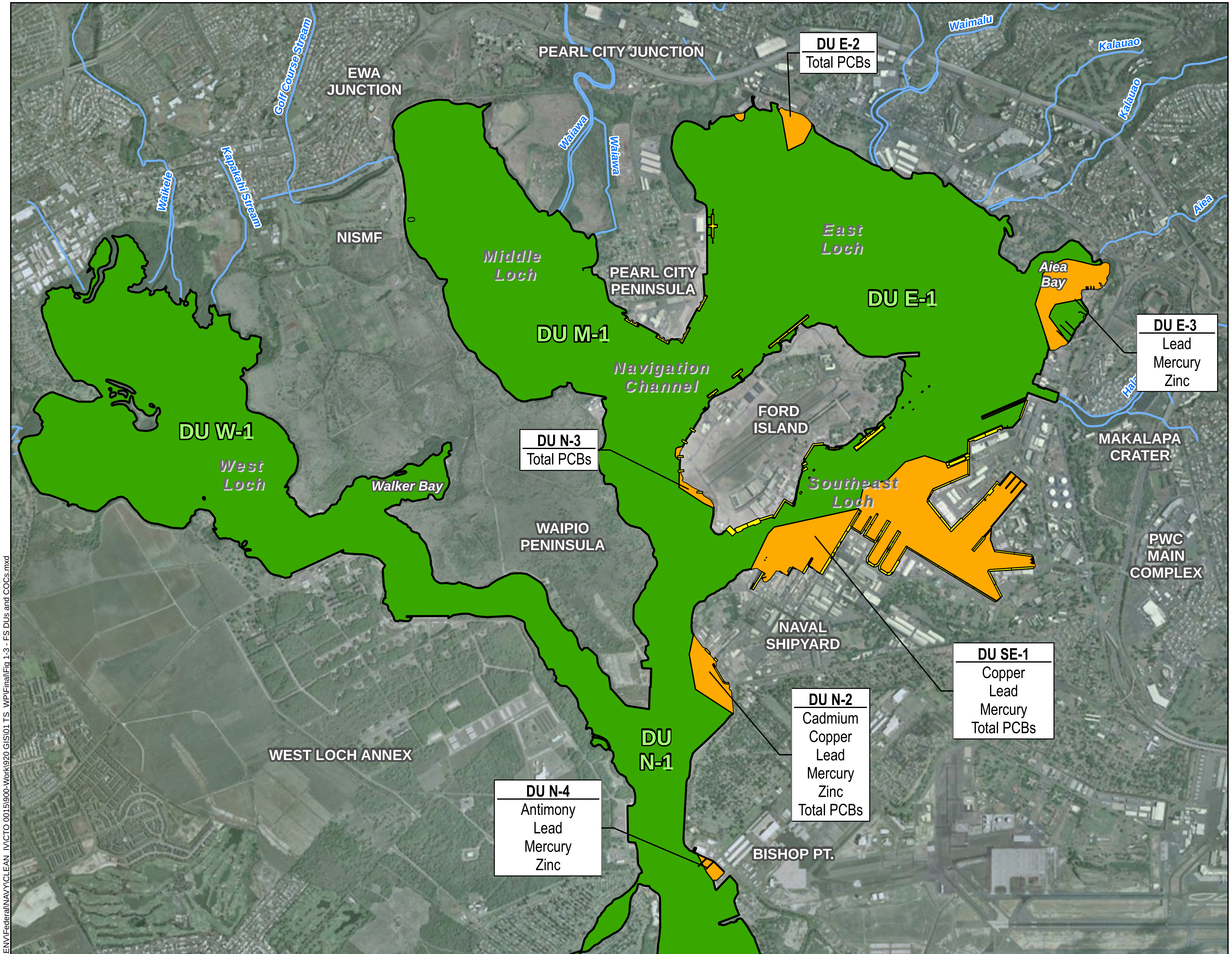
1.3.1 Physical Characteristics

Visual surveys were conducted at 11 under-pier locations within DU SE-1 and DU N-2. A survey of the bottom surface under the pier at each location was conducted along a single transect. Table 1-1 presents the physical observations documented during the visual survey. Figure 1-4 presents the bottom profiles along the survey transects under selected piers along with photographs of the bottom. The following is a summary of key observations from the survey:

- Pier widths range from 17 to 65 feet, as measured from the bulkhead (landside edge of the pier) to the edge of the piers (waterside edge of the pier).
- Spacing of pier pilings along the width of the piers range from 7 to 12 feet.
- Shallow water depths near the bulkheads are approximately 4 feet mean lower low water (MLLW), except at Sierra 8 Pier (SCP-07) and Yankee 3B Pier (SCP-09), which have water depths at the bulkhead of approximately 30 and 20 feet MLLW, respectively.
- The bottom profile is generally characterized by steep slopes (23–41 degrees), except for SCP-07, which is relatively flat (1 degree).
- The surface of the under-pier bottom floor is generally composed of soft sediments at the edge of the piers, transitioning to rip-rap and rocks with a thin veneer of sediments toward the bulkhead.
- Concrete rubble, metal debris, rock outcrop, shell fragments, and other hard substrates were observed at most locations.

Sediment samples from three under-pier locations (SCP-02, SCP-03, and SCP-04) were also analyzed for particle size distribution (PSD), as summarized in Table 1-2. The sample from SCP-02 at Bravo 1 Pier consisted primarily of sand and silt, whereas the sample from SCP-03 at Bravo 19 Pier was predominately silt. For SCP-04 at Bravo 22 Pier, surface sediment is primarily silt-sized particles overlying soft clay sediments.

Additional geotechnical data were collected using Sedflume analysis from location SCP-03 (Bravo 22 Pier), as presented in Table 1-3. The Sedflume data indicate critical shear stress values that are increasing with depth from 0.3 pascal (Pa) to a maximum of 1.23 Pa at the deepest depth interval sampled (17 cm below sediment–water interface [bswi]), indicating increasing sediment stability and resistance to erosion with depth. The relatively coarser particle size and lower shear stress characteristics near the sediment–water interface would facilitate easier penetration and mixing of amendment material for treatment of sediments in the biologically active zone (BAZ).



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LEGEND

- DU Identified for Sediment Remediation
- No Active Remediation DU
- Pier Structure
- Stream

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Decision Units (DUs) Identified for Sediment Remediation:
   DU SE-1: Southeast Loch
   DU N-2: Oscar 1 and 2 Piers Shoreline
   DU N-3: Off Ford Island Landfill and Camel Refurbishing Area
   DU N-4: Bishop Point
   DU E-2: Off Waiau Power Plant
   DU E-3: Aiea Bay
4. No Active Remediation (NAR) DUs:
   DU N-1: Majority of Navigation Channel
   DU W-1: West Loch
   DU M-1: Middle Loch
   DU E-1: Majority of East Loch

N

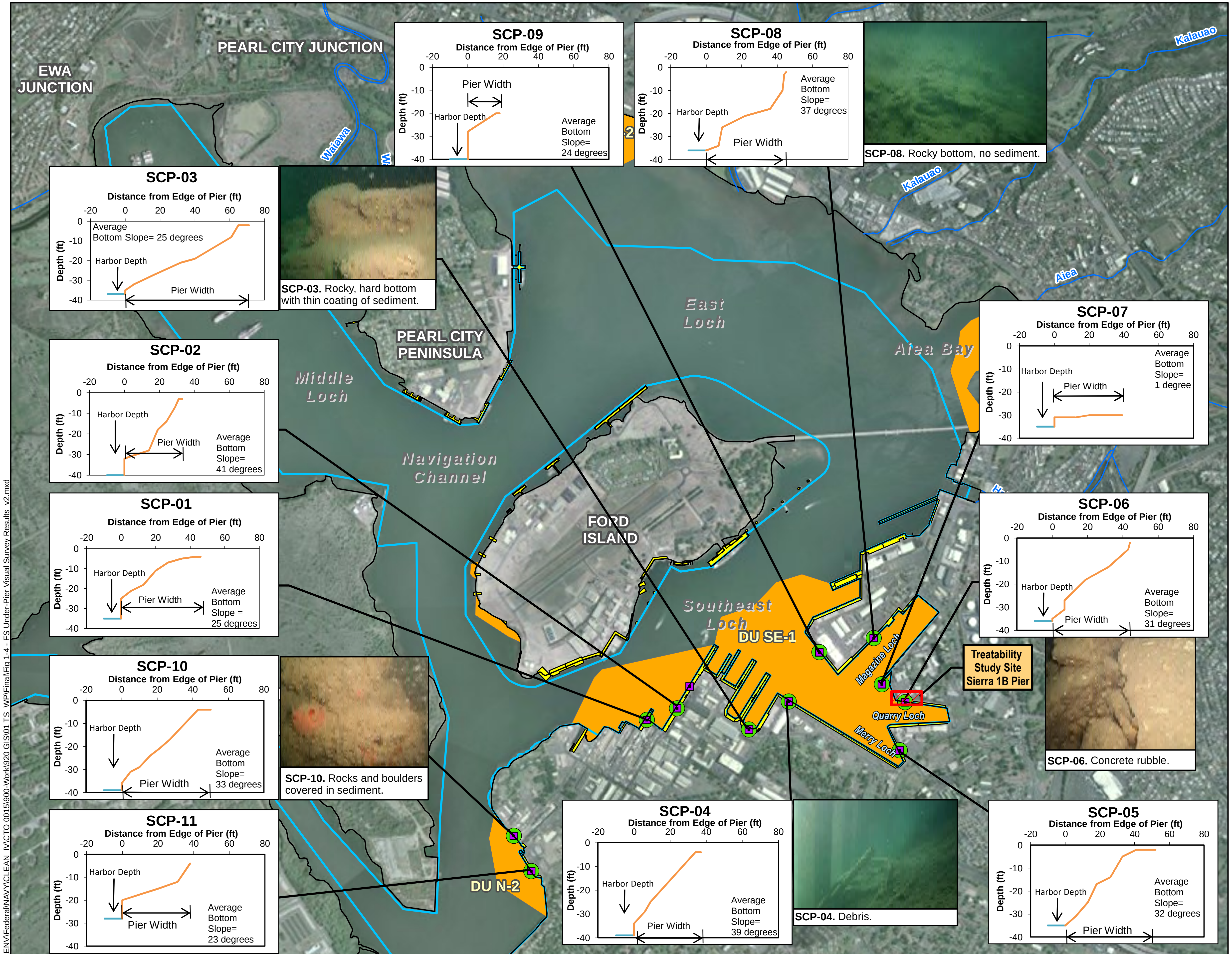
0 0.25 0.5 1 Mile

Figure 1-3
FS Decision Units
and Chemicals of Concern
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

Table 1-1: **Under-Pier Sediment Visual Observation Summary, Pearl Harbor FS Field Investigation**

Sample ID	Pier ID	Pier Width (ft) [a]	Water Depth (ft MLLW)		Mean Slope [b]	Visual Observations Along Transect from Pier's Edge to Bulkhead
			Pier Edge	Bulkhead		
SCP-01	GD 2	46	25	4	25	7 rows of pier piles between pier's edge and bulkhead, with 6–8 feet of spacing. The bottom floor at the first pile at the pier's edge is composed of soft, silty sediment with shell fragments. No shell fragments were observed in the silty sediment along the third pile, but are present along the fifth pile. A concrete drain, 2.5 feet wide and 5 feet high, was noted at the fourth pile with large keyholes and a drainpipe extending out of the block. Between the sixth and seventh pile, 35 feet inward from the pier's edge, the bottom is composed of rip-rap.
SCP-02	Bravo 1	33	32	3	41	6 rows of pier piles between pier's edge and bulkhead, with 4–10 feet of spacing. The bottom at the first pile is composed of soft, silty sediment with pebbles. The pebbles are not present in sediment at the second pile, and are replaced by the presence of shell fragments. This bottom type extends to approximately 23 feet inward from the pier's edge, where small stones and coral rubble are noted to be present in the sediments. The slope is relatively gentle within the first 15 feet of the transect from the pier's edge toward the bulkhead, followed by much steeper slope up to a 3-foot-wide ledge where the bulkhead sits. Rocks up to 3 feet in diameter are observed to be present on the ledge. Above the water, the gap between the pier deck and the hard substrate continues back approximately 20 feet from the bulkhead inland.
SCP-03	Bravo 19	71	35	2	25	6 rows of pier piles between pier's edge and bulkhead. The pier spacing is variable, between 5 and 20 feet apart. The bottom floor at the first pile is composed of soft, silty sediment. Behind the second row of pier piles, a band of rocks up to 0.5 foot in diameter is present. Interspersed silt and rocks bottom is observed between the second and fourth piles. The slope is relatively constant, with slight steepening at the sixth pile, 62 feet from the pier's edge, up to a ~7-foot ledge where the bulkhead sits. Concrete rubble is noted to be present on the ledge.
SCP-04	Bravo 22	37	34	4	39	5 rows of pier piles noted along transect of a steep slope up to a 4-foot-wide ledge where the bulkhead sits. The pilings are arranged in two sets: one set of three piles located within 10 feet in from the pier's edge, and another set of two piles at the ledge near the bulkhead. The sets are separated by approximately 25 feet where no piles are present. Bottom sediment is composed of soft silt intermixed with leaves and twigs along the first pile, extending toward the third pile where debris (1-foot-diameter rocks, concrete rubble pilings) are observed. The slope farther inshore is composed primarily of silt with scattered rocks 1 foot in diameter, leaves, twigs, and coral fragments. The ledge where the bulkhead sits is composed primarily of small pebbles.
SCP-05	Mike 1	52	35	2	32	8 rows of pier piles spaced relatively regularly between 5–8 feet apart are noted along transect. The bottom at the first pile is composed of soft, silty sediment with pebbles. Rock outcrop is noted at the third pile, approximately 13 feet inward from the pier's edge. The rock outcrop transitioned to a friable conglomerate of pebbles, clay, and sediment toward the bulkhead. This bottom type extends toward the sixth pile, approximately 34 feet in from the pier's edge, where 1-foot-diameter boulders are present. The rocky bottom extends to the bulkhead, which sits on a ledge at a water depth of 2 feet.
SCP-06	Sierra 1B	44	35	2	31	6 rows of pier piles are present under the pier, approximately 5–15 feet apart. The bottom is composed of very soft, silty sediment at the first pile. A vertical scarp is present at the second pile, approximately 7 feet in from the pier's edge. The scarp was formed by clay and debris backed up against the second row of piles. The slope from the scarp to the sixth and last pile is composed of clay, silt, and shells. The slope steepens from the sixth pile to the bulkhead (distance of approximately 2 feet), where the bottom consists of debris, rock, and concrete.
SCP-07	Sierra 8	39	31	30	1	3 rows of pier piles are present. The pier's edge extends approximately 12 feet from the first pile on one end, and 3 feet at the other end of the finger pier. The bottom is relatively flat and composed entirely of soft, silty sediment. Batter piles were observed extending down at an angle from the pier's deck, and were not intersected by the diver.
SCP-08	Sierra 21	45	36	2	37	6 rows of pier piles along transect, variable spacing of 3–20 feet. Soft silt sediment at first pile. 8-foot-high scarp noted approximately 6 feet inward from the pier's edge at the second pile. Silty muddy substrate is present behind the second pile. Soft sediment extends to a water depth of 10 feet, from which the slope steepens toward the bulkhead and the bottom is composed of rocks and concrete. Rip-rap is presented at the bulkhead. Intermittent batter piles are also present under the pier.
SCP-09	Yankee 3B	18	28	20	24	3 rows of pier piles noted along transect, approximately 6–10 feet apart. The bottom sediment at the first pile is composed of gravel and rocks up to 1 inch in diameter overlain with silt. This bottom type extends 16 feet inward from the pier's edge up to a ledge where the bulkhead sits. Rocks up to 0.5 foot in diameter are occasionally observed. The flat ledge where the bulkhead sits is covered by silt, concrete rubble, and debris.
SCP-10	Oscar 2	50	36	4	33	8 rows of pier piles noted along transect, spaced approximately 5–10 feet apart. The bottom sediment at the first pile is composed of soft silt with 1.5-foot-diameter rocks and shell fragments. The sediment thins at the third pile, and the diameter of the rock fragments decreases down to 0.5 foot. At the sixth row of piles, approximately 27 feet in from the pier's edge, the bottom is coarse sediment, debris, and rocks up to 0.5–1 foot in diameter. This bottom type extends up to the slope to a ledge, approximately 43 feet in from the pier's edge, where the bulkhead sits. Hard bottom is exposed, and coarse sediment covers much of the ledge. A concrete storm drain exits here, and the coarse sediment appears to come from the drain, appearing similar to black sand.
SCP-11	Oscar 1	38	20	4	23	2 rows of pier piles are noted along transect, spaced approximately 32 feet apart. The bottom is composed of sand with scattered concrete rubble. The bottom slopes gently upward consisting of rocks to 0.2 foot in diameter, coarse sediment, and pebbles. At the second pile, large boulders up to 4 feet in diameter appear with some debris. The bottom slopes upward more steeply after the second pile, with the presence of rocks up to 2 feet in diameter.

Source: AECOM (2014).
Note: Shaded row represents data collected under the pier selected for the TS (Sierra 1B).
ft foot/feet
ID identification
[a] Measured as the distance from bulkhead to the edge of the pier.
[b] Average slope in degrees, calculated as the water depth at pier edge minus the water depth at bulkhead and divided by the distance between pier edge and bulkhead.



LEGEND

- FS Under-Pier Sediment Sampling Location
- FS Under-Pier Visual Survey Location
- DU Recommended for Active Remediation
- Pier Structure
- Maintenance Dredging Footprint
- Stream
- Site Boundary

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Depth is measured in feet below mean lower low water (MLLW).
4. No photos at locations SCP-01, SCP-02, SCP-05, SCP-07, SCP-09, SCP-11 due to poor visibility.
5. Average bottom slope is calculated as the difference in depth between the start and end of the pier, divided by the pier width.

DU: Decision Unit

N

0 0.25 0.5 1 Mile

Figure 1-4
Under-Pier Bottom Profiles and Visual Observations from the FS Field Investigation
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

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Table 1-2: Particle Size Distribution Results for Under-Pier Locations, Pearl Harbor FS Field Investigation

Sediment Sampling Location ID	Pier ID	Descriptive Sample ID	Client ID	Sample Type	Grain Size (%)				PSD (µm)	
					Gravel	Sand	Silt	Clay	Mean	Median
DU SE-1 (Southeast Loch)										
SCP-02	Bravo 1	FR-SS-190-S-D1.0	FR0600	Surface	0.00	45.6	47.5	6.97	126	40.8
		FR-SC-190-S-D2.0	FR0601	Subsurface	0.00	53.4	40.7	5.91	133	68.6
SCP-03	Bravo 19	FR-SS-191-S-D1.0	FR0602	Surface	0.00	7.42	77.5	15.1	16.2	7.23
		FR-SC-191-S-D2.0	FR0603	Subsurface	0.00	10.1	80.9	8.98	21.1	10.6
		FR-SC-191-S-D3.0	FR0604		0.00	24.2	62.3	13.5	43.8	11.4
SCP-04/GT-04	Bravo 24	FR-SS-192-S-D1.0	FR0396	Surface	0.00	33.2	55.7	11.1	81.2	15.4
		FR-SC-192-S-D2.0	FR0397	Subsurface	0.00	42.1	47.0	10.9	68.5	35.1
		FR-SC-192-S-D3.0	FR0398		0.00	56.8	36.6	6.56	87.5	69.2

Source: AECOM (2014).
% percent
µm micrometer

Table 1-3: Sedflume Analysis Results for Under Bravo 22 Pier Sample SF-2 (DU SE-1), Pearl Harbor FS Field Investigation

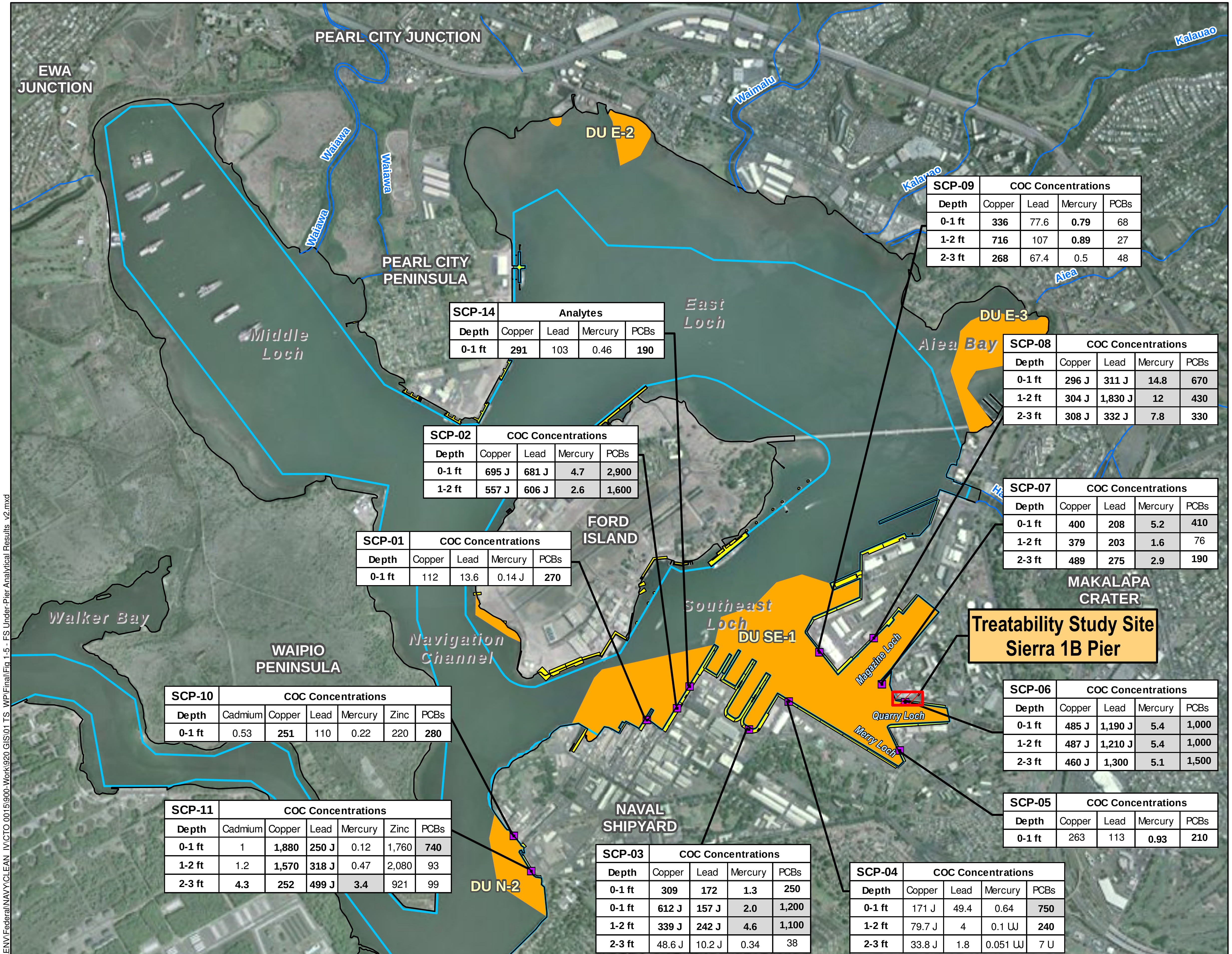
Water Depth (MLLW)					Depth (cm bswi)		Power Law Best-Fit Variables for Specified Core Depth Intervals					
Feet	Meters	Core Description	Mean Grain Size	Interval #	Start	Finish	A	N	R^2	Median Grain Size (D_{50}) (µm)	Bulk Density (ρ_b) (g/cm^3)	Critical Shear Stress Power Law (τ_{cr}) (Pa)
34.12	10.4	Loose, tan-colored silt that developed black-colored anoxic patches on the perimeter of the core sediment. The anoxic patches did not propagate horizontally into the sediment. A 2-mm-thick low-density sediment layer was present on the core surface. The top of the core also contained six white-colored worm tubes (diameters less than 0.5 mm) that extended deep into the sediment. One tube was present within the final depth interval of 17.4 cm. Clam shells and shell fragments were also present.	10.77 (silt)	1	0	1.55	0.0018	2.7	0.99	9.83	1.20	0.34
				2	2.7	7.15	0.0006	2.76	0.96	10.51	1.30	0.53
				3	9.2	11.7	0.0013	2.59	0.94	10.45	1.36	0.37
				4	13.1	16.5	0.0007	1.52	0.90	9.45	1.28	0.28
				5	17.4	18.6	3.76E–05	4.64	1.00	13.59	1.29	1.23
									Mean:	*10.77*	*1.29*	*0.55*

Source: AECOM (2014).
g/cm^3 gram per cubic centimeter
mm millimeter

1.3.2 Contamination in Under-Pier Areas

Sediment cores from under the piers up to 3 feet bswi were collected during the FS field effort and analyzed for DU-specific COCs at 1-foot depth intervals. Concentrations above the PRGs were reported for copper, lead, mercury, zinc, and total PCBs; however, only mercury and total PCBs have concentrations above the RALs developed in the FS. The concentration distributions of mercury and total PCBs in sediments within DU SE-1 and DU N-2 are shown on Figure 1-5. Analytical results of the under-pier sediment sampling are summarized as follows:

- DU SE-1 (Southeast Loch)
  - PCBs are prevalent in under-pier sediments within DU SE-1, with total PCB exceedances of the PRG reported for all but one of the under-pier sampling locations (SCP-09 under the Yankee 3B Pier). The maximum total PCB concentration (2,900 µg/kg) represents a surface sediment sample collected at SCP-02 (from under Bravo 1 Pier near the Dry Docks). The total PCB concentration reported for the surface sediment sample collected from under Sierra 1B Pier (the site of the TS) was 1,000 µg/kg. Elevated mercury concentrations are also widely distributed, with exceedances of the PRG reported for all locations except SCP-01 and SCP-14 (off the Dry Docks) and SCP-04 (off Bravo 22 Pier), and concentrations ranging up to 14.8 mg/kg (SCP-08, Magazine Loch). The mercury concentration reported for the surface sediment sample collected from under Sierra 1B Pier (the site of the TS) was 5.4 mg/kg.
  - Other exceedances of PRGs for metals include copper and lead, which are typically collocated with mercury exceedances. The maximum copper concentration (716 mg/kg) was reported for a subsurface (1–2 foot bswi) sediment sample collected at SCP-09. The maximum lead concentration (1,830 mg/kg) was reported for a subsurface (1–2 foot bswi) sample collected at SCP-08. The subsurface sediment data show no increasing or decreasing vertical concentration trends over the 0–3 foot depth interval.
- DU N-2 (Oscar-1 Pier)
  - Due to refusal, only a surface sediment (0–1 foot bswi) sample was collected from under Oscar 2 Pier (SCP-10); as shown on Figure 1-5, the copper and total PCB concentrations reported for this sample slightly exceed the screening criteria.
  - At Oscar 1 Pier (SCP-11), copper, lead, zinc, and total PCB concentrations exceeding the screening criteria were reported for the surface sediment samples, while cadmium and mercury exceedances were reported only for the subsurface samples. No total PCB exceedances were reported for the subsurface sediment samples from SCP-11. The copper and zinc concentrations reported for SCP-11 are relatively high, with values that are greater than 5× the screening criteria.



SCP-09	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	336	77.6	0.79	68
1-2 ft	716	107	0.89	27
2-3 ft	268	67.4	0.5	48

SCP-14	Analytes			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	291	103	0.46	190

SCP-08	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	296 J	311 J	14.8	670
1-2 ft	304 J	1,830 J	12	430
2-3 ft	308 J	332 J	7.8	330

SCP-02	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	695 J	681 J	4.7	2,900
1-2 ft	557 J	606 J	2.6	1,600

SCP-07	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	400	208	5.2	410
1-2 ft	379	203	1.6	76
2-3 ft	489	275	2.9	190

SCP-01	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	112	13.6	0.14 J	270

SCP-06	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	485 J	1,190 J	5.4	1,000
1-2 ft	487 J	1,210 J	5.4	1,000
2-3 ft	460 J	1,300	5.1	1,500

SCP-10	COC Concentrations					
Depth	Cadmium	Copper	Lead	Mercury	Zinc	PCBs
0-1 ft	0.53	251	110	0.22	220	280

SCP-05	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	263	113	0.93	210

SCP-11	COC Concentrations					
Depth	Cadmium	Copper	Lead	Mercury	Zinc	PCBs
0-1 ft	1	1,880	250 J	0.12	1,760	740
1-2 ft	1.2	1,570	318 J	0.47	2,080	93
2-3 ft	4.3	252	499 J	3.4	921	99

SCP-03	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	309	172	1.3	250
0-1 ft	612 J	157 J	2.0	1,200
1-2 ft	339 J	242 J	4.6	1,100
2-3 ft	48.6 J	10.2 J	0.34	38

SCP-04	COC Concentrations			
Depth	Copper	Lead	Mercury	PCBs
0-1 ft	171 J	49.4	0.64	750
1-2 ft	79.7 J	4	0.1 UJ	240
2-3 ft	33.8 J	1.8	0.051 UJ	7 U

LEGEND

- FS Under-Pier Sediment Sampling Location
- DU Recommended for Active Remediation
- Pier Structure
- Maintenance Dredging Footprint
- Stream
- Site Boundary

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. PCB results are reported as Total NOAA-18 PCB concentrations.
4. Sampling depth is in feet bswi.
5. Metals are reported in mg/kg; PCBs are reported in µg/kg.
6. Bold value indicates exceedance of PRG; shaded value indicates exceedance of RAL.
7. Data qualifiers:
   J - Estimated concentration
   U - Non-detect
   UJ - Estimated non-detect concentration
8. Sediment PRG and RAL:

Chemical of Concern	Preliminary Remediation Goal (PRG)	Remedial Action Level (RAL)	
Cadmium	3.2 mg/kg	N/A	
Copper	214 mg/kg	N/A	
Lead	119 mg/kg	N/A	
Mercury	0.71 mg/kg	DU SE-1	1.3 mg/kg
		DU N-2	1.4 mg/kg
Zinc	330 mg/kg	N/A	
Total PCBs	170 µg/kg	DU SE-1	420 µg/kg
		DU N-2	380 µg/kg

N/A RAL not developed for chemical of concern

Acronyms:
bswi below sediment water interface
COC Chemical of Concern
DU Decision Unit

N

0 0.25 0.5 1 Mile

Figure 1-5
Under-Pier Sediment Sampling Analytical Results from the FS Field Investigation
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

P:\ENV\Federal\NAVY\CLEAN IV\CTO 0015\900-Work\920 GIS\01 TS_WP\Final\Fig 1-5 - FS Under-Pier Analytical Results_v2.mxd

1.3.3 Sediment Transport and Deposition Rate in Under-Pier Areas

The 2012 FS field investigation also deployed single-point acoustic doppler velocimeters to characterize waves and currents at under-pier areas within DU SE-1 and DU N-2. Results of the measurements are summarized as follows:

- Horizontal current velocities under the piers were extremely low, rarely exceeding 0.1 meter per second (m/s).
- Average current velocity magnitudes were generally less than 0.01 m/s.
- The lack of measurable waves precluded accurate derivations of significant wave height (H_s), peak wave period (T_p), and peak wave direction (D_p); H_s was estimated at less than 10 cm, and T_p at less than 5 seconds, which are indicative of very small wind-induced waves.

Three sediment cores were collected from three under-pier locations (two in DU SE-1; one in DU N-2) and submitted for radioisotope analysis to calculate sediment deposition rates. Sediment deposition rates are summarized as follows:

- *DU SE-1.* Two geochronology cores (RIP-01 and RIP-02) representing under-pier locations were submitted for radioisotope analysis. The estimated sediment deposition rate for under-pier locations in DU SE-1 is 0.43–1.4 inches per year (in/y) (1.1–3.6 centimeters per year [cm/y]).
- *DU N-2.* One geochronology core (RIP-03) representing an under-pier location was submitted for analysis. The estimated sediment deposition rate in DU N-2 is 0.44 in/y (1.1 cm/y).

The sediment transport measurements and radioisotope data indicate that under-pier areas are typically characterized by a low-energy depositional environment, with very low current velocities and limited wave action; therefore, amendment material placed on surface sediment under these conditions will likely not be remobilized, and treatment of contaminated sediments with amendment materials should continue to be effective in the long term.

1.3.4 Potential Data Gaps in Under-Pier Investigation

Although the Pearl Harbor FS field investigation included a significant investigation of the under-pier areas, additional information is needed to prepare an effective remedial design. Of the 14 locations sampled for sediment, six had limited core recoveries due to refusal because of encountering hard substrate. This suggests non-uniform thickness of sediments present under the piers and potential preferential deposition of sediments due to uneven underlying substrate. Most locations had COC exceedances extending to the bottom of the core; thus, the vertical extent of contamination was not fully delineated. Visual surveys under the 14 piers identified substantial pieces of debris, rocky bottom substrate, and steep slopes. Physical obstructions such as pilings and debris, if not accurately delineated, will cause complications with remedy implementation. Under-pier bottom steepness and sediment characteristics affect the stability of the sediment or placement of material. For steep slopes, additional measures may be needed to keep the amendment materials in place. Although the FS field investigation took measurements to evaluate contaminant concentrations, sediment characteristics, and under-pier physical conditions, further data to establish the baseline extent of contamination, evaluate the current bioavailability of the chemicals, and provide an accurate physical depiction of under-pier conditions are required to implement and monitor an amendment treatment.

1.4 POTENTIAL REMEDIATION TECHNIQUES FOR UNDER-PIER SEDIMENTS

The Pearl Harbor Sediment Draft Final FS report evaluated the need for active remediation in under-pier areas using the data presented on Figure 1-5 and the DU-specific RALs developed in the FS (AECOM 2013). The FS recommended that under-pier areas with surface sediment COC concentrations exceeding the RAL criteria be evaluated for remedial alternatives, as highlighted on Figure 1-6. The COCs exceeding the RALs that would be addressed through remediation are mercury and total PCBs. Approximately 13 acres of under-pier areas in DU SE-1 and 0.7 acre in DU N-2 were recommended for remediation.

Conventional remediation techniques for contaminated sediment include removal through dredging (e.g., mechanical or hydraulic), monitored natural recovery (MNR) or enhanced natural recovery (ENR), in-situ containment (e.g., capping), and in-situ treatment (e.g., amendment). The feasibility of each technique to remediate sediments in under-pier areas of Pearl Harbor is assessed in the Draft Final FS report (AECOM 2014), as summarized below. The FS report proposed thin-layer capping/in-situ treatment as the technology to remediate under-pier sediments in DU SE-1 and DU N-2.

1.4.1 Dredging

Mechanical dredging would not be feasible in the under-pier areas of Pearl Harbor because the equipment cannot be maneuvered under the piers. Hydraulic dredging could be an option with the assistance of a diver guiding the intake. However, hydraulic dredging requires the sediment to be agitated into a slurry, which would require a large dewatering system and suspend sediments in the water column, increasing the potential for recontamination. Additionally, diver-assisted suction dredging under piers would not remove all contaminated sediment and would leave a residual layer of contamination that may require capping.

Other concerns associated with diver-operated dredging include limited visibility, diver safety concerns (physical hazards and resuspended contaminants), and low production rates. The presence of debris and other material combined with the limited access would most likely preclude effective dredging in under-pier areas.

1.4.2 Monitored/Enhanced Natural Recovery

Natural recovery of in-place contaminated sediments involves one or more physical, chemical, and biological processes that effectively reduce COC concentrations, restrict mobility of the COCs, or reduce their toxicity over time. MNR and ENR are remedial technologies that involve long-term monitoring of ongoing natural recovery. Natural recovery typically relies on adsorption/sequestration of the COCs combined with burial and mixing with clean sediments deposited over time. ENR refers to placement of a relatively thin layer of clean material, typically sand, to enhance and accelerate ongoing natural recovery processes by covering and mixing with the natural surface sediments. Application thicknesses of approximately 6–12 inches are common, producing an immediate reduction in surface sediment COC concentrations. For MNR and ENR, successful reduction of COC bioavailability would not be achieved in the short term and an extensive monitoring program would be required. If remedial goals are not achieved in the short term, then under-pier areas also represent a potential source of recontamination for other areas of Pearl Harbor.

LEGEND

Under-Pier Area Recommended for Thin-Layer Capping/In-Situ Treatment

Under-pier No Action Area

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.

N

0 375 750 1,500 Feet

Figure 1-6
Under-Pier Remediation Footprint
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

1.4.3 Conventional In-Situ Capping

Capping can quickly reduce exposure to contaminants, and compared to removal, requires less equipment and infrastructure for material handling, dewatering, treatment, and disposal. A well-designed and well-placed cap can quickly reduce the risk to fish and other aquatic receptors that live in the water column. Although capping will eliminate much of the benthic community in the short term, the habitat can be recolonized relatively quickly if the cap materials are compatible with the existing sediments. Capping is applicable to areas where access is limited (e.g., under piers where remedial actions such as dredging may compromise the integrity of the structure).

Geotechnical properties of surface sediment (e.g., shear strength, plasticity, consolidation, and grain size) must be evaluated to determine the suitability of in-situ cap application. Most contaminated sediment in Pearl Harbor is fine-grained, with high water content and relatively low shear strength. Although a cap can be constructed on sediment with low shear strength, the ability of the sediment to support a cap and the potential for displacement of contaminated sediment during cap construction must be considered. A risk associated with a conventional cap is that COCs from subsurface sediments may migrate into the overlying cap and water column, but this can be minimized by ensuring that the cap thickness is sufficient for the location of concern. The primary concern associated with in-situ containment is that contaminated sediments are left in place, and therefore, could potentially be exposed or dispersed if the cap is compromised.

1.4.4 Amendment Treatment

Amendment treatment consists of placing sorbent material over the existing sediment surface, limiting exposure of the contaminants. Amendment material refers to the technology where reactive materials (e.g., AC) are placed on top of contaminated sediment or mixed into the existing surface sediment to react and bind with, and thereby reduce bioavailability of, the COCs. The use of these techniques depends on location-specific considerations. All remedial actions beneath and adjacent to the piers must account for the potential structural ramifications of amendment addition, as well as the difficulty of implementing remedial actions in limited-access areas.

Because in-situ treatment frequently involves addition of reactive materials to conventional sediment capping materials, some of the potential concerns associated with this technology are similar to those described above for in-situ capping. Additional factors that can affect successful treatment with amendment materials include amendment selection, material stability, uniform placement, proper dosing, particle size, mixing, bioturbation, and benthic effects. Amendment treatment can be an appropriate remedial alternative for sediments in areas where dredging is not likely to be feasible, such as under piers and around pilings, at locations where overdredging is not possible, in areas with subsurface debris, and at ecologically sensitive sites where dredging would damage or destroy habitat.

For under-pier locations in Pearl Harbor, amendment treatment is likely to be more resilient and effective for remediating contaminated sediment in the long term compared to dredging or conventional capping. In-situ treatment with sorbent materials such as AC will not decrease chemical concentrations in the sediments, but can decrease the mobility and bioavailability of the COCs within a relatively short period, resulting in decreased exposure to benthic and aquatic organisms and higher-trophic-level receptors (including humans) through ingestion, dermal absorption, and bioaccumulation. Over long periods, sedimentation is expected to occur, covering the amendment treatment layer. If incoming sediments are contaminated, an amendment material could continue to bind COCs, effectively providing long-term remediation in areas with low sedimentation rates, such as under piers. In addition, because the AC, binder, and weighting material is mixed into the sediment (e.g., with bioturbation), the sediment's effective particle size is increased, thereby potentially creating a more stable layer that is more resistant to resuspension. If the sediment does become resuspended and is transported, the amendment will also be transported, thus continuing to bind contaminants.

2. Project Quality Objectives for the Treatability Study

2.1 STATE THE PROBLEM

Concentrations of total PCBs and mercury in certain under-pier sediments in Pearl Harbor exceed the RALs identified in the Draft Final Pearl Harbor Sediment FS report (AECOM 2014). It has been determined that dredging and MNR/ENR in under-pier areas are not viable remedial options (AECOM 2014).

In-situ treatment of contaminated sediment through the installation of amendment materials has been identified in the Draft Final Pearl Harbor FS as the most viable remedial option for these under-pier areas. The TS will answer questions related to material options, effectiveness, placement techniques, and stability. Information gathered and documented during this study will allow for more efficient placement of the amendment over the additional under-pier areas requiring remediation.

2.2 IDENTIFY STUDY GOALS

This project is intended as a pilot-scale test of the application of AC to decrease the bioavailability of PCBs and other COCs in contaminated sediments with the eventual goal of using this methodology, as needed, on a larger scale within Pearl Harbor. Due to their affinity for organic carbon, clays, and oxides/hydroxides of aluminum, iron, and manganese, the COCs identified for Pearl Harbor sediments (copper, lead, mercury, and total PCBs) have limited mobility in the dissolved phase; therefore, treating with “active” materials such as AC, organoclays, or other sorptive materials is likely to be particularly effective in Pearl Harbor. The amendment treatment would consist of a thin layer of bulk AC or AC delivery material over the existing sediment surface. This would effectively contain the contamination in-situ, preventing or limiting exposure to COCs in the sediments. Amendment treatment refers to the technology where reactive or sorptive materials (e.g., AC slurry, AquaGate+PAC [powdered AC], or SediMite) are placed on top of contaminated sediments or mixed into the existing surface sediments to react and bind with the COCs and reduce bioavailability.

The TS objectives are to evaluate constructability of applying a thin-layer of amendment material over the existing sediment surface given the restricted space and access of under-pier areas, and to assess the effectiveness of the approach for reducing risks to human and ecological receptors by decreasing the bioavailability of mercury and total PCBs. The specific goals of the TS are as follows:

- Identify the type of amendment material that will provide optimal performance, balanced by constructability and cost.
- Identify how to effectively place and stabilize an amendment in an under-pier area.
- Determine if amendment material can reduce the bioavailability of COCs in an under-pier area to acceptable levels, and develop and test methods for monitoring to confirm successful remediation.

2.3 IDENTIFY THE INFORMATION INPUTS

To evaluate the effectiveness of the sediment amendments, performance monitoring is specifically designed to assess physical parameters (placement, distribution, stability, and mixing), chemical parameters (bulk sediment and porewater chemistry), and biological parameters (bioturbation evidence, comparison of porewater results to known toxic effects levels, and laboratory bioaccumulation testing).

Physical performance of the amendment will be evaluated using the following parameters:

- *Placement and Distribution.* The study will document how effective and efficient the placement of the material is and whether it was installed in the under-pier area per the design specifications. Proper placement is crucial since good lateral coverage and the minimum designed thickness are necessary for long-term remediation success. Many factors can affect the proper placement of the amendment material. A variety of placement techniques may be used to accommodate different under-pier conditions.
- *Stability.* The study will evaluate the stability of the amendment during the placement, immediately after installation, and at the 9- and 18-month monitoring events. During the physical evaluation of the pre-placement under-pier setting, divers will document areas that show evidence of slope stability issues, propeller wash scour, and stormwater outfall scour. Based on findings presented in the RI report (Earth Tech 2007), RI Addendum report (AECOM 2013), and Draft Final FS report (AECOM 2014), currents and wave action are not expected to adversely affect stability. Over time, as the amendment continues to mix with the top layer of sediment and new sediment is deposited, stability will continue to improve.
- *Mixing.* The study will document the degree that AC from the amendment material mixes with the top layer of sediment. A certain amount of gravity mixing is expected, but the mixing by bioturbation can be variable. The level of mixing based on visual and chemical evidence will be documented. Mixing will be evaluated using sediment profile imaging (SPI) to visualize the vertical distribution of the AC in the sediment, with the expectation that as time passes, the AC mixing will become more uniform. Mixing will also be numerically quantified by measuring the total organic carbon (TOC) and black carbon content of the sediment. Because AC is a direct addition of black carbon to the sediment, it is expected that TOC and black carbon concentrations will increase in direct proportion to the percentage of AC added.

Chemical performance is primarily based on COC porewater chemistry. It is expected that porewater COC concentrations will reduce in the treated sediment over time. This parameter can be greatly influenced by how effectively the AC has mixed with the surface sediments. As porewater chemistry is monitored, a relationship should be evident between mixing depth and percent reduction. This relationship will be documented through comparison of the physical parameters with the analytical data. The study will also attempt to document this relationship over time by analyzing porewater in selected locations at the depth where mixing is observed and at the interval below that level. It is possible that additional time will be necessary to achieve complete mixing of the amendment by natural processes. The study will document the progress of the treatment over the 18-month period and estimate the time required for the treatment to reach maximum effectiveness. If porewater contaminant concentrations have been reduced to acceptable levels in the observed BAZ where AC mixing is taking place, then the chemical performance will be considered effective and successful.

Biological performance will be based on the bioaccumulation of PCBs in test organisms, because PCBs are the primary human health risk drivers identified in the FS. Ex-situ bioassays will be conducted using sediment samples collected from the site. If the bioaccumulation tests show that PCB concentrations are reduced, then the treatment will be considered successful. Laboratory benthic infauna assessment samples will also be collected during the baseline and 18-month performance monitoring to document taxonomy and populations.

The monitoring of multiple parameters will enable an evaluation of the amendment performance in an active harbor setting, including the feasibility of deep-water amendment placement, the stability of the amendment, the reduction of COC bioavailability, and the observable impact to or enhancement of the benthic community (ESTCP 2012). The performance parameters will be used to verify that the amendment is working as designed and that the lines of evidence are being supported. These parameters will also assist in the determination of areas to improve or modify in the event that the amendment treatment is not completely effective.

Data inputs for the physical, chemical, and biological parameters necessary to complete the TS are detailed below.

2.3.1 Physical Performance Inputs

A critical element of the TS is to understand the under-pier physical setting, including sediment characteristics.

2.3.1.1 Diver Surveys of Under-Pier Physical Conditions

Diver surveys will be conducted along transect lines to assess the under-pier physical setting and to conduct a visual inspection of surface sediment. Transects will begin 10 feet from the northwestern end of the pier and are spaced 25 feet apart. Survey locations are located at 5, 15, 25, and 35 feet from the leading edge of the pier along each transect. The visual inspection results will be documented through photographs and notes taken by the divers. Photographs of specific locations will be documented and replicated following amendment treatment. Divers will also document conditions along the perimeters of the test plots.

Divers will document the following information:

- Visual aspects of the sediment surface (i.e., soft sediment, silt, sand, rock, rubble, or other debris) at each sampling location, and evidence of recent sediment movement or changes in slope
- Debris or boulders that may impede amendment placement
- Sediment thickness at each survey location by manually pushing a ½-inch-diameter sediment probe to 3 feet bswi or refusal
- Bottom depth every 5 feet along each transect (depth below the water surface elevation at time of measurement)
- Installation of sediment thickness gauges at certain locations to evaluate sediment deposition and amendment placement
- Visual evidence of propeller wash scour or existing slope failures
- Pile spacing

2.3.1.2 Sediment Profile Imaging

SPI will be used to visually characterize sediment in the under-pier area. SPI is an optical coring device that generates a periscope-like cross-sectional image of the upper layer of sediment (Germano et al. 2011). The SPI device will record a high-quality image of the upper 20 cm of sediment. The primary use of the SPI images will be to provide vertical imagery of the sediment to assess the vertical distribution of amendment and evidence of bioturbation in the under-pier area.

2.3.1.3 GEOCHEMICAL AND GEOTECHNICAL PARAMETERS

This data input consists of measurements of the geochemical and geotechnical characteristics that affect potential stability, chemical partitioning, and bioavailability in the sediment environment. Each sediment sample will be inspected and photographed in the field. The following characteristics will be recorded on sediment sampling logs:

- Estimated sampling depth (bswi)
- Sediment texture (i.e., estimated percentages of sand, silt, and clay)
- Presence of biota or debris
- Extent of bioturbation
- Color changes

Sediment samples from locations along the transect lines will be submitted for laboratory analysis of the following geochemical and geotechnical parameters by the indicated methods:

- pH (EPA SW-846 Method 9040C)
- Wet bulk density (WBD) (ASTM [2005] D2937)
- Moisture content (NOAA 1993)
- TOC (Lloyd Kahn [1988] method) and black carbon (Gustafsson 2001)
- PSD (ASTM [2007] D422)
- Atterberg limits (ASTM [2010b] D4318)
- Hydraulic conductivity (ASTM [2010c] D5084)

2.3.2 Chemical Performance Inputs

Baseline monitoring of the chemical characteristics of the under-pier sediments is vital to establishing a pre-amendment starting point for the monitoring of changes over time during the TS.

2.3.2.1 BULK SEDIMENT CHEMISTRY

This data input consists of analytical data representing COC concentrations detected in surface sediments (0–6 inches bswi) to supplement existing data for a more complete understanding of the horizontal extent of contamination in the under-pier area. Surface sediment samples will be analyzed for total PCBs, copper, lead, and mercury. The bulk sediment chemistry data will also be used to evaluate correlation between COC concentrations in the surface sediment and associated porewater. This correlation may assist in evaluating future sites based on data representing whole sediment samples, and verifying the relationship with a limited number of porewater samples.

Surface sediment samples will be collected at locations along the transects (at the same locations as the geochemical samples). Divers will collect sediment cores using either a polycarbonate-tube push corer or a hammer corer to a minimum recovery of 6 inches bswi.

At each designated sampling location, the diver will insert the tube vertically into the sediment until refusal or full penetration is reached. If refusal is reached before 6 inches bswi, then the diver will relocate the sampling location within 2 feet of the original location, making a maximum of three relocation attempts.

Sediment samples will be sent to an analytical laboratory for analysis of total PCBs (2 times the sum of the National Oceanic and Atmospheric Administration [NOAA]-18 congeners) by U.S. Environmental Protection Agency (EPA) SW-846 Method 8082A, mercury by EPA SW-846 Method 7471B, and copper and lead by EPA SW-846 Method 6020A. Sample preparation, preservation, shipping, and analytical procedures will be identical to those used for the FS field investigation, as reported in the Pearl Harbor Sediment FS report (AECOM 2014) and detailed in the FS WP (AECOM 2012).

2.3.2.2 POREWATER CHEMISTRY

This data input consists of analytical data representing COC concentrations in sediment porewater collected using passive sediment samplers. The passive sampling technologies to be used are solid-phase micro-extraction (SPME) and diffuse gradients in thin film (DGT). SPME and DGT will be used to assess the porewater concentrations of total PCBs and metals, respectively:

- *SPME Device.* A SPME device consists of a length of fiber-optic cable. The inner core of the fiber is inert glass, which does not absorb hydrophobic chemicals, while the outer insulating coating consists of the polymer polydimethylsiloxane (PDMS), an absorptive material shown to be an effective passive sampler for hydrophobic chemicals (EPA 2012). The PDMS coating can range from 10 to 100 micrometers thick. Because the device will be deployed in sediment, which typically has higher COC concentrations than the water column, the PDMS coating should be relatively thin. The fiber should be as long as the surface interval of 6 inches. The concentration of dissolved COC in the porewater (COC_D) can be calculated from the COC concentration measured in the passive sampler (COC_{SPME}) by dividing by the SPME-dissolved phase partition coefficient ($K_{SPME,D}$) (EPA 2012):

$$COC_D = \frac{COC_{SPME}}{K_{SPME,D}} * 1{,}000$$

  SPME devices are useful because they can easily penetrate an installed treatment layer and achieve equilibrium more quickly than other polymer-based passive samplers (e.g., polyethylene and polyoxymethylene). Devices placed (by divers) into shallow sediments can provide an indication of whether or not the amendment is currently working to limit bioavailability. Devices placed more deeply into the sediment can provide an indication of possible future amendment success or failure. The SPME fibers will be placed in a stainless-steel mesh tubing to protect them during deployment.

- *DGT Probe.* A DGT probe is a useful monitoring tool for metals in complex chemical environments. DGT uses a three-layer system consisting of a resin-impregnated hydrogel layer, a hydrogel diffusion-layer, and a filter membrane. Metal ions diffuse through the filter membrane and hydrogel layer and are accumulated in the resin layer. This resin layer is then digested with acid and analyzed. Given a known temperature during the time the probe is deployed, the concentration of metals in the sediment porewater can be calculated. The DGT device, therefore, passively accumulates bioavailable chemical species from solution while deployed in-situ.

Divers will deploy the SPME and DGT samplers in the surface sediment (0–6 inches bswi) in a vertical orientation along the transects. The samplers will be deployed for periods of approximately 28 days. Divers will retrieve the samplers at the end of the deployment period. The samplers will be shipped to an analytical laboratory for analysis.

2.3.3 Biological Performance Inputs

Diver surveys, SPI, and laboratory analysis will be used to assess the benthic community before and after implementation of the amendment treatment. The benthic community will be evaluated for visual evidence of bioturbation in the upper 1 foot of sediment. Diver observations will be conducted at the physical survey locations, and a SPI survey will be conducted as discussed in Section 2.3.1.2.

In addition to field observations, benthic infauna samples will be collected during the baseline and 18-month performance monitoring for laboratory assessment. A taxonomic analysis will be performed to accurately identify all organisms contained within study area samples, to the lowest possible taxonomic category. An accurate count of the organisms in each identified taxon will be documented. Results will be used to compare benthic communities before and after placement of amendment.

Bioaccumulation Exposure Study - Under-pier sediment bioaccumulation will be assessed with ex-situ bioassays. Sediment samples will be collected during the baseline survey and during the 18-month monitoring event. Sediment samples submitted for bioaccumulation exposure studies should be representative of the entire study area. Nine undisturbed cores will be collected from each test plot.

The sediment core samples will be sent to a biological laboratory for use in bioaccumulation exposure studies. These studies will consist of 28-day clam exposures using wild *Macoma nasuta*. The 28-day exposure studies will be conducted using standard and modified methods as defined in EPA (1993), EPA and USACE (1991, 1998), and ASTM (2010a) guidance. Once the 28-day exposure period is complete, organisms will be removed from the study sediment and allowed to purge for 24 hours in clean water with no sediment. After the purge period, the clams will be shucked, rinsed with deionized water, placed in certified clean glass jars provided by the analytical laboratory, and frozen. The frozen samples will be shipped on ice to the analytical laboratory where they will be analyzed for total PCBs (NOAA-18 congeners), lipids, and percent moisture.

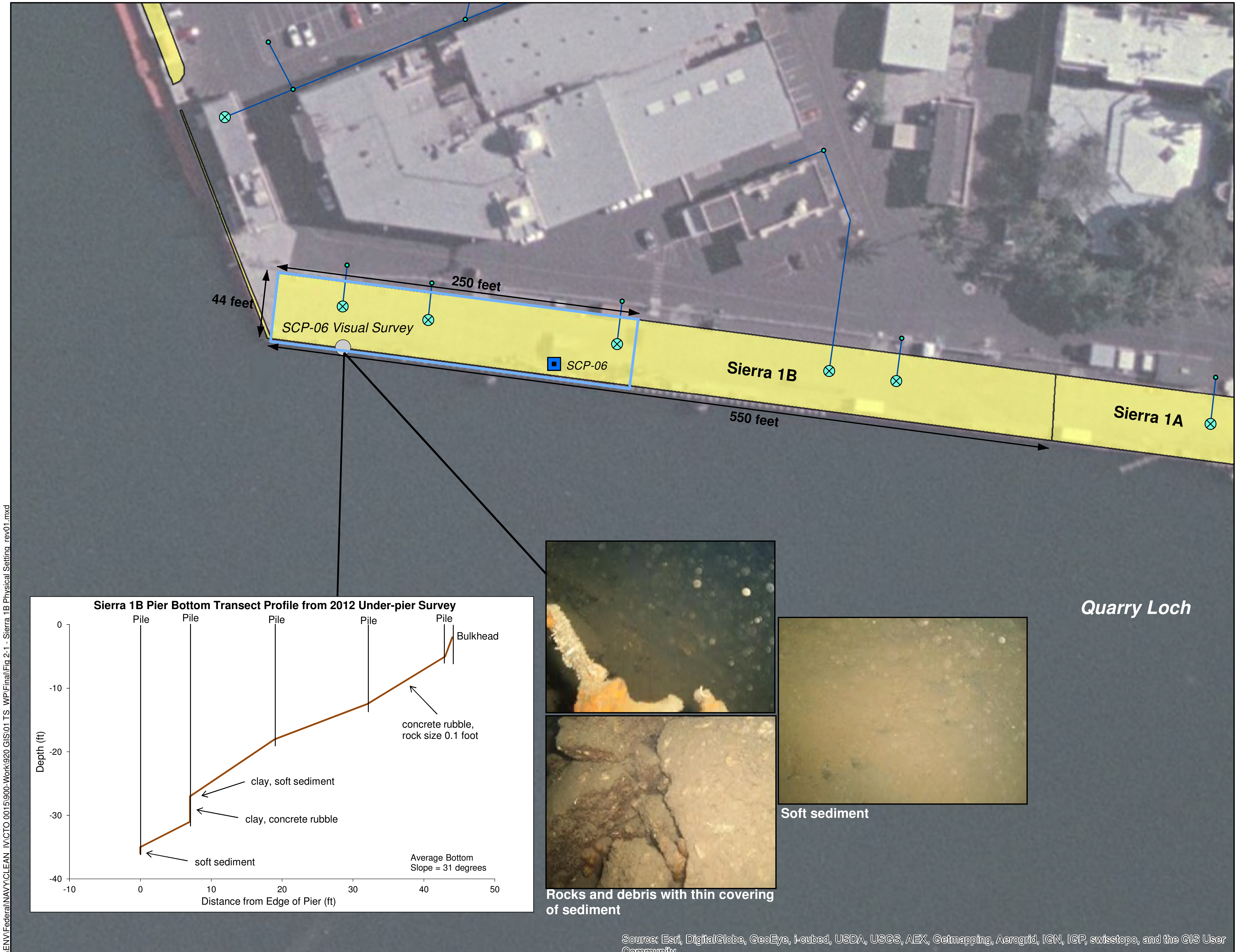
Bioassays will be conducted on sediment samples collected during the baseline sampling event and again on sediment collected 18 months post-construction. Bulk sediment samples for COC analysis will also be collected at the same locations as the bioaccumulation study sampling locations.

2.4 DEFINE THE BOUNDARIES OF THE STUDY

2.4.1 Spatial Boundaries

The horizontal boundary of the TS is defined by the westernmost 250-foot section of Sierra 1B Pier, as shown on Figure 2-1. Sierra 1B Pier was chosen for the TS due to the presence of COC concentrations exceeding the RALs identified in the FS report (AECOM 2014), and the moderate slopes that exist in areas where soft sediments have accumulated under this pier.

The vertical boundary of the TS is the BAZ, defined as the depth of bioturbation where the majority of the benthic invertebrate community lives in or on the sediment, and where benthic organisms and bottom fish are exposed to chemicals adsorbed to sediment or dissolved in sediment porewater. For the Pearl Harbor Sediment RI and FS, the agreed-upon extent of the BAZ is the upper 1 foot (~30 cm) of the sediment column, based on the observed vertical extent of bioturbation activities (AECOM 2013, 2014). However, sampling efforts for the TS will focus on the top 6 inches of sediment where most amendment mixing is expected to be observed.



P:\ENV\Federal\NAVY\CLEAN IV\CTO 0015\900-Work\920 GIS\01 TS_WP\Final\Fig 2-1 - Sierra 1B Physical Setting_rev01.mxd

LEGEND

- Study Area
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Under-pier profile data and photos from Pearl Harbor Sediment Feasibility Study (AECOM 2013a).

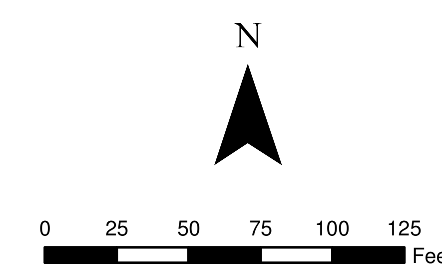


Figure 2-1
Sierra 1B Pier Physical Setting
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

2.4.2 Temporal Boundaries

2.4.2.1 Baseline Assessment of Under-Pier Conditions

A baseline assessment is necessary to establish under-pier conditions prior to placement of the amendment. The baseline assessment will be used to document control conditions to be used for comparison during the monitoring phase of the TS. The baseline assessment will also be used to refine the conceptual site model for the under-pier area of Sierra 1B Pier for use in designing the treatment. The baseline assessment will document physical (i.e., SPI, geochemical and geotechnical, and diver surveys), chemical (i.e., bulk sediment and porewater chemistry), and biological (benthic assessment and bioaccumulation) inputs described in Section 2.3.

2.4.2.2 Post-Construction Amendment Placement Verification

Immediately following construction of the amendment layer, the placement of the material will be verified. This verification will consist of diver-supplied photographs of the placement, sediment gauge measurements, bucket tests, and SPI. Sediment thickness gauges and buckets will be attached to piles or anchored to the bottom prior to amendment placement. After placement, divers will check the sediment gauges to measure the change in bottom elevation. The buckets will collect the amendment as it covers the bottom, which can be quantified after placement. Amendment thickness will be measured after placement as an added check for uniform installation. The purpose of the placement verification is to ensure that the amendment is installed in accordance with the design specifications.

2.4.2.3 Performance Monitoring (at 9 and 18 months)

The performance of the amendment treatment will be evaluated at two time intervals (i.e., 9 and 18 months) post-construction of the placement. The results of the evaluations will be compared against the baseline assessment to determine the overall success of the amendment. The performance monitoring will collect physical (i.e., SPI, geochemical and geotechnical, and diver surveys), chemical (i.e., bulk sediment and porewater chemistry), and biological (i.e., bioaccumulation at 18 months post-construction) inputs described in Section 2.3.

2.5 Develop Decision Rules

The TS goal is to test the viability of establishing stable sediment amendments to reduce the bioavailability of COCs in sediments that could be applied full scale to under-pier areas. The viability of the amendment treatment will be evaluated through performance objectives designed to assess physical parameters (i.e., placement, distribution, mixing, and stability), chemical parameters (i.e., changes in COC partitioning between sediments and porewater), and biological parameters (i.e., evidence of reduced COC bioaccumulation). Amendment treatment will be considered effective and viable if the following lines of evidence are observed:

- **Evidence of proper amendment placement, distribution, mixing, and stability** based on visual observation of effective lateral coverage of amendment material, SPI observations of effective amendment thickness, amendment vertical distribution and newly deposited sediment, and analytical results demonstrating carbon content in sediment is maintained at an effective level.
- **Evidence of a significant (i.e., more than 50 percent) reduction in porewater concentrations of COCs** based on analytical results from sediment porewater samples.
- **Evidence of a significant (i.e., more than 50 percent) reduction in bioaccumulation of COCs** based on laboratory bioaccumulation study on test organisms.

3. Treatability Study Options Evaluation

The TS will consist of placing amendment material under Sierra 1B Pier. The objective of the amendment placement will be to reduce the bioavailability of COCs in the sediment. Five amendment options are evaluated in this section.

3.1 OPTION 1 – SEDIMITE

Option 1 involves constructing an amendment layer consisting of SediMite over the under-pier study area. SediMite (Sediment Solutions, Ellicott City, MD) is a relatively new product designed to deliver amendment materials to sediment for in-situ remediation. It is an agglomerate composed of a treating agent, a weighting material, and an inert binder. The treating agent, typically AC, is the amendment material that will be responsible for binding chemicals in the sediment and porewater to reduce their overall bioavailability. AC is a preferred amendment because it strongly adsorbs hydrophobic chemicals, such as PCBs, polynuclear aromatic hydrocarbons, dioxins/furans, and pesticides. The weighting material is used to ensure that the AC has sufficient density to sink in water and to resist resuspension. The inert binder holds the AC and weighting material together long enough for the material to be placed. Once the SediMite pellets are placed, water slowly penetrates the pellets, causing the AC to separate from the weighting material. Over time, the AC will be mixed into the sediment BAZ by bioturbation and other natural processes.

Placement of amendment material such as SediMite can use conventional equipment, such as mechanical placement, surface discharge from a barge or hopper, or spraying of a slurry from the surface or with a submerged system (Bailey and Palermo 2005). Traditional placement methods may need to be adapted for under-pier placement because maneuvering of the equipment will be complicated by the pier structure. This will be further evaluated during the forthcoming design phase.

SediMite is purchased in either 30-pound buckets or 1,800-pound bulk bags from Sediment Solutions. The design will include the quantity of material needed and the technique used to place the material in a stable, uniform layer under Sierra 1B Pier.

The amount of material to be placed depends primarily on the percent increase of carbon desired, the bulk density of the sediment, and the volume of sediment to be amended. The sediment in Southeast Loch has an average native TOC content of 2.55 percent (AECOM 2014). The goal of the TS is to have a TOC content of approximately 5 percent at the study site, which is based on literature review. Thus, approximately 2.5 percent AC will be added to the study area based on site conditions. The area-specific TOC content in sediment at the test plot locations at Sierra 1B Pier will be determined during the baseline assessment. Based on data collected during the FS (AECOM 2014), the dry bulk density of sediment in Southeast Loch is 0.85 gram per cubic centimeter (53 lbs/ft^3). For Option 1, a section of approximately 11,000 ft^2 under Sierra 1B Pier would be remediated with SediMite. The goal is for the amendment to eventually penetrate the entire BAZ (defined as 1 foot for Pearl Harbor).

SediMite consists of 45 percent AC by weight and has a dry bulk density of 45 pounds per cubic foot (lb/ft^3). Based on TOC measurements and sediment density, approximately 41,250 pounds of material would need to be placed to reach the remediation goal (calculation of required AC amendment thickness is presented in Appendix B). The amendment would need to be approximately 1 inch thick, and materials would cost approximately \$123,750 or \$11.25/ft^2 for an 11,000-ft^2 area. The site-specific conditions would be used for final amendment quantities.

3.2 OPTION 2 – AQUAGATE+PAC

Option 2 involves constructing an amendment layer consisting of AquaGate+PAC over the under-pier study area. AquaGate+PAC (AquaBlok Ltd., Toledo, OH) is a product similar in design to SediMite. It has a dense aggregate core that is coated with clay (i.e., bentonite) and fine-grained AC, such that it resembles small rocks. AquaGate is a permeable material, intended to treat sediment and porewater rather than isolating the contamination under an impermeable cap. Like SediMite, the PAC will separate from the aggregate core after placement in an aqueous environment and will mix with the sediment.

Placement options and design considerations are essentially the same as for SediMite. AquaGate+PAC is obtained in either 1–5 gallon buckets or 1–2 ton bulk bags. As with Option 1 (Section 3.1), the goal for Option 2 is to add 2.5 percent AC to the sediment to reach a total carbon content of 5 percent. For Option 2, an approximately 11,000-ft^2 section under Sierra 1B Pier would be remediated with AquaGate+PAC. AquaGate+PAC consists of 5 percent AC by weight and has a dry bulk density of 90 lb/ft^3. Based on the properties of the sediment and product, placement of approximately 288,750 pounds of material would be required to reach the remediation goal (calculation of required AC amendment thickness is presented in Appendix B). This would create a 3.5-inch treatment layer, costing approximately \$144,375, or \$13.13/ft^2 for an 11,000-ft^2 area for the material only. The site-specific conditions would be used for final amendment quantities.

3.3 OPTION 3 – AC SLURRY+SAND COVER

Option 3 involves application of AC slurry to the surface of the sediment with a sand cover. AC has been used in both granular (GAC) and powdered (PAC) form. AC is a lightweight material, making it difficult to place in an underwater environment without the aid of a delivery system. Several sediment remediation projects have successfully implemented AC using various techniques to place the material and prevent resuspension of the AC once in place. For a pilot study at Trondheim Harbor, Norway, AC was mixed with a sodium chloride solution and pumped to the sediment bed. The saline solution made the slurry denser than the surrounding water, enabling it to sink to the bed. Other methods used in the study included adding a thin sand cap on top of the AC, and mixing bentonite clay with the AC to prevent erosion of the amendment. The pilot study showed that the AC+clay slurry method produced the best results (Norwegian Research Council 2011). These placement techniques rely on natural bioturbation processes to mix the AC into the contaminated sediment.

AC can also be mixed into the sediment hydraulically by a tine sled or other injection system, or mechanically by a rototiller or Aquamog, as demonstrated in pilot studies at Grasse River (Alcoa 2007) and Hunters Point (ESTCP 2005). The cost for bulk AC is approximately \$1.25/ft^2, excluding shipping costs, assuming an application of 5 percent AC by dry weight (EPA 2013). Additional costs would be incurred for specialized placement by pumping, turbidity control, and sand cover installation. Material costs for treatment of the entire 11,000-ft^2 study area is estimated at \$75,000.

3.4 OPTION 4 – REACTIVE MAT WITH SAND COVER

Option 4 involves installing a reactive core mat (RCM) consisting of organoclay and AC in the under-pier study area. A RCM (CETCO Remediation Technologies, Hoffman Estates, IL) is a permeable composite mat consisting of reactive material(s) encapsulated in a non-woven core matrix bound between two geotextiles. The upper geotextile is a needle-punched, non-woven fabric heat-laminated to a matrix of nonwoven fibers needle-punched into a woven geotextile. RCM can combine two active materials, if required.

RCMs stabilize the sediment and physically isolate the COCs in the sediment. A sand cap would be placed over the mats to secure their placement and for additional stability. This new sand layer would also be a base layer of new sedimentation and provide clean benthic habitat. As porewater passes through the AC and organoclay, COCs beneath the RCM would be adsorbed to the amendment material.

The RCMs typically come in 15-foot × 100-foot rolls. The RCMs typically have either 0.4 pound of GAC per square foot, or 0.8 pound of organoclay per square foot. RCMs have been successfully deployed and used to treat sediments in-situ at the Anacostia River demonstration project, using a barge-mounted crane to submerge and unroll a roll of RCM (Olsta and Darlington 2005). Additional costs would be expected for placement of the mat and sand cover in the under-pier areas. This has been estimated as 10 times open water placement. Material costs for the RCMs and sand cover over the entire 11,000-ft^2 study area would be approximately $138,000 based on custom mat dimensions and 1-foot sand thickness.

3.5 OPTION 5 – SIDE-BY-SIDE COMPARISON OF SEDIMITE AND AQUAGATE+PAC

Option 5 involves installing SediMite and AquaGate+PAC amendments at two areas under the Sierra 1B Pier separated by a buffer control area between them.

Both products are delivery systems for the amendment AC. Both systems have performed well in pilot- and large-scale applications in delivering AC to the sediment surface and eventually mixing amendment material into the targeted top layer of sediment. A side-by-side installation may assist in determining each product's advantages and disadvantages related to installation in an under-pier environment. Option 5 would also enable installation techniques for both products to be studied and documented.

Based on the material costs and AC needed for treatment detailed in Options 1 and 2, Option 5 would require 16,500 pounds of SediMite and 115,500 pounds of AquaGate+PAC, at costs of $49,500 and $57,750, respectively.

4. Analysis of Amendment Treatment Effectiveness

Nine criteria specified in the *National Oil and Hazardous Substances Pollution Contingency Plan* (NCP) (40 Code of Federal Regulations 300) are used to evaluate the relative performance of the amendment treatment options identified in Section 3. This analysis is used to identify the most feasible and effective amendment treatment option for the under-pier sediment TS. The nine evaluation criteria are described in Table 4-1. The first two criteria are threshold criteria representing the minimum requirements a response action must meet. The next five criteria are the primary balancing criteria upon which selection of a response action is based. The last two criteria are modifying criteria that are not used at this stage of evaluation.

Table 4-1: NCP Criteria for Detailed and Comparative Evaluation of Options

Criterion	How the Criterion is Applied
Threshold Criteria	
Overall protection of human health and the environment	Assesses the ability of an option to eliminate, reduce, or control the risks associated with exposure pathways, including direct contact, potential migration, and risks to ecosystems.
Compliance with ARARs/TBCs	Evaluates the potential of an option to achieve chemical-, location-, and action-specific ARARs and TBC criteria.
Primary Balancing Criteria	
Long-term effectiveness and permanence	Measures the ability of an option to permanently protect human health and the environment.
Reduction in toxicity, mobility, and volume through treatment	Evaluates the ability of an option to permanently or significantly reduce the toxicity, mobility, or volume of the constituents particularly through treatment.
Short-term effectiveness	Assesses the capability of an option to protect human health and the environment during a response action.
Implementability	Evaluates technical feasibility and the difficulty of applying the option at the site, the reliability of the technology, the unknowns associated with the option, and the need for treatability studies. Assesses regulatory agency concurrence and the need for permits and waivers. Assesses mobilization needs and the accessibility of equipment and trained personnel required to complete the option.
Cost (Capital, Operations and Maintenance, and Net Present Value)	Assesses the capital, operation, and maintenance costs of each option.
Modifying Criteria	
Regulatory agency acceptance	(Not applicable in the TS.) Evaluates the technical and administrative issues and concerns the state may have regarding the option.
Community acceptance	(Not applicable in the TS.) Assesses the issues and concerns the public may have regarding the option.

ARAR applicable or relevant and appropriate requirement
TBC to be considered

Using these criteria, a detailed evaluation of the five amendment treatment options is presented in Section 4.1, a comparative evaluation in Section 4.2, and rating and scoring of the options in Section 4.3.

4.1 Detailed Evaluation of Amendment Treatment Options

The detailed evaluation of the five amendment treatment options against the above criteria is presented in Table 4-2.

4.2 COMPARATIVE EVALUATION OF AMENDMENT TREATMENT OPTIONS

Following the detailed evaluation presented in Section 4.1 and Table 4-2, the performance of the five amendment treatment options is compared below using the same nine evaluation criteria.

4.2.1 Threshold Criteria

4.2.1.1 OVERALL PROTECTION OF HUMAN HEALTH AND ENVIRONMENT

All amendment treatment options are likely to provide similar (very good) levels of overall protection of human health and the environment by reducing the bioavailability of contaminants to human and ecological receptors. The main consideration to meet this criterion is the proper placement of the amendment or RCMs and the amendment's ability to mix with the contaminated layer or the mat's ability to stay in place. Amendment treatment is a proven technology for the COCs in the under-pier areas.

If the pre-placement survey identifies evidence of sediment surface scour from vessel propeller wash, current, or storm drainage effects, certain levels of armoring or sand cover may be necessary to keep the amendment in–place. Of the commercially available products evaluated, Option 2: AquaGate+PAC may provide a slight increase in stability due to its make-up and increased bentonite clay content, over Option 1: SediMite. Stability of the under-pier sediment will be evaluated during the pre-placement survey. If significant stability issues are observed, it may be necessary to protect certain areas to ensure the amendment remains in place.

4.2.1.2 COMPLIANCE WITH ARARS AND TBCS

All options have the potential to be compliant with chemical-specific action levels identified in the FS. Periodic post-application monitoring will be necessary once full-scale installations begin. This monitoring will ensure that the amendment is performing as designed, specifically regarding contaminant bioavailability in the BAZ and amendment integrity.

4.2.2 Primary Balancing Criteria

4.2.2.1 LONG-TERM EFFECTIVENESS AND PERMANENCE

When placed correctly, all amendment materials considered in this evaluation have potential to provide a long-term permanent remedy at the site. Because amendment treatment is a relatively new technology, the assumed long-term effectiveness and permanence is based on relatively short-term studies. As the amendment is covered by newly deposited sediment, the treatment will become more permanent. The TS will evaluate the effectiveness of the amendment treatment both visually and analytically over an 18-month period. Once the amendment material mixes with the top layer of sediment (or the RCM is placed and covered), the bioavailability of the COCs will begin to decrease. If under-pier sediment is moved by natural processes or maintenance activities, the amendment will move with it. This amendment movement relates only to Options 1, 2, 3, and the combined Option 5 because the amendment material mixes with the sediment and is not incorporated into a reactive mat.

Based on information gathered during the Pearl Harbor Sediment RI, RI Addendum, and FS, the under-pier areas are relatively low-energy areas with limited current, wave action, and propeller wash. This low-energy environment increases the probability that the amendment will stay in place and will provide a permanent, long-term remedy.

Table 4-2: Detailed Evaluation of Options for Sierra 1B Pier Pearl Harbor Sediment TS

Criterion		Option 1: SediMite Amendment	Option 2: AquaGate+PAC Amendment	Option 3: AC Slurry+Sand Cover	Option 4: RCM with Sand Cover	Option 5: SediMite and AquaGate+PAC Amendments
Threshold Criteria						
Overall protection of human health and the environment		Would reduce risk to human health and the environment by decreasing the bioavailability of COCs in BAZ. Amendment material would adsorb and bind contaminants preventing them from continuing to bioaccumulate in organisms and move up through the food chain.	Would reduce risk to human health and the environment by decreasing the bioavailability of COCs in BAZ. Amendment material would adsorb and bind contaminants preventing them from continuing to bioaccumulate in organisms and move up through the food chain.	Would reduce risk to human health and the environment by decreasing the bioavailability of COCs in BAZ. Amendment material would adsorb and bind contaminants preventing them from continuing to bioaccumulate in organisms and move up through the food chain.	Would reduce risk to human health and the environment by decreasing mobility and bioavailability of COCs in BAZ. Amendment material would adsorb and bind contaminants preventing them from continuing to bioaccumulate in organisms and move up through the food chain.	Would reduce risk to human health and the environment by decreasing the bioavailability of COCs in BAZ. Amendment material would adsorb and bind contaminants preventing them from continuing to bioaccumulate in organisms and move up through the food chain.
Compliance with ARARs/TBCs		Would comply with ARARs/TBCs by protecting human health and the environment over time with reduction of contaminant bioavailability.	Would comply with ARARs/TBCs by protecting human health and the environment over time with reduction of contaminant bioavailability.	Would comply with ARARs/TBCs by protecting human health and the environment over time with reduction of contaminant bioavailability.	Would comply with ARARs/TBCs by protecting human health and the environment over time with reduction of contaminant bioavailability and mobility.	Would comply with ARARs/TBCs by protecting human health and the environment over time with reduction of contaminant bioavailability.
Primary Balancing Criteria						
Long-term effectiveness and permanence		Would be effective in treatment of sediments in the BAZ in the long term by natural mixing with the top layer of sediment via bioturbation and binding of contaminants. Deposition of new sediments on top of the amendment would ensure permanence. Treatment of potentially contaminated new sediments deposited above the amendment is likely due to bioturbation mixing of underlying amendment with newly deposited sediment. After implementation, periodic monitoring would be required to confirm treatment material integrity and accumulation of clean sediment over the amendment.	Would be effective in treatment of sediments in the BAZ in the long term by natural mixing with the top layer of sediment via bioturbation and binding of contaminants. The higher density of the amendment due to heavier inert materials in the mixture allows deeper penetration into the BAZ. Deposition of new sediments on top of the amendment will lead to permanence. Treatment of potentially contaminated new sediments deposited above the amendment is likely due to bioturbation mixing of underlying amendment with newly deposited sediment. After implementation, periodic monitoring would be required to confirm treatment material integrity and accumulation of clean sediment over the amendment.	Would be effective in treatment of sediments in the BAZ in the long term by natural mixing with the top layer of sediment via bioturbation and binding of contaminants. Deposition of new sediments on top of the sand cover will ensure permanence. Treatment of potentially contaminated new sediments deposited above the sand cover is likely due to bioturbation mixing of underlying amendment with newly deposited sediment. After implementation, periodic monitoring would be required to confirm cover integrity and accumulation of clean sediment over the amendment.	Would be effective in treatment of sediments in the BAZ in the long term by reducing the bioavailability of COCs in sediments under the mat. RCMs, when covered with sand, will remain in place permanently and continue to treat underlying contaminated sediment. Newly deposited sediment will assist with the permanent placement. After implementation, periodic monitoring would be required to confirm cover integrity and accumulation of clean sediment over the amendment.	Would be effective in treatment of sediments in the BAZ in the long term by natural mixing with the top layer of sediment via bioturbation and binding of contaminants. Deposition of new sediments on top of the amendment would lead to permanence. Both treatment layers would provide treatment of potentially contaminated new sediments deposited above the amendment due to bioturbation mixing of underlying amendment with the newly deposited sediment. After implementation, periodic monitoring would be required to confirm treatment material integrity and accumulation of clean sediment over the amendment.
Reduction in toxicity, mobility, and volume through treatment		Treatment of sediment by the amendment material would reduce toxicity and mobility by binding and adsorption of COCs, reducing bioavailability by as much as 90%. No reduction of bulk contaminant volume.	Treatment of sediment with amendment material would reduce toxicity and mobility by binding and adsorption of COCs, reducing bioavailability by as much as 90%. Additional reduction in mobility is achieved due to additional amounts of clay and aggregate material in the product. No reduction of bulk contaminant volume.	Treatment of sediment by the amendment material would reduce toxicity and mobility by binding and adsorption of COCs, reducing bioavailability by as much as 90%. No reduction of bulk contaminant volume.	Treatment of sediment with the RCM with sand cover would reduce toxicity and mobility by physical isolation and by binding and adsorption of COCs in sediments under the RCM, thereby reducing bioavailability by as much as 90%. No reduction of bulk contaminant volume.	Treatment of sediment with amendment material would reduce toxicity and mobility by binding and adsorption of COCs, reducing bioavailability by as much as 90%. Additional reduction in mobility is achieved due to additional amounts of clay and aggregate material in the product. No reduction of bulk contaminant volume.
Short-term effectiveness		Would be effective in the short term; separation of AC (and therefore immediate treatment of sediments) from sand and clay of the amendment material occurs within first day following emplacement.	Would be effective in the short term; separation of AC (and therefore immediate treatment of sediments) from aggregate and clay of the amendment material occurs within first day following emplacement. Potential deeper placement of material due to higher bulk density of the mixture.	Would be effective in the short term; AC is immediately made available to treat surface sediment.	Would be effective in the short term by isolating contaminated sediment and providing new layer of clean sand for benthic community to populate. BAZ porewater will be improved as amendment in mat adsorbs contaminants.	Would be effective in the short term; separation of AC (and therefore immediate treatment of sediments) from sand and clay of the amendment material occurs within first day following emplacement. SediMite AC would separate from the binder faster than the AquaGate+PAC AC. AquaGate+PAC has the potential for deeper initial placement of material due to higher bulk density of the mixture.
Implementability	Technical feasibility	Proven option that has been implemented at other sediment sites to treat COCs at the site.	Proven option that has been implemented at other sediment sites to treat COCs at the site.	Proven amendment to treat COCs at the site; however, not used or studied as extensively as Option 1 or 2. Potential challenges in implementation due to turbidity issues.	Proven option to isolate and treat COCs at the site; however, potential technical challenges in installing reactive mat in an area with tight spacing of pier pilings and uneven bottom profile and presence of debris.	Proven option that has been implemented at other sediment sites to treat COCs at the site.
	Administrative feasibility	Would have proper engineering controls and monitoring requirements to show success of amendment placement and mixing into surface sediment. Porewater monitoring required to show reduction in bioavailability and compliance with ARAR/TBCs.	Would have proper engineering controls and monitoring requirements to show success of amendment placement and mixing into surface sediment. Porewater monitoring required to show reduction in bioavailability and compliance with ARAR/TBCs.	Would have proper engineering controls and monitoring requirements to show success of amendment placement and mixing into surface sediment. Turbidity monitoring required during installation. Porewater monitoring required to show reduction in bioavailability and compliance with ARAR/TBCs.	Would have proper engineering controls and monitoring requirements to show success of amendment placement and mixing into surface sediment. Porewater monitoring required to show reduction in bioavailability and compliance with ARAR/TBCs.	Would have proper engineering controls and monitoring requirements to show success of amendment placement and mixing into surface sediment. Porewater monitoring required to show reduction in bioavailability and compliance with ARAR/TBCs.
	Availability of services and materials	Materials readily available with shipping from the U.S. mainland. Suppliers would need to consult with local contractors for proper placement of material.	Materials readily available with shipping from the U.S. mainland. Suppliers would need to consult with local contractors for proper placement of material.	Materials readily available with shipping from the U.S. mainland. Suppliers would need to consult with local contractors for proper placement of material.	Materials readily available with shipping from the U.S. mainland. Suppliers would need to consult with local contractors for proper placement of material.	Materials readily available with shipping from the U.S. mainland. Suppliers would need to consult with local contractors for proper placement of material.
Total Cost		$123,750 (material) $244,400 (placement)	$144,375 (material) $244,400 (placement)	$75,000 (material) $350,000 (placement)	$138,000 (material) $325,000 (placement)	$107,250 (material) $200,000 (placement)
Modifying Criteria						
Regulatory agency acceptance		Not applicable in the TS. The TS results will be used in the remedial design; EPA and the State of Hawaii Department of Health will have the opportunity to comment about the acceptance of the proposed option.				
Community acceptance		Not applicable in the TS. The TS results will be included in the FS report, and a proposed plan will be published for the site in the future. The public will be welcome to comment on the proposed plan.				

4.2.2.2 REDUCTION IN TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Bulk amendment material and reactive mats can effectively reduce the toxicity and mobility in the under-pier areas. The actual volume of contamination is not reduced by these remedies, but the bioavailability of the COCs can be significantly reduced (as much as 90 percent). All options perform well with respect to this criterion.

4.2.2.3 SHORT-TERM EFFECTIVENESS

Short-term effectiveness will vary with Options 1, 2, 3, and 5 due to natural bioturbation or mixing of the material. Ideally, the benthic organisms will immediately begin to populate the amendment layer and carry the AC deeper into the BAZ. This process takes time and will be monitored both visually (with SPI and cores) and analytically through SPME and DGT porewater analysis. Option 4 has an immediate impact on isolation of contaminated sediment.

4.2.2.4 IMPLEMENTABILITY

The under-pier areas identified as needing remediation in the FS are highly variable in regards to construction, water side access, deck height, bottom slope, sediment contaminant concentration, and sediment type. This is one reason that amendment treatment was identified as a viable remediation option, as many configurations and delivery options can be employed. The majority of under-pier areas are suitable for effective treatment with amendment material directly applied to the sediment surface. There may be areas identified in the pre-design sediment surveys (e.g., scour areas, stormwater outfalls) that require more stability. For the TS, Sierra 1B Pier has been identified as a site that represents sediments likely to be targeted for remediation in the majority of the under-pier areas. Placement of the amendment, whether applied as a covered RCM or as material spread directly on the sediment surface, will be challenging. Each pier location is unique and will require a pre-design survey to facilitate proper and stable amendment placement. In addition, as noted in Table 4-2, the implementability of Option 4 (RCM) would be more difficult than Options 1, 2, 3, and 5 in the areas with tight spacing of pier pilings, uneven bottom profile, and presence of debris.

4.2.2.5 COST

Overall costs for the different amendment options are very similar, but the costs are quite different in terms of material costs versus installation costs. Engineered amendment materials (SediMite and AquaGate+PAC) are relatively expensive for the material purchase, but less expensive than the other options for installation. AC Slurry and the RCMs have relatively low material costs but higher implementation costs. Of the five options, costs for commercial absorbent material are the lowest (Option 1 SediMite at $368,150, Option 2 AquaGate+PAC at $388,775, and Option 5 side-by-side comparison at $307,250). AC slurry and RCMs have estimated costs at $425,000 and $463,000, respectively. These costs are based on a standard pier area, average waterside access, average slope and depth, and median sediment type, carbon content, and contaminant concentration.

4.3 RATING AND SCORING OF AMENDMENT TREATMENT OPTIONS

Based on the results of the detailed evaluation (Section 4.1) and comparative evaluation (Section 4.2), the performance of each amendment treatment option is rated and scored in Table 4-3.

Table 4-3: Rating and Scoring of Options for Pearl Harbor Sediment TS

Criterion	**Option 1:** SediMite Amendment	**Option 2:** AquaGate+PAC Amendment	**Option 3:** AC Slurry +Sand Cover	**Option 4:** RCM with Sand Cover	**Option 5:** SediMite and AquaGate+PAC Amendment
Threshold Criteria					
Overall protection of human health and the environment	3 – Very Good	3 – Very Good	3 – Very Good	3 – Very Good	3 – Very Good
Compliance with ARARs/TBCs	4 – Excellent	4 – Excellent	4 – Excellent	4 – Excellent	4 – Excellent
Primary Balancing Criteria					
Long-term effectiveness and permanence	4 – Excellent	4 – Excellent	4 – Excellent	4 – Excellent	4 – Excellent
Reduction in toxicity, mobility, and volume through treatment	4 – Excellent	4 – Excellent	4 – Excellent	4 – Excellent	4 – Excellent
Short-term effectiveness	3 – Very Good	3 – Very Good	3 – Very Good	4 – Excellent	3 – Very Good
Implementability	3 – Very Good	3 – Very Good	2 – Good	1 – Fair	3 – Very Good
Cost [a]	3 – Very Good $368,150	3 – Very Good $388,775	1 – Fair $425,000	1 – Fair $463,000	3 – Very Good $307,250
Modifying Criteria					
Regulatory agency acceptance	Not applicable in the TS.				
Community acceptance	Not applicable in the TS.				
Overall Rating (Average Score) [b]	**24 – Very Good to Excellent**	**24 – Very Good to Excellent**	**21 – Good**	**21 – Good**	**24 – Very Good to Excellent**

[a] Estimated costs based on actual supplier quotes for Options 1, 2, and 5, and on EPA guidance documents, former studies, full-scale implementation, and FS cost models for Options 3 and 4. All costs have been adjusted for location.

[b] Ratings and scoring are based on a 0 to 4 scale (0=poor, 1=fair, 2=good, 3=very good, 4=excellent). The individual criterion scores for each option are summed to determine the option’s overall score.

5. Selected Option for the Treatability Study

The placement of SediMite and AquaGate+PAC over separate plots (Option 5) was selected for the TS. This selection was made based on the evaluation of the different amendment materials where both Options 1 and 2 scored high, and the need to compare the AC delivery method of the two products. SediMite and AquaGate+PAC are similar in the mechanism used in the final treatment and AC characteristics, but differ significantly regarding the product make-up. SediMite has a significantly greater AC percentage than the AquaGate+PAC product (45 percent versus 5-10 percent). In addition, SediMite uses sand and bentonite clay as a binder and weighting for amendment placement, whereas AquaGate+PAC binds bentonite and AC to a piece of aggregate for placement.

The study area is approximately 11,000 ft^2. The two amendment plots will be 100 feet × 44 feet. The two selected amendments will be studied side-by-side at the selected under-pier area (western 250 feet of Sierra 1B Pier), with a 50-foot buffer area between the two test plots. This location was selected based on under-pier analytical results and the physical setting. Both amendment products have the ability to effectively treat the sediment, but will be successful only if proper placement of the material occurs and the amendment remains in contact with the contaminated sediment and is distributed throughout the BAZ (i.e., upper 1 foot).

A detailed design, including drawings and specifications on existing conditions, site layout, amendment layer thickness, and placement tolerances, will be prepared prior to implementing the TS. A pre-design diver survey will be conducted to collect information to further develop and fin-tune a placement strategy for the amendment. It is anticipated that certain steep, rocky, and debris areas will be identified during the pre-design survey. This information will be used to target locations of soft sediment and focus on areas requiring treatment.

A TS health and safety plan is presented in Appendix A.

5.1 Amendment Treatment Study Area

5.1.1 Study Area Layout

The proposed study area will be a 250-foot × 44-foot section of Sierra 1B Pier. This under-pier area is characteristic of many under-pier areas targeted for remediation in the Draft Final FS (AECOM 2014). The pier is constructed on piles, with the leading edge in approximately 35 feet of water and the bottom elevation sloping upward to a bulkhead, where the water depth is 2–3 feet. The bottom slope, where areas of soft sediment were observed during a previous under-pier survey, is approximately 60 percent (31 degrees). Additional details of the study area will be obtained during the pre-design diver survey. Divers will gather elevation and observational data along set transects. These data will be used to further develop a placement strategy for the amendment.

The study area will be subdivided into two plots divided by a buffer control area (Plots A, B, and C) to allow for a direct comparison of the amendment performance by the two selected options in very similar conditions. The control area (Plot C) will be used to separate the two materials so there is no mixing, and will act as a close proximity control plot to gather data on a similar, untreated area.

5.1.2 Amendment Placement Options

Options for amendment placement will be presented in the detailed design. Several options for placement of both SediMite and AquaGate+PAC are available, and their use depends on site conditions. Both amendment materials need to be placed at certain, predetermined uniform thicknesses, based on the carbon content needed. The amendment materials are designed to fall through the water column and rest on or slightly beneath the sediment surface. Some placement options include a pneumatic blower, mechanical spreader, barge- or deck-mounted conveyor system, gravity feeder, small mobile spreader, and manual placement. In addition to placement options, consideration will also need to be given for the temporary dry storage of the material prior to use.

Final amendment placement technique will depend on the existing under-pier conditions. The placement subcontractor and material suppliers will work closely together to develop an effective material delivery system. Multiple techniques may need to be used to treat all under-pier areas. For example, a mobile conveyor system may be effective for the outer 10–15 feet of the under-pier area, but a smaller-scale hopper and mechanical spreader may be needed in the more confined areas closer to the bulkhead.

5.1.3 Amendment Placement Verification

Verification of amendment placement will be conducted immediately after installation. This will be completed by manual thickness measurements taken by divers and by using SPI. In addition to thickness measurements, before and after photos will be taken at certain predetermined locations. A certain weight of amendment material per square foot of coverage will be established. This ratio will also be verified during installation by comparing the area treated with the weight of material used. The amendment material will also be inspected at 9 and 18 months after installation. Diver inspection of amendment thickness may guide placement of additional amendment material in areas that do not meet specifications. Slight over-application is not a concern, as the additional carbon will be available to treat newly deposited sediment. Under-application is a concern, however, as targeted carbon concentrations may not be met.

5.2 TREATMENT OPTION EVALUATION

Treatment option evaluation will be conducted to document the amendment performance over the 18-month performance monitoring period. The evaluation data will be used to assist in the selection of in-situ treatment materials and placement techniques that could be applied full scale for other under-pier areas. The evaluation will document the treatment effectiveness at different stages of completion. Amendment effectiveness depends greatly on natural processes to mix the AC with the upper 1 foot of contaminated sediment. This mixing takes place as the benthic community repopulates the placed material layer and carries the amendment down through the BAZ. The evaluation has been designed to document this natural mixing of the amendment.

Successful sediment treatment will be confirmed based on the following lines of evidence and characteristics:

- Adequate amendment mixing
- Stability of amendment material
- Observed benthic activity
- Improvements of porewater quality (reduction in bioavailability) over time
- Reduction of bioaccumulation potential over time

All the above lines of evidence or characteristics may not be fully developed over the 18-month study period, but significant progress or signs of improvement should be evident. Several physical, analytical, and biological parameters will be documented and evaluated to determine if the amendment treatment is a viable remediation option for under-pier areas. The following subsections outline details of the pre- and post-construction observations and testing planned for the TS.

5.2.1 Amendment Mixing and Evidence of Bioturbation

Amendment mixing results will be observed and recorded in two ways. First, the SPI survey will document the depth into the soft sediment where bioturbation is occurring by photographing evidence of benthic organisms and amendment in-situ at depth. Second, sediment core samples will be collected to a depth of 1 foot below the new sediment-water interface. The core contents will be photographed, observations of organisms and amendment will be logged, and TOC and black carbon content of the sediment will be measured in the upper 6 inches based on observed amendment mixing.

The degree of mixing observed at the 9- and 18-month performance monitoring events will be evaluated to determine whether it is sufficient. The depth at which the amendment is observed beneath the surface and visual evidence of bioturbation will be used as part of the overall evaluation of the amendment.

5.2.2 Amendment Stability

Stability of the amendment is necessary to provide continued treatment over time. The under-pier areas are very low-energy environments with little current or wave action, as documented in the FS report (AECOM 2014). Scour from propeller wash and stormwater outfalls will be evaluated during the pre-installation survey.

To assess the stability of the proposed treatment material to be placed on the existing sediment beneath the pier, it will be necessary to characterize the composition of the sediment in the area to be treated, as well as the geometry of the surface. The proposed amendment material, which is in a pelletized or granular form, is to be placed by spreading through standing water. When the amendment material reaches the surface to be treated, its surface texture (microstructure) will affect how it initially rests upon, and ultimately adheres, to the surface. If the overall slope of the base material (macrostructure) is too steep, then the treatment material may slide before adhering to the surface sediment. This issue may be initially addressed through a program of in-situ observation by divers. It is expected that certain under-pier areas (both natural and man-made) will be too steep for the amendment or to contain soft sediment. Additional study and testing may be required in a laboratory or in-situ to assess how the treatment material accumulates and adheres to the existing harbor under-pier base. This additional testing could include Direct Shear Tests (ASTM [2011] D3080) and will be employed based on observations made during the baseline assessment.

One advantage of amendment treatment is that the amendment becomes incorporated into the top layer of sediment. If sediment is moved by natural processes or due to maintenance activities, then the amendment moves with it. In addition, if newly deposited contaminated sediment settles on top of the amendment, this sediment could also be treated through bioturbation. Over time, clean sediment will deposit over the mixed amendment layer and provide a new, clean BAZ. Newly deposited sediment over the amendment material will be documented with SPI images and sediment cores.

Stability will be monitored and documented over the course of the study through visual inspection, SPI images, and sediment cores. The stability of each material will be used as part of the overall assessment of the amendment treatment.

5.2.3 Benthic Community Observations and Laboratory Assessment

Benthic organisms will be responsible for some of the mixing in the top layer of sediment. Based on previous studies, both SediMite and AquaGate+PAC, at the thicknesses and dosages proposed for this study, will support benthic organisms. The organisms that exist in the sediment now will continue to populate the upper 1 foot of material after placement of the amendment. Observations of benthic organisms and evidence of their presence will be documented during the baseline survey and performance monitoring. These observations will be made visually by divers, and by examining SPI results and sediment cores.

In addition to visual field observations, sediment cores will be collected from each test plot for benthic infauna laboratory assessment. Samples will be collected during the baseline assessment and the 18-month performance monitoring. A taxonomic analysis will be performed to accurately identify all organisms contained within study area samples, to the lowest possible taxonomic category. An accurate count of the organisms in each identified taxon will be documented. Results will be used to compare benthic communities before and after placement of amendment.

5.2.4 Porewater Quality Improvement and Analytical Results

Porewater COC levels and their relationship to bioavailability of contaminants are important drivers of this study. Reducing the COC bioavailability to benthic organisms and bottom-feeding fish will reduce the contaminants' capacity to biomagnify through the food chain.

Measurement of contaminants in porewater can be used to evaluate amendment treatment. For this study, the use of SPME and DGTs are proposed for PCBs and metals (mercury, copper, and lead), respectively. These techniques emulate the potential uptake of contaminants to living tissue and may correlate with bioaccumulation test results as an additional line of evidence that the amendment is effective. Porewater COC concentrations will be documented pre-installation and at 9 and 18 months post-placement for comparison. This comparison will assist in the evaluation of the treatments' effectiveness. The porewater sampling will focus on only the top 0–6 inches of sediment, as this zone is expected to have the potential of being adequately mixed during the short study window. It is possible that the amendment will not be fully mixed within 18 months of material introduction. The study will measure porewater COC concentrations in the top 0–6 inches of sediment and, at certain locations, the 0–12 inch below the new sediment–water interface interval, if complete mixing is observed.

5.2.5 Bioaccumulation Testing

Bioaccumulation studies provide an additional line of evidence on the bioavailability of COCs in sediment. Ex-situ bioassays will be used to assess bioaccumulation of COCs in sediment collected from each test plot. Bioassays will be conducted on sediment collected during the baseline sampling event (pre-treatment) and again on sediment collected 18 months post-construction. Comparison between bioaccumulation results from the baseline and at 18 months post-construction will be used to assess whether bioavailability of COCs is being reduced by the amendment treatment in each plot and the degree of any observed reduction. The following procedure will be followed:

- Undisturbed cores will be used to closely mimic under-pier conditions in the laboratory. This is important because the effectiveness of an amendment treatment relies on the ability for it to stay in place and efficiently mix into the top layer of sediment. Undisturbed sediment cores will be diver-collected from each amendment test plot (Test Plot A - SediMite and Test Plot B - AquaGate +PAC). Nine undisturbed rectangular polycarbonate cores (10 cm × 15 cm) will be collected to a depth of 1 foot bswi from separate locations within each test plot. The cores will be immediately capped, with no head space or water over the sediment, and shipped in an undisturbed state directly to the bioaccumulation laboratory.

- The bioaccumulation lab will create three replicate bioaccumulation tests for each plot. Each replicate will be composed of three of the undisturbed cores. Sediment will be extruded from the cores, undisturbed to the extent possible, into aquariums designed to fit the rectangular cores side by side and maintain the collected sediment depth. The size of the tanks will be chosen to keep the cores as undisturbed as possible. Clean seawater and test organisms will then be added to each testing tank and the bioaccumulation exposure testing will begin. Approximately 10–15 wild *Macoma nasuta* (clams) will be added to each tank. A 28-day exposure study will be conducted on the clams using standard and modified methods as defined in EPA (1993), EPA and USACE (1991, 1998), and ASTM (2010a) guidance. Once the 28-day exposure period is complete, organisms will be removed from the study sediment and allowed to purge for 24 hours in clean water with no sediment. After the purge period, the clams will be shucked, rinsed with deionized water, placed in certified clean glass jars provided by the analytical laboratory, and frozen. Each replicate will provide approximately 45–60 grams of wet weight tissue, assuming 100 percent survival. All frozen samples will be shipped on ice to the analytical laboratory.
- The analytical lab will receive six tissue samples (three from each test plot) from the bioaccumulation lab for chemical analysis for each event (baseline and 18-month performance monitoring). Samples will be analyzed for total NOAA-18 PCBs by EPA Method 1668C (to accommodate low detection limits), lipids, and percent moisture. Analytical results will be used for comparison of pre-treatment and 18-month post-treatment bioaccumulation.

5.2.6 Survey and Sampling Design

Observations, surveys, and samples will be used to document conditions during pre-construction, post-construction, 9-month performance monitoring, and 18-month performance monitoring. Table 5-1 and Table 5-2 summarize the survey and sampling activities, analyses, number of samples, and rationales for the test plots and the control plot, respectively. Locations and analyses were selected to evaluate multiple elements of the study. Proposed sampling locations for each field activity are shown on Figure 5-1–Figure 5-6; a compilation of all survey and sampling locations and timeline listing of activities is presented on Figure 5-7. Additional observations will be made at the outer extents of the test plots to document the amendment placement to determine how precisely the material can be installed.

5.2.6.1 Baseline Survey

During the baseline survey, a full suite of analyses will be conducted to characterize the study area prior to treatment. Data inputs include a physical survey, a SPI survey, bulk sediment sampling, passive porewater sampling, sediment sampling for geotechnical and geochemical parameters, benthic infauna assessment, and bioaccumulation sampling. Survey and sampling details are as follows:

- *Physical Survey* (Figure 5-1). Observations including thickness of soft sediment, sediment type, current velocity measurements (using a hand-held meter), presence of debris and biota, evidence of sediment failure or scour, and elevations will be documented at 16 locations in each test plot and at two locations in the control plot. Photos will be taken at certain locations that can be replicated during post-construction and performance monitoring. Physical survey observations along the test plot borders will also be documented.

- *SPI Survey* (Figure 5-2). SPI images will be recorded at 12 locations in each test plot and at two locations in the control plot. SPI images will be used to document sediment characteristics, presence of biota, and evidence of bioturbation.
- *Bulk Sediment Sampling* (Figure 5-3). Bulk sediment chemistry will be analyzed at nine locations in each test plot and at two locations in the control plot to provide baseline data on COC concentrations in bulk sediment.
- *Porewater Sampling* (Figure 5-4). Passive samplers (SPME and DGT) will be placed at six locations in each test plot and at two locations in the control plot to provide baseline data on the concentrations of COCs in porewater. Porewater locations are collocated with bulk sediment samples to facilitate a comparison between porewater and sediment COC concentrations.
- *Geotechnical and Geochemical Sampling* (Figure 5-5). Sediment samples for geotechnical and geochemical analysis will be collected at six locations in each test plot and at two locations in the control plot. Atterberg limits samples will be collected at two locations in each test plot. Hydraulic conductivity samples will be collected at one location in each test plot.
- *Bioaccumulation and Benthic Assessment Sampling* (Figure 5-6). Nine undisturbed cores will represent each test plot. Sediment samples will be collected from nine discrete locations per plot to prepare three bioaccumulation test replicates. Each replicate sample will be submitted for ex-situ bioaccumulation testing. Sample cores will also be collected at each of the nine locations to create a composite benthic infauna assessment sample. One sample from each test plot will be submitted for taxonomy and population assessment.

5.2.6.2 Post-Construction Verification

Immediately following placement of the amendment material, post-construction verification surveys will take place. A physical survey, photographs, and a SPI survey will be conducted at the same locations described in the baseline survey (Figure 5-1 and Figure 5-2). This information will document material thickness and lateral placement. In addition to the photos and SPI verification, bucket tests will be conducted at each test plot. Buckets will be anchored to the bottom to collect amendment as it covers the bottom. Thickness of amendment will be measured after the placement as an added check for uniform installation.

Table 5-1: Summary of Survey and Sampling Activities and Rationale for the Test Plots

Field Activity	Sample Type	Analysis	Number of Sampling Locations per Plot	Rationale
Baseline Survey				
Physical Survey	N/A	Visual Observation	16	Collect baseline physical data (slope, sediment thickness, current velocity, debris and biota presence).
SPI	N/A	Sediment Column Cross-Section Profile	12	Collect baseline sediment cross-section profile (sediment characteristic, biota presence, evidence of bioturbation).
Sediment Sampling	Discrete	COC Chemistry: PCBs, Hg, Cu, Pb	9	Collect baseline bulk sediment COC discrete concentration data.
		Geochemistry: pH, TOC, Black Carbon	6	Collect baseline bulk sediment geochemical data.
		Geotechnical: Moisture, PSD, WBD	6	Collect baseline bulk sediment geotechnical data.
		Geotechnical: Atterberg Limits	2	
		Geotechnical: Hydraulic Conductivity	1	
	Discrete Undisturbed Cores	Bioaccumulation Potential	9	Assess bioaccumulation potential under initial undisturbed condition.
	Discrete	Benthic Infauna Assessment	1	Collect baseline composite sediment benthic taxonomy and population data.
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT): PCBs, Hg, Cu, Pb	6	Collect baseline discrete porewater concentration data, collocated with discrete bulk sediment sampling to facilitate comparison between porewater and bulk sediment COC concentrations.
Post-Construction Verification				
Physical Survey	N/A	Visual Observation	16	Document surface condition (uniform coverage, sediment + amendment thickness, biota presence).
SPI	N/A	Sediment Column Cross-Section Profile	12	Verify thickness of amendment; document biota presence and evidence of bioturbation).
9-Month Monitoring				
Physical Survey	N/A	Visual Observation	16	Document surface condition (amendment coverage, sediment + amendment thickness, biota presence).
SPI	N/A	Sediment Column Cross-Section Profile	12	Document extent of amendment mixing and evidence of bioturbation.
Sediment Sampling	Discrete	COC Chemistry: PCBs, Hg, Cu, Pb	6	Evaluate changes in COC concentration in upper 6 inches of sediment.
		Geochemistry: pH, TOC, Black Carbon	6	Evaluate changes in geochemical condition in upper 6 inches of sediment.
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT): PCBs, Hg, Cu, Pb	6	Evaluate changes in porewater COC concentration in upper 6 inches of sediment; evaluate changes in porewater COC concentration changes relative to bulk sediment COC concentration changes.
18-Month Monitoring				
Physical Survey	N/A	Visual Observation	16	Document surface condition (amendment coverage, sediment + amendment thickness, biota presence).
SPI	N/A	Sediment Column Cross-Section Profile	12	Document extent of amendment mixing and evidence of bioturbation.

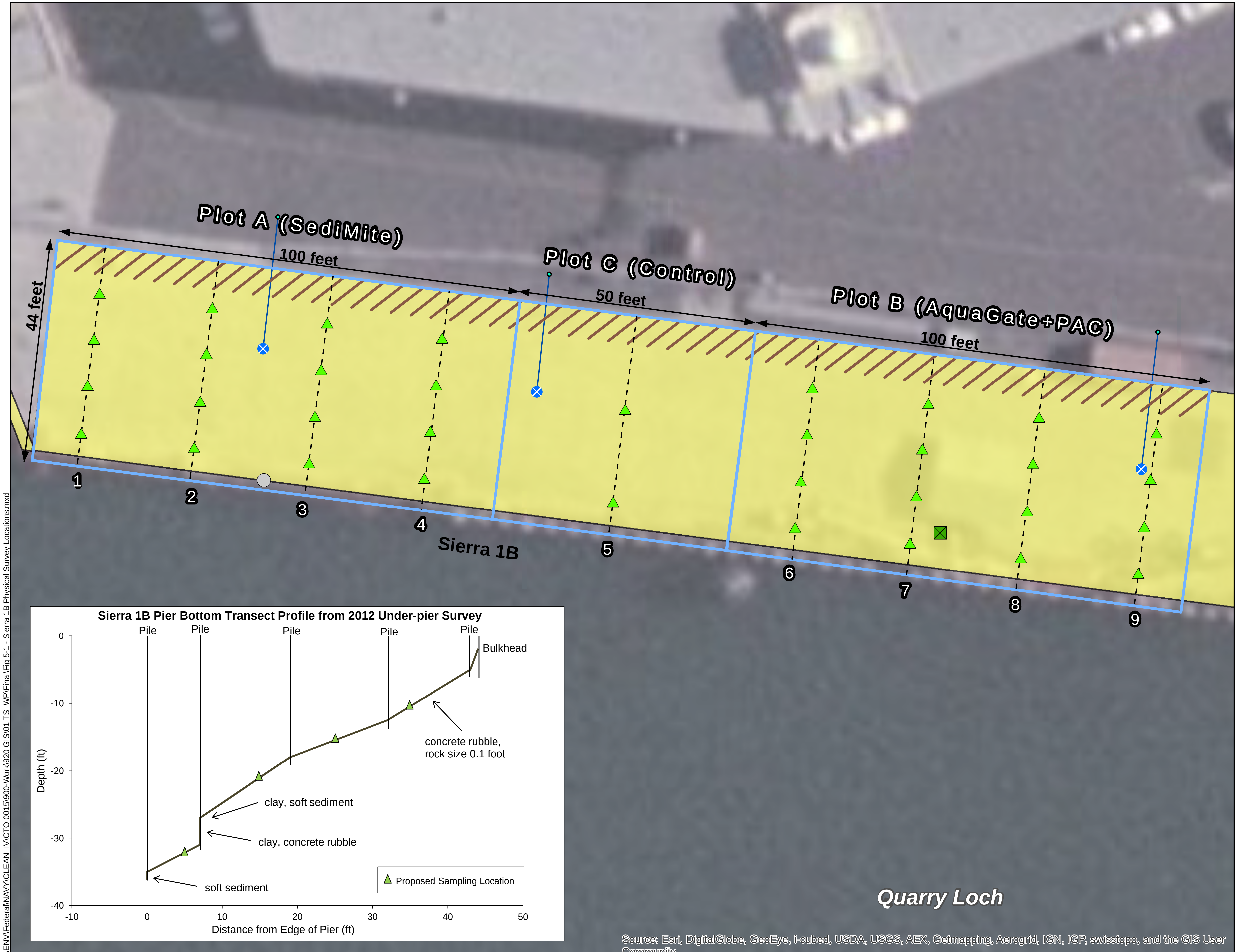
Field Activity	Sample Type	Analysis	Number of Sampling Locations per Plot	Rationale
Sediment Sampling	Discrete	COC Chemistry: PCBs, Hg, Cu, Pb	9	Evaluate changes in COC concentrations in upper 6 inches of sediment.
		Geochemistry: pH, TOC, Black Carbon	6	Evaluate changes in geochemical condition in upper 6 inches of sediment.
		Geotechnical: Moisture, PSD, WBD	6	Evaluate changes in geotechnical condition in upper 6 inches of sediment.
		Geotechnical: Atterberg Limits	2	
		Geotechnical: Hydraulic Conductivity	1	
	Discrete Undisturbed Cores	Bioaccumulation Potential	9	Assess bioaccumulation potential changes from amendment.
	Discrete	Benthic Infauna Assessment	1	Collect composite sediment benthic taxonomy and population data for comparison to baseline.
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT): PCBs, Hg, Cu, Pb	6	Evaluate changes in porewater COC concentrations in upper 6 inches of sediment; evaluate changes in porewater COC concentration changes relative to bulk sediment COC concentration changes.

Cu copper
Hg mercury
N/A not applicable
Pb lead

Table 5-2: Summary of Survey and Sampling Activities and Rationale for the Control Plot

Field Activity	Sample Type	Analysis	Number of Sampling Locations per Plot	Rationale
Baseline Survey				
Physical Survey	N/A	Visual Observation	2	Collect baseline physical data (slope, sediment thickness, current velocity, debris and biota presence).
SPI	N/A	Sediment Column Cross-Section Profile	2	Collect baseline sediment cross-section profile (sediment characteristic, biota presence, evidence of bioturbation).
Sediment Sampling	Discrete	COC Chemistry: PCBs, Hg, Cu, Pb	2	Collect baseline bulk sediment COC discrete concentration data.
		Geochemistry: pH, TOC, Black Carbon	2	Collect baseline bulk sediment geochemical data.
		Geotechnical: Moisture, PSD, WBD	2	Collect baseline bulk sediment geotechnical data.
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT): PCBs, Hg, Cu, Pb	2	Collect baseline discrete porewater concentration data; collocated with discrete bulk sediment sampling to facilitate comparison between porewater and bulk sediment COC concentrations.
Post-Construction Verification				
Physical Survey	N/A	Visual Observation	2	Document potential amendment presence extending outside of treatment plots.
SPI	N/A	Sediment Column Cross-Section Profile	2	Document potential amendment presence extending outside of treatment plots.
9-Month Monitoring				
Physical Survey	N/A	Visual Observation	2	Document potential transport of amendment outside of treatment plots.
SPI	N/A	Sediment Column Cross-Section Profile	2	Document potential transport of amendment outside of treatment plots.
Sediment Sampling	Discrete	COC Chemistry: PCBs, Hg, Cu, Pb	2	Evaluate changes in COC concentrations in upper 6 inches of untreated sediment.
		Geochemistry: pH, TOC, Black Carbon	2	Evaluate changes in geochemical condition in upper 6 inches of untreated sediment.
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT): PCBs, Hg, Cu, Pb	2	Evaluate changes in porewater COC concentrations in upper 6 inches of untreated sediment; evaluate changes in porewater COC concentration changes relative to untreated bulk sediment COC concentration changes.
18-Month Monitoring				
Physical Survey	N/A	Visual Observation	2	Document potential transport of amendment outside of treatment plots.
SPI	N/A	Sediment Column Cross-Section Profile	2	Document potential transport of amendment outside of treatment plots.
Sediment Sampling	Discrete	COC Chemistry: PCBs, Hg, Cu, Pb	2	Evaluate changes in COC concentrations in upper 6 inches of untreated sediment.
		Geochemistry: pH, TOC, Black Carbon	2	Evaluate changes in geochemical condition in upper 6 inches of untreated sediment.
		Geotechnical: Moisture, PSD, WBD	2	Evaluate changes in geotechnical condition in upper 6 inches of untreated sediment.
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT): PCBs, Hg, Cu, Pb	2	Evaluate changes in porewater COC concentrations in upper 6 inches of untreated sediment; evaluate changes in porewater COC concentration changes relative to untreated bulk sediment COC concentration changes.

Cu copper
Hg mercury
N/A not applicable
Pb lead



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LEGEND

- Physical Survey Location
- Physical Survey Transect
- 2012 Under-Pier Visual Survey Location
- Study Area
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

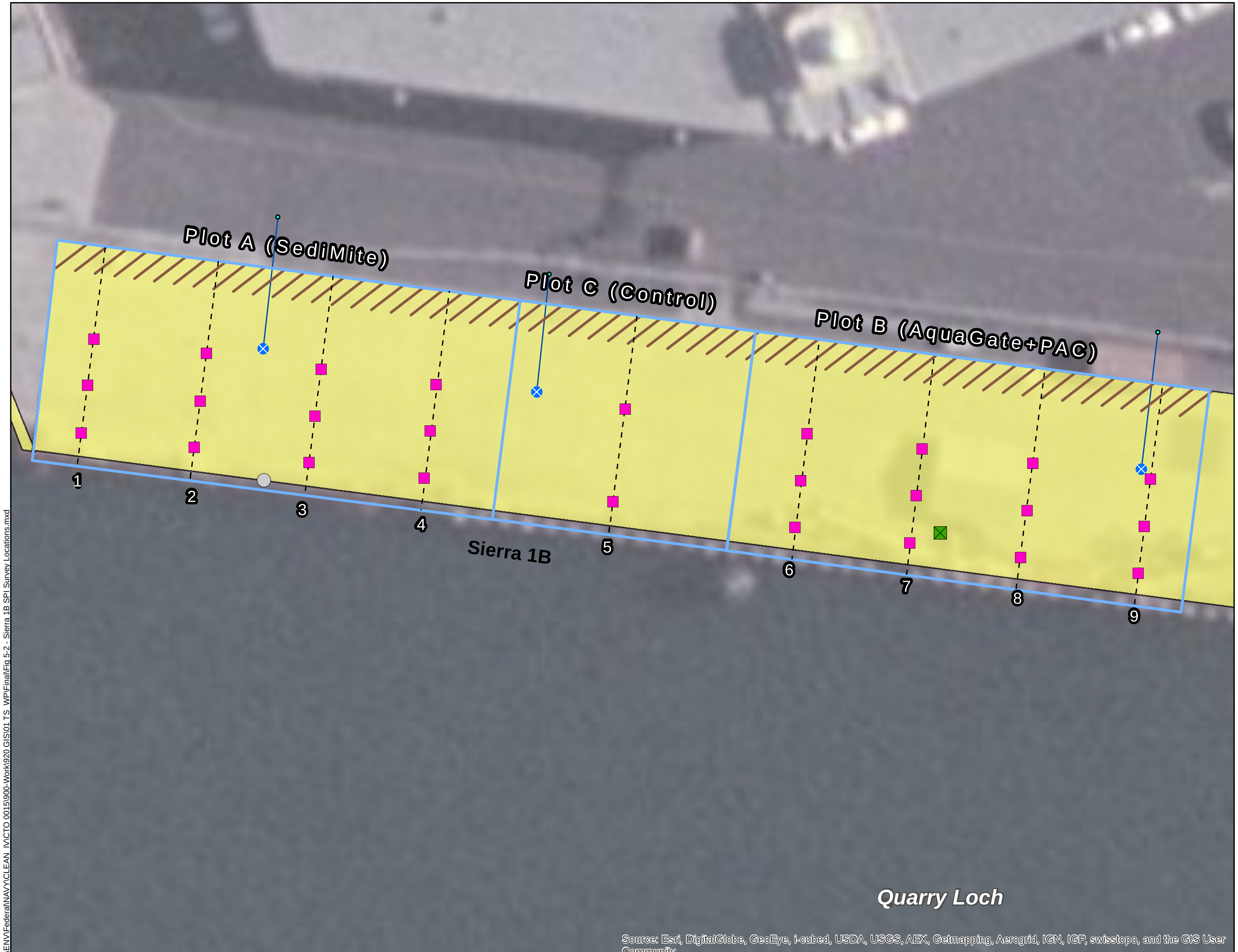
1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transects are spaced 10 feet from the outer edge, and 25 feet between transects.
4. Sampling locations are spaced every 10 feet, starting 5 feet from the leading edge of the pier.
5. Under-pier profile data from Pearl Harbor Sediment Feasibility Study (AECOM 2013a).

PAC: Powdered Activated Carbon

N

0 10 20 30 40 Feet

Figure 5-1
Sierra 1B Pier
Proposed Physical Survey Locations
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii



LEGEND

- Study Area
- SPI Survey Location
- Physical Survey Transect
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transcts are spaced 10 feet from the outer edge, and 25 feet between transects.
4. SPI sampling locations are spaced every 10 feet, starting 5 feet from the leading edge of the pier.

PAC: Powdered Activated Carbon
SPI: Sediment Profile Imaging

N

0 10 20 30 40 Feet

Figure 5-2
Sierra 1B Pier
Proposed SPI Survey Locations
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

P:\ENV\Federal\NAVY\CLEAN_IV\CTO 0015\900-Work\920 GIS\01 TS_WP\Final\Fig 5-2 - Sierra 1B SPI Survey Locations.mxd

LEGEND

- Study Area
- Sediment Sampling Location: baseline, 9 and 18 month monitoring
- Sediment Sampling Location: baseline and 18 month monitoring
- Physical Survey Transect
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transects are spaced 10 feet from the outer edge, and 25 feet between transects.
4. Additional sediment samples may be collected pending results of baseline survey.

PAC: Powdered Activated Carbon

N

0 10 20 30 40 Feet

Figure 5-3
Sierra 1B Pier
Proposed Sediment Sampling Locations
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

P:\ENV\Federal\NAVY\CLEAN IV\CTO 0015\900-Work\920 GIS\01 TS WP\Final\Fig 5-3 - Sierra 1B Sediment Sampling Locations.mxd

LEGEND

- Study Area
- Porewater Sampling Location
- Physical Survey Transect
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transects are spaced 10 feet from the outer edge, and 25 feet between transects.

PAC: Powdered Activated Carbon

N

0 10 20 30 40 Feet

Figure 5-4
Sierra 1B Pier
Proposed Porewater Sampling Locations
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

P:\ENV\Federal\NAVY\CLEAN IV\CTO 0015\900-Work\920 GIS\01 TS_WP\Final\Fig 5-4 - Sierra 1B Porewater Sampling Locations.mxd

LEGEND

- Study Area
- Geotechnical Sampling Location
- Collocated Geotechnical and Atterberg Limits Sampling Location
- Collocated Geotechnical, Atterberg Limits, and Hydraulic Conductivity Sampling Location
- Physical Survey Transect
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transects are spaced 10 feet from the outer edge, and 25 feet between transects.
4. Geotechnical sample analysis includes pH, moisture content, wet bulk density, particle size distribution, total organic carbon, and black carbon.

PAC: Powdered Activated Carbon

N

0 10 20 30 40 Feet

Figure 5-5
Sierra 1B Pier
Proposed Geotechnical Sampling Locations
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

LEGEND

- Study Area
- Bioaccumulation Sediment Sampling Location
- Infauna Assessment Sampling Location
- Physical Survey Transect
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

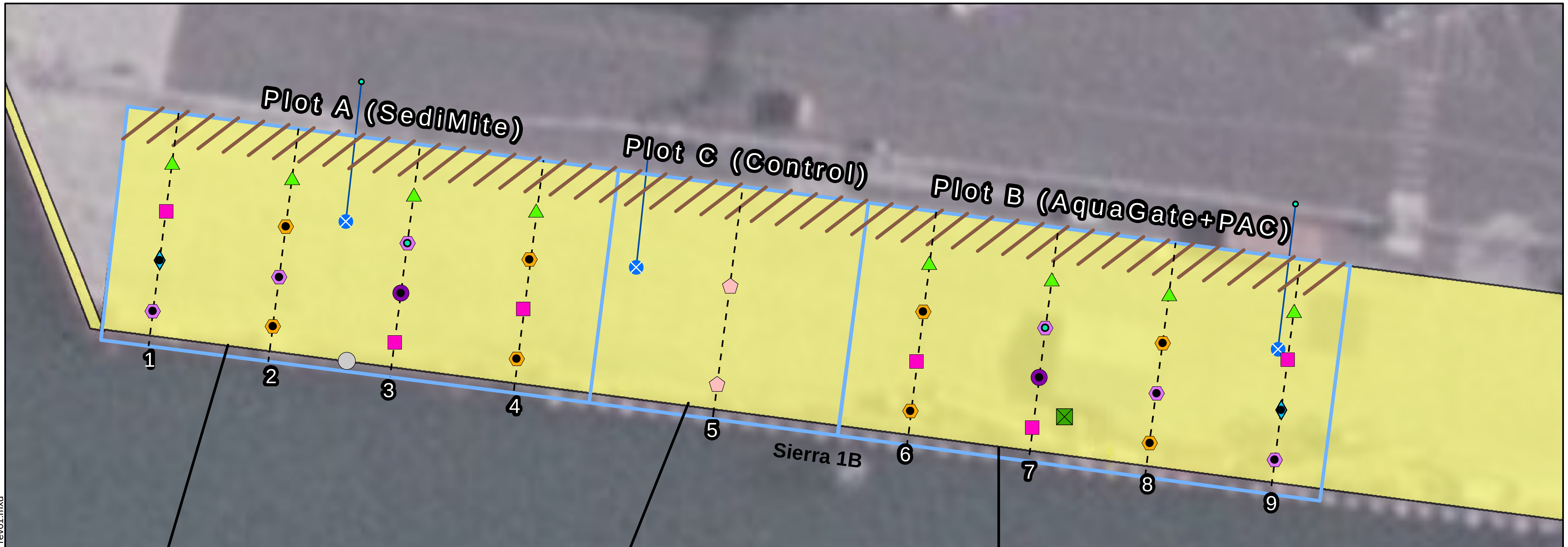
1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transcets are spaced 10 feet from the outer edge, and 25 feet between transects.

PAC: Powdered Activated Carbon

N

0 10 20 30 40 Feet

Figure 5-6
Sierra 1B Pier
Proposed Bioaccumulation and Infauna Assessment Sampling Locations
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii



PLOTS A & B		
Field Activity	Sample Type	Analysis
Baseline Survey		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
Sediment Sampling	Discrete	COC Chemistry
		Geochemistry: pH, TOC, Black Carbon
		Geotechnical: Moisture, PSD, WBD, Atterberg Limit, Hydraulic Conductivity
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT)
Bioaccumulation	Discrete	Bioaccumulation Potential
Infauna Survey	Discrete	Infauna Taxonomic Assessment
Post-Construction Verification		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
9-Month Monitoring		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
Sediment Sampling	Discrete	COC Chemistry
		Geochemistry: pH, TOC, Black Carbon
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT)
18-Month Monitoring		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
Sediment Sampling	Discrete	COC Chemistry
		Geochemistry: pH, TOC, Black Carbon
		Geotechnical: Moisture, PSD, WBD, Atterberg Limit, Hydraulic Conductivity
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT)
Bioaccumulation	Discrete	Bioaccumulation Potential
Infauna Survey	Discrete	Infauna Taxonomic Assessment

PLOT C		
Field Activity	Sample Type	Analysis
Baseline Survey		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
Sediment Sampling	Discrete	COC Chemistry
		Geochemistry: pH, TOC, Black Carbon
		Geotechnical: Moisture, PSD, WBD
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT)
Post-Construction Verification		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
9-Month Monitoring		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
Sediment Sampling	Discrete	COC Chemistry
		Geochemistry: pH, TOC, Black Carbon
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT)
18-Month Monitoring		
Physical Survey	N/A	Visual Observation
Sediment Profile Imaging	N/A	Sediment column cross-section profile
Sediment Sampling	Discrete	COC Chemistry
		Geochemistry: pH, TOC, Black Carbon
		Geotechnical: Moisture, PSD, WBD
Porewater Sampling	Discrete	COC Chemistry (SPME, DGT)

Quarry Loch

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

LEGEND

- Study Area
- Infauna Assessment Sampling Location
- Bioaccumulation Sediment Sampling Location
- Collocated Physical Survey, SPI, and Sediment Sampling Location (baseline & 18 month monitoring)
- Collocated Physical Survey, SPI, Sediment, Geochem and Porewater Sampling Location (baseline, 9 & 18 month monitoring)
- Physical Survey Location
- SPI Survey Location
- Collocated Physical Survey,SPI, Sediment, Porewater, Geochem and Atterberg Limits Sampling Location
- Collocated Physical Survey,SPI, Sediment, Porewater, Geochem, Atterberg Limits, and Hydraulic Conductivity Sampling Location
- Collocated Physical Survey, SPI, Sediment, Geochem and Porewater Sampling Location
- Physical Conditions Survey Transect
- 2012 Under-Pier Visual Survey Location
- 2012 Under-Pier Sediment Sampling Location
- Storm Drain Outfall
- Storm Drain Inlet
- Storm Drain Conduit
- Pier Area
- Expected Concrete Rubble

NOTES

1. Basemap source: USGS Earthdata.
2. Map projection: Hawaii State Plane Zone3, NAD83.
3. Transects are spaced 10 feet from the outer edge, and 25 feet between transects.
4. Sampling locations are spaced every 10 feet, starting 5 feet from the leading edge of the pier.
5. Additional sediment samples may be collected pending results of baseline survey.

PAC: Powdered Activated Carbon
SPI: Sediment Profile Imaging

N

0 10 20 30 40 50 Feet

Figure 5-7
Sierra 1B Pier
Proposed Survey and Sampling Locations and Timeline of Activities
Pearl Harbor Sediment TS WP
PHNC National Priorities List Site
JBPHH, Oahu, Hawaii

P:\ENV\Federal\NAVY\CLEAN IV\CTO 0015\900-Work\920 GIS\01 TS WP\Final\Fig 5-7 - Sierra 1B Survey-Sampling Locations and Activity Timeline rev01.mxd

5.2.6.3 PERFORMANCE MONITORING – 9 MONTHS

The first performance monitoring will be conducted 9 months following the amendment installation. The mid-study monitoring will be used to document treatment material stability, amendment mixing, and porewater results. Survey and sampling details for the 9-month performance monitoring are as follows:

- *Physical Survey* (Figure 5-1). Observations including presence of amendment layer, evidence of amendment mixing, presence of biota, photographs, and evidence of sediment failure or scour will be documented at 16 locations in each test plot and at two locations in the control plot.
- *SPI Survey* (Figure 5-2). SPI images will be recorded at 12 locations in each test plot and at two locations in the control plot. SPI images will be used to document sediment characteristics, presence of biota, evidence of bioturbation, and extent of amendment mixing.
- *Bulk Sediment Sampling* (Figure 5-3). Bulk sediment chemistry will be analyzed at six locations in each test plot and at two locations in the control plot to provide data on COC concentrations in bulk sediment. Changes in sediment COC concentrations will be evaluated.
- *Porewater Sampling* (Figure 5-4). Passive samplers (SPME and DGT) will be placed at six locations in each test plot and at two locations in the control plot to provide data on the concentrations of COCs in porewater. Porewater locations are collocated with bulk sediment samples to evaluate changes in porewater COC concentrations relative to changes in bulk sediment COC concentrations.
- *Geochemical Sampling* (Figure 5-5). Sediment samples for geochemical analysis will be collected at six locations in each test plot and at two locations in the control plot to evaluate changes in carbon content and pH. No geotechnical samples (i.e., Atterberg limits, hydraulic conductivity, WBD, moisture content, and PSD) will be collected during the 9-month performance monitoring.

5.2.6.4 PERFORMANCE MONITORING – 18 MONTHS

The second performance monitoring will be completed 18 months following the amendment installation. The final monitoring results will be used to compare to baseline and 9-month data. Survey and sampling details for the 18-month performance monitoring are as follows:

- *Physical Survey* (Figure 5-1). Observations including presence of amendment layer, evidence of amendment mixing, presence of biota, photographs, and evidence of sediment failure or scour will be documented at 16 locations in each test plot and at two locations in the control plot.
- *SPI Survey* (Figure 5-2). SPI images will be recorded at 12 locations in each test plot and at two locations in the control plot. SPI images will be used to document sediment characteristics, presence of biota, evidence of bioturbation, and extent of amendment mixing.
- *Bulk Sediment Sampling* (Figure 5-3). Bulk sediment chemistry will be analyzed at nine locations in each test plot and at two locations in the control plot to provide data on COC concentrations in bulk sediment. Changes in sediment COC concentrations will be evaluated.
- *Porewater Sampling* (Figure 5-4). Passive samplers (SPME and DGT) will be placed at six locations in each test plot and at two locations in the control plot to provide data on the concentrations of COCs in porewater. Porewater locations are collocated with bulk sediment

samples to evaluate changes in porewater COC concentrations relative to changes in bulk sediment COC concentrations.

- *Geotechnical and Geochemical Sampling* (Figure 5-5). Sediment samples for geotechnical and geochemical analysis will be collected at six locations in each test plot and at two locations in the control plot. Atterberg limits samples will be collected at two locations in each test plot. Hydraulic conductivity samples will be collected at one location in each test plot.
- *Bioaccumulation and Benthic Assessment Sampling* (Figure 5-6). Nine undisturbed cores will represent each test plot. Sediment samples will be collected from nine discrete locations per plot to prepare three bioaccumulation test replicates. Each replicate sample will be submitted for ex-situ bioaccumulation testing. Sample cores will also be collected at each of the nine locations to create a composite benthic infauna assessment sample. One sample from each test plot will be submitted for taxonomy and population assessment.

5.2.7 Reporting

Baseline data will be gathered during the TS detailed design. Detailed design documents will be implemented by the contractor. Post-construction verification and 9- and 18-month performance monitoring will be documented. At the end of the 18-month period, a report will be prepared with recommendations on full-scale implementation. More data may be required at the end of the 18-month period due to the possibility of only partial treatment being accomplished at that point. The parameters being monitored for evaluation will allow the study to determine whether treatment is progressing at an acceptable rate or additional time is required.

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