Intermediate (60 Percent) Design
Lockheed West Seattle Superfund Site
Remediation Project

May 1, 2017

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REVISION TABLE					
				Change Description	
Revision Number	**Prepared By**	**Submittal To**	**Submittal Dates**	**Section**	**Narrative (of Items Affected)**
0	Tetra Tech, Inc.	EPA	10/31/2016	All	Draft 30% Design
1	Tetra Tech, Inc.	EPA	05/01/2017	All	Draft 60% Design

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ACRONYMS

ARAR	applicable or relevant and appropriate requirement
ASCE	American Society of Civil Engineers
ASTM	ASTM International
AWQC	ambient water quality criteria
BMP	best management practice
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CHASP	Contractor’s Health and Safety Plan
cm	centimeter
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CPT	cone penetration test
CQA	Construction Quality Assurance
CQAP	Construction Quality Assurance Plan
CSL	cleanup screening level
cy	cubic yard
dBA	A-weighted decibels
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
ESCP	Erosion and Sediment Control Plan
ENR	enhanced natural recovery
EPA	U. S. Environmental Protection Agency
ESA	Endangered Species Act
ESD	Explanation of Significant Differences
FoS	Factor of Safety
FSP	Field Sampling Plan
GHG	greenhouse gas
GPS	global positioning system
GSR	Green and Sustainable Remediation
HASP	Health and Safety Plan
IC	institutional control
ICIAP	Institutional Controls Implementation and Assurance Plan

KCC	King County Code
LDW	Lower Duwamish Waterway
Lockheed Martin	Lockheed Martin Corporation
LTMMP	Long-Term Monitoring and Maintenance Plan
mg/L	milligram per liter
MHHW	mean higher high water
MLLW	mean lower low water
mm	millimeter
MTCA	Model Toxics Control Act
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NMFS	National Oceanic and Atmospheric Administration National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
OSHA	Occupational Safety and Health Administration
OSWER	(U.S. EPA) Office of Solid Waste and Emergency Response
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
Port	Port of Seattle
PSCAA	Puget Sound Clean Air Agency
PSR	Pacific Sound Resources
QAPP	Quality Assurance Project Plan
RAL	remedial action level
RAO	Remedial Action Objective
RAWP	Remedial Action Work Plan
RCW	Revised Code of Washington
RDWP	Remedial Design Work Plan
RI/FS	Remedial Investigation/Feasibility Study
RML	residual management layer
RNA	regulated navigation area
ROD	Record of Decision
SEPA	State Environmental Policy Act
Site	Lockheed West Seattle Superfund Site
SMP	Shoreline Master Program

SMC	Seattle Municipal Code
SMS	sediment management standards
SOW	Statement of Work
SQS	sediment quality standards
TBC	to-be-considered criteria
TBT	tributyltin
TI	technical impracticability
TSS	total suspended solids
U&A	Usual and Accustomed
UAO	Unilateral Administrative Order
UECA	Uniform Environmental Covenants Act
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USCG	U.S. Coast Guard
WAC	Washington Administrative Code
WISHA	Washington Industrial Safety and Health act
WQMP	Water Quality Monitoring Plan
WRDA	Waterway Resource Development Act

Section 1
Introduction

This Intermediate (60 Percent) Design has been prepared as part of the remedial design phase for implementation of the remedial action set forth in the Record of Decision (ROD) for the Lockheed West Seattle Superfund Site (EPA, 2013) and in the associated Explanation of Significant Differences (ESD; EPA, 2015a). This Intermediate Design is required by Section IV.B of the Statement of Work (SOW), Appendix B to the Unilateral Administrative Order (UAO) (U.S. Environmental Protection Agency [EPA] Docket No. 10-2015-0079/Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]) for the Remedial Design and Remedial Action for the Lockheed West Seattle Superfund Site (Site; EPA, 2015b) (Figure 1-1).

This Intermediate Design is submitted on behalf of the Lockheed Martin Corporation (Lockheed Martin). The UAO, the ROD and associated ESD, and the EPA Superfund Remedial Design and Remedial Action Guidance (Office of Solid Waste and Emergency Response [OSWER] Directive 9355.0-4A) were followed to prepare, and will be followed to implement, the Remedial Design.

1.1 SITE BACKGROUND

The Site was placed on the National Priorities List on March 7, 2007. Prior to this, the Site was listed as a sediment cleanup priority project under State of Washington authority through the requirements of the Model Toxics Control Act (MTCA). Lockheed Martin submitted the *Final Remedial Investigation/Feasibility Study for the Lockheed West Seattle Superfund Site* to EPA Region 10 in May 2012 (RI/FS; Tetra Tech, 2012). The RI/FS concluded that sediments within the Site contained elevated levels of a number of hazardous contaminants. Analytical data from surface and subsurface sediment samples indicate that metals, polychlorinated biphenyls (PCBs), tributyltin, and polycyclic aromatic hydrocarbons (PAHs) are the most frequently detected compounds in the study area. Dioxins and furans also were identified as contaminants of concern (COCs) based on their assumed presence at the Site.

On August 28, 2013, EPA issued the ROD for the Site based on the area identified in the RI/FS that warranted remedial action. The ROD presented a Selected Remedy (Figure 1-2) to address unacceptable human health risks associated with seafood consumption, net fishing, clamming, and beach play, as well as ecological risks posed to benthic invertebrates, fish, and birds. The EPA Selected Remedy is described in detail in Section 1.3. The cleanup under this ROD represents the final remedial action for the Site.

In February 2015, EPA issued an ESD to correct errors in Tables 12 and 23 of the ROD that set forth Cleanup Levels. The ESD replaced the tables and described the differences between the ROD and the final details for COC Cleanup Levels.

On April 2, 2015, EPA issued the UAO for Remedial Design and Remedial Action, documenting Lockheed Martin's responsibility for cleanup of the Site. The SOW, attached as Appendix B to the UAO, defines the work to be accomplished in the remedial design and remedial action. The final plans and specifications, general provisions, and special requirements necessary to implement the ROD are developed in the remedial design. The remedial action, the implementation phase of the ROD, including necessary long-term monitoring and maintenance, performance monitoring, and implementation of special requirements such as institutional controls, will be based on the approved remedial design. Lockheed Martin does not currently own, lease, or otherwise control any of this property as per 1992 agreement with Port of Seattle (when the property was purchased by the Port from Lockheed Martin), but is responsible to perform the work described in the UAO.

To support the design for the EPA Selected Remedy, Lockheed Martin performed a pre-design field investigation of surface and subsurface sediment, a geotechnical investigation in upland and offshore areas, structural evaluations, and additional bathymetric and debris surveys in November 2015 and January 2016. The complete report of this investigation can be found in the Pre-Design Investigation Field Sampling Data Report (Tetra Tech, 2016). The results of this pre-design investigation are used to refine the Selected Remedy as discussed in Section 1.3 and utilized in development of this Intermediate Design. Previous site investigations and the most recent pre-design field investigations are summarized in Section 3.

1.2 LOCKHEED WEST AREA

The Site is located near the confluence of the West Waterway and Elliott Bay, in Seattle, Washington (Figure 1-1). The Site is bordered by Elliott Bay on the north, the Harbor Island West Waterway Operable Unit on the east, Pacific Sound Resources (PSR) Marine Sediment Unit on the west, and the Port of Seattle (Port) Terminal 5 to the south. The Site includes the in-water marine sediments where the former Lockheed Shipyard No. 2 was located (the shipway and dry docks were located in the water over the sediments). The Site also includes a narrow shoreline intertidal bank (exposed by low tides) defined for this site as areas extending from plus [+] 11.3 feet mean higher high water (MHHW) to minus [-] 10 feet mean lower low water (MLLW) along the northern and eastern shorelines, as well as subtidal sediments (never exposed by low tides) that extend to -40 to -50 feet MLLW in historically dredged areas. The Site is impacted by tides, with additional influence from the Lower Duwamish Waterway (LDW) that flows into the West Waterway. In addition, numerous pilings remain within the footprint of the former shipway and pier structures remain along the northern shoreline and in the northwestern portion of the Site.

In total, the Site encompasses 40 acres of aquatic lands, including approximately 33 acres of state-owned aquatic lands managed by the Washington State Department of Natural Resources (DNR) and 7 acres of Port-owned aquatic tidelands. The Site and adjacent aquatic areas are designated as Tribal Usual and Accustomed (U&A) Fishing Areas. The bank and intertidal portions of the Site are accessible from the water. Access via land is currently restricted due to security fencing around Terminal 5.

The Site is located in a historically industrialized and commercial area of Seattle. There are several nearby environmental cleanup projects in the vicinity (Figure 1-1). The primary land uses near the Site have been industrial and maritime for over a century. The adjoining area of the West Waterway includes a federally maintained navigation channel and numerous privately maintained berthing areas.

1.3 DESCRIPTION OF REMEDIAL ACTION

In the Lockheed West ROD, the EPA selected a remedy comprising four key elements to address contaminated sediments at the Site (Figure 1-2):

1. Removal and disposal of identified debris in shorelines and pilings in the former shipway

2. Sediment remedial action, including sediment removal and disposal, intertidal backfill placement, and residuals management and enhanced natural recovery (ENR) layer placement
3. Institutional controls
4. Long-term monitoring and maintenance

Source control activities were completed previously by others under a separate Order with the Washington State Department of Ecology (Ecology) and are not part of the EPA Selected Remedy. The UAO does not require prevention of releases of hazardous substances originating outside the boundaries of the Site and not attributable to Site conditions (i.e., recontamination from off-site sources, as defined in the UAO). The expected outcome of the Selected Remedy is removal of the most highly contaminated sediments at the Site with concentrations of total PCBs, arsenic, copper, lead, mercury, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), tributyltin (TBT), and all other COCs that exceed the Cleanup Levels associated with the Site remedial action objectives (RAOs; see Section 2.1). Residual risks from the removal actions for these and other COCs would be mitigated through placement of a 6- to 9-inch layer of clean imported material and use of institutional controls (ICs).

Sediment remedial action boundaries in the EPA Selected Remedy have been refined based on the pre-design field investigation results (Figure 1-3). An evaluation of the results for sediment samples collected from the former shipway area during the pre-design investigation found that PAH contamination at depth is similar to the PAH contamination in sediment samples collected from the Pacific Sound Resources (PSR) site, indicating that source of the deeper PAH contamination in the former shipway area is likely from the adjacent PSR site. Therefore, the dredging removal depth was determined based on the clean interval above the PAHs found at depth, thereby leaving the contamination associated with PSR in place. Further discussion of this refinement and other design refinements is provided in Section 3.6 and in Appendix A where pre-design chemistry data and extent of dredge verification are discussed.

1.3.1 Design Coordination with the Port

Lockheed Martin is coordinating design and implementation of the remediation project with the Port. The Port has initiated two projects at the Site. The first project is T-5 Pile Removal and Disposal project, which includes; the removal of existing piles from Piers 23 and 24; removal of piles and decking from Piers 25 and 26; and removal of piles from the former shipway area between the Inner and Outer Harbor lines. The piles are to be removed per the lease termination agreement with DNR, the current manager of the state-owned aquatic lands in this portion of the Site. The anticipated start of the Port's pile removal project is mid-2017. This Port project is significant for the design in areas of the Site where the remedy includes dredging contaminated sediment in the former shipway and placement of an ENR sand layer over the footprint of Piers 23 and 24. The remediation design will incorporate the Port's plans for removal of these piles.

The other Port project is modernization of the existing marine cargo facilities at Terminal 5 which consists of vessel berth deepening, dock and power upgrades, and upland improvements to serve large cargo vessels. Contingent on the city, state, and federal authorizations and approvals of the project, the anticipated start for construction is mid-2018, with completion expected by 2020. Upland/landside construction elements would continue throughout this time period while the proposed in-water wharf improvements would be limited to three consecutive in-water work seasons to protect endangered species. Lockheed Martin has determined that the location of the Terminal 5 improvement project does not overlap with the remediation project. Lockheed Martin will continue to track progress of the Terminal 5 project through regular communications with the Port.

Another major project in progress is the U.S. Army Corps of Engineers (USACE) Seattle District's Seattle Harbor Navigational Improvement East and West Waterways Deepening Project. The USACE has prepared a draft Integrated Feasibility Report and Environmental Assessment, which documents the process of developing potential solutions to evaluate the environmental impact of deepening the East and West Waterways of the Seattle Harbor (USACE, 2016). The federal navigation channel of West Waterway is proposed to be deepened to -57 feet MLLW from existing authorized depths of -34 feet MLLW to accommodate the largest ships anticipated at the Port. The schedule for project implementation is dependent on project authorization and appropriation of federal construction funds, for which a timeline has not been defined in the feasibility study (USACE, 2016). Refer to Section 3.1.2 for further discussion of Port's T-5 improvement project and USACE's Seattle Harbor Navigation Improvement Project.

1.3.2 Design Coordination with Other Cleanup Actions

Other cleanup actions in the vicinity of the Site include LDW activities. The EPA is currently overseeing the remedial design activities on the Lower Duwamish Superfund site along with the related remedial activities at Early Action sites in the LDW. Lockheed West remediation work will be coordinated with other LDW projects to the extent applicable. Another adjacent remediation site is PSR to the west where EPA is currently performing long-term monitoring. During the implementation stage, coordination activities with other ongoing cleanup work will likely include general navigation, barge traffic, and transloading facility use.

1.3.3 Roles and Responsibilities

Lockheed Martin is responsible for completion of the design and implementation of the project per the UAO. The management roles and responsibilities for the Site cleanup implementation will be defined in the Construction Quality Assurance Plan (CQAP) to be developed at further stages of the project.

1.4 REPORT ORGANIZATION

The project includes the following actions based on the key elements of the EPA Selected Remedy and as defined in the EPA (2013) ROD.

- Design and construct shoreline bank and intertidal sediment remedial actions: Identify debris, failing bulkheads, and pilings removal; dredge sediment to the remedial action levels (RAL); and backfill to grade with clean sediments that promotes colonization by aquatic organisms which may incorporate soft or organic-rich substrates beneficial to salmonids and other Site-specific aquatic organisms (e.g., “fish mix”' or a silt-sand mix).
- Design and construct subtidal sediment remedial actions: Removal of subtidal sediment to the RALs depending on the EPA Selected Remedy description, disposal and placement of a 6-inch dredge residuals management layer in dredged areas and placement of an ENR layer in remaining subtidal areas.
- Handle/transport/dispose of dredged sediments to an upland disposal facility that is consistent with the nature and concentrations of the contaminants found in the materials to be disposed of.
- Perform construction monitoring and long-term monitoring.

The remedial design basis, details, and discussions of the project elements are presented in the remainder of this document, organized into the following sections:

Section 2 – Regulatory Requirements

Section 3 – Site Conditions

Section 4 – Debris and Piling Removal and Disposal

Section 5 – Sediment Removal and Disposal

Section 6 – Backfill, Residual Management Layer, and Enhanced Natural Recovery Layer Placement

Section 7 – Short-term Environmental Control Measures

Section 8 – Project Permitting and Site Access

Section 9 – Construction Sequence, Schedule, and Cost Estimate

Section 10 – Institutional Controls

Section 11 – Long-Term Monitoring and Maintenance

Section 12 – Environmental Sustainability

Section 13 – Next Stages of Design

Section 14 – References

Tables and figures are included at the end of their respective sections. This document is also supported by the following appendices:

Appendix A – Pre-Design Chemistry Data Summary and Dredge Extent Verification

Appendix B – Intermediate (60 Percent) Design Drawings

Appendix C – Draft Outline of Technical Specifications

Appendix D – Basis of Design Calculations

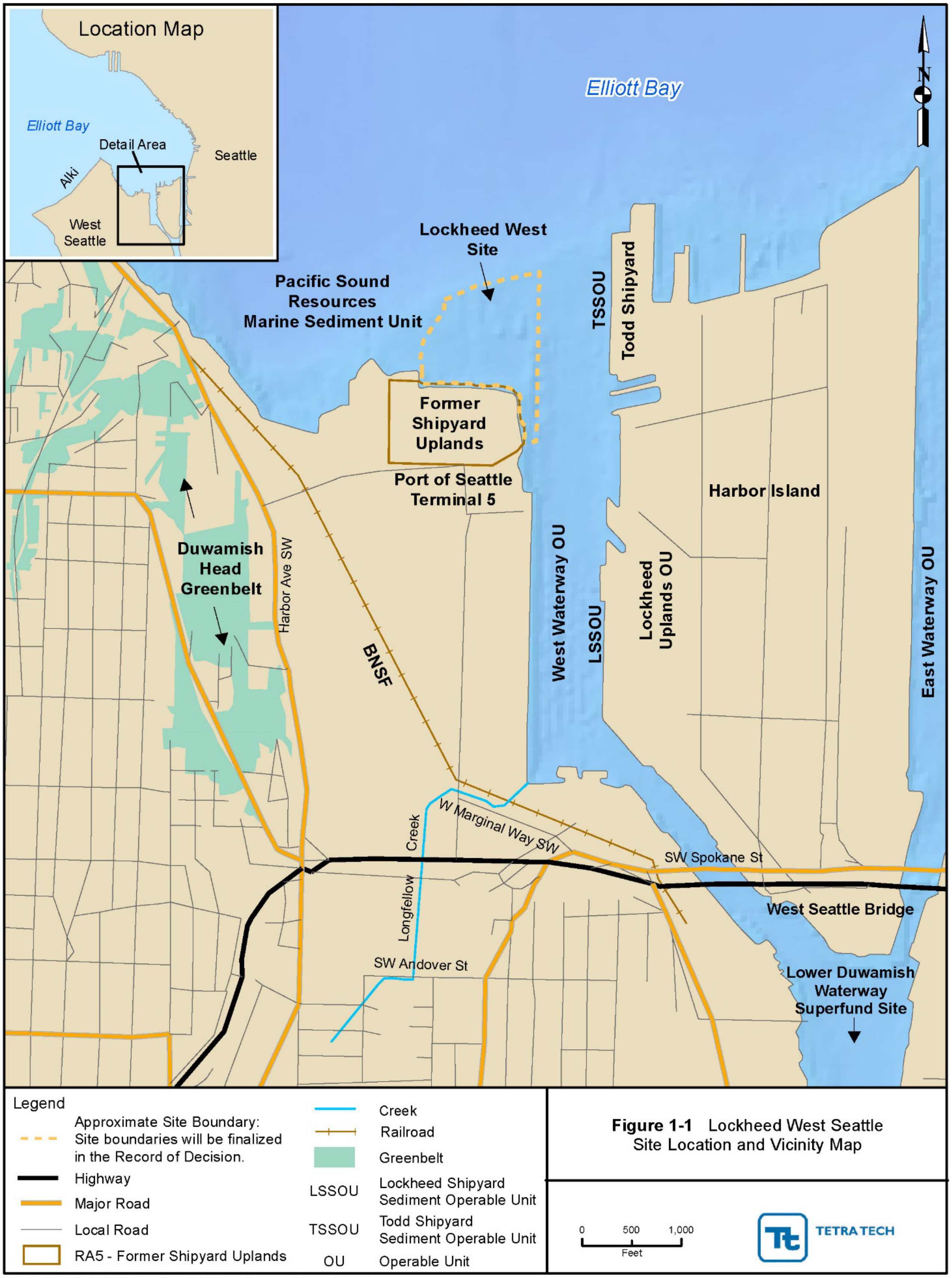
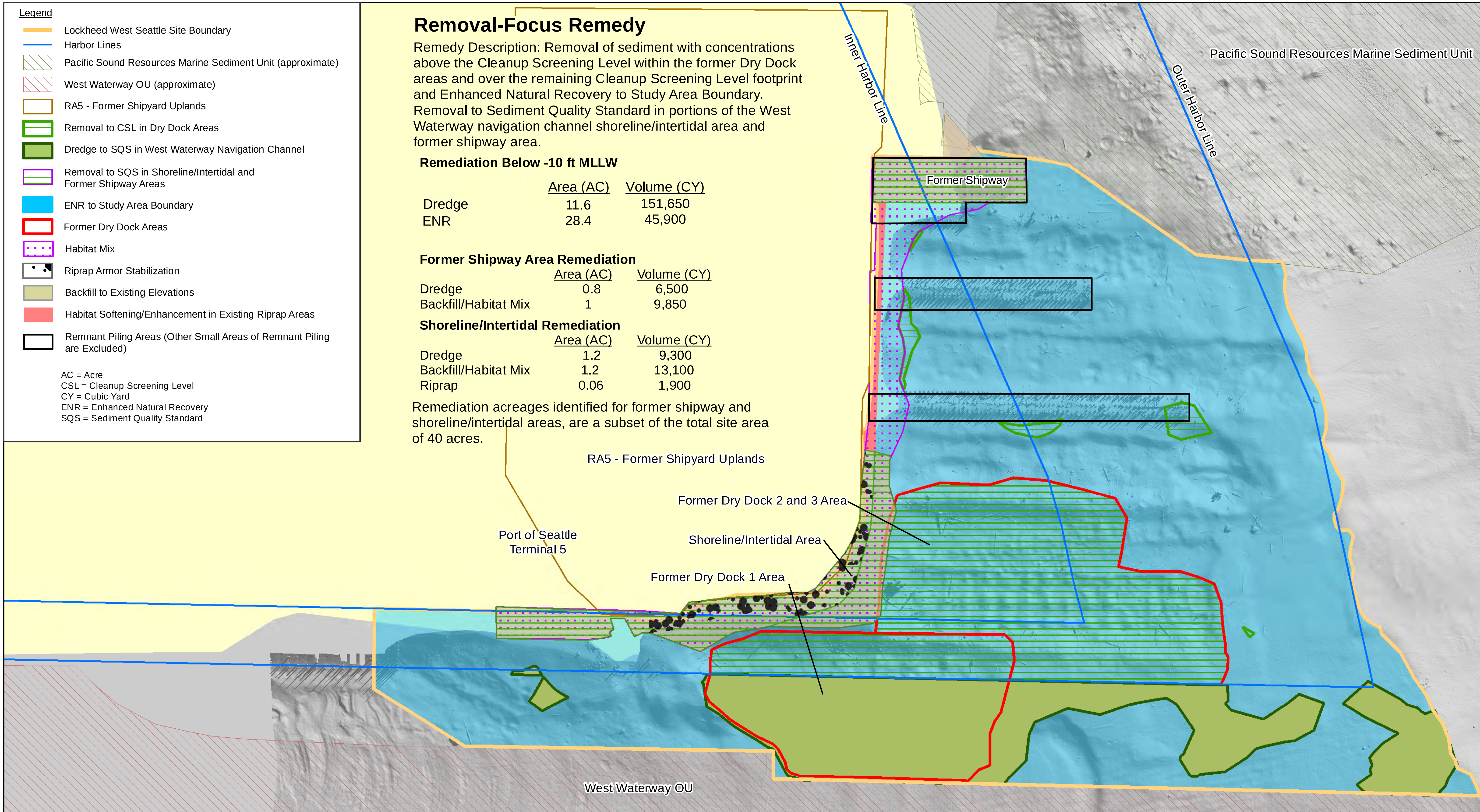


Figure 1-1 Lockheed West Seattle Site Location and Vicinity Map



Removal-Focus Remedy

Remedy Description: Removal of sediment with concentrations above the Cleanup Screening Level within the former Dry Dock areas and over the remaining Cleanup Screening Level footprint and Enhanced Natural Recovery to Study Area Boundary. Removal to Sediment Quality Standard in portions of the West Waterway navigation channel shoreline/intertidal area and former shipway area.

Remediation Below -10 ft MLLW

	Area (AC)	Volume (CY)
Dredge	11.6	151,650
ENR	28.4	45,900

Former Shipway Area Remediation

	Area (AC)	Volume (CY)
Dredge	0.8	6,500
Backfill/Habitat Mix	1	9,850

Shoreline/Intertidal Remediation

	Area (AC)	Volume (CY)
Dredge	1.2	9,300
Backfill/Habitat Mix	1.2	13,100
Riprap	0.06	1,900

Remediation acreages identified for former shipway and shoreline/intertidal areas, are a subset of the total site area of 40 acres.

Lockheed West Seattle Superfund Site Seattle, WA

Figure 1-2

EPA Selected Remedy Lockheed West Seattle Superfund Site

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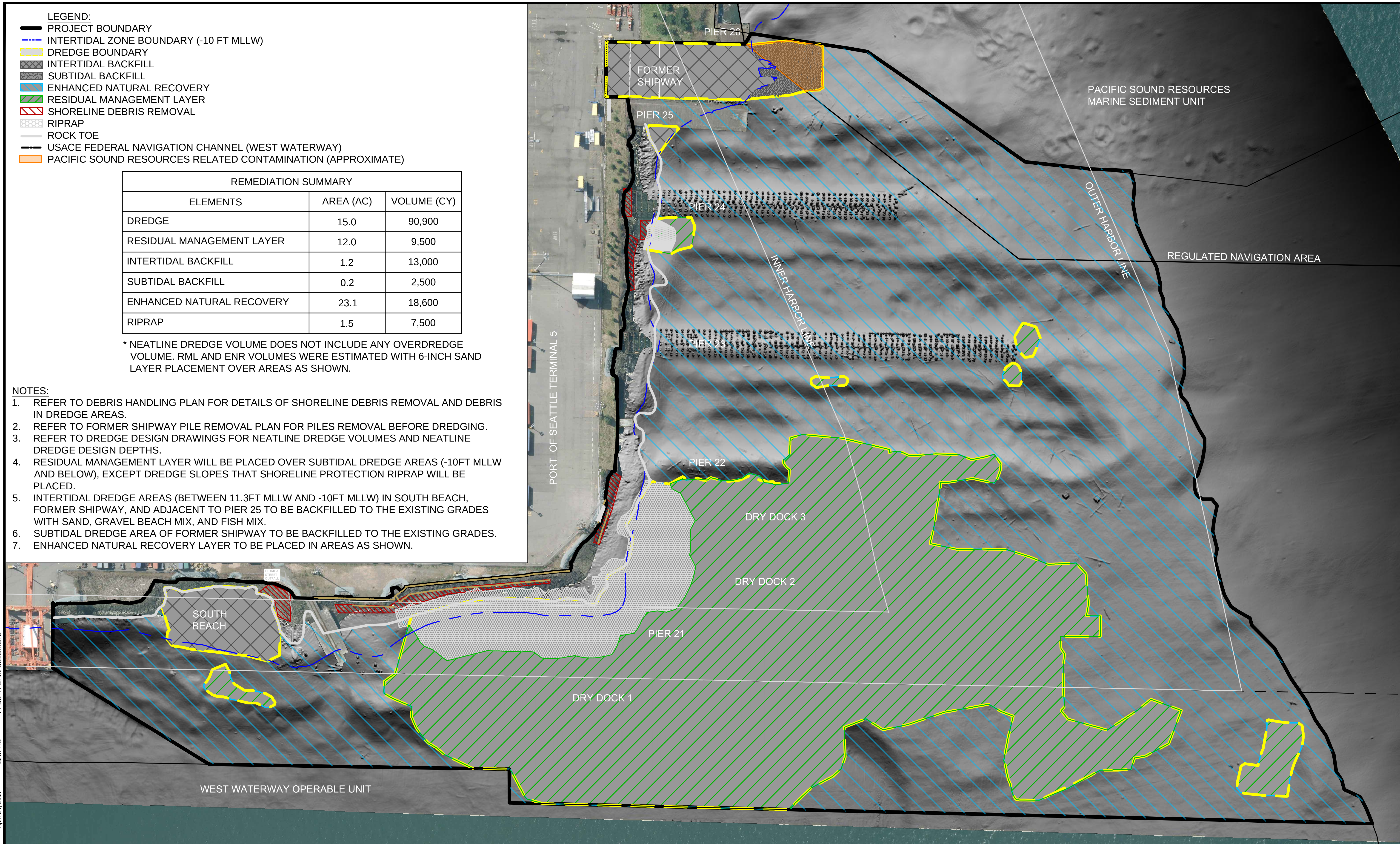

LEGEND:

- PROJECT BOUNDARY
- INTERTIDAL ZONE BOUNDARY (-10 FT MLLW)
- DREDGE BOUNDARY
- INTERTIDAL BACKFILL
- SUBTIDAL BACKFILL
- ENHANCED NATURAL RECOVERY
- RESIDUAL MANAGEMENT LAYER
- SHORELINE DEBRIS REMOVAL
- RIPRAP
- ROCK TOE
- USACE FEDERAL NAVIGATION CHANNEL (WEST WATERWAY)
- PACIFIC SOUND RESOURCES RELATED CONTAMINATION (APPROXIMATE)

REMEDIATION SUMMARY		
ELEMENTS	AREA (AC)	VOLUME (CY)
DREDGE	15.0	90,900
RESIDUAL MANAGEMENT LAYER	12.0	9,500
INTERTIDAL BACKFILL	1.2	13,000
SUBTIDAL BACKFILL	0.2	2,500
ENHANCED NATURAL RECOVERY	23.1	18,600
RIPRAP	1.5	7,500

* NEATLINE DREDGE VOLUME DOES NOT INCLUDE ANY OVERDREDGE VOLUME. RML AND ENR VOLUMES WERE ESTIMATED WITH 6-INCH SAND LAYER PLACEMENT OVER AREAS AS SHOWN.

NOTES:

1. REFER TO DEBRIS HANDLING PLAN FOR DETAILS OF SHORELINE DEBRIS REMOVAL AND DEBRIS IN DREDGE AREAS.
2. REFER TO FORMER SHIPWAY PILE REMOVAL PLAN FOR PILES REMOVAL BEFORE DREDGING.
3. REFER TO DREDGE DESIGN DRAWINGS FOR NEATLINE DREDGE VOLUMES AND NEATLINE DREDGE DESIGN DEPTHS.
4. RESIDUAL MANAGEMENT LAYER WILL BE PLACED OVER SUBTIDAL DREDGE AREAS (-10FT MLLW AND BELOW), EXCEPT DREDGE SLOPES THAT SHORELINE PROTECTION RIPRAP WILL BE PLACED.
5. INTERTIDAL DREDGE AREAS (BETWEEN 11.3FT MLLW AND -10FT MLLW) IN SOUTH BEACH, FORMER SHIPWAY, AND ADJACENT TO PIER 25 TO BE BACKFILLED TO THE EXISTING GRADES WITH SAND, GRAVEL BEACH MIX, AND FISH MIX.
6. SUBTIDAL DREDGE AREA OF FORMER SHIPWAY TO BE BACKFILLED TO THE EXISTING GRADES.
7. ENHANCED NATURAL RECOVERY LAYER TO BE PLACED IN AREAS AS SHOWN.

Z:\PROJECTS\194-8650 LOCKHEED WEST\FIGURES\.SHEET FILES\REMEDIATION OVERVIEW FIGURE.DWG
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TETRA TECH

W S N E

0' 80' 160' 320'

LOCKHEED WEST SEATTLE SUPERFUND SITE
SEATTLE, WA

FIGURE 1-3
REMEDIATION OVERVIEW

Section 2
Regulatory Requirements

Implementation of the remedial design, as described in the Record of Decision (ROD), Explanation of Significant Differences (ESD), and Unilateral Administrative Order (UAO) Scope of Work (SOW), will be conducted in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) United States Code [U.S.C.] 9601-96, as amended, and, to the extent practicable, the National Contingency Plan and the Administrative Record for the Lockheed West Seattle Superfund Site (Site).

Section 121(d) of CERCLA requires selection of a remedial action that is protective of human health and the environment. The U.S. Environmental Protection Agency's (EPA) approach to determining protectiveness involves risk assessment, considering applicable or relevant and appropriate requirements (ARARs), and to-be-considered criteria (TBC). This section presents a description of the cleanup objectives, a brief description of the ARARs identified in Section 2.10.4 of the ROD, as well as TBC for the Site. ARARs are derived from promulgated Federal standards, or more stringent promulgated state standards. The identification of ARARs was an iterative process and was considered complete with preparation of the ROD.

The ROD selected a combination of sediment remedial actions including dredging and disposal, backfill of intertidal removal areas, residuals management, enhanced natural recovery (ENR) layer placement, removal of debris and pilings, institutional controls, and long-term monitoring and maintenance as the remedy for achieving the Site cleanup objectives. Source control activities in the upland Terminal 5 area were completed previously by others under a separate order with the Washington State Department of Ecology (Ecology) and are not part of the selected remedy. The UAO does not require additional source control activities or the prevention of releases of hazardous substances originating outside the boundaries of the Site and that are not attributable to Lockheed Martin (e.g., potential releases from nearby sources). See Section 11 for additional discussion of long-term monitoring and maintenance requirements after the remediation is completed.

The Selected Remedy will meet the ARARs, as described further below. However, a technical impracticability (TI) waiver of the Federal ambient water quality criteria (AWQC) for arsenic is part of the Selected Remedy because it is technically impracticable for remediation of contaminated sediments at the Site to measurably improve the overall water quality for arsenic within the larger Elliott Bay. If it is determined that surface water exceeding AWQC concentrations is within the site boundaries after the remedial actions are completed, a TI waiver of the AWQC for other contaminants may also be necessary and will be discussed with the EPA and Ecology.

Following implementation of the Selected Remedy, the Site would be suitable for its current and anticipated future use, which includes a navigation channel. However, due to potential ongoing presence of other contaminant sources throughout Elliott Bay, the Site will not be suitable for unrestricted consumption of fish and will continue to be subject to the existing Elliott Bay-wide fish consumption advisory.

2.1 CLEANUP OBJECTIVES

The ROD defined the following Remedial Action Objectives (RAOs) to address the risks posed to human health and the environment:

- Human Health Risks:
  - **RAO 1** – Reduce human health risks associated with the consumption of resident seafood by adults and children with the highest potential exposure.
  - **RAO 2** – Prevent human health risks from direct exposure (skin contact and incidental ingestion) to contaminated sediments during netfishing, clamming, and beach play.
- Ecological Risks:
  - **RAO 3** – Prevent risks to benthic invertebrates from exposure to contaminated sediments.
  - **RAO 4** – Prevent risks to crabs, fish, and birds from exposure to contaminated sediments.

The ROD and associated ESD set Cleanup Levels for contaminants of concern (COCs). These levels represent Site-specific concentration limits to be achieved at the sediment surface (i.e., upper 10 centimeters [cm] in subtidal zone, upper 45 cm in intertidal zone) after dredging or excavation and placement of the dredge residual management/ENR layers or intertidal backfill, and provide the basis for meeting the RAOs. The Cleanup Levels for demonstrating compliance are listed in Table 2-1.

The Cleanup Levels meet the RAOs in the following ways:

- Human Health Risks:
  - **RAO 1** is met when Site-wide average concentrations of COCs in the upper 45 cm of intertidal sediment and in the upper 10 cm of subtidal sediment do not exceed Cleanup Levels that are based on human consumption of seafood caught or gathered at the Site.
  - **RAO 2** is met when Site-wide average concentrations of COCs in the upper 45 cm of intertidal sediment and in the upper 10 cm of subtidal sediment do not exceed the Cleanup Levels that are based on direct contact with sediment during netfishing, Tribal clamming, or beach play.
- Ecological Risks:
  - **RAO 3** is met when point-by-point concentrations of COCs in the upper 10 cm of intertidal and subtidal sediments do not exceed Cleanup Levels that are based on protection of benthic invertebrates (Sediment Quality Standards [SQS][1] values).
  - **RAO 4** is met when Site-wide average concentrations of COCs in the upper 10 cm of intertidal and subtidal sediments do not exceed Cleanup Levels that are based on protection of crabs, fish, and birds.

In addition to the Cleanup Levels, numeric construction performance standards for the Site remedial action include the following:

- Remedial Action Levels (RAL) – Contaminant concentrations to be achieved at the bottom of the dredge prism after dredging or excavation is complete and before placement of the dredge residual management layer or intertidal backfill. The RALs are based primarily on the SQS and cleanup screening levels (CSLs). The RAO 3 Cleanup levels will be achieved by remediating sediment above the SQS across the Site with removal of sediment in non-navigation areas to the CSL. The more stringent SQS values correspond to sediment quality that has no acute or chronic adverse effects on benthic marine organisms, the less stringent CSL values are levels above which minor adverse effects may occur in benthic marine organisms. The RALs and locations where they will be applied are listed in Table 2-2.
- Construction Activity Limits – Defined limits on environmental impacts related to construction activities, including AWQC and other ARARs to be defined in the Construction Quality Assurance Plan (CQAP) and associated documents.

[1] ARARs were frozen at the time the ROD was signed (August 2013). Therefore, the revised (2014) Washington State Sediment Management Standards (SMS) terminology is not used at this site because it was not an ARAR at the time the ROD was signed. The CSL and SQS terminology will be used for all work related to the Site.

2.2 KEY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

Remedial design sampling and analysis evaluations and remedial design construction drawings and specifications conducted under this SOW must provide sufficient data to ensure that the requirements of several different regulatory programs are met. As identified in the ROD, the requirements of the key programs in relation to remedial action for the Site are as follows:

- **Washington State Model Toxics Control Act (MTCA) (Revised Code of Washington [RCW] 70.105D; Washington Administrative Code [WAC] 173-340)**: MTCA is applicable or relevant where the substantive requirements are more stringent than CERCLA and the National Contingency Plan (NCP). The more stringent requirements of MCTA include, but are not limited to, acceptable excess cancer risk standards and the default to natural background for final remedies where risk-based threshold concentrations are below background.
- **Sediment Management Standards (WAC 173-204):** The SMS are a statutory requirement under MTCA and applicable or relevant and appropriate under CERCLA. The SMS set numerical standards for the protection of benthic marine invertebrates. The Selected Remedy will meet requirements of the SMS. SQS of the SMS are the standard for protection of benthic invertebrates.
- **Clean Water Act, Section 304(a) (40 Code of Federal Regulations [CFR] 131):** Federally recommended Water Quality Criteria that are more stringent than state criteria and that are relevant and appropriate apply to the Site. As noted above, the Selected Remedy includes a TI waiver for the AWQC for arsenic.
- **Endangered Species Act of 1973 (ESA; 50 CFR 17, 222-224, 226.212 to 402):** To protect threatened species under the ESA, including Puget Sound Chinook salmon, environmental windows (or "fish windows") have been established for Elliott Bay. These are designated periods, generally from October through February, when effects of in-water construction are minimized, largely because juvenile salmon are not migrating through the area. As part of remedial action implementation, EPA will consult with the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service to obtain a Biological Opinion.

2.3 OTHER ARARs

Other ARARs identified in the ROD may impose requirements on the remedial design in addition to those established by the key ARARs discussed above:

- **Washington Water Pollution Control Act – State Water Quality Standards for Surface Water (RCW 90.48; WAC 173-303):** State surface water quality standards are applicable where the state has adopted, and EPA has approved, Water Quality Standards (Aquatic Life Criteria).

- **Resource Conservation and Recovery Act (40 CFR 260-279), Toxic Substances Control Act (40 CFR 761.61), and Washington State Dangerous Waste Regulations (RCW 70.105; WAC 173-303)**: Federal and state hazardous waste management regulations, respectively. No known listed or characteristic hazardous wastes are present at the Site. However, if such wastes are encountered during Site cleanup, portions of the Resource Conservation and Recovery Act and Washington State Dangerous Waste Regulations related to hazardous waste determination and analytical testing, and onsite storage, treatment, and disposal may be ARARs to this project. State dangerous waste is defined more broadly than Federal hazardous waste. In addition, no known Toxic Substances Control Act wastes are present at the Site. If such wastes are encountered during Site cleanup, disposal of PCBs may be applicable.
- **Solid Waste Disposal Act (40 CFR 257-258) and Solid Waste Handling Standards (RCW 70.95; WAC 173-350):** Federal and state regulations that cover nonhazardous waste generated during remedial activities, unless wastes meet recycling exemptions.
- **Clean Water Act (40 CFR 121.2, 230, 231; 33 CFR 320, 322, 323), Rivers and Harbor Appropriations Act (33 U.S.C. 403, 33 U.S.C. 408), and Hydraulic Code Rules (RCW 77.65; WAC 220-110)**: Federal and state requirements for in-water dredging, filling, and other in-water construction.
- **Marine Protection, Research, and Sanctuaries Act (33 U.S.C. 1401-1445) and Dredged Materials Management Program (RCW 79.105.500; WAC 332-30-166(3))**: Federal and state regulations for dumping of dredged material in open water.
- **National Pollutant Discharge Elimination System (NPDES; 40 CFR 122, 125) and Discharge Permit Program (RCW 90.48; WAC 173-216, 220, 226)**: Federal and state point source standards for new discharges to surface water. Remediation discharges must comply with the substantive requirements of NPDES rules. If upland handling of sediment is planned, construction stormwater requirements will be addressed, including development of a stormwater pollution prevention plan and implementation of best management practices. NPDES program and state permitting requirements will be reviewed as part of project final design.
- **Coastal Zone Management Act (16 U.S.C. 1451 *et seq*) and Shoreline Management Act (WAC 173-16):** These Federal and state regulations are applicable to construction activities within 200 feet of the shoreline.
- **Clean Water Act Section 404(b)(1), Migratory Bird Treaty Act (16 U.S.C. 703-712; 50 CFR 10, 17), Eagle Protection Act (50 CFR 22); and City of Seattle Master Plan Seattle Municipal Code 23.60**: In addition to the ESA, these Federal and local laws address the conservation of endangered or threatened species. As noted above, habitat mitigation will be assessed and addressed in the remedial design as necessary. EPA will consult with the appropriate agencies to obtain Biological Opinions.

2.4 STATE LAWS AND REGULATIONS (TBCs)

Other requirements to be considered include the following:

- **Washington Industrial Safety and Health Act:** The Washington Industrial Safety and Health Act (WISHA; WAC 296-155) sets safety standards for construction. This code specifies health and safety standards for responding to releases or substantial threats of release of hazardous substances at hazardous waste sites. WISHA requirements are generally more stringent than Occupational Safety and Health Administration (OSHA) requirements. All cleanup activities will adhere to WISHA standards. Detailed health and safety training requirements, and details on how the Contractor will comply with WISHA standards, will be included in the Construction Health and Safety Plan (HASP).
- **Solid Waste Disposal Regulations:** Minimum Functional Standards for Solid Waste Handling (WAC 173-304) are applicable to non-hazardous waste management generated during remedial activities. Non-hazardous sediment will be handled and disposed in accordance with these requirements. The cleanup will use existing permitted disposal and recycling facilities that are compliant with the solid waste disposal regulations and are permitted to accept impacted materials.
- **State Environmental Policy Act:** The State Environmental Policy Act (SEPA) Chapter 43.21C RCW and related rules, WAC 197-11, require an environmental review of proposed project actions such as construction projects or adoptions of agency plans that may affect the environment. The purpose of SEPA is to fully and publicly disclose potential impacts, provide opportunity for public input, and ensure potential impacts are considered in decision-making. National Environmental Policy Act (NEPA) documents and procedures may be used to comply with SEPA requirements. The substantive requirements of SEPA are met by the CERCLA process.
- **Water Pollution Control Act:** The Water Pollution Control Act (Chapter 90.48 RCW) establishes permitting requirements for point source discharges to surface waters of Washington State. It includes narrative and quantitative limitations for compliance with surface water standards. The Water Quality Monitoring Plan (WQMP) and the Remedial Action Work Plan (RAWP) will define measures to be taken to comply with surface water standards and with requirements of the water quality criteria.
- **Hydraulic Code Regulations; Construction in State Waters:** Regulations governing construction in State waters below the ordinary high water mark are established by RCW 77.55, Construction Projects in State Waters and by the Hydraulic Code rules, WAC 220-110. These regulations provide for protection of fish and shellfish during in-water construction. The substantive requirements of the regulations will be confirmed through consultation with the state Department of Fish and Wildlife and will be incorporated in planning and design of the cleanup. The requirements will also be addressed by the conservation measures and best management practices (BMP) identified in the ESA Section 7 Consultation Biological Assessment.
- **Shoreline Management Act:** The Shoreline Management Act (RCW 90.58 and related rules) manages appropriate uses and developments along shorelines of the state via state-monitored, locally administered permitting programs (see additional discussion in Section

2.5.2 related to the King County Shoreline Master Program [SMP]). The act establishes preferences for water-dependent uses, protection of shoreline ecological resources, and public access with the shoreline jurisdiction, defined as aquatic areas and lands within 200 feet of the ordinary high water mark. Consistent with state Enrolled Senate Bill 1653, shoreline critical areas are regulated under the local Shoreline Master Program regulations.

2.5 LOCAL CODES AND REGULATIONS (TBCs)

2.5.1 Air Quality Requirements

Air quality requirements for workers are governed by OSHA and ambient air quality requirements for the Puget Sound region are governed by the Puget Sound Clean Air Agency (PSCAA). PSCAA Regulation I includes criteria for visual emissions, suspended particulates less than 10 microns in diameter, lead, and carbon monoxide. Air monitoring will be conducted to maintain worker and community health and safety as required by OSHA and as specified in the project HASP (to be developed at later stages of the project).

2.5.2 King County Code

King County's SMP (King County Code [KCC] Title 25) manages construction and uses within the shoreline district. The Site is designated as aquatic shoreline in King County's updated SMP dated January 2013. Cleanup activities along the shoreline will be in substantive compliance with these policies and regulations through the use of dredging, water quality, and erosion control BMPs, as well as measures to protect fish, marine mammals, and other aquatic species, and implementation of both worker and community health and safety plans. Under the SMP (KCC 21A.25.190), dredging and backfilling associated with cleanup actions are allowed. Shoreline stabilization where the project is remediating a contaminated site is allowed under KCC 21A.25.170.

Potential public access requirements of the SMP are not applicable because the cleanup project does not establish a new/future public use of the site.

The King County Clearing and Grading Code (KCC 16.82) regulates excavation, grading, and earthwork within unincorporated King County, as well as stormwater, erosion and sedimentation, and aquatic habitat impacts/loss. It also protects water quality from adverse impacts associated with erosion and sedimentation and critical areas from adverse clearing and grading activities. The RAWP and Erosion and Sediment Control Plan (ESCP) will define measures that provide substantive compliance with these regulations. A summary of temporary erosion and sediment control measures is provided in Section 7.

King County Noise Code (KCC Title 12.88) governs construction through the timing restrictions and the noise limits included in the King County noise code requirements (KCC, Chapter 12.88). This rule defines maximum permissible sound levels based on the zoning of the source. Note that receiving properties adjacent to the site are within the city of Seattle and would be subject to limits established in the Seattle Municipal Code (SMC).

The substantive requirements of applicable county regulations have been incorporated in the planning and design of the cleanup.

2.5.3 Seattle Municipal Code

The City of Seattle Land Use Code (Seattle Municipal Code, Title 23) provides codes and standards applicable to shoreline modifications, specifically within the Seattle Shoreline Master Program Regulations (SMC Title 23, Chapter 23.60A). Within the Seattle Shoreline Master Program Regulations, standards applicable to shoreline modification are given within SMC 23.60A, Subchapter III, Part 4 (Standards Applicable to Shoreline Modifications), 23.60A.172 (Applicable Standards for Shoreline Modifications).

Standards for Dredging are described in SMC 23.60A.182. This section requires that the dredging operations be designed, located, constructed, and managed to minimize impacts to stability of slopes on and off the site. SMC 22.170 (Grading Code) requires that the final graded slopes no steeper than is safe for the intended use, not steeper than 2 horizontal to 1 vertical; and designing and constructing the dredged slopes in a manner that will minimize erosion. Cleanup activities along the shoreline will be in substantive compliance with these policies and regulations.

SMC, Chapter 25.08 restricts maximum permissible sound levels for sound sources located within the city of Seattle. For the purposes of this project, it will be assumed that construction noise will be generated from an industrial source (dredging area zoned as industrial) with the receiving property being industrial. In addition, the noise-producing activity is Construction, as defined by the SMC. Using these assumptions, and based on the applicable codes, the maximum permissible sound level for the industrial area is 90 A-weighted decibels (dB(A)) for Industrial noise generation between the hours of 7:00 a.m. and 10:00 p.m. on weekdays and 9:00 a.m. and 10:00 p.m. on weekends and legal holidays (New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day and the day after, and Christmas Day). The maximum permissible sound levels are measured within 50 feet of the equipment. Specific permissible sound levels associated with various equipment used on construction sites are described in SMC 25.08.425.

Based on the current use classifications for the Site area (heavy industrial or marine industrial), there are currently no hours of work restriction, and construction activities are assumed to be allowed 24 hours per day, 7 days per week. Lights may be required for winter work when the sun sets around 5:00 p.m. Per SMC 23.50.046, performance standards for this project for acceptable light emissions for receiving properties is 1.0 foot candle as specified for commercial/industrial areas.

Table 2-1
Summary of Cleanup Levels for Contaminants of Concern in Sediment

COC	Risk Driver?	Units[1]	Spatial Scale of Exposure[2]	RAO 1 Human Seafood Consumption[3] (0 to 10 cm)	RAO 2 Human Direct Contact[3] (0 to 45 cm)	RAO 3 Benthic Organisms[4] (0 to 10 cm)	RAO 4 Ecological[5] (0 to 10 cm)
Total PCBs	Yes	µg/kg dw	Subtidal	2 (nat. bkgd)	n/a	n/a	100 (RBTC – fish)
			Intertidal	2 (nat. bkgd)	n/a	n/a	n/a
			Point	n/a	n/a	12 mg/kg-OC/ 180 (SQS)	n/a
cPAHs	Yes	µg TEQ/kg dw	Subtidal	9 (nat. bkgd)	550 (RBTC)[6]	n/a	n/a
			Intertidal	9 (nat. bkgd)	15 (RBTC)[7]	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Arsenic	Yes	mg/kg dw	Subtidal	7 (nat. bkgd)	7 (nat. bkgd)	n/a	n/a
			Intertidal	7 (nat. bkgd)	7 (nat. bkgd)	n/a	n/a
			Point	n/a	n/a	57 (SQS)	n/a
Lead	Yes	mg/kg dw	Subtidal	11 (nat. bkgd)	n/a	n/a	n/a
			Intertidal	11 (nat. bkgd)	n/a	n/a	50 (RBTC – sandpiper)
			Point	n/a	n/a	n/a	n/a
Tributyltin	Yes	µg/kg dw	Subtidal	430 (RBTC – child)	n/a	n/a	150
			Intertidal	2,000 (RBTC – child)[8]	n/a	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Copper	Yes	mg/kg dw	Subtidal	400 (RBTC – child)	n/a	n/a	114 (RBTC – fish)
			Intertidal	400 (RBTC – child)[8]	n/a	n/a	420 (RBTC – sandpiper)
			Point	n/a	n/a	390 (SQS/CSL)	n/a
Mercury	Yes	mg/kg dw	Subtidal	0.41 (RBTC – child)	n/a	n/a	n/a
			Intertidal	0.17 (RBTC – child)	n/a	n/a	n/a
			Point	n/a	n/a	0.41 (SQS)	n/a
Dioxins/ Furans	Yes	ng TEQ/kg dw	Subtidal	2 (nat. bkgd)	37 (RBTC)[8]	n/a	n/a
			Intertidal	2 (nat. bkgd)	13 (RBTC)[8]	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Antimony	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	150 (LAET/SL)	n/a
Cadmium	No	mg/kg dw	Subtidal	0.398 (nat. bkgd)	n/a	n/a	n/a
			Intertidal	0.398 (nat. bkgd)	n/a	n/a	n/a
			Point	n/a	n/a	n/a	n/a
Chromium	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	260 (SQS)	n/a
Cobalt	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	10 (LAET/SL)	n/a

Table 2-1
Summary of Cleanup Levels for Contaminants of Concern in Sediment

COC	Risk Driver?	Units[1]	Spatial Scale of Exposure[2]	RAO 1 Human Seafood Consumption[3] (0 to 10 cm)	RAO 2 Human Direct Contact[3] (0 to 45 cm)	RAO 3 Benthic Organisms[4] (0 to 10 cm)	RAO 4 Ecological[5] (0 to 10 cm)
Nickel	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	140 (LAET/SL)	n/a
Selenium	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	1 (LAET/SL)	n/a
Vanadium	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	57 (LAET/SL)	n/a
Zinc	No	mg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	410 (SQS)	n/a
Pentachloro-phenol	No	µg/kg dw	Subtidal			n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	360 (SQS)	n/a
Bis(2-ethylhexyl)-phthalate	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	47 mg/kg-OC/ 710 (SQS)	n/a
Acenaph-thene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	16 mg/kg-OC/ 240 (SQS)	n/a
Benzo(a)-anthracene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	110 mg/kg-OC/ 1,700 (SQS)	n/a
Benzo(a) -pyrene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	99 mg/kg-OC/ 1,500 (SQS)	n/a
Benzo(g,h,i) -perylene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	31 mg/kg-OC/ 470 (SQS)	n/a
Total Benzofluor-anthenes	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	230 mg/kg-OC/ 1,800 (SQS)	n/a
Chrysene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	110 mg/kg-OC/ 1,700 (SQS)	n/a

Table 2-1
Summary of Cleanup Levels for Contaminants of Concern in Sediment

COC	Risk Driver?	Units[1]	Spatial Scale of Exposure[2]	RAO 1 Human Seafood Consumption[3] (0 to 10 cm)	RAO 2 Human Direct Contact[3] (0 to 45 cm)	RAO 3 Benthic Organisms[4] (0 to 10 cm)	RAO 4 Ecological[5] (0 to 10 cm)
Dibenz(a,h)-anthracene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	12 mg/kg-OC/ 180 (SQS)	n/a
Fluor-anthene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	160 mg/kg-OC/ 2,400 (SQS)	n/a
Indeno(1,2,3-cd)pyrene	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	34 mg/kg-OC/ 510 (SQS)	n/a
Phenan-threne	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	100 mg/kg-OC/ 1,500 (SQS)	n/a
Total HPAH	No	µg/kg dw	Subtidal	n/a	n/a	n/a	n/a
			Intertidal	n/a	n/a	n/a	n/a
			Point	n/a	n/a	960 mg/kg-OC/ 14,400 (SQS)	n/a

1 Unless noted differently in RAO-specific values
2 The spatial scale of exposure is measured as site-wide (i.e., all subtidal and intertidal sediments), intertidal sediments only, and point measurements at single locations throughout the site (i.e., all subtidal and intertidal sediment locations) or at single locations in intertidal sediment only. The spatial scale is RAO-specific, with site-wide exposures applicable to human seafood consumption, human direct contact, and exposures of fish and crab. Intertidal-only exposures are applicable to human consumption of clams from intertidal areas and exposures of sandpiper. Point exposures are applicable to benthic organisms, which are evaluated at single station locations. The statistical metric for site-wide and intertidal evaluation of alternatives and compliance monitoring is the upper confidence limit on the mean, whereas point exposures are evaluated with concentration data at single locations.
3 Cleanup levels are based on 10^{-6} cancer risk for carcinogens (e.g., PCBs, cPAHs, arsenic) or on a child exposure hazard quotient of 1 for noncarcinogens (lead, tributyltin, copper). Where Cleanup Levels are based on carcinogenic risks below background, the background concentration is selected; where no background values are available (chlordanes and DDT), the method detection limit (MDL) is selected.
4 Applicable on a point exposure only. Values for PCBs and PAHs (except total benzofluoranthenes) are the organic carbon-normalized SQS and the dry weight equivalent based on an average sediment total organic carbon content of 1.5%; for all other compounds values are dry weight. Under the SMS, sediment cleanup standards are established on a site-specific basis within an allowable range. The SQS and CSL define this range. For chemicals without SMS, LAET and 2LAET values or the SL and ML of the DMMP define this range.
5 Cleanup levels for site-wide exposure are the lowest for either fish or crab; Cleanup levels for intertidal exposure are for sandpiper.
6 The cleanup level for site-wide direct contact is based on netfishing.
7 The cleanup level for intertidal direct contact is based on the lowest for either Tribal clamming or child beach play exposures.
8 The cleanup for intertidal seafood consumption is based on consumption of clams from the intertidal sediment.

Notes:
µg/kg dw = micrograms per kilogram dry weight
µg TEQ/kg dw = micrograms Toxicity Equivalents per kilogram dry weight
COC = contaminant of concern
cm = centimeter(s)
cPAH = carcinogenic polycyclic aromatic hydrocarbon
CSL = cleanup screening level
DMMP = dredge material management program
dw = dry weight
HPAH = heavy weight polycyclic aromatic hydrocarbon
LAET = lowest apparent affect threshold
ML = maximum level
mg/kg-dw = milligrams per kilogram dry weight
n/a = compounds do not present a risk for the RAO scenario
Nat Bkgd = natural background
ng TEQ/kg-dw = nanograms toxicity equivalents per kilogram dry weight
OC = organic carbon (1.5%)
PCB = polychlorinated biphenyl
RAO = remedial action objective
RBTC = risk-based threshold concentrations
SL = screening level
SMS = Sediment Management Standards
SQS = sediment quality standards

Table 2-2
Remedial Action Levels to be Achieved at Sediment Surface Following Excavation and Dredging

COC	Risk Driver?	Compliance Zone[1]	RAL	Units	Source
Total PCBs	Yes	0 to 10 cm	12	mg/kg-OC	SQS
			180	µg/kg dw	
cPAHs	Yes	Not applicable			
Arsenic	Yes	0 to 10 cm	57	mg/kg-dw	SQS
Lead	Yes	0 to 10 cm	530	mg/kg-dw	CSL
Tributyltin	Yes	Not applicable			
Copper	Yes	0 to 10 cm	390	mg/kg-dw	SQS and CSL
Mercury	Yes	0 to 10 cm	0.41	mg/kg-dw	SQS
Dioxins/Furans	Yes	Not applicable			
Chromium	No	0 to 10 cm	260	mg/kg-dw	SQS
Cobalt	No	0 to 10 cm	10	mg/kg-dw	LAET/SL
Nickel	No	0 to 10 cm	140	mg/kg-dw	LAET/SL
Selenium	No	0 to 10 cm	1	mg/kg-dw	LAET/SL
Vanadium	No	0 to 10 cm	57	mg/kg-dw	LAET/SL
Zinc	No	0 to 10 cm	410	mg/kg-dw	SQS
Pentachlorophenol	No	0 to 10 cm	360	mg/kg-dw	SQS
Bis(2-ethylhexyl)-phthalate	No	0 to 10 cm	47	mg/kg-OC	SQS
			710	µg/kg dw	
Acenaphthene	No	0 to 10 cm	16	mg/kg-OC	SQS
			240	µg/kg dw	
Benzo{a)anthracene	No	0 to 10 cm	110	mg/kg-OC	SQS
			1,700	µg/kg dw	
Benzo(a)pyrene	No	0 to 10 cm	99	mg/kg-OC	SQS
			1,500	µg/kg dw	
Benzo(g,h,i)perylene	No	0 to 10 cm	31	mg/kg-OC	SQS
			470	µg/kg dw	
Total Benzofluoranthenes	No	0 to 10 cm	230	mg/kg-OC	SQS
			1,800	µg/kg dw	
Chrysene	No	0 to 10 cm	110	mg/kg-OC	SQS
			1,700	µg/kg dw	
Dibenz(a,h)anthracene	No	0 to 10 cm	12	mg/kg-OC	SQS
			180	µg/kg dw	
Fluoranthene	No	0 to 10 cm	160	mg/kg-OC	SQS
			2,400	µg/kg dw	
Indeno(1,2,3-cd)pyrene	No	0 to 10 cm	34	mg/kg-OC	SQS
			510	µg/kg dw	
Phenanthrene	No	0 to 10 cm	100	mg/kg-OC	SQS
			1,500	µg/kg dw	
Total HPAH	No	0 to 10 cm	960	mg/kg-OC	SQS
			14,000	µg/kg dw	
Remedial Action Levels for Dry Docks (Area 4) and Localized Subareas (Area 5)					
Total PCBs	Yes	0 to 10 cm	65	mg/kg-OC	CSL
			960	µg/kg dw	
cPAHs	Yes	Not applicable			
Arsenic	Yes	0 to 10 cm	93	mg/kg-dw	CSL

Table 2-2

Remedial Action Levels to be Achieved at Sediment Surface Following Excavation and Dredging

COC	Risk Driver?	Compliance Zone[1]	RAL	Units	Source
Lead	Yes	0 to 10 cm	530	mg/kg-dw	CSL
Tributyltin	Yes	Not applicable			
Copper	Yes	0 to 10 cm	390	mg/kg-dw	SQS and CSL
Mercury	Yes	0 to 10 cm	0.59	mg/kg-dw	CSL
Dioxins/Furans	Yes	Not applicable			
Chromium	No	0 to 10 cm	270	mg/kg-dw	CSL
Cobalt	No	0 to 10 cm	n/a	mg/kg-dw	
Nickel	No	0 to 10 cm	n/a	mg/kg-dw	
Selenium	No	0 to 10 cm	n/a	mg/kg-dw	
Vanadium	No	0 to 10 cm	n/a	mg/kg-dw	
Zinc	No	0 to 10 cm	960	mg/kg-dw	CSL
Pentachlorophenol	No	0 to 10 cm	690	mg/kg-dw	CSL
Bis(2-ethylhexyl)-phthalate	No	0 to 10 cm	78	mg/kg-OC	CSL
			1,200	µg/kg dw	
Acenaphthene	No	0 to 10 cm	57	mg/kg-OC	CSL
			860	µg/kg dw	
Benzo(a)anthracene	No	0 to 10 cm	270	mg/kg-OC	CSL
			4,100	ug,/kg-dw	
Benzo(a)pyrene	No	0 to 10 cm	210	mg/kg-OC	CSL
			3,200	µg/kg dw	
Benzo(g,h,i)perylene	No	0 to 10 cm	78	mg/kg-OC	CSL
			1,200	µg/kg dw	
Total Benzofluoranthenes	No	0 to 10 cm	450	mg/kg-OC	CSL
			6,800	µg/kg dw	
Chrysene	No	0 to 10 cm	460	mg/kg-OC	CSL
			6,900	µg/kg dw	
Dibenz(a,h)anthracene	No	0 to 10 cm	33	mg/kg-OC	CSL
			500	µg/kg dw	
Fluoranthene	No	0 to 10 cm	1,200	mg/kg-OC	CSL
			18,000	µg/kg dw	
incleno(1,2,3-cd)pyrene	No	0 to 10 cm	88	mg/kg-OC	CSL
			1,300	µg/kg dw	
Phenanthrene	No	0 to 10 cm	480	mg/kg-OC	CSL
			7,200	µg/kg dw	
Total HPAH	No	0 to 10 cm	5,300	mg/kg-OC	CSL
			79,500	µg/kg dw	

[1] The Compliance Basis is Subtidal Surface Sediment (point), and is the same for all COCs.

Notes:

µg/kg dw = micrograms per kilogram dry weight
µg TEQ/kg dw = micrograms Toxicity Equivalents per kilogram dry weight
COC = contaminant of concern
cm = centimeter(s)
cPAH = carcinogenic polycyclic aromatic hydrocarbon
CSL = cleanup screening level
dw = dry weight
HPAH = heavy weight polycyclic aromatic hydrocarbon
LAET = lowest apparent affect threshold
mg/kg-dw = milligrams per kilogram dry weight
n/a = compounds do not present a risk for the RAO scenario
ng TEQ/kg-dw = nanograms toxicity equivalents per kilogram dry weight
OC = organic carbon (1.5%)
PCB = polycholorinated biphenyl
RAL = remedial action level
SL = screening level
SQS = sediment quality standards

Section 3
Site Conditions

This section presents background and environmental setting information regarding the Lockheed West Seattle Superfund Site (Site) and surrounding area. This section also presents a summary of the existing data for the Site.

3.1 SITE DESCRIPTION, OWNERSHIP, AND SITE USE

The Site encompasses the in-water portion of what was formerly known as Lockheed Shipyard No. 2, located near the confluence of the West Waterway and Elliott Bay, in the city of Seattle, Washington (Figure 1-1).

The Site includes the in-water marine sediments where the former Lockheed Shipyard No. 2 was located (the shipway and dry docks were located in the water over the sediments). The Site includes a narrow shoreline bank and intertidal sediments along the northern and eastern shorelines and subtidal sediments that extend from -40 to -50 feet mean lower low water (MLLW) in historically dredged areas. It is impacted by tides, with additional influence from the Lower Duwamish Waterway (LDW) that flows into the West Waterway. In addition, numerous pilings remain within the footprint of the former shipway and pier structures in the northwestern portion of the Site.

Several other Superfund sites resulting from separate industrial operations are located near the Site:

- Pacific Sound Resources (PSR) Superfund Site borders the Site on the west
- Harbor Island Superfund Site, including the following:
    - Todd Shipyard (currently known as Vigor Shipyard) Sediment Operable Unit on the east side of the West Waterway and northwest side of Harbor Island
    - Lockheed Shipyard No.1 Sediment Operable Unit on the west side of Harbor Island along the West Waterway
    - West Waterway Operable Unit
    - East Waterway Operable Unit
- LDW Superfund Site, which flows into the West and East Waterways of Harbor Island and into Elliott Bay

In addition to these Superfund sites, the Washington State Department of Ecology (Ecology) issued state MTCA cleanup orders for the remediation of four areas (Remediation Area [RA]-1, -2, -3, and -5) located in the Terminal 5 upland area adjacent to the Site. There is also one upland area (RA-4) associated with the PSR Superfund site. The predominant cleanup action applied to these upland remediation areas was capping to keep soil contamination in place and prevent surface water infiltration into the underlying groundwater and contaminated subsurface soil.

The 40-acre Site includes approximately 33 acres of state-owned aquatic lands and 7 acres of Port of Seattle (Port)-owned aquatic tidelands, as shown by the color-shaded areas on Figure 3-1. The Port-owned tidelands and Port-managed harbor areas are adjacent to the Port's Terminal 5 facility upland operations, which include container transfer and handling associated with marine terminal operations[2]. The state-owned aquatic lands include:

- 18 acres of State Harbor Area in Elliott Bay (Washington State Department of Natural Resources [DNR] managed harbor area)
- 8 acres of State Harbor Area managed by the Port under a Port Management Agreement, of which approximately 3 acres are located within the harbor area north of the Site, and 5 acres of harbor area are located east of the Site (Port-managed harbor area)
- 7 acres of State Waterway in West Waterway (DNR-managed waterway). The U.S. Army Corps of Engineers (USACE) has jurisdiction for maintaining the West Waterway navigation channel, currently authorized to -34 feet MLLW, which is coincident with the state-platted West Waterway.

3.1.1 Current Site Use

The upland areas adjacent to the Site are typically used by the Port for shipping container storage, and this area is undergoing renovations and improvements by the Port until 2020. Occasionally, barges are temporarily moored along the existing pier structures using tug boats. In addition, non-commercial vessel traffic such as recreational boats may pass through the Site. Commercial vessels operating in the vicinity of the Site are controlled by the U.S. Coast Guard and are required to use the established navigational channels and berth approaches.

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[2] The Site overlaps West Waterway, a federal navigation channel and a regulated navigation area (RNA) for the sediment cap associated with the Pacific Sound Resources Marine Sediment Unit adjacent to the former shipway. An RNA is a water area within a defined boundary for which regulations for vessels navigating within the area are established under 33 Code of Federal Regulations (CFR) 165. The purpose of the RNA is to protect the integrity of the sediment cap by restricting activities that would disturb the cap surface, such as anchoring, grounding, or spudding.

The Site and adjacent aquatic areas are designated as Tribal Usual and Accustomed (U&A) Fishing Areas of both the Suquamish and Muckleshoot Indian Tribes. The bank and intertidal portions of the Site are accessible from the water. Access via land is currently restricted due to security fencing around Terminal 5.

The current fish advisory for Puget Sound Marine Recreational Area 10 (Elliott Bay) includes no rockfish consumption and no more than two meals per month of flatfish (Washington State Department of Health, 2015). The Site is not a major recreational resource compared with other water bodies in the area but there is Tribal U&A fishing and some recreational fishing in the area.

3.1.2 Potential Site Future Uses

The Port envisions expanding Terminal 5 pier structures to include a multi-modal container terminal along the West Waterway. Container ships use the navigational channel and offload in the West Waterway at Terminal 5. Port of Seattle and Northwest Seaport Alliance completed a final environmental impact statement (FEIS) for the Terminal 5 Cargo Wharf Rehabilitation, Berth Deepening, and Improvements Project in October 2016 (Port of Seattle, 2016). Per the proposed alternative described in the FEIS, the subtidal sediments in the existing vessel berth area adjacent to the rehabilitated wharf would be deepened by underwater dredging to a Project depth of –55 feet MLLW. An additional 1 foot of advanced maintenance dredge would be completed beyond the Project depth in critical and shoaling areas to avoid frequent redredging. The required Project grade is, therefore, –56 feet MLLW. It is also anticipated that up to an additional 2 feet of allowable overdepth would be dredged, resulting in a maximum depth of –58 feet MLLW.

In 2010 and 2011, the Port requested Waterway Resource Development Act (WRDA) authorization to revise the navigation channel from its current authorization (-34 feet MLLW) to deeper depths. The Port described potential future development in letters to the U.S. Environmental Protection Agency (EPA) in November 2010, May 2011, and September 2011. The USACE initiated the Seattle Harbor Navigation Improvement Project in response to this request. The current preferred alternative related to this project is deepening both the West Waterway and East Waterway to -57 feet MLLW. The Draft Integrated Feasibility Report and Environmental Assessment is expected to be completed in 2017 (USACE, 2014; 2016). The remediation activities to be conducted at the Site would not impact these future improvement projects at and adjacent to the Site. The location of Terminal 5 improvement project does not overlap with the remediation project. Per the ROD, the portion of the Site within the navigational channel will be dredged to the Sediment Quality

Standards (SQS) remedial action level (RAL). The vertical extent of contamination above the Cleanup Level is up to an elevation of approximately -52 feet MLLW. Refer to Section 3.6 for sediment chemical characteristics and Appendix B for 60% design dredging plans. Also see Section 1.3.1 for discussion of design coordination.

In addition, the Tribes have treaty rights for unimpeded/unrestricted fishing, clamming, and access to the Site. As the aquatic land manager, DNR is also responsible for permitting water-dependent uses at the Site.

3.2 PREVIOUS SITE INVESTIGATIONS

Since 1984, an extensive series of studies have been independently conducted by Lockheed Martin and the Port to investigate the nature and extent of sediment contamination at the Site (Tetra Tech, 2008). Much of this information was compiled by Parametrix (1994a and b) and by Enviros (1990) to support characterization of the Site as part of harbor development planning by the Port. Available historical sediment quality information in the vicinity of the Site includes samples collected prior to 1998 and in 2003 as part of a due diligence investigation (Hart Crowser, 2003a). The Site remedial investigation fieldwork was conducted from 2006 through 2008 and is summarized in the Remedial Investigation/Feasibility Study (RI/FS; Tetra Tech, 2012). To support the design for the Selected Remedy, Lockheed Martin performed a pre-design investigation of surface and subsurface sediment, a geotechnical investigation in upland and offshore areas, structural evaluations, and additional bathymetric and debris surveys in November 2015 and January 2016. The complete report of this investigation can be found in the Pre-Design Investigation Field Sampling Data Report (Tetra Tech, 2016). The results of the data summarized in the RI/FS and this pre-design investigation are used to refine the EPA Selected Remedy.

3.3 SOURCE CONTROL

Understanding the potential sources of recontamination to the Site is important to determine whether the Selected Remedy will likely remain protective. Historical shipyard operations at the Site were discontinued in 1987 and there is no current ongoing source of contamination from present uses of the Site. However, there are upland and upstream sources of contamination in the vicinity of the Site. These potential off-site sources could represent future sources of contamination to the Site.

Surface water and sediment conditions at the Site are influenced by the natural counterclockwise flow of water and tidal influences in Elliot Bay. Elliott Bay is affected by nearby urbanization, and overall concentrations of certain contaminants in bay sediments are higher than concentrations identified as being protective of human consumption of seafood. Thus, contaminated sediment could migrate to the Site as a result of off-site sediment transport from adjacent areas after completion of remediation.

Based on sediment sample testing at the PSR site (EPA, 2009) as well as an evaluation performed for the RI/FS (Tetra Tech, 2012), contaminant of concern (COC) concentrations in Site sediments may reach a long-term equilibrium level above natural background but still below Sediment Quality Standards (SQS) concentrations in the post-construction period as a result of elevated sediment concentrations from Elliott Bay migrating to the Site.

3.4 HABITAT AND NATURAL RESOURCES

The aquatic environment at the Site consists of estuarine waters and sediments. The shoreline habitat is typical of the industrial shoreline in much of the Duwamish Waterway with armoring and sheet pile bulkheads, along with broken pilings, deteriorating wooden bulkheads, and debris. A single, small intertidal beach area of about 2 acres is present along the West Waterway between the Terminal 5 pier and the South Florida Street Outfall. Current shoreline conditions within the remainder of the Site boundary indicate a highly modified and impacted industrial shoreline with little to no natural intertidal habitat.

Flora and fauna of the in-water area and shoreline include bivalves, crustaceans, and worms in the fine sediments. Crustaceans (such as shrimp and crabs) and mollusks (clams and snails) are typically found in coarser sediments. The Site environment also supports birds (such as sandpiper), crabs, resident fish (such as perch, sculpin, rockfish), as well as anadromous fish (such as salmon).

Puget Sound Chinook salmon are listed as threatened under the Endangered Species Act (ESA), as noted earlier in Section 2.2. Based on the findings of the RI/FS (Tetra Tech, 2012), critical habitat does not appear to be present at the Site. However, as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process, a Biological Assessment will be prepared and EPA will consult with the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) and with the U.S. Fish and Wildlife Service to show substantive compliance.

There are no known cultural resources such as Native American graves, sacred sites, historic sites or structures, or archaeological resources associated with the Site.

3.5 SITE PHYSICAL CHARACTERISTICS

The Site consists of approximately 40 acres of in-water sediments where the former Lockheed Shipyard No. 2 was located. It is tidally affected with additional influence from the LDW, which flows into the West Waterway. The Site is predominantly subtidal, with mudline elevations extending from -10 feet MLLW to -40 to -50 feet MLLW in historically dredged areas. Shallower areas are present beneath the former shipyard piers (elevations of -20 to -30 feet MLLW). The intertidal and shoreline portions of the Site extend from mean high higher water at +11.3 feet MLLW to -10 feet MLLW.

The Duwamish Estuary and Elliott Bay have experienced extensive development and urban growth during the 20th century. Tidal flats and marshes that once dominated the mouth of the river were dredged and filled to form Harbor Island and the upland areas of the Site. The shoreline is densely armored with riprap, and includes wooden bulkheads and steel sheet pile walls. The shipyard used to have five major piers (remnants of Piers 23 and 24 and all of Pier 25 remain today), three dry docks, and a shipway. Since closure of the shipyard, the Port has demolished Piers 21 and 22 and removed the decking from Piers 23 and 24. Pilings for Piers 23 and 24 and the former shipway area still exist, and the Port is required to remove pilings between the inner and outer harbor area per the lease termination agreement with DNR, the current manager of the state-owned lands in this portion of the Site. A narrow intertidal zone extends along the landward edge of the Site, wrapping around the eastern and northern shoreline between the West Waterway and the PSR Superfund site. Numerous pilings within the footprint of the former shipway and pier structures (remnants of Piers 23 and 24) remain in the northern portion of the Site.

3.6 SEDIMENT CHEMICAL CHARACTERISTICS

Metals, polychlorinated biphenyls (PCB), tributyltin (TBT), and polycyclic aromatic hydrocarbons (PAH) are the most frequently detected contaminants in sediment samples collected from the Site. The results from the remedial investigation and pre-remedial design investigation sampling found that the highest concentrations of contaminants in the sediment were generally located in the area of the former dry docks and former shipway. The concentrations of contaminants tend to decrease away from these areas toward the Site boundaries. An evaluation of the results for sediment samples collected from the former shipway area during the pre-design investigation found that PAH contamination at depth is similar to the PAH contamination in sediment samples collected from the Pacific Sound Resources (PSR) Site, indicating likely origin of contaminants from the adjacent PSR site (see Section 3.6.3).

Data from 83 cores and 61 surface grab samples collected during the RI/FS and pre-design investigations were used to determine the horizontal and vertical extents of contamination for the design. Nine of the surface grab samples are in the intertidal area of the Site with all other locations in the subtidal area of the Site. In addition, two samples were collected from the sediment accumulated on the concrete pad of the shipway. These two cores were not used in determining the horizontal and vertical extent of contamination across the rest of the Site because the sediment in this area is physically separate. A summary of the data showing the number of samples with concentrations above the remedial action levels by site area is presented in Table 3-1.

The data collected in the pre-design investigation were used to refine the horizontal and vertical extents of contamination for removal in:

- The intertidal beach/shoreline area along the West Waterway
- At the northeast corner of the Site (TT34)
- The area off the intertidal beach (TT04)
- The areas along Pier 23 (TT20 and Ecology-197)
- The shoreline area between Piers 23 and 24
- The former shipway area
- The former dry dock areas

3.6.1 Horizontal Extent of Contamination

A summary of the chemical analyses for the risk driver COC data for all samples from the historic investigations, RI, and pre-design investigation is presented in Table A-2 of Appendix A. Data collected during the pre-design investigation was targeted to address data gaps for the horizontal extents for areas with contamination identified in a small number of samples (intertidal beach and shoreline areas, northeast corner, former piers 22 and 23 and the former shipway).

Cores collected in the intertidal beach and along the shoreline were used to refine the extent of removal between +4 feet and -10 feet MLLW. In addition, the extent of existing rip rap/rock was used to refine areas of the shoreline removal. Cores TT-CS127 to TT-CS132 along with the RI intertidal beach samples were used to refine the intertidal beach removal area up to the rip rap covered Florida Street storm drain outfall.

Cores collected during the pre-design survey refined the extent of contamination at the northeast corner of the Site where contamination above the cleanup goals was found during the RI (TT34). Two new cores around TT34 (i.e., TT-CS137 and TT-CS138) refined the horizontal extents of sediment contamination to be removed in this area.

In the area of former Pier 22, the pre-design investigation core TT-CS118 refined the extent of removal to the west from the dry docks area.

Cores and surface sediment samples collected in the area of former Pier 23 around RI locations TT20 and the Ecology location (Ecology 197) were used to refine the extent for removal in these two areas. The pre-design data allowed for the refinement of the areas around these two points for removal.

Along the shoreline between former Pier 23 and Pier 24, two cores (TT-CS109 and TT-CS110) were collected to refine the extent of removal. The extent of removal for this area is refined based on the contamination present in the one core (TT-CS109) and the concentrations in TT-CS110 being below the Site action levels for removal.

Eight cores (TT-CS101 to TT-CS108) were collected from the former shipway to refine the extent of contamination for removal in this area. The data from the eight cores along with the intertidal samples from the RI were used in the design to refine the extent of removal in this area.

3.6.2 Vertical Extent of Contamination in Removal Areas

Depth of contamination in areas for removal was determined from the core profiles and defined as the bottom of the deepest sample interval with any concentration for the risk-driver COC above the SQS or CSL depending on the area of the Site for the sample location. Where the collected core encountered a refusal and the deepest collected interval had concentrations above the SQS or CSL level, the estimated depth of contamination for the sample location is based on the depth of the refusal encountered.

The vertical extent of contamination was found to be deepest in the area of the former dry docks where the depth of sediment with contamination above the Cleanup Level is up to 10 feet and an elevation of approximately -52 feet MLLW. The extents of vertical contamination are extrapolated from the core data to capture the extent of contamination within a prism across the dry dock and former shipway areas expected to be contaminated based on the similarity of Site features to the sampling core locations.

Cores collected during the pre-design investigation defined the vertical extent of contamination in the northeast corner of the Site (TT34), along the western edge of the of the dry dock removal area (TT30), at the area of the intertidal beach (TT04), and in the areas along Pier 23 (TT20 and Ecology-197). In addition, the eight cores collected from the former shipway defined the vertical extents for the removal. In the cores collected at the end of the former shipway area, a gap of cleaner material appears to be present above a deeper sediment layer with elevated PAH contamination. The vertical extent of the contamination in the shipway related to the former shipyard activities is limited to the upper sediment zones, whereas the deeper PAH contamination appears to be related to other sources, as discussed below.

3.6.3 Nature and Source of PAHs in Shipway

Deeper cores in the former shipway area of the site had elevated concentrations of PAHs present at depth below intervals of lower contamination related to the former shipway activities (see Table A-2 of Appendix A). The deeper PAHs are very likely associated with creosote contamination originating from the PSR site adjacent to the Lockheed West Site. The PSR sediments are capped to isolate the PAH contamination that has migrated offshore from the creosoting operations that historically took place at this site.

PAHs come from many historic and ongoing sources. The source of PAH contamination can be determined using the PAH profile and PAH ratios.

Data for core interval samples from PSR sample locations (EB113 and EB012) nearest the former shipway on the Site show a pattern for PAHs consistent with a pyrogenic source creosote material with a relatively high fraction of the total PAHs being light PAHs (naphthalene, acenaphthene, and phenanthrene). The surface samples from the PSR RI and shallow core intervals from the pre-design investigation show the mid- to heavy weight PAHs making a larger fraction of the total PAHs in the samples. The deep core interval samples with higher concentrations for PAHs from the shipway show a relatively high fraction of the acenaphthene and phenanthrene similar to that found in the samples from the PSR site sediment cores (Figure 3-2).

The ratio of heavier weight PAHs can be used to determine similarities between the sources of PAHs in samples. These PAH ratios are generally conservative in that they change little over time because there is limited degradation of the PAHs in the environment. Two common PAH ratios used for this purpose are fluoranthene/pyrene and benz(a)anthracene/chrysene. Data from samples collected in the marine area of the PSR site indicate a likely similarity of contamination source for these samples and the deeper shipway core samples collecting during the PDI.

Based on the PAH profiles and PAH ratios, it is likely that the source for the PAHs found at depth in the former shipway is similar to that for the PAHs in the PSR marine site and potentially linked to the DNAPL in the PSR upland area. Therefore, the design set the dredging removal depth based on the clean interval above the PAHs found at depth, thereby leaving the contamination associated with PSR in place.

Figure 3-3 shows the refinements to the removal areas from the FS to the draft design.

3.7 SEDIMENT PHYSICAL CHARACTERISTICS

The shoreline area is composed of medium sand, shell hash, small- to medium-size cobbles, medium to large riprap, concrete keel blocks, cut-off and broken-off wood pilings, and debris, including trash, wire rope, concrete and ductile iron piping, and portions of deteriorated wooden bulkheads. Numerous debris piles and multiple pilings are present in the intertidal and subtidal areas of the former dry docks and shipway.

3.7.1 Existing Bathymetry and Debris

During the pre-design site investigations, the multibeam sonar system provided a high-resolution bathymetry of the project area (Tetra Tech, 2016). Hydrographic images including elevation contour lines and hillshade three-dimensional representation of the mudline surface were developed. The extent of shoreline riprap was determined using data from the high-resolution bathymetry survey and the sidescan sonar survey that was performed during low tide. The rock toe generally follows the -10 feet MLLW contour (Figure 1-3). Bottom features include the presence of near uniform and widely spaced surface protrusions (humps) under the former dry docks, which are most prominent under the former Dry Dock #2 area. Previous characterizations of these humps and recent investigation results, including targeted magnetometer and sidescan surveys, suggested presence of sand blast grit accumulations (Tetra Tech, 2008, 2016).

The sidescan sonar and magnetometer surveys identified debris items in subtidal areas as tires, trees, poles, metal debris, and other debris. The magnetometer survey was completed along widely spaced transect lines to identify areas with concentrated metallic debris. The shoreline survey identified debris to remove from the shorelines as part of remediation of intertidal areas.

Current bathymetry is used as the base map to design dredge prisms, shoreline and shipway area remediation, and enhanced natural recovery (ENR) layer placement areas. Design details, dredge slopes, and remediation volume calculations (e.g., dredge, backfill, ENR) are based to the mudline elevations determined by the current bathymetry. The extent of rock along the shoreline was utilized to determine the extent of removal and perform geotechnical stability analysis of shoreline slopes. Debris survey results were used to identify and quantify approximate amount of debris present in the dredge areas to be managed during the remediation and presented in the design drawings. Further details are provided in Pre-Design Investigation Field Sampling Data Report (Tetra Tech, 2016).

3.7.2 Geotechnical Properties

Site subsurface conditions were recently investigated through upland and offshore borings, cone penetration tests (CPT), and geotechnical characterization laboratory testing (Tetra Tech, 2016). Overall findings are consistent with the historical investigations conducted at the site since 1990s (Enviros, 1990; Hart Crowser, 1995; URS, 2003; Hart Crowser, 2003b; Tetra Tech, 2008). The simplified site profile is composed of an upper layer of 3 to 5 feet of very loose sandy silt alluvium, followed by a 10- to 20-foot layer of interbedded loose sandy silt and loose to medium dense silty sand, mostly non-plastic, with rare clay lenses underlain by medium dense to dense silty sand to a depth of 75 to 100 feet, below which the material becomes very dense. This pattern is consistent with deltaic deposits of alluvial origin from the Duwamish River system or fill derived from these materials (Hart Crowser, 2003a).

Pre-design geotechnical field work included CPT soundings of continuous subsurface profile of tip resistance, friction ratio, pore pressure, soil behavior type, and standard penetration test. Seismic CPT results are presented as a shear wave velocity profiles. Selected geotechnical core samples collected from upland and offshore locations at every 5 feet were analyzed for geotechnical properties including moisture content, organic matter, specific gravity, particle size analysis, and Atterberg limits. The results were utilized to analyze stability of shoreline slopes and stability of sheet pile wall at former shipway after the piles removal and after dredging. The geotechnical data were also evaluated for dredgeability, turbidity controls, and sediment dewatering. Details of the geotechnical investigation and data are presented in the Pre-Design Investigation Field Sampling Data Report (Tetra Tech, 2016). Geotechnical properties of sediment to be dredged are presented in Table 5-1 and the geotechnical profiles of the Site are included in the basis of design calculations (Appendix D).

3.7.3 Sediment Dewatering Characteristics

The dewatering tests consisted of mechanical dredging simulation, sediment characterization, gravity dewatering, and bench-scale testing of sediment mixed with amendments and adsorbents (Tetra Tech, 2016). The tests were conducted at the WaterSolve LLC's laboratory in Caledonia, Michigan in February and August, 2016. After simulation of mechanical dredging, sediment from three areas within the Site, including the former shipway, Dry Dock #1, and Dry Dock #2/3, were tested for basic dewatering characteristics (i.e., percent solids, specific gravity, unit weight, and organic matter). The amendment testing was performed with Calcimite, Portland cement, and superabsorbent Solve 1880 at different concentrations. The results of dewatering parameters (i.e., solids concentration [% dry weight], specific gravity, unit weight, and organic matter) are summarized in Table 3-2. All samples failed the paint filter test when no amendment was added. A minimum 4 percent Calcimite or Portland cement was needed for the dry dock samples (i.e., "Dry Dock #1" and "Dry Dock #2/3") to pass the paint filter test, or a concentration of 0.4 percent of Superabsorbent to pass the paint filter test. The Shipway #1 sample required concentrations of 4 percent Calcimite, 6 percent of Portland cement, or 0.4 percent of Superabsorbent to pass the paint filter test (Table 3-3).

Gravity dewatering characteristics of sediment samples were also tested and the results are as follows:

- Shipway #1—The sample was sandy with some black silt present, some crushed shell, a few pieces of wood, and decaying organic matter. It had good stackability and held its form with some slumping. The free water was dirty and slow to release. By 20 hours of dewatering, there was little to no free water visible.
- Dry Dock #1—The sample was sandy with black silt present. It had good stackability and held its form with no noticeable slumping. The free water was dirty and quicker to release than the Shipway #1 sample. By 20 hours of dewatering, there was little to no free water visible.
- Dry Dock #2/3—The sample was sandy with black silt present, with more sand than the Dry Dock #1 sample. It had good stackability and held its form with no noticeable

slumping. The free water was cleaner and quicker to release than the Shipway #1 sample. By 20 hours of dewatering, there was little to no free water visible.

Gravity dewatering test results also indicated that all samples dried faster within the first 100 hours to 120 hours (about 5 days). Solids concentrations and unit weight of each sample at the beginning and at the end of gravity dewatering test are summarized in Table 3-4.

3.8 SHORELINE STRUCTURES

The embedment depth of the sheet pile wall at the northeast corner of the Site was investigated. A structural condition assessment of the sheet pile walls at the northeast corner and shipway of the Site was performed. This section presents the result of the structural assessment.

3.8.1 Sheet Pile Embedment Depth

Seismic wave records showed two distinct shifts in the character of the data: one at approximately 17.5 feet and another at 47.5 feet from the top of the sheet pile wall. These shifts indicate the exposed and burial depth of the piles. Wave action and wind appeared to create high frequency noise in the data. Recorded seismic data indicated that the bottom of the sheet pile wall was approximately at 50 ±2.5 feet below ground surface with approximately 15 to 17 feet above mudline and 30 feet of embedment. Based on this investigation, it was assumed that the total height of sheet pile bulkhead wall in the former shipway is about 45 feet with an embedment to exposed depth ratio of 2:1 in deflection and stability analysis. These analyses are summarized in Section 4.5 and Section 5.7.

3.8.2 Structural Field Inspection and Testing

The inspected walls were constructed with different sheet pile sections. The wall dimensions were measured in the atmospheric zone, where the corrosion rate has been minimal. The inspections focused on the intertidal and splash zones where corrosion was an obvious concern. No corrosion protection coating was found on any of the wall components.

At northeast corner section, more than 3 feet below the top of the wall the sheet pile is severely corroded and has a heavy corrosion scale encrusted on the surface within the splash zone. The top of the wall where minimal corrosion loss appeared was gauged at 0.45 inches. At the shipway, the original nominal thickness was estimated at 0.375 inches. The wall was severely corroded with heavy scale encrusted. The ultrasonic wall thickness measurements indicated a wall loss of up to 84 percent in the splash zone at the northeast corner section, and up to 100 percent wall loss at the shipway section. Tensile strength tests were performed at steel coupons collected from the sections where the original thickness of the walls remained. Current conditions of sheet pile bulkhead at the shipway were considered during the stability analysis.

Table 3-1
Summary of Remedial Action Level Exceedances

Site Area	Number of Samples > Remedial Action Level								
	Surface/ Subsurface	Number of Samples	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
South Beach	Surface	6	1	0	1	0	0	0	0
	Subsurface	29	0	0	0	7	1	1	0
Dry Docks Dredge Area West Waterway	Surface	13	3	5	1	8	11	7	0
	Subsurface	53	4	5	2	10	8	5	2
Dry Docks Dredge Area	Surface	13	3	5	1	9	10	8	1
	Subsurface	100	19	31	11	39	37	19	5
Former Shipway Dredge Area	Surface	6	4	3	0	0	1	2	0
	Subsurface	18	12	8	2	6	2	9	0
Piers and Shoreline Dredge Areas	Surface	4	2	1	0	0	0	0	0
	Subsurface	11	3	2	1	3	1	0	0
ENR Areas	Surface	24	0	0	0	0	8	5	0
	Subsurface	109	4	2	1	4	2	1	0

Table 3-2
Sediment Dewatering Parameters

Sample	Percent Solids	Specific Gravity	Unit Weight (g/mL) / (pcf)	Organic Carbon (g C/g Soil)
Shipway #1	61.7	2.4	1.8 / 112	0.0264
Dry Dock #1	67.4	2.5	1.9 / 119	0.0199
Dry Dock #2/3	75.9	2.9	2.1 / 131	0.016
g/mL = gram per milliliter; pcf = pound per cubic feet g C/g soil = grams of Carbon per gram of soil				

Table 3-3
Amendment Dewatering - Paint Filter Test Results

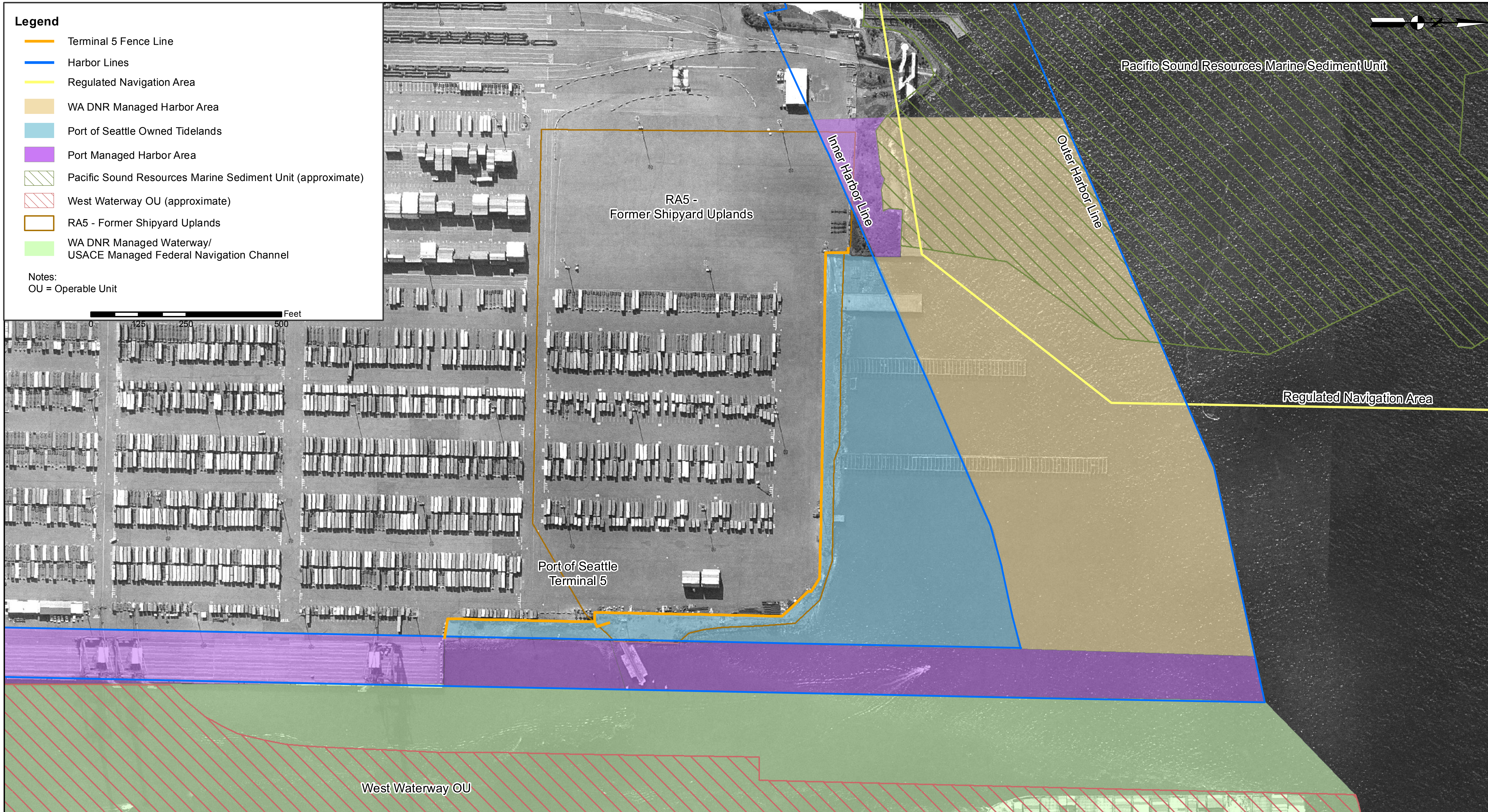
Amendment[1]	Sediment Sample (each 500 g)								
	Shipway			Dry Dock #1			Dry Dock #2/3		
	Result	Unit Weight (g/mL)	% Solids	Result	Unit Weight (g/mL)	% Solids	Result	Unit Weight (g/mL)	% Solids
None	Fail	1.8	61.7	Fail	1.9	69.5	Fail	1.9	75.9
Calcimite (20 g, 4%)	Pass	1.8	65.6	Pass	1.8	72.1	Pass	2.0	79.1
Calcimite (5 g, 1%)	Fail	1.8	64.2	Fail	1.9	68.9	Fail	2.1	77.7
Portland Cement (30 g, 6%)	Pass	1.8	65.6	Pass	-	-	Pass	-	-
Portland Cement (20 g, 4%)	Fail	1.8	65.5	Pass	1.9	70.7	Pass	2.1	80.3
Portland Cement (5 g, 1%)	Fail	-	-	Fail	1.9	70.4	Fail	2.1	78.1
Superabsorbent (2 g, 0.4%)	Pass	1.7	63.5	Pass	1.8	66.5	Pass	1.6	78.3
Superabsorbent (0.5 g, 0.1%)	Fail	1.7	62.0	Fail	1.6	66.0	Fail	1.3	76.9

[1]Amount added in gram and percentage; g = gram; Unit weight in g/mL = gram per milliliter

Table 3-4
Gravity Dewatering Test Results

Sample	% Solids		Unit Weight (g/mL) / (pcf)	
	Initial	After Dewatering	Initial	After Dewatering
Shipway #1[1]	58.7	92.5	1.6 / 100	1.5 / 94
Dry Dock #1[1]	73.4	93.2	1.9 / 119	1.7 / 106
Dry Dock #2/3[2]	79.2	94.6	2.1 / 131	1.8 / 112

[1]Results after 288 hours of dewatering
[2] Results after 204 hours of dewatering
g/mL = gram per milliliter; pcf = pound per cubic feet



TETRA TECH

Lockheed West Seattle Superfund Site, Seattle, WA

Figure 3-1
Current Management and Ownership

P:\projects_2006\Lockheed\maps\RIFS_Report\Fig_3-1_current_ownership_management.mxd

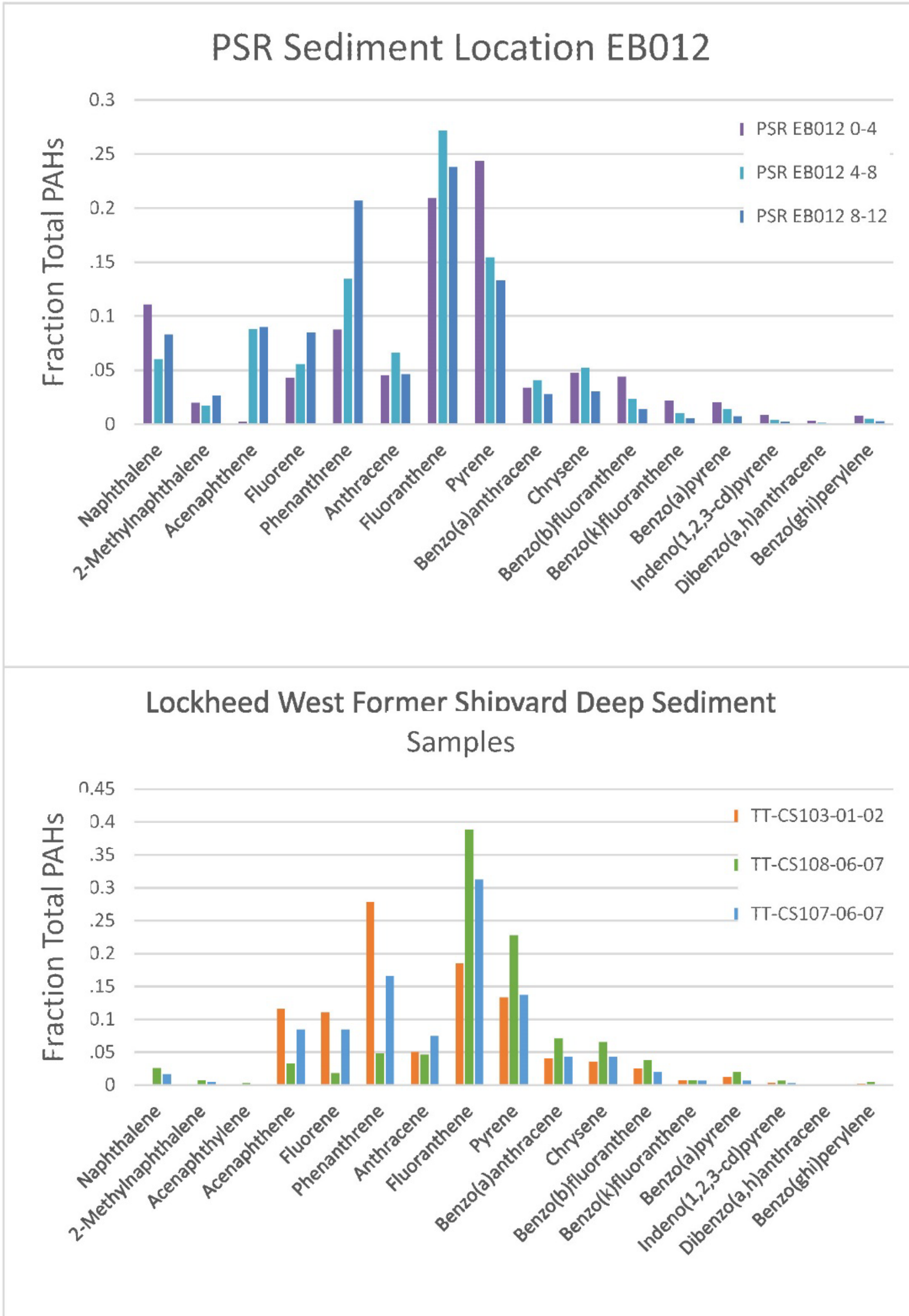


Figure 3-2
Pacific Sound Resources PAH contamination in Deep Former Shipway Sediments

Lockheed West Seattle Superfund Site
Seattle, WA

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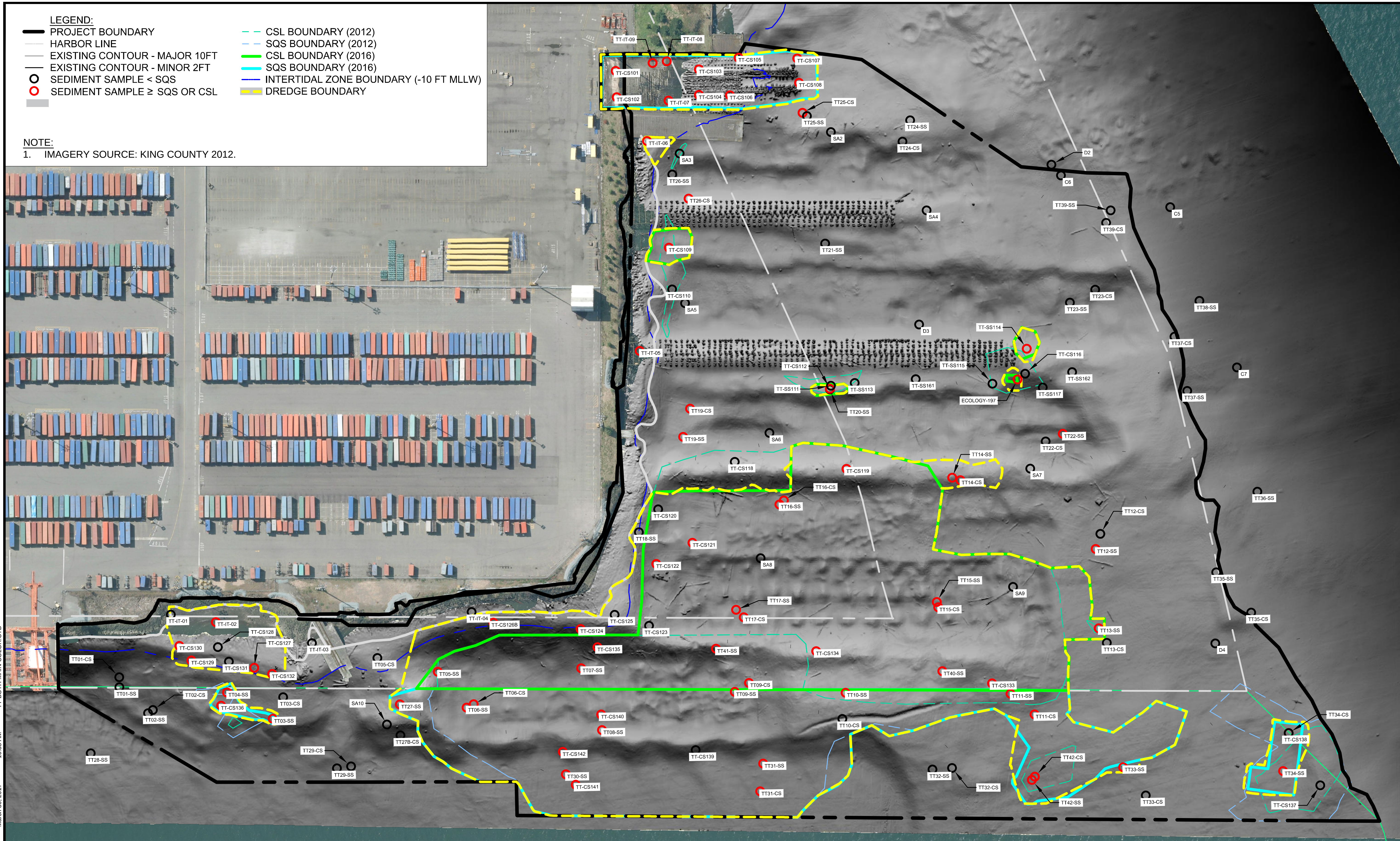

TETRA TECH

N S E W

0' 80' 160' 320'

LOCKHEED WEST SEATTLE SUPERFUND SITE

SEATTLE, WA

FIGURE 3-3

CSL AND SQS BOUNDARY

Z:\PROJECTS\194-8650 LOCKHEED WEST\FIGURES\SHEET FILES\DREDGE PLAN FIGURE.DWG
TT-BOTH-MAIN-COLOR.CTB
10:38 AM
March 30, 2017
PLOT DETAILS: MATHIS, TOM

Section 4

Debris and Piling Removal and Disposal

The primary purpose of this activity will be to remove pilings and debris along the shoreline and where such items may hinder dredging (e.g., in subtidal areas and in the former shipway). Additional wood, metal, amalgamated sandblast grit and slag debris and portions of failing wooden bulkheads along the shorelines have also been identified as requiring removal. Stability evaluations were performed to determine whether these materials are necessary to stabilize the bank or support current upland activities. The removed debris, piles, and other materials will be disposed of in an approved off-site location.

The debris and piling removal design basis and construction methodology described in this section are based on and consistent with the primary purpose and performance standards as described in the Record of Decision (ROD). The methods for achieving the performance standards for removal and disposal of all materials are provided in this section and will be detailed further in the Construction Quality Assurance Plan (CQAP) to be developed at later stages of design. In addition, all in-water work at the Site will be subject to the applicable or relevant and appropriate requirements (ARAR) and short-term monitoring standards presented in this design report (Sections 7 and 8), which will further be defined in the CQAP and associated planning documents.

4.1 DESIGN BASIS AND ASSUMPTIONS

The following design basis and assumptions were considered to identify and quantify debris and piling removal from shorelines and former shipway area:

- The design basis for shoreline debris removal is the overall cleanup of materials that could pose an environmental hazard in the intertidal area.
- Large debris removal along shorelines will be followed by placement of quarry spall/riprap in void areas to maintain the integrity of the existing shoreline protection.
- The design basis for the former shipway area debris and piling removal is to prepare the area before environmental dredging followed by placement of clean backfill to existing grades.

- All wood piles removed from the Site are considered creosote-treated and will be handled and disposed of by following the guidelines established by the Washington Department of Natural Resources (DNR, 2013) and U.S. Environmental Protection Agency Region 10 (EPA, 2016).
- Existing outfalls and utilities will be protected.
- As-built engineering drawings of the former shipway area and other shoreline structures were not located. The quantities are estimated through field survey. All debris shown on the design drawings will be verified in the field by the Contractor.

Refer to the design drawings in Appendix B for identified debris to be removed from shoreline/intertidal areas, existing debris in subtidal dredge areas, and the pile removal plan in the former shipway. Debris screening may be needed during handling and disposal of dredge sediment due to the presence of debris in subtidal dredge areas. Debris handling in dredge areas is discussed in Section 5.

All work associated with debris removal will be performed from the waterside with the exception of utility closure activities, if applicable. All work will be coordinated/scheduled with the Port of Seattle (Port). The sequence and methodology of debris removal will be refined in the Contractor work plans to be developed as part of the Remedial Action Work Plan (RAWP).

4.2 UTILITY PROTECTION

Existing utilities will be protected during all remedial activities. The Contractor will coordinate with the Port for utility clearance. There is only one active outfall for stormwater from Terminal 5 labeled as Florida Street Outfall in the design drawings. This outfall structure and outfall protection rocks will be protected. There are abandoned outfalls along the north shore. Lockheed Martin will not do any work related to abandoned utilities connected to the upland and to the piers that remain intact.

4.3 SHORELINE DEBRIS REMOVAL

The following debris will be removed from the shorelines:

- Large trash, wire rope, concrete, and ductile iron piping, and portions of deteriorated wooden bulkheads and broken-off wood pilings
- Debris piles of amalgamated sandblast grit and slag
- Abandoned steel frame in intertidal area between Piers 23 and 24

Observations of debris in shoreline areas indicate that it is overlying existing riprap. In the unexpected event that evidence of contaminated soil is observed (e.g., staining, odor), EPA will be consulted for further actions. Refer to the design drawings for the debris to be removed. Items identified in the design drawings will need to be field verified. Large debris removal along the shorelines will be followed by backfilling any cavities with riprap/quarry spall to maintain the integrity of existing shoreline revetment. Refer to Appendix D for stable rock size estimates for this placement.

Debris may be removed with a crane or excavator and placed onto a barge. The work surface on the barge deck will include a containment basin to handle and segregate debris for transport and disposal.

4.4 PILINGS REMOVAL IN FORMER SHIPWAY

Pilings, associated wood structures, and identified sheet piles in the former shipway area within the Inner Harbor line will be removed during remedial construction. The Port will remove the rest of the pilings beyond the Inner Harbor line within the Site. Pilings will be removed using equipment staged on a barge. Removed pilings and other material will likely be placed on a barge for staging and handling for transport and disposal.

In 2005, Lockheed Martin completed a similar pile removal action at its former shipyard, Lockheed Shipyard Sediments Operable Unit (LSSOU) of the Harbor Island Superfund Site (TRC, 2005). The remediation included removal of four piers including about 7,000 piles, replacement of an existing deteriorated bulkhead wall, and dredging adjacent to the bulkhead. Lessons learned from this remedial construction are summarized in Section 4.4.3.

The Washington Department of Natural Resources (DNR) has established best management practices (BMPs) for derelict creosote piling removal and disposal in Washington State (DNR, 2013). A U.S. Environmental Protection Agency (EPA) Region 10 guidance document also details BMPs associated with piling removal and placement in Washington State (EPA, 2016). The applicable procedures detailed in these BMP guidance documents are applicable to all pile removal activities (including the Port’s piling removal project) and will be followed during removal of piles in the former shipway.

4.4.1 Piles Extraction

Wood piles will be removed from the former shipway between the Inner Harbor line and the Port's Terminal 5 uplands. Due to the close spacing of the piling in the shipway and the top of pile elevations relative to the mudline, some minor excavation may be necessary to facilitate pile extraction. While use of vibratory extraction is the preferred method to remove pilings, it is recognized that many of the piles may break and will need to be cut at or near the dredge elevations due to the deteriorated condition or short extension from mudline. Per EPA and DNR guidance documents, broken and damaged pilings that cannot be removed by either the vibratory hammer or direct pull may be removed with either a clamshell bucket or environmental clamshell in deeper areas. If the pile breaks at or near the existing substrate and cannot be removed by other methods, the piles will be cut at dredge elevation using a pneumatic underwater bucket, a clamshell bucket, or another type of equipment to be selected by the Contractor at dredge elevation. Piles will be cut off at lowest practical tide condition and at slack water to reduce turbidity and potential short-term water column impacts.

Per DNR and EPA BMPs, the work surface on the barge deck will include a containment basin for all debris and any sediment removed during pulling. A floating surface boom equipped with absorbent pads to contain any oil sheens will be deployed to capture floating surface debris and to control potential creosote releases to the extent practicable. Collected debris will be disposed of, along with cut-off piling. Refer to Section 7 for further BMPs adapted from EPA and DNR guidance documents.

4.4.2 Removal of Other Debris and Structural Components

In the former shipway, there are other scattered wood debris, lateral and longitudinal wood beams, and remnants of sheet pile walls that require removal to prepare the area for dredging. Estimated quantities are noted in the design drawings. Minor excavation and cutting wood members at the Site may be needed. Removed debris will be segregated in the containment basin of the barge.

4.4.3 Lessons Learned from Pile Removal at LSSOU

During demolition and bulkhead construction at LSSOU, there were occasions when piling removal created localized soil instability (TRC, 2005). Vibratory removal of piling, especially in very dense arrays in shipways, can produce a large amount of energy that liquefies sediments to some extent. In addition, removal of piling creates voids, further reducing soil stability.

When this removal activity was conducted near the deteriorated sheet pile bulkhead, about 50 feet of the bulkhead failed through leaning several feet. This structure was extremely corroded, especially at the mudline, and had lost essentially all the wall thickness from corrosion, spalling of corrosion products, and subsequent additional corrosion of the newly exposed surfaces. In addition, the tie backs were made of steel which had corroded through in two cases. This structure was marginally stable prior to demolition of the immediately adjacent north shipway.

At the south shipway, sheets comprising the new bulkhead were driven but the concrete pile cap was not constructed prior to demolition of. Some deflection of the new bulkhead was noted and the demolition was stopped until the situation could be addressed. For structures that were in place, it was recommended that no piling removal be conducted within 50 feet and that monitoring for movement be undertaken. For the remainder of the bulkhead, the recommendation was to alter the demolition/construction sequence so the demolition would be completed ahead of the bulkhead construction. To protect the shoreline, a temporary wall of large interlocking concrete ecology blocks was constructed between where the old bulkhead was removed and the shoreline until the steel sheets could be driven. Most pilings were successfully removed and the pilings that were left in place did not inhibit necessary cleanup.

4.5 SHORELINE STABILITY EVALUATIONS

4.5.1 Bank Stability Evaluations

Debris removal is not anticipated to cause any bank stability issues. Per the design criteria, large debris removal along the shorelines will be followed by reinstallation of quarry spalls and riprap of void areas to maintain the integrity of the existing shoreline protection. Vertical pilings along the West Waterway shorelines and around the corner of the Site that do not affect the remedial action at this location will remain.

4.5.2 Sheet Piles Stability Evaluations

Stability of the sheet pile bulkhead in the former shipway was analyzed to determine the stability conditions after removal of piles and after dredging. Stability analysis after dredging is discussed in Section 5.7.2. Detail calculations are included in Appendix D.

Based on the sheet pile embedment depth investigation (Section 3.8.2), it was assumed that the total vertical height of the sheet pile bulkhead wall in the former shipway is about 45 feet, with an embedment to exposed depth ratio of 2:1. The total horizontal extent of the sheet pile bulkhead is about 200 feet. Stability evaluations were performed at three locations where the dredge cuts are in the range of 6 feet to 13 feet. A software program, PYWALL, was utilized. The program automatically generates active earth pressure acting on the wall based on the input geometry and soil profile. Passive soil resistance due to embedment of the wall is computed automatically by the program using nonlinear soil-resistance curves. The program provides curves of wall deflection versus depth, as well as shear force versus depth and bending moment versus depth. To represent the conditions after removal of piles, a minimum passive soil resistance was assumed. Refer to Table 5-4 in Section 5 for deflection versus depth estimates in current conditions and after removal of piles. This analysis indicated that if all the piles in the shipway were removed without any attempt to stabilize the nearby sheet pile wall, there would likely be instability of the sheet pile wall. Note that partial removal of piling (perhaps followed by backfill) and/or installing temporary wall structures are among a number of options to stabilize the existing sheet pile wall prior to piling removal. Refer to Section 4.4.3 for lessons learned from pile removal operations completed at LSSOU in 2005. Further discussion on the stability of the sheetpile wall after dredging is provided in Section 5.7.

4.6 DEBRIS TRANSPORT AND DISPOSAL

The work surface on the barge deck will include a containment basin for all debris and any sediment removed during pulling.

All removed wood piles are considered creosote-treated. Per EPA guidance, creosote-treated wood piling and sections will be disposed of in a manner that precludes their further use by cutting them into 4-foot or shorter lengths before disposal. Pilings and other amalgamated slag/sandblast grit removed from shorelines will be disposed of in a Subtitle D landfill that meets the liner and leachate standards of the Minimum Functional Standards, Chapter 173-304 Washington Administrative Code (WAC). Concrete, stone, and metal debris will be segregated, cleaned, and recycled to the extent practicable at an approved recycling facility. Concrete and metal debris will be swept and brushed clean of adhering sediment and visually inspected to ensure that it is visibly clean. Refer to Section 5.10 for handling debris removed during dredging subtidal sediment.

Section 5

Sediment Removal and Disposal

The primary purpose of dredging is to remove contaminated sediment in specific areas of the Site to fully accomplish the remedy selected by U.S. Environmental Protection Agency (EPA) in the Lockheed West Seattle Record of Decision (ROD) (EPA, 2013) and as outlined in the Unilateral Administrative Order (UAO/Statement of Work (SOW; EPA, 2015c).

Contaminated sediment in the intertidal zone (above -10 feet mean lower low water [MLLW] and below the edge of shoreline protection rock [elevation varies between -10 feet MLLW and 8 feet MLLW]) and in subtidal zones (below -10 feet MLLW) will be removed by in-water dredging. This section provides a discussion of design criteria and assumptions, sediment properties, dredge design and operations, water management, sediment transloading, and disposal and confirmation sampling. An overview of the dredge plan is shown in Figure 5-1. Refer to the design drawings in Appendix B for complete set of intermediate design dredging plans and sections at the Site.

5.1 DESIGN BASIS AND ASSUMPTIONS

The following design basis and assumptions were considered for sediment removal and disposal design:

- The shoreline bank and intertidal zone, shipway, and the navigational channel will be dredged to the Sediment Quality Standards (SQS) remedial action level (RAL). Portions of Dry Dock #1 area outside of the navigation area, Dry Docks #2/3, and other localized subtidal areas throughout the Site will be dredged to the cleanup screening level (CSL) RAL. Refer to Table 2-2 for RALs. The sample intervals below the depth for removal have concentrations of COCs below the RALs. A complete list of sediment sample interval analytical data for the COCs is presented in Table A-2 of Appendix A.
- Performance standards for sediment removal shall be consistent with the ROD and applicable or relevant and appropriate requirements (ARAR) including the Clean Water Act, Rivers and Harbors Act, and Endangered Species Act (ESA) requirements as discussed in Section 2. The contaminated sediment shall be disposed of in a permitted and EPA-approved upland disposal site, also approved by Lockheed Martin. All materials removed from the Lockheed West Seattle Superfund Site (Site) must be managed or disposed of in accordance with the Off-Site Rule (Comprehensive Environmental Response, Compensation and Liability Act [CERCLA] Section 121(d)(3)).

- Dredge cuts will be to the required depths and areal extent to remove the contaminants. Final slope angles will not create slope stability conditions any worse than the existing conditions.
- Generated residuals (sediment disturbed by the cleanup action) and undisturbed residuals will be managed by placement of clean residual management sand layer.
- Dredged areas in the intertidal zone and the shipway will be backfilled to existing grades after removal to minimize loss of aquatic habitat.

5.2 SEDIMENT PROPERTIES

Sediment properties—specifically sediment composition, solids content, cohesiveness, and organic content—are important parameters to consider in dredge design, selection of dredge equipment, planning dredge operations, and during sediment handling, dewatering, and disposal. Based on the geotechnical investigations, sediment properties within the dredge areas are summarized in Table 5-1 and discussed below.

5.2.1 Sediment Cohesiveness

Cohesiveness of sediment is an important parameter in managing resuspension of particulates and selecting the dredge type and operations. In general, finer, less cohesive sediments have the greatest potential for resuspension. It is also an important parameter in dredge cut slope stability analysis, which is discussed in Sections 5.3 and 5.7. Sediment cohesiveness of Site sediment was evaluated based on soil classifications and Atterberg limit testing data. Sediment to be dredged at the Site is characterized as low to non-plastic, suggesting that typical dredge operations for resuspension controls will be applicable and special washing measures to clean the dredge bucket will not be needed.

5.2.2 Sediment Density

Sediment density was evaluated using the boring logs, cone penetration test (CPT) readings (cone tip and frictional resistance), and from laboratory tests. These values indicate the presence of soft, fine-grained sediment and loose to medium dense granular sediment. Sediment density data indicate that the sediment is dredgeable with standard practice dredge equipment. Refer to Section 5.8 for dredging methodology to remove Site sediments.

5.2.3 Percent Solids

The percent solids by weight is the ratio of weight of dry solids to total weight of the dredged material as removed. The percent solids in the material as it is removed and transported by the dredge will have a major impact on the production rate and the compatibility of the dredging operation with subsequent handling, treatment, and disposal of the material. Typically, a higher solids content delivered by the dredge translates to more feasible handling, treatment, and disposal of water and sediment. Percent solids by weight of sediment in shipway and dry docks was tested during determination of dewatering characteristics of sediment. The results indicated that shipway sediment has 59 percent to 62 percent solids, and dry dock sediment 67 percent to 79 percent solids. Higher percentage of solids content in dry dock sediments suggest that higher production rates and less dewatering time could be achieved during dredging dry dock sediment compared to dredging sediment in the shipway. Refer to Tables 3-1 and 3-3 for detailed data.

5.3 DREDGE PRISM DESIGN

Contaminated sediment will be removed from intertidal and subtidal areas. The design dredge prism represents the elevations, grades, and horizontal extent of contaminated sediment (i.e., sediment with concentrations greater than the cleanup levels) that will be removed to implement the remedial action. The dredge plan overview is shown in Figure 5-1. The intermediate design neatline dredge volume is approximately 90,900 cubic yards (cy) over 15 acres and approximately 115,000 cy with an overdredge of 1 foot across the affected area (Table 5-2).

5.3.1 Neatline Dredge Depths and Slopes

The design dredge surface is composed of a series of stepped level dredge cuts to reach design depths to fully remove sediment that exceeds the RALs. Data interpretation, which dictates the dredge depths, was based primarily on available chemistry data (see Appendix A, Table A-2). Sediment geotechnical properties were also utilized to analyze stable dredge slopes that assist in developing the prism.

The dredge design slope represents the slope expected to be stable during construction and to prevent slope failure and minimize sloughing during implementation. A slope of 3H:1V (three run horizontal to one rise vertical) was selected as the default dredge slope. The dredge cut slopes along a portion of the shorelines and over some of the existing surface ridges and humps were selected as 2H:1V based on the existing side slopes and required dredge depths to meet cleanup goals. Dry dock shorelines and dredge area adjacent to Pier 24 will be dredged at slopes slightly steeper than 2H:1V to dredge contaminated sediment along the slopes. These areas will be further stabilized by riprap to restore the stable conditions. Refer to Section 5.7 for detailed discussion.

Gentler slopes than 3H:1V were used as much possible to mimic existing bottom contours. A submerged dredge cut slope stability analysis was for 2H:1V slope was also performed. Potential “bathtub effect” was also considered during development of dredge prisms. The slopes are relatively gentle and the area covered is large. For example, in the area of former Dry Dock #1, the average dredge cut is 6 feet over about 2 acres. The high ratio of area versus dredged depth and the designed side slopes tapering into adjacent elevated mudlines would not create a condition where water would be trapped and cause a bathtub effect. Geotechnical slope stability analyses of dredge cuts are discussed in Section 5.7 and detailed calculations are provided in Appendix D.

5.3.2 Extent of Dredging

The extent of dredging was originally defined in the EPA Selected Remedy based on the extent of contamination exceeding RALs (SQS and CSLs) determined during the feasibility study (Tetra Tech, 2008). Pre-design site investigations resulted in refinement of these RAL boundaries and the required dredge extent. Further discussion is provided in Section 3.6, and an evaluation is presented in Appendix A of the dredge design surface relative to the site data and interpreted CSL and SQS boundaries. Designed dredge cuts were extended to these redefined CSL and SQS boundaries while maintaining 12 inches of dredge cut or the required dredge depth determined by the closest core chemistry data (Figure 5-1).

5.3.3 Overdredge

The accuracy of mechanical dredging is typically operator-dependent but special attachments (e.g., level cut or environmental buckets) can be incorporated to improve dredging accuracy. An overdredge of 1 foot below the neatline elevation is planned at this stage of the design, but may be modified depending on the accuracy of dredging that may be achievable and measureable.

5.4 SHORELINE/INTERTIDAL SEDIMENT REMOVAL

The intertidal areas are defined as nearshore areas with bathymetric elevations greater than -10 feet MLLW and below the edge of existing shoreline protection rock. Additional sediment core data from the pre-design field investigation refined the required dredge depths in shoreline/intertidal areas. The south beach intertidal dredge area located next to the Port of Seattle’s (Port) Terminal 5 wharf will be dredged to the elevations shown in the design drawings after shoreline debris removal. Some of the debris is buried (e.g., woody debris, pieces of concrete piles) and will likely be removed during dredging. The area to be dredged extends between the edge of existing shoreline protection rock at approximately +8 feet MLLW and -10 feet MLLW elevation contour. The area will be backfilled to the existing grades as discussed in Section 6.2.

The intertidal dredging area near the former dry docks is very narrow because the toe of rock is approximately at -2 feet MLLW, and the existing shoreline slope is about 2H:1V to reach -10 feet MLLW contour. Areas to be dredged along the shorelines next to Pier 23 and Pier 24 do not include any intertidal area because the toe of the existing shoreline protection rock follows the approximately -10-foot MLLW contour. The intertidal area to be dredged next to Pier 25 will be backfilled to the existing grades as discussed in Section 6.2. In the former shipway, the intertidal area portion of the dredge prism covers an area between +10 feet MLLW at the project boundary and the -10-foot MLLW level. The area will be backfilled to the existing grades as discussed in Section 6.2. Refer to the design drawings for detailed information.

The majority of intertidal areas (i.e., south beach, adjacent to Pier 25 and shipway) are below zero feet MLLW and are permanently inundated between the tidal cycles. The contamination depth in the portions that are exposed to tidal cycles are shallow enough that dredging of contaminated sediment can be completed during a single tide-cycle, pending confirmation sampling. As a BMP, goetextile fabric may be deployed over dredged areas if needed to control resuspension and to comply with the project's water quality requirements. Detailed methodology will be developed in EPA-approved Remedial Action Work Plan (RAWP).

5.5 FORMER SHIPWAY SEDIMENT REMOVAL

Former shipway sediment will be dredged to the RALs after the derelict piles and identified debris are removed from the area. Required dredge depths were determined by the SQS RALs. The stability of the existing sheet pile wall located on the western side of the former shipway after removal of 6 feet to 13 feet of sediment was analyzed (Section 5.7.2). Dredge plan view and dredge cross-sections are provided in the design drawings (Appendix B). The area will be backfilled to the existing grades (see Section 6.2).

5.6 SUBTIDAL SEDIMENT REMOVAL

The subtidal sediment removal area covers areas below -10 feet MLLW to -54 feet MLLW to achieve RALs mainly in dry dock areas, and a few other locations in the West Waterway, the northeast corner of the site, between Pier 23 and the dry docks, and adjacent to Pier 23, Pier 24, and Pier 25 (Figure 5-1). Existing bathymetry is very irregular throughout the Site and in the dredge areas, with the presence of surface protrusions, assumed to be sand blast grit, concentrated within the footprint of the dry docks. A number of stepped level dredge cuts are designed to achieve the RALs at elevations ranging between -33 feet MLLW and -54 feet MLLW. The dredge footprint was extended to reach the defined SQS and CSL boundaries. Residual management layer will be placed over the dredged areas as discussed in Section 6. Dredged shoreline slopes along the dry docks and adjacent to Pier 24 will be stabilized by riprap shoreline protection rock (Section 5.7.1). Dredge plan view and dredge cross-sections in dry docks and other subtidal sediment dredging areas are provided in the design drawings (Appendix B). Refer to Table 5-2 for a summary of the preliminary design dredge volumes.

5.7 SHORELINE STABILITY EVALUATIONS

5.7.1 Bank Stability Evaluations

The slope stability of dredge cuts along the shorelines was analyzed. These locations include the West Waterway south beach dredge area, shorelines of the dry docks, the dredge area adjacent to Pier 24, and the former shipway.

Shoreline slopes along the West Waterway south beach dredge area and former shipway will be backfilled to the existing grades. The backfill will consist of sand, gravel beach mix, and fish mix. The gradation of gravel beach mix was designed to withstand wind and water level conditions associated with the occurrence of a 50-year return period storm. Refer to Section 6.1 for the design criterion. The stability of dredge slopes in West Waterway south beach dredge area and former shipway is anticipated to either remain the same as the current conditions or improve due to backfilling the dredged areas to the existing grades with sand, gravel beach mix, and fish mix. A slope stability analysis along the profile of former shipway after backfilling confirmed that post backfill slopes would be stable (Table 5-3).

Representative dredge slopes along the shorelines of the dry docks and near Pier 24 were selected for stability analysis. . Conventional two-dimensional limit-equilibrium analyses were performed to investigate the stability of the dredge cuts. The computer program SLOPE/W was used to calculate the factor of safety (FoS) against potential failure. This factor is defined as the ratio of resisting (i.e., stabilizing) forces to the driving forces trying to displace the slope. A FoS greater than 1 implies that the slope is theoretically stable. A FoS less than 1 implies that the slope is not stable and slope movement is possible. The design criterion is to maintain the stability of slopes the same after the construction under both static and seismic conditions. For seismic conditions, a seismic event of 50 percent probability of exceedance in 75 years, which corresponds with a return period of 108 years (nominal 100 years), was analyzed.

Historic geotechnical data, pre-design geotechnical investigation results, and the Port's Terminal 5 modernization project geotechnical basis of design report (Hart Crowser, 2016) were reviewed to select the stability analysis parameters and the analysis methodology. Slope stability analysis was performed by defining a minimum slip surface depth of 3 to 5 feet, which removes any slip surfaces with depths less than the minimum from the results. This is a common method when analyzing frictional material to remove surficial sloughing result. Surficial "raveling" types of soil movement will be mitigated by placement of riprap protection on the dry dock and adjacent to Pier 24 shoreline dredge slope surfaces.

Slope stability analysis results are summarized in Table 5-3 and detailed calculations are included in Appendix D. The results indicate that post-dredge and riprapped slopes are theoretically stable, with FoS generally equal or greater than the current conditions. The FoS values for the seismic stability of the slopes are currently less than 1.0, while the post-construction conditions show improvement in the FoS compared to the current conditions. The results also indicate stability of submerged dredge cut slopes at 2H:1V and the conditions in the former shipway after backfilling. Refer to Section 6.2 for details of backfilling former shipway after dredging.

5.7.2 Sheet Piles Stability Evaluations

Stability of the sheet pile bulkhead in the former shipway was analyzed to determine the stability conditions after removal of piles and after dredging. The stability analysis after removal of piles is summarized in Section 4.5.2; detailed calculations are included in Appendix D.

Analysis methodology and assumptions are described in Section 4.5.2. Stability evaluations were performed at three locations where the dredge cuts are in the range of 6 feet to 13 feet. The PYWALL software program was utilized to estimate wall deflections after the removal of the piles, and after dredging. Deflection versus depth estimates for current conditions, after removal of piles and after dredging, are summarized in Table 5-4. The area will be backfilled to the existing grades; however, estimated deflections of the sheet pile wall are expected to occur during the construction. This analysis indicated that the sheet pile wall would be unstable after removal of piles and dredging.. This finding is consistent with Lockheed Martin's experience at Lockheed Shipyard Sediments Operable Unit (LSSOU) discussed in Section 4.4.3. Potential mitigation approaches include leaving a portion of the piles in place, improvement of the wall, installation of new sheet piles, or modification/excavation of the upland backfill behind the wall to reduce the lateral earth pressure. Currently, the Port is developing plans to implement a mitigation approach to reduce the lateral earth pressure by cutting a portion of sheet pile wall at mudline and excavating upland backfill behind the wall. The anticipated start of this construction along with the Port's pile removal project is mid-2017.

5.8 DREDGE METHOD AND OPERATIONAL CONTROLS

This section provides brief information about the potential dredge equipment and construction approach. Detailed methodology, equipment selection, and operational controls will be refined in the Contractor work plans to be developed as part of the EPA-approved Remedial Action Work Plan (RAWP). The Contractor's dredge plan will include any proposed modifications to the design dredge surface that may better accommodate the Contractor's proposed equipment and construction approach for complete and accurate removal to or below the design dredge surface. The Contractor's plan will specify the construction approaches for removal of debris within the dredging area, dredging of sediments, dewatering and transloading.

5.8.1 Dredging Methodology

The Contractor's selection of dredging equipment will be based on the Site and project characteristics:

- Contaminated sediment is required to be removed both at intertidal and subtidal areas.
- The equipment must be suited for sediment removal both on a slope and a level bed and should be able to dredge to -55 feet MLLW.
- The equipment and operations controls should be designed to minimize the generation of dredge residuals and water quality impacts.
- The Site is subject to tidal fluctuations, and equipment must maintain correct locations through the tidal changes.
- The sediments are typically finer grained but there are substantial amounts of debris within the dredge footprints.

The dredging equipment best suited to the Site conditions is mechanical dredging equipment. The advantages of mechanical dredging include:

- Ability to meet project requirements, including compliance with applicable water quality criteria and minimizing sediment resuspension;
- Ability to achieve higher solids loadings in the dredged materials, without necessitating costly and area-intensive dewatering methods;
- Greater availability of equipment and expertise within the Pacific Northwest; and
- Ability to use mechanical dredging equipment for other remedial activities such residual management layer and enhanced natural recovery layer placement.

For mechanical dredging, an environmental bucket or specially constructed closed dredging buckets are available to reduce turbidity during dredging. Closed buckets are typically lightweight in construction and typically not suitable for digging denser materials. A grapple or standard clamshell bucket might be most effective at removing denser materials and debris prior to or during dredging. Subsurface debris can require the use of a more conventional style bucket or grapple. A modified digging or grapple bucket may be required to remove submerged and surface debris and may also be needed for removing denser substrate. The equipment must be able to reach to -55 feet MLLW. A different dredge system with a shallow draft and sized appropriately for sloped areas may be required. A hydraulically actuated, fully enclosed bucket (Young or similar) can also be used when Site conditions allow (i.e., in areas of minimal debris and where the depth of water supports the use of a hydraulic barge-mounted excavator). The mechanical dredging would require scows, tug boats, and support boats for transporting dredge material and relocating the dredge barge.

A typical mechanical dredging sequence is as follows:

- Dredging sediment;
- Placing dredged sediment in a haul barge, where passive dewatering occurs (Section 5.9);
- Transporting dredged sediment to an upland offloading and staging area (Section 5.10);
- Dewatering sediment either directly on the haul barge or offloading sediment to a stockpile area for further dewatering (Section 5.9);
- Collecting and treating (if necessary) effluent from the dredge stockpile and discharging it to approved treatment works;
- Loading the sediment into rail cars and/or trucks for upland transport; and
- Transporting contaminated sediment to a permitted landfill facility by truck or rail.

5.8.2 Dredge Operations

Dredging operations will be performed over individual dredge units such that required dredge depths can be verified through the bathymetric surveys and confirmation sampling can be conducted. The design drawings include a series of dredge areas determined by the location and dredge depths (Appendix B). These dredge areas will be revised to dredge management units, which will be defined at 90% design and in the Contractor's RAWP. Dredging at higher tides in intertidal and shallow subtidal areas will likely be needed to provide the required draft for the dredge and material barges. Dredging will progress from upper to lower slope to reduce the possibility of surface recontamination and to maintain slope stability. The progress of the dredging will be monitored by the Contractor in the daily reports, progress surveys, and oversight by EPA and Lockheed Martin.

Dredge equipment will be configured with global positioning system (GPS) -based, real-time (real-time kinetic) or equivalent, integrated, computerized horizontal and vertical (x, y, z) positioning systems to enhance accuracy of dredging and reduce excess dredge volume. Other operational considerations due to Site characteristics include the following:

- There are shallow dredge cuts at the Site (less than 5 feet in most places) that require experienced operators to minimize any over-dredge beyond that required to achieve RALs.
- A minimum number of dredge passes is desired to minimize dredge residuals and sediment suspension.
- Surface debris surveys indicate that most of the debris is present in the dry dock areas. Unknown buried debris will also likely be encountered.
- Dredge cut elevations will be monitored in real time to recognize the difference in the dredgability of loose, fine, unconsolidated sediment and stiff, dense sediment and make any operations adjustments as needed.

Operational controls will be used to limit water quality impacts, recontamination, and dredge residuals to the extent practicable. These controls include BMPs, water quality monitoring, and operational adjustments. Refer to Section 7 for a summary of these controls.

The average dredging rate is estimated to be between 400 to 800 cy per day based on the following assumptions:

- an average 5 cubic yard bucket grab at 3- to 5-minute cycle times for shallower areas (down to -20 feet MLLW) and 5- to 10-minute cycle times for deeper areas (-20 feet to -55 feet MLLW);
- 50 percent and 70 percent bucket fill factors; and

- an average 12-hour effective time of dredging per day (a 16-hour work day; two active 8-hour shifts).

The lower production rate will likely occur if dredging is slowed due to encountering debris and water quality issues related to resuspension of sediment. All in-water construction will be conducted during the designated in-water work window unless an extension is granted. The final work window will be defined and coordinated in consultation with the Tribes and other resource agencies before implementation.

5.9 SEDIMENT DEWATERING

Dredged sediment will begin to be dewatered at the barge before being transferred to an upland location for further dewatering. Passive gravity dewatering is generally preferred provided the project has adequate space and time to allow sediment to dewater. Water quality effects from de-watering will be monitored according to the WQMP to be developed at 90% design. EPA will write a Section 401 Water Quality Memorandum that will regulate sediment dewatering during construction activities via BMPs and sampling protocols and standards. Refer to Section 7.1 for water quality control BMPs.

5.9.1 Barge Dewatering

Mechanically dredged sediment will initially be placed on the barge positioned adjacent to the dredge site to allow gravity drainage of sediment. Some degree of gravity drainage will occur on the barge. Sideboards or Jersey barriers can be installed around the perimeter of a flat-deck barge and along scuppers at the deck line. Water released from the sediment is filtered through a filter medium (e.g., woven geotextile fabric) placed across the scuppers, which also controls and prevents sediment discharges. The objective(s) for the discharge water and the configuration and type and specifications of the geotextile cloth and other BMPs on the barge that will filter the water before it is released to surface water will be identified in the EPA's 401 Water Quality Memorandum. The barge can be staged within the dredging area to allow continued dewatering before transport to a transloading location and subsequent offloading.

5.9.2 Upland Dewatering

Upland dewatering operations include transload of sediment to an upland location to a dewatering pad/stockpile area. Gravity dewatering of the dredged material is the current design assumption. The Contractor can explore more active dewatering methods such as additives, filter or belt presses, or hydrocyclones, depending on site-specific sediment characteristics. If the Contractor chooses to build an upland dewatering location, such as at adjacent Port uplands, dewatering pads and stockpiles will include engineering controls such as liners, covers, and/or run-off controls necessary to protect human health and the environment. An upland dewatering facility would have to substantively comply with all applicable permits discussed in Section 2 and Section 8. An upland dewatering pad will be constructed with a sloping base and a sump to facilitate further drainage and collection of water released from the sediment. Dewatering pads will have storage capacity to hold dredged sediment to be produced during a reasonable construction period to accommodate time for dewatering and loading dredged sediment.

5.9.3 Wastewater Treatment

Management, and treatment to meet applicable Water Quality Standards, of the water collected over the dewatering area will be required before disposal. At the sediment staging area, dewatering will be accomplished either passively on a dewatering pad or through a mechanical process. Depending on the setup of transloading facility, rainwater captured within containment systems, in addition to the water generated from dewatering, will be managed through treatment before disposition. The Contractor will build and permit an on-site water treatment system unless transloading occurs at a facility permitted to treat water. The objectives of water treatment and the treatment process (i.e., filtration only, clarification followed by separation and filtration, etc.) will be identified at 90% design. The BMPs and the standards that need to be met will be identified in EPA's Section 401 Water Quality Memorandum.

Options for final disposal of the treated water include discharge to the publicly owned treatment works in accordance with a permit to be issued by King County, a permitted wastewater treatment facility, or discharge to the waterway through a permit to be issued by Department of Ecology and City of Seattle. Discharge will require that the effluent be routinely sampled, in accordance with discharge permit requirements.

5.10 SEDIMENT TRANSLOAD AND DISPOSAL

The Contractor will provide a detailed sediment transload and disposal plan in the RAWP. At this stage of the design, it is assumed that the dredged material will be placed on haul barges and transported to an established and permitted sediment transload facility on the Lower Duwamish

Waterway (LDW). The Contractor may choose to build its own transloading facility or may enter into a lease agreement with the Port to use adjacent uplands as transloading and dewatering area.

The debris to be encountered during the dredging will range in size and be managed with the sediment. A sediment transload facility typically includes barge offloading and truck or train loading (for transport to an EPA- and Lockheed Martin–approved disposal facility). Any water from the barge and sediment stockpiles at the facility will be managed by the transload operation in compliance with all appropriate rules and regulations.

5.10.1 Sediment Transloading

The Contractor can consider existing and permitted transloading facilities to dewater and transport dredged materials to the disposal facility. There are several transloading facilities that have operated or are permitted to operate on the LDW including the LaFarge cement plant, Pacific Pile and Marine, and Duwamish Reload Facility operated by Waste Management. As discussed above, the Contractor may also consider developing their own transloading facility specifically for this remedial action. The Contractor would need to substantively comply with all applicable permits, similar to the existing facilities. If this option is selected by the contractor, additional details regarding the requirements that would need to be met will be added at the 90% design. The transloading location would be set up to offload materials from the project in a manner that prevents loss of materials to the water (such as spill plates), and would provide containment of materials prior to off-site shipping by truck and/or rail to the permitted landfill.

5.10.2 Disposal

Dredged material will be disposed of at a Subtitle D landfill that has been approved under the EPA Off-Site Rule (CERCLA Section 121(d)(3)) for waste disposal from a Superfund site. There are several off-site Subtitle D solid waste landfills in the region that are licensed to accept dredged sediment from the Site. These facilities include the Greater Wenatchee Regional Landfill in Wenatchee, Washington, and the Columbia Ridge Landfill in Arlington, Oregon, both operated by Waste Management, and the Roosevelt Regional Landfill in Klickitat County, Washington, operated by Allied/Rabanco.

Requirements regarding disposal of sediments at most Subtitle D landfills include provisions that the sediment be dewatered so that it will pass the paint filter test for free water. Of the landfills listed above, only the Greater Wenatchee Regional Landfill has this requirement. Roosevelt

Regional Landfill operated by Allied/Rabanco and the Columbia Ridge Landfill operated by Waste Management are licensed to accept sediments that have excess water, or wet sediment. The amount of free water that is acceptable over a certain time period is written into the operating permit of the landfills. Rail cars used to transport wet sediment, if any, may need to be lined to prevent water spillage. The current design assumptions include dewatering of sediment before transport and disposal to reduce the amount of weight and the cost of the project.

5.11 DREDGE VERIFICATION AND CONFIRMATION SAMPLING

During dredging, progress surveys will verify that required dredge elevations have been met. Based on the progress surveys, in locations where the required elevations have not been achieved, the Contractor will be required to remove additional material. The completion of dredging will be determined with a post-dredge bathymetric survey and post-dredge confirmation sediment sampling. A bathymetric survey will be completed after dredging to confirm that the design elevations have been met. After confirmation of achieving the design depths, sediment samples will be collected for chemical analysis to confirm that impacted sediments have been removed. All dredging confirmation activities will be done on pre-determined dredge management units. Details for the post-dredge bathymetry survey and the post-dredge confirmation sampling will be developed in the Construction Quality Assurance Plan (CQAP) and the contractor Construction Quality Control Plan.

Table 5-1
Geotechnical Properties of Dredge Sediment

Sampling Location/ Dredge Area	Exploration Designation	Classification	Depth (feet)	Moisture Content (%)	Organic Content (%)	Specific Gravity	PI[1]	Gravel (%)	Sand (%)	Fines (%)
Former Shipway	TT-143,S-1	Silty sand (SM)	3.5-4.0	76.4	10.66	2.39	NP	17.8	50.4	31.8
	TT-143,S-2	Silt (ML)	9.5-10.0	50.3			NP			78.6
Between Piers 24 and 25	TT-145,S-1	Silt (ML)	3.0-4.0	38.7				0.2	29.1	70.7
	TT-145,S-2	Poorly-graded silty sand (SP-SM)	5.5-6.5	21	0.73		NP		90	10
Between Piers 23 and 24	TT-146,S-1	Poorly-graded sand (SP)	3.0-3.5	22.4				0	97.2	2.8
	TT-146,S-2	Silty sand (SM)	5.0-5.5	35	2.75	2.65				23.1
Dry Dock	TT-148,S-1	Poorly-graded sand (SP)	5.0-6.0	21.9						4.3
	TT-148,S-2	Silty sand (SM)	8.5-9.5	36	4.95	2.63		3.1	78.4	18.5
	TT-150,S-1	Silt (ML)	5.5-6.0	25.3		2.67		0.6	47.3	52.1
	TT-151,S-1	Silty sand (SM)	6.0-7.0	35.6		2.64		0	78.7	21.3
	TT-153,S-1	Poorly-graded silty sand (SP-SM)	4.0-4.5	25.6				0.1	92.5	7.3
	TT-153,S-2	Silt (ML)	6.5-7.0	29.4						54.7
South Beach and West Waterway	TT-154,S-1	Poorly-graded silty sand (SP-SM)	3.5-4.0	44	4.1	2.64	10		32.7	67.3
	TT-154,S-2	Silty sand (SM)	6.0-7.0	68.1				0.9	49.7	49.4
	TT-154,S-3	Elastic silt (MH)	8.0-9.0	77.7	7.86	2.87	13	7.9	6.1	85.9

[1] PI = Plasticity Index; NP = Non-plastic

Table 5-2
Dredge Volume Summary Table

Location	Depth of Cut (feet)	Area (ac)	Neatline Volume (cy)	Overdredge Volume[1] (cy)
South Beach	1.0 to 5.5	0.6	2,250	1,000
Dry Docks	1.0 to 12.0	13.1	77,600	21,250
Piers 23, 24, & 25	1.0 to 5.5	0.3	700	450
Former Shipway	1.0 to 15.0	0.9	10,350	1,420
Total =	-	15.0	90,900	24,150

[1] Approximate overdredge volume for 12-inch cuts.
ac = acre, cy = cubic yard

Table 5-3
Slope Stability Analysis

Location[1]	Condition	FoS (3')	FoS (5')
Dry docks (Section B4)	Current – Static	1.28	1.32
	Post-dredge and post-riprap placement – Static	1.39	1.39
	Current – Seismic	0.64	0.66
	Post-dredge and post-riprap placement – Seismic	0.77	0.77
Dry docks (Section B19)	Current – Static	1.42	1.52
	Post-dredge and post-riprap placement – Static	1.61	1.61
	Current – Seismic	0.70	0.75
	Post-dredge and post-riprap placement – Seismic	0.85	0.85
Pier 24 (Section C5)	Current – Static	1.39	1.52
	Post-dredge and post-riprap placement – Static	1.46	1.46
	Current – Seismic	0.70	0.75
	Post-dredge and post-riprap placement – Seismic	0.86	0.86
Submerged dredge slope (Section B6)	Post-dredge – Static	1.48	1.63
Former shipway (Section D2)	Post-backfill – Static	3.94	3.96

[1] Refer to Design Drawings for section locations
FoS = Factor of Safety for 3 feet and 5 feet minimum slip surfaces
Seismic = Peak ground acceleration of 0.155g

Table 5-4
Sheet Pile Wall Deflection Analysis

Location[1]	Condition	Free Height (ft) / Embedment Depth (ft)[2]	Deflection (inch)	Demand/ Capacity ratio
Section D3	Current	5/40	0.3	0.05
	After removal of piles	8/37	0.9	0.12
	After dredging	11/34	2.4	0.24
Section D4	Current	10/35	1.7	0.19
	After removal of piles	13/32	4.6	0.40
	After dredging	16/29	10.4	0.71
Between D4 and end of sheet pile wall	Current	12/33	3.5	0.32
	After removal of piles	15/30	8.1	0.6
	After dredging	25/20	n/a	n/a

[1] Refer to Design Drawings for section locations
[2]Assumed dimensions
n/a = analysis do not converge which suggests instability; ft = feet

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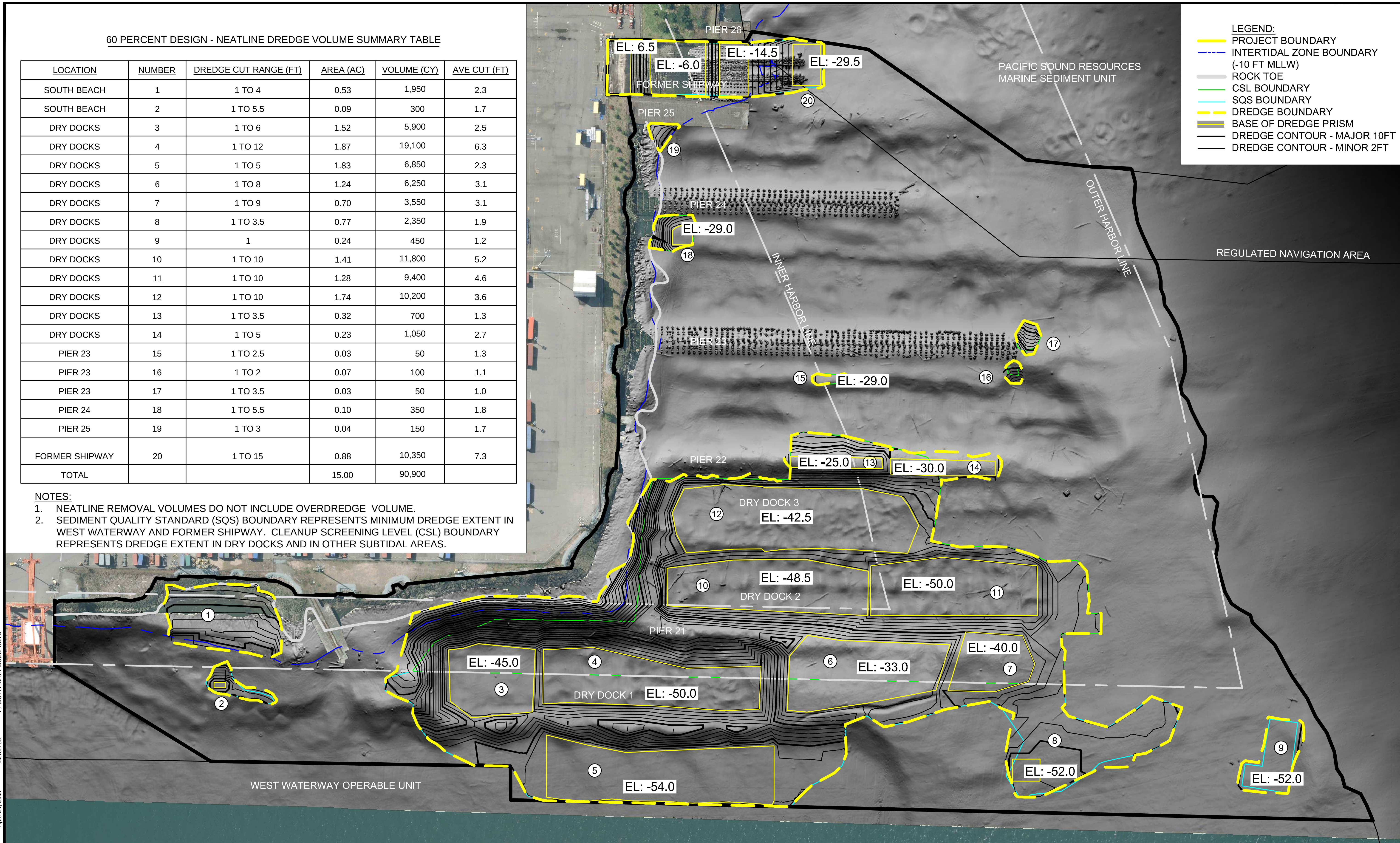
60 PERCENT DESIGN - NEATLINE DREDGE VOLUME SUMMARY TABLE

LOCATION	NUMBER	DREDGE CUT RANGE (FT)	AREA (AC)	VOLUME (CY)	AVE CUT (FT)
SOUTH BEACH	1	1 TO 4	0.53	1,950	2.3
SOUTH BEACH	2	1 TO 5.5	0.09	300	1.7
DRY DOCKS	3	1 TO 6	1.52	5,900	2.5
DRY DOCKS	4	1 TO 12	1.87	19,100	6.3
DRY DOCKS	5	1 TO 5	1.83	6,850	2.3
DRY DOCKS	6	1 TO 8	1.24	6,250	3.1
DRY DOCKS	7	1 TO 9	0.70	3,550	3.1
DRY DOCKS	8	1 TO 3.5	0.77	2,350	1.9
DRY DOCKS	9	1	0.24	450	1.2
DRY DOCKS	10	1 TO 10	1.41	11,800	5.2
DRY DOCKS	11	1 TO 10	1.28	9,400	4.6
DRY DOCKS	12	1 TO 10	1.74	10,200	3.6
DRY DOCKS	13	1 TO 3.5	0.32	700	1.3
DRY DOCKS	14	1 TO 5	0.23	1,050	2.7
PIER 23	15	1 TO 2.5	0.03	50	1.3
PIER 23	16	1 TO 2	0.07	100	1.1
PIER 23	17	1 TO 3.5	0.03	50	1.0
PIER 24	18	1 TO 5.5	0.10	350	1.8
PIER 25	19	1 TO 3	0.04	150	1.7
FORMER SHIPWAY	20	1 TO 15	0.88	10,350	7.3
TOTAL			15.00	90,900	

NOTES:
1. NEATLINE REMOVAL VOLUMES DO NOT INCLUDE OVERDREDGE VOLUME.
2. SEDIMENT QUALITY STANDARD (SQS) BOUNDARY REPRESENTS MINIMUM DREDGE EXTENT IN WEST WATERWAY AND FORMER SHIPWAY. CLEANUP SCREENING LEVEL (CSL) BOUNDARY REPRESENTS DREDGE EXTENT IN DRY DOCKS AND IN OTHER SUBTIDAL AREAS.



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TETRA TECH

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LOCKHEED WEST SEATTLE SUPERFUND SITE
SEATTLE, WA

FIGURE 5-1
DREDGE PLAN OVERVIEW

Section 6

Backfill, Residual Management Layer, and Enhanced Natural Recovery Layer Placement

This section explains the following components of the Selected Remedy for the Lockheed West Seattle Superfund Site (Site): intertidal area and former shipway area backfill, enhanced natural recovery (ENR) layer placement, and dredge residual management layer (RML) placement.

The design basis, material specifications, and construction methodology described in this section are based on and consistent with the primary purpose and performance standards for the ENR and RML placement as described in the Record of Decision (ROD). Performance requirements will further be detailed in Construction Quality Assurance Plan (CQAP) to be developed at later stages of design.

6.1 DESIGN BASIS AND ASSUMPTIONS

The following design basis and assumptions were considered for backfill of intertidal and shipway, ENR, and RML placement design:

- Dredged intertidal areas will be backfilled to grade with clean imported backfill material (e.g., sand, silty sand) that promotes colonization by aquatic organisms to extent practical. This material may incorporate soft or organic-rich substrates beneficial to salmonids and other Site-specific aquatic organisms (e.g., "fish mix" or a silt-sand mix).
- Intertidal area backfill will incorporate gravel beach mix (i.e., dynamically stable gravel beach) to provide stability in the intertidal zone. The beach mix gradation will be sized to withstand wind and water level conditions associated with the occurrence of a 50-year return period storm.
- Chemical concentrations of import material(s) for backfill, ENR and dredge RML placed within the intertidal and subtidal zone will be consistent with the project cleanup goals.
- ENR and dredge RML will be placed as a 6-inch layer of imported clean material that promotes colonization by aquatic organisms.

- All backfill, ENR, and RML material may incorporate soft or organic-rich substrates beneficial to salmonids and other Site-specific aquatic organisms (e.g., fish mix or a silt-sand mix) to the extent practical.

6.2 INTERTIDAL AREA AND FORMER SHIPWAY AREA BACKFILL

Intertidal areas in the south beach area of the Site in West Waterway, in the former shipway, and in the dredge area next to Pier 25 will be backfilled to the existing grades after dredging. Gravel beach mix and 6 inches of fish mix will be placed at south beach and Pier 25 dredge areas. Shipway area will be backfilled with sand as the base layer, followed by gravel beach mix and 6 inches of fish mix in intertidal areas. The basis of design of intertidal backfill is consistent with typical mixed-sediment beaches of Puget Sound. The gravel portion of beach mix is expected to form a stable intertidal zone providing erosion protection from wind/wave forces. The subtidal dredge area of the former shipway will also be backfilled to the existing grades. Approximate intertidal and subtidal backfill quantities are summarized in Table 6-1. Design basis calculations for beach mix are provided in Appendix D. Refer to the design drawings (Appendix B) for plan views and sections of intertidal backfill.

6.2.1 Backfill Material Specifications

The sand backfill for shipway will be imported, clean, granular material free of roots, large organic material, debris, contaminants, and all other deleterious material. The gravel beach gradation was evaluated using the daily and 50-year design wave conditions for gravel sizes of 0.5-, 1-, and 1.5-inch stone. An iterative design process using various median gravel sizes was used to determine an equilibrium beach profile closest to the natural foreshore slope. A gravel beach mix with median grain size of 1.5 inches was selected at the south beach area in West Waterway, in the shipway, and small intertidal dredge area adjacent to Pier 25. Over the gravel beach mix, finer fish mix (silt-sand mix) will be placed to enhance the gravel beach mix and provide a substrate beneficial to salmonids and other Site-specific aquatic organisms.

In Puget Sound, forage fish are a significant part of the prey base for sea birds and fish populations, including salmonids identified as Site-specific aquatic organisms (Section 3.4). Forage fish typically spawn on the upper intertidal zone, approximately between mean tide level and mean higher high water (MHHW) (Herrera, 2005). Surf smelt, one of the forage fish species, spawn on substrate ranging in size from 1 to 7 millimeters (mm) in diameter, a size range commonly referred to as “coarse sand” (2 mm to 5 mm) or “pea gravel” (6 mm to 16 mm). Suitable habitat substrate mix gradation as reported in Puget Sound will be incorporated into the gradation and specifications for the fish mix.

Import backfill material gradation and chemistry testing will be required before acceptance of materials. Detailed backfill material specifications will be provided at 90% design.

6.2.2 Placement Methodology

Intertidal backfill can be placed by conveyor system or mechanical dredging equipment bucket. Work will be planned around the tide fluctuations to complete the construction. Grading of intertidal backfill is required to achieve slopes and design thickness specified on the drawings. Subtidal backfill in the former shipway will be placed by low-energy methods controlling the mass rate and velocity of the material delivery so it minimally disturbs the substrate Acceptable methods for low-energy placement of sand layer include the use of broadcast spreaders, conveyor systems, hydraulic pumping and placement with the use of diffusers or tremies, the excavator bucket or clamshell release of material just above the water surface, submerged clamshell releases of material just above the receiving layer surface, and washing of materials from barges minimizing the drop height (free fall) and material mounding.

6.3 RML AND ENR LAYER PLACEMENT

The primary purpose of placing the dredge residuals management layer (RML) and ENR layer is to provide a clean 6-inch layer of imported material that promotes colonization by aquatic organisms. The gradation of material will be selected such that soft or organic-rich substrates beneficial to salmonids and other Site-specific aquatic organisms (e.g., fish mix or a silt-sand mix) can be incorporated.

In subtidal areas where dredging occurs, the RML will address potential redeposition of suspended or dislodged contaminated sediment onto sediments during dredging operations. In areas where dredging does not occur (i.e., the remainder of the subtidal area), the layer will promote ENR. Approximately 9,500 cubic yards (cy) of RML material will be placed over about 12 acres of dredged area. Note that the rest of the dredged area (about 3 acre) includes intertidal dredging and dry dock slopes where will either be backfilled to the grades (at south beach, adjacent to Pier 25 and shipway) or placed riprap (over the dry dock dredge slopes). Approximately 18,600 cy of ENR material will be placed over 23.1 acres of the project area. Refer to Table 6-1 for preliminary design RML and ENR placement quantities.

6.3.1 RML and ENR Material Specifications

The Contractor will select materials that meet the project's quality requirements from an existing commercial source or sources. Sand will consist of clean, naturally occurring rounded or sub-rounded, well-graded material free from deleterious substances, having hard, strong, durable particles free from adherent coating and free from clay balls, debris, wood, organic matter, and other extraneous material. Both RML and ENR material will be graded so that the material is classified as SW, SP, SW-SM, SW-SC, SP-SM, SP-SC, SM, SC, or SC-SM in accordance with American Society for Testing and Materials (ASTM) D2487. Gradation and chemistry testing will be required before acceptance of materials. The project specifications will be developed at 90% design.

6.3.2 RML and ENR Placement Methodology

The placement of material will generally occur starting at lower elevations and working to higher elevations. Low-energy placement methods applicable to subtidal backfill of shipway area will be used for placement of RML and ENR layers. The contractor may need to utilize specialized equipment to achieve placement the ENR layer under or through Piers 23, 24, and 25. Intertidal backfill placement methodology will be applicable for placement of RML and ENR layers in shallower areas and will require planning the work based on the tidal fluctuations to complete the construction.

6.4 PLACEMENT VERIFICATION

Placement will be verified through cores, set volume, placement rates and tonnage, lead line measurements, and pre- and post-bathymetry information or similar to confirm adequate coverage during and following material placement. A pre-placement and post-placement bathymetry survey will be completed to document the placement. A combination of bathymetry and other verification methods will be used to confirm that the layer thickness meets the design.

6.5 ENR EFFECTIVENESS

The placement of the ENR layer will address surface sediments contaminant concentrations by reducing the exposure for benthic organisms to below the Sediment Quality Standards (SQS) levels and for the Site-wide surface weighted average concentrations in conjunction with the dredging to below the Site-wide cleanup levels. A conservative estimate of the ENR effectiveness assumes the

6-inch placed layer will fully mix with the upper 6 inches of underlying Site sediment resulting in a 50 percent reduction in the surface sediment concentrations as presented in the Remedial Investigation/Feasibility Study (RI/FS; Tetra Tech, 2012). Experience at other sites with the controlled placement of a thin sand layer using low-impact methods is that the underlying sediment is likely to mix with the first 3 inches of sand placement and the upper 3 inches of sand will be relatively unmixed.

Based on the 50 percent reduction from the RI/FS, surface sediments with concentrations up to two times the SQS level will be reduced to below the SQS level for benthic organisms. For the Site-wide weighted average concentrations, the ENR material and post-dredge RML material will provide a surface with COC concentrations below the cleanup levels in the compliance zone.

Table 6-1

RML, ENR, and Backfill Estimated Volume Summary

Residual Management Layer[1]		
Location	**Area (ac)**	**Volume (6-inch, cy)**
South Beach	0.1	75
Dry Docks	11.5	9,275
Piers 23, 24	0.2	150
Total	12.0	9,500
Enhanced Natural Recovery Layer[1]		
Location	**Area (ac)**	**Volume (6-inch, cy)**
Total	23.1	18,600
Backfill[2]		
Location	**Area (ac)**	**Volume (cy)**
Intertidal Total (South Beach, Pier 25, Former Shipway)	1.20	13,000
Subtidal Total (Former Shipway)	0.24	2,500

[1] RML and ENR material for 6-inch layer placement.
[2] Intertidal backfill includes gravel beach mix and fish mix in south beach and adjacent to Pier 25; sand, gravel beach mix and fish mix in former shipway. Subtidal backfill includes sand only in former shipway.
ac = acre, cy = cubic yard

Section 7
Short-term Environmental Control Measures

This section describes measures that will be taken to ensure that the remedial construction does not adversely impact human health and the environment. These measures are also discussed in Sections 4, 5, and 6 where relevant to specific actions related to the piling, debris, and sediment removal activities. Short-term environmental impacts of construction will also be mitigated by implementing best management practices (BMPs). Short-term environmental control measures and construction BMPs are summarized in this section. These measures will further be described in their respective plans to be developed at further stages of design or in Contractor work plans to be developed as part of the Remedial Action Work Plan (RAWP).

7.1 SHORT-TERM WATER QUALITY IMPACTS

The Washington Water Pollution Control Act - State Water Quality Standards for Surface Water (Revised Code of Washington [RCW] 90.48; Washington Administrative Code [WAC] 173-201A) establishes permitting requirements for point source discharges to surface waters of Washington State. Based on the use designations of surface waters within the jurisdiction of the State, numeric water quality parameters and narrative criteria are assigned to a water body to protect the existing and designated uses. The Water Quality Monitoring Plan (WQMP) and the RAWP to be developed at later stages of the project will define measures to be taken to comply with surface water standards.

Criteria pertaining to marine waters of "Excellent Quality" (WAC 173-201A-210; Specific Classifications—Marine Waters) designated for waters with salmonid and other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning are applicable to this project.

The Project WQMP will describe water quality monitoring during construction and further sampling and laboratory analysis methodology. In-water construction activities include dredging of sediments and barge dewatering, removal of piles and debris, backfilling, residual management layer (RML) placement, and enhanced natural recovery (ENR) layer placement of the dredged area.

Field monitoring of turbidity, dissolved oxygen (DO), pH, and temperature will take place at the edge of the compliance zone, at an early warning location, and in background (upstream, as adjusted for the tides) locations during in-water activities. Water samples may also be collected for laboratory analysis of sediment contaminants of concern (COCs) and total suspended solids (TSS), if required by the Section 401 Water Quality Memorandum that will be issued by EPA. The frequency of sampling and analysis will be specified in the WQMP.

The anticipated criteria as specified in WAC 173-201A-210 are summarized below:

- Temperature – Per Table 210 (1)(c), the temperature must be below 16 degrees Celsius (°C) for an excellent quality aquatic life.
- DO – Per Table 210(1)(d), the lowest 1-day minimum must exceed 6.0 milligrams per liter (mg/L) at the point of compliance. When DO is lower than the criteria in Table 210 (1)(d) (or within 0.2 mg/L of the criteria) and that condition is due to natural conditions, then human actions (i.e., construction) may not cause the DO to decrease more than 0.2 mg/L.
- Turbidity – Per Table 210 (1)(e), turbidity must not exceed 5 nephelometric turbidity units (NTU) above background when background turbidity is 50 NTU or less. If background turbidity is greater than 50 NTU, turbidity cannot be increased more than 10 percent above background.
- pH – Table 210 (1)(f) states that pH must be between 7.0 and 8.5.
- COCs – At the point of compliance, COC concentrations shall not exceed the numeric toxic substances chronic criteria for marine waters (WAC 173-201A-240).

The WQMP will detail further water quality monitoring requirements to confirm compliance with water quality standards (as defined by substantive requirements of Clean Water Act Section 401 Water Quality Memorandum) during in-water construction. Refer to Section 13.3.2 for additional details of the WQMP.

7.1.1 In-water Work Window

In-water work will be performed consistent with the joint regulatory agency-approved fish protection work windows mitigating salmonid exposure to turbidity and other contaminants by allowing in-water work to only occur within the Elliott Bay work window (July 16 through February 15). The final work window will be defined and coordinated in consultation with the resource agencies and Suquamish and Muckleshoot Tribes before implementation.

7.1.2 Turbidity Control BMPs

Dredging can result in short-term turbidity in the water column. Excessive turbidity can be due to inadequate operator control of the bucket during dredging, bank or side slope sloughing, scour of sediment that sticks to or is captured on the outside of the bucket, and/or release of sediment due to debris preventing tight closure of the bucket.

Turbidity and other water quality parameters will be monitored to ensure construction activities are in compliance with Washington State Surface Water Quality Standards (WAC 173-201A) and in accordance with the WQMP to be developed at later stages of design. Appropriate BMPs will be employed to minimize sediment loss and turbidity generation during dredging. Depending on the results of the water quality monitoring program, enhanced BMPs may also be implemented to further control turbidity. BMPs may include, but are not limited to the following:

- Eliminating multiple bites while the bucket is on the seafloor.
- No stockpiling of dredged material on the seafloor.
- No seafloor leveling.
- Slowing the velocity (i.e., increasing the cycle time) of the ascending loaded clamshell bucket through the water column.
- Pausing the dredge bucket near the bottom while descending and near the water line while ascending.
- Placing filter material over the barge scuppers to filter and clear return water.
- Using surface or near-surface silt curtains during dredging operations.
- Completing each pass of the clamshell dredge bucket.
- Managing barges such that the dredged sediment load does not exceed the capacity of the barge. The load will be placed in the barge to maintain an even keel and avoid listing.
- No discharging of the sediment to the waterway, including but not limited to shoveling material off the barge onto the waterway and hosing off of material into waterway.
- All barges handling dredged materials within the site will have hay bales and/or filter fabric placed over the barge scuppers to help filter suspended sediment from the barge effluent.
- Barges leaving the West Waterway and Elliott Bay sites will be sealed such that no discharge of water or suspended sediment occurs in the receiving waters.
- No petroleum products or other deleterious materials will enter surface waters.
- Project activities will not degrade water quality to the detriment of fish life.

Refer to Section 7.4 for further BMPs.

7.2 TEMPORARY EROSION AND SEDIMENT CONTROLS

The work includes implementing temporary erosion and sedimentation control (TESC) measures, including stormwater pollution prevention measures to prevent debris, dredged sediment, and contaminated stormwater from entering to the West Waterway and Elliott Bay.

The Contractor will be prepared to install turbidity curtains at appropriate locations to limit suspended sediment transport and to help meet the water quality requirements if conditions at the Site are appropriate (i.e., considering river flow and tides). The curtains will be supported by floats at the top (to keep the top of each silt curtain above the water surface) and weights at the bottom.

The following TESCs will be implemented during intertidal zone construction:

- Shorelines will not be used as a staging area for storing construction materials or stockpiling.
- Activities will be conducted to minimize siltation of the beach area.
- Intertidal backfill will be placed in a manner that will avoid erosion and siltation to the maximum degree possible.
- Majority of intertidal areas (i.e., south beach, adjacent to Pier 25 and shipway) to be dredged are below zero feet MLLW and permanently inundated between the tidal cycles. The contamination depth in the portions that are exposed to tidal cycles are shallow enough that dredging of contaminated sediment can be completed during a single tide-cycle, pending confirmation sampling. As a BMP, goetextile fabric may be deployed over intertidal dredged areas if needed to control resuspension and to comply with the project's water quality requirements.

The current design is based on the Contractor utilizing a transloading facility to unload sediment at the facility, dewater, loading to trucks or rail for transport to landfill facility. If the Contractor utilizes adjacent Port of Seattle (Port) uplands or another upland location for sediment handling, the Contractor will detail upland TESCs to be implemented. Refer to Section 7.4 for transloading facility BMPs and ESC measures.

7.3 NOISE, AIR QUALITY, AND ODOR CONSIDERATIONS

Ambient air quality requirements for the Puget Sound region are governed by the Puget Sound Clean Air Agency (PSCAA). Air quality monitoring, if required in the Contractor's Health and Safety Plan (CHASP), will be performed to protect on-site workers during construction to ensure compliance with these standards. TESC BMPs will be employed to prevent air pollution. Dust particles and odors from the project activities will be controlled at all times including weekends, holidays and hours when work is not in progress.

Seattle Municipal Code (SMC) Chapter 25.08 restricts maximum permissible sound levels for sound sources located within the City of Seattle. Refer to Section 2.5.2 for sound level restrictions during construction.

The CHASP will describe measures to be taken and the methods for ensuring that the applicable standards are met. The CHASP will also describe how community members can voice complaints/comments during construction.

7.4 CONSTRUCTION BMPs

The following (BMPs will be considered during implementation of the project.

7.4.1 Pile Removal and Disposal BMPs

The following pile removal BMPs are adapted from the U.S. Environmental Protection Agency guidance (EPA, 2013) and Washington Department of Natural Resources (DNR, 2007):

- Prior to commencement of the work, the project engineer or contractor should assess the condition of the piling, and identify whether piling will be removed using a barge or upland equipment. The contractor's work plan must include procedures for extracting and handling piling that break off during removal. In general, complete extraction of piling is always preferable to partial removal.
- The contractor will initially vibrate piles to break the friction bond between piles and soil.
- To help minimize turbidity, the contractor will engage the vibrator to the minimum extent required to initiate vertical pile movement, and will disengage the vibrator once pile have been mobilized and are moving upward.
- The piles will be removed in a single, slow, and continuous motion to the extent possible.
- Upon removal from the substrate, piles will be moved expeditiously from the water to a barge and then offloaded for disposal or recycling if possible.
- Piles should be removed slowly and in a direction that is an extension of the longitudinal centerline of each pile to minimize the disturbance of the bed and the suspension of contaminated sediments into the water column.
- Extracted piles will be placed immediately in a containment basin constructed on the barge or adjacent upland to capture and contain the extracted piles, adhering sediments, and water.
- The extracted piles will not be shaken, hosed off, left hanging to drip, or made subject to any other action intended to clean or remove adhering material from the pile.

- Pile cutoff will be an acceptable alternative where vibratory extraction or pulling is not feasible as described below. In addition, if a pile is broken or breaks during vibratory extraction, the contractor will employ the following methods:
    - A chain will be used if practicable to attempt to entirely remove the broken pile.
    - If the entire pile cannot be removed, the pile will be cut at the mudline or dredge elevation as designated in the plans.
    - Pile cutoff can be an acceptable alternative in areas where removal of the existing piles may result in adverse impact to stability. Refer to Section 4.4 for piles removal methodology, and Sections 4.5 and 5.7.2 for discussions on the stability of the sheet pile wall at the former shipway, and potential mitigation measures.
    - Generally, piling should be cut off at the mudline if sediments are contaminated and the mudline is subtidal, to minimize disturbance of the sediment. Piling should be cut off at least 1 foot below the mudline in intertidal areas where the work can be accomplished in the dry. Piling should be cut off at least 1 foot below the mudline in subtidal areas where the sediments are not contaminated.
    - Repeated attempts to remove pile with a clamshell bucket (i.e., "grubbing") should not occur in contaminated sediments, or below the water line.
    - Piles should be cut off at lowest practical tide condition and at slack water. This is intended to reduce turbidity due to reduced flow and short water column through which pile must be withdrawn.
    - Hydraulic jetting devices should not be used to move sediment away from piling, in order to minimize turbidity and releases to the water column and surrounding sediments.
    - If a pile cannot be removed or breaks off at or near the existing substrate, then the pile should be cut off using a pneumatic underwater bucket, a clamshell bucket, or another type of suitable equipment at dredge elevation. Every effort should be made to properly size the bucket to the job and operate it in ways that minimize sediment disturbance. Areas where piles are cut off will be covered with EPA-approved materials to contain the remaining contamination associated with the piles.
    - Cut-off pile stubs will be captured whenever feasible, removed, and deposited in the containment basin constructed on the barge or adjacent upland.
    - Sawdust from cutting pile stubs should be captured whenever feasible, removed, and deposited in the containment basin constructed on the barge or adjacent upland.
- A floating surface boom should be installed around the pile extraction site to capture floating pile debris. Floating pile debris will be removed and deposited in a containment basin constructed on the barge or adjacent upland.
- The floating surface boom will be equipped with absorbent pads to contain any oil sheens. The absorbent pads will be removed and deposited in the containment basin constructed on the barge or adjacent upland.
- A containment basin will be constructed on the barge deck or adjacent upland to receive the piles, pile stubs, water, sawdust, and any sediment.

- The containment basin should be constructed of durable plastic sheeting with sidewalls supported by hay bales or support structure.
- To the extent possible, pile extraction should be conducted during periods when the water currents are low.
- The piles, pile stubs, sawdust, and absorbent pads from the floating surface boom will be removed and disposed of in accordance with applicable federal and state regulations.
- The water captured in the containment basin will be removed and disposed of in accordance with the EPA's Section 401 Water Quality Memorandum.
- The containment basin will be removed and disposed of in accordance with applicable federal and state regulations.
- Extracted piles within the containment basin or disposal container will be cut to size as required by container and disposal contractors. All sawdust and cuttings will be contained within the containment basin or disposal container.
- The cut-up piles, sediments, sawdust, water, absorbent pads from the floating surface boom, and plastic from the containment basin will be packed into a disposal container and transported to an approved upland disposal site.
- The use of a boom and the other measures listed above to contain and properly dispose of debris should also be employed during removal of wooden bulkhead or dock structures. Specific removal methods for these structures will be appropriate to the structure and location (e.g., a backhoe or clamshell may be used rather than a vibratory hammer or chain to remove sections of treated wood from a dock or bulkhead).

7.4.2 Dredge and In-water Material Placement Operation Control BMPs

The overall goal of the dredging BMPs is to minimize the dispersion of contaminated sediments and limit the development and production of dredge-related residuals while removing the impacted sediments. In-water residual cover and ENR material BMPs will be utilized to control resuspension of sediments. The use of appropriate BMPs will be required in the project specifications and will be addressed during development and review of the Contractor's RAWP.

Dredge BMPs

In addition to the equipment specification and the dredge plan described above, the following BMPs will be required of the Contractor:

- The work will limit migrating salmonid exposure to turbidity by allowing dredging to only occur within the Elliot Bay work window (August 1 to February 15). Allowable turbidity range will be defined in EPA's Section 401 Water Quality Memorandum.
- Maneuvering of tugs and barges will be kept to the minimum necessary for safe and efficient operation of the dredging and transloading activities to avoid resuspension of sediments due to prop wash.

- The grounding of barges will be prohibited.
- Scour will be minimized by controlling minimal depths for vessel draft and movement.
- Glory holing will not be allowed.
- Dredge buckets will not be overfilled.
- No bottom stockpiling will be allowed.
- Leveling of the dredge surface by dragging/sweeping the bucket will not be allowed.
- The loaded bucket will be retrieved from the bed at a slow and continuous rate, anticipated not to exceed 2 feet per second.
- The bucket will have a closed/open sensor.
- The loaded bucket will pause after it breaks the water surface if the bucket sensor indicates it is closed.
- The passage of the bucket over open water prior to release of sediment from the bucket into the haul barge will be minimized. This distance will be indicated in the dredge plan in the RAWP, where EPA will have the opportunity to review and approve the Contractor's proposed approach.
- Once the bucket is above the water line it can only be opened on the barge.
- Barges will not be overloaded; sediment will not spill over the edges of the barges or be above the sidewalls at any time during transit.
- Subsurface release of partially full or full dredge buckets will not be allowed; i.e., once a bucket is closed underwater, it may not be opened until it is positioned over the barge, even if the operator believes it is empty.
- Dredging will occur from higher to lower elevations to reduce the potential for sloughing.
- Stable cut slopes will be maintained during dredging to reduce the potential for sloughing.
- Multiple bites with the dredge bucket will not be allowed.
- An environmental bucket will be used to the extent practicable (e.g., use of digging bucket for hard-to-dredge substrate) to reduce the potential for suspension of contaminated sediment during dredging. A sub-foot geographical positioning system will be used for accurate bucket positioning.
- A grapple or standard clamshell bucket might be most effective at removing denser materials and debris prior to or during dredging. A modified digging or grapple bucket may be required to remove submerged and surface debris and may also be needed for removing denser substrate.
- Dredged material will be placed on a barge immediately after removal for gravity dewatering. All water will be filtered through an EPA-approved filter medium placed across the barge scuppers. The filter material will consist of a woven geotextile fabric with apparent opening size (between #30 and #100). The scuppers will be plugged prior to the barge leaving the Sediment Area for transload. Water quality effects from de-watering will be strictly monitored according to the WQMP to be developed at later stages of design.

- A Transportation and Disposal Plan including appropriate BMPs for material handling will be developed by the Contractor as part of the RAWP.
- Slope dredging will be initiated at the top of the slope and then proceed in the down-slope direction.

In-Water Material Placement BMPs

For placement of ENR materials and residual cover layers, the following measures will be followed:

- The placement of material will generally occur starting at lower elevations and working to higher elevations.
- Set volume, tonnage, lead line measurements, and bathymetry information or similar will be used to confirm adequate coverage during and following material placement.
- Imported materials will be pre-approved by EPA and consist of clean, granular material free of roots, organic material, contaminants, and all other deleterious material.

7.4.3 Dredge Operational Adjustments

If water quality criteria exceedances are measured, the following operational changes can be made to reduce sediment resuspension:

- Reducing the speed of bucket ascension
- Placing a tarp/barrier between the dredge and haul barge where the loaded bucket is moved above the water surface
- Reducing the number of bucket penetrations, which can cause sediment to be expelled from the vents in the bucket or cause sediment to become piled on top of the bucket, which then erodes during bucket retrieval
- Reducing the rate of bucket movement at impact with sediment; however reducing the bucket velocity just before impact may result in reduced penetration (resulting in additional passes).
- A change in the method of operating the dredge or the timing of dredging, based on changing site conditions such as tides, waves, currents, and wind
- Temporarily suspending work

7.4.4 Barge Operations BMPs

- Construction barges will be restricted to tide elevations adequate to prevent grounding of the barge.
- Due to the size of the site and water depths, restriction of anchoring in contaminated sediment is not practical, and anchoring will need to be accommodated. Disturbance during anchoring and spudding will be minimized to the extent practicable.
- Dewatering is not allowed while in transit.

- Whenever feasible, the barge location will be fixed through the use of methods that do not disturb contaminated sediments (e.g., mooring dolphins, docks, piers, upland structures, and anchoring in non-contaminated areas). Where these methods are not feasible, spuds may be used. The use of walking spuds will not be permitted.
- Live boating should be held to an absolute minimum.
- Motorized vessel operation will be restricted to tidal elevations adequate to prevent prop scour disturbance to the contaminated sediments.
- Minimal propulsion power will be used when maneuvering barges or other vessels to prevent prop scour disturbance to the contaminated sediments.

7.4.5 Sediment Transloading Facility and Disposal BMPs

Dredged material will be placed on haul barges and transported to an established sediment transloading facility that has been approved by EPA as part of the RAWP. The debris to be encountered during the dredging will range in size and will be managed with the sediment. A sediment transloading facility typically includes barge offloading and truck or train loading (for transport to an EPA-approved disposal facility). There may or may not be a dewatering operation associated with the transloading facility. Any water from the barge and sediment stockpiles at the facility will be managed by the transloading operation in compliance with all appropriate rules and regulations.

BMPs to ensure the clean and safe transfer of materials at the transloading facility will be required prior to any handling of sediment. The goals of the BMPs include:

- No spilling of contaminated material into surface water
- No tracking of contaminated material off site or into any area where it may contact water that would be uncontrolled by containment
- No dewatering from the barge at the transloading site
- Containment measures (e.g., straw bales/wattles, filter fabric) will be used to capture water running down the apron
- Preventing material spilling from the truck or train during transport from the transfer facility to the disposal facility.

Specific BMPs for the transloading facility include:

- Loading of sediment and debris into lined intermodal containers will be performed in lined containment areas.
- The transloading facilities will be permitted through its industrial Stormwater Pollution Prevention Plan (SWPPP) to operate as a transload facility for the anticipated Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) waste streams.

- Containment areas will be designed so that fluids from the transloading operations can be collected separately from other site stormwater.
- The fluid collected from transloading operations will be disposed of with the other waste generated from the site (included with the sediment for disposal) or sampled, treated, and discharged in accordance with approved permits of the transload facility or disposed at a licensed commercial facility.
- Rail cars or trucks will be water tight if the sediment does not pass the paint filter test (Method 9095). This may require liners and covers.
- The sides of trucks or rail cars will be protected with shields or spill aprons from waste material that may drop prematurely from transfer buckets.
- Trucks or rail cars will not be filled completely, such that a minimum free board distance of 6 or 36 inches, respectively, is maintained.
- Inside the transload facility, material deflected from spill aprons will land on secondary containment areas outside the area typically traveled by trucks or rail cars to avoid tracking material on tires or wheels.
- Transload facility will be designed with a spill apron to prevent material from falling into the water between the barge and the dock.
  - The apron must be made of impermeable material and not have seams that would allow leakage into the water.
  - The apron will collect material dripped from the clamshell, including rainfall and route it back into the barge or into dock-side containment structure.
  - The spill apron must be wide enough that material will not fall off the sides and may include wing walls to increase the level of protection.
  - Material shall not be allowed to accumulate on the spill apron.
  - Containment measures (e.g., straw bales/wattles, filter fabric) should be used to capture water running down the apron.
  - The apron must be able to track up and down with the barge during tidal fluctuations in order to prevent separation of the apron from the barge.
- Before moving the crane/excavator, the spill apron and bucket must be decontaminated with a pressure washer and the water captured and contained. Wash water will not be left on the barge.
- If Solidification/Stabilization agents are being used to reduce the spreading of material through splash and dripping, indicate what stabilizer, mixing locations, etc.
- The facility must be able to keep the barge tied up close to dock during tidal fluctuations
- Decking and all surfaces that can come in contact with dredged sediment and associated water must be made of solid (no slats) impermeable materials.
- The travel of buckets used to transfer sediment from barges to trucks or rail cars will be limited such that they are always above the barge, the spill apron, or a lined loading area.

- The operator of the equipment used to remove material from the transport barge is required to maintain the swing path of the transfer bucket over the spill apron and dump the transfer bucket in such a way that splashing is minimized.
- The operator of the equipment used to load railcars and/or trucks will be required to maintain the swing path of the transfer bucket over a spill apron and to load the railcars and/or trucks in such a way to minimize splashing.
- The loading areas will be inspected following loading of each truck and/or railcar. Any spilled material will be immediately cleaned up to minimize tracking of impacted material.
- Trucks and rail cars will be thoroughly inspected before the truck or rail car is cleared to leave the containment pad.
  - Material spilled on the containment pad will be immediately cleaned up to protect tires that may come in contact with the waste and to minimize contamination of precipitation that may fall on the pad.
- Trucks or rail cars will not be overloaded. Under loading may be required to ensure that loss from sloshing does not occur. Railcars or trucks will be sealed or lined in such a way as to prevent spills and contain splashes.
- The transload area and all equipment used in transloading will be cleaned and decontaminated upon completion.
- A wheel wash must be installed if sediment is getting on the deck (dock) where trucks or other vehicles are passing through.
- Wheel wash water cannot be allowed to enter surface waters or storm drains. Wheel wash wastewater must be collected and hauled off for proper disposal or routed to sanitary sewer with proper local sewer district approval.

It is anticipated that these safeguards and BMPs will be defined in the specific operating permit for the transload facility and that monitoring to ensure compliance will be part of the operating permit.

An important part of the transload and disposal facilities includes the ability to track the waste. CERCLA waste must be tracked from the Site to ultimate disposal. It is also acknowledged that there may be other work ongoing at the same time as the project cleanup and there may be other dredging work in the area where the removed sediment could be processed through an existing sediment transload facility. If this situation arises, the weight of sediment from project area will be accurately measured prior to offloading by the barge displacement method. Compatible wastes from each site (e.g. non-hazardous waste, non-TSCA waste) can then be comingled once removed from the individual sites' barges. Tracking waste from the transload site to the final disposal will be accomplished by recording individual containers/trucks that leave the transload site and recording when the individual container/truck is weighted and unloaded at the final disposal site.

7.4.6 Other Construction BMPs

The Site Management Plan will be developed at further stages of design. The Plan will describe how access, security, contingency procedures, management responsibilities, and waste disposal are to be handled. Several design elements will be either part of the Site Management Plan or to be developed separately including (a) Contingency Plan, (b) Pollution Control and Mitigation Plan, (c) Transportation and Disposal Plan, (d) Green and Sustainable Remediation Plan, and (e) Climate Change Adaptation Plan. Refer to Section 13 for draft content of these plans.

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Section 8
Project Permitting and Site Access

This section demonstrates how the project will comply with the permitting requirements identified in the design and address any real property and easement requirements. Substantive compliance with applicable permitting requirements was addressed in Section 2 and is summarized below. A Permitting and Site Access Plan will be prepared at later stages of design. Refer to Section 13.3.4 for required content of this plan.

8.1 COMPLIANCE WITH ARARS AND TBCS

Substantive compliance with applicable or relevant and appropriate requirements (ARARs) and to-be-considered criteria (TBC) does not include formal submission of permit applications to the agencies to provide permits or approvals. Instead, information sufficient to demonstrate compliance with the requirements will be presented to the U.S. Environmental Protection Agency (EPA) and coordinated with other agencies. Regulatory requirements, project-specific notes to explain how these regulations apply to the project and how the design and construction will substantively comply with the regulations are summarized in Table 8-1.

8.2 ACCESS AGREEMENTS

Lockheed Martin Corporation (Lockheed Martin) will coordinate all work elements with the Port of Seattle (Port). The Lockheed West Seattle Superfund Site (Site) is accessible from the water. Dredging in Port-owned tidelands and Port-managed harbor area will be coordinated with the Port. Access via land is currently restricted due to fencing around Terminal 5. Access to Port property for shoreline remediation (e.g., debris removal) will be coordinated with the Port under the Port's Homeland Security requirements including compliance with the Transportation Worker Identification Credential program. Site access will be coordinated by identifying the security screening and site use criteria for the Port's Homeland Security personnel, security requirements for waters adjacent to Port facilities, and compliance with Transportation Worker Identification Credential requirements.

Similarly, Lockheed Martin will coordinate with Washington State Department of Natural Resources (DNR) for the in-water construction work within the DNR-managed harbor area of the Site.

8.3 OTHER AGREEMENTS

The Site is within the “Usual and Accustomed” fishing area of both the Suquamish and Muckleshoot Indian Tribes. Lockheed Martin will coordinate with the Tribes to attempt to maintain an active fishing presence around the Site from July to December. This agreement will remain active for the duration of the project and serve as a basis for coordinating project construction activities with treaty-reserved fishing access.

8.4 VESSEL MANAGEMENT

The purpose of a Vessel Management Plan is to describe anticipated vessel operations necessary to complete the cleanup, including plans to avoid and minimize impacts to fish and shellfish harvesting, navigation and commerce. The plan will also include information regarding vessel operations, including types of vessels, access points, and vessel frequency. Lockheed Martin will coordinate with the U.S. Army Corps of Engineers (USACE), U.S. Coast Guard, Suquamish and Muckleshoot Tribes, Port of Seattle and their lessees, Todd Shipyard (currently known as Vigor Shipyard) and any other agencies necessary to implement the remedial action.

In-water construction work schedule and the vessel navigation routes will also be coordinated with the U.S. Coast Guard to avoid or reduce impacts to navigation during construction activities. The Site overlaps part of an authorized navigation channel and has a regulated navigation area (RNA) for the sediment cap in Pacific Sound Resources Marine Sediment Unit. An RNA is a water area within a defined boundary for which regulations for vessels navigating within the area are established under 33 Code of Federal Regulations (CFR) 165. The purpose of the RNA is to protect the integrity of the sediment cap by restricting activities that would disturb the cap surface, such as anchoring, grounding, or spudding.

The Vessel Management Plan to be developed during later stages of design will be based on the remedial design team's best professional judgment regarding the types of equipment typically needed to complete this work, the sizes of marine construction equipment typically available in Puget Sound, and production rates that have been achieved for similar projects.

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Table 8-1
Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria (page 1 of 2)

Topic	Standard or Requirement	Regulatory Citation		Project-Specific Comments/ Substantive Compliance
		Federal	State or Local	
Hazardous Waste Cleanup	Washington State cleanup standards		Washington State Model Toxics Control Act (RCW 70.105D; WAC 173-340)	MTCA is applicable or relevant and appropriate where the substantive requirements are more stringent than CERCLA and the NCP. The more stringent requirements of MTCA include, but are not limited to, acceptable excess cancer risk standards and the default to natural background for final remedies where risk-based threshold concentrations are below background. • Project cleanup levels were determined per SMS, a statutory requirement under MTCA.
Sediment Quality	Sediment quality standards, cleanup screening levels		Sediment Management Standards (WAC 173-204)	The SMS are a statutory requirement under MTCA and applicable or relevant and appropriate under CERCLA. Numerical standards for the protection of benthic marine invertebrates. Final remedy will meet requirements of the SMS. SQS of the SMS are the standard for protection of benthic invertebrates. • Project cleanup levels were determined per SMS, a statutory requirement under MTCA. The remedial design addresses contaminated sediment to meet SMS.
Surface Water Quality Standards	Surface water quality standards	Ambient Water Quality Criteria established under Sections 304(a) of the Clean Water Act (33 U.S.C. 1251et seq; , 40 CFR 131) http:// water,epa,gov/scitech/swguidance/ standards/criteria/current/index.cfm	Washington Water Pollution Control Act - State Water Quality Standards for Surface Water (RCW 90.48; WAC 173-201A)	State surface water quality standards are applicable where the state has adopted, and EPA has approved, Water Quality Standards (Aquatic Life Criteria), as are the National Toxics Rule standards. Federal-recommended Water Quality Criteria established under Section 304(a) of the Clean Water Act that are more stringent than state criteria and that are relevant and appropriate also apply. Both marine chronic and acute standards are used as appropriate. • Project includes a TI waiver for the AWQC for arsenic.
Waste Treatment, Storage, and Disposal	Hazardous Waste Management	Resource Conservation and Recovery Act (42 U.S.C. 6901-6992K, 40 CFR 260-279, 265)	Washington State Dangerous Waste Regulations (RCW 70.105; WAC 173-303)	No known listed or characteristic hazardous wastes are present at the Site. However, if such wastes are encountered during Site cleanup, portions of RCRA and Washington State Dangerous Waste Regulations related to hazardous waste determination and analytical testing, and onsite storage, treatment, and disposal may be ARARs to this project. State criteria for dangerous waste are applicable; Federal criteria may be relevant and appropriate. • The Site Management Plan to be developed at later stages of design will include Contingency Plan to address this regulation.
Land Disposal of Waste	Management and disposal of materials containing PCBs	Toxic Substances Control Act (15 U.S.C. 2605; 40 CFR 761.61)	Washington State Dangerous Waste Regulations (RCW 70.105; WAC 173-303, 140, 141)	No known TSCA wastes are present at the Site. However, if such wastes are encountered during Site cleanup, disposal of PCBs may be applicable.
	Hazardous waste	Resource Conservation and Recovery Act Land Disposal Restrictions (42 U.S.C. 6901-6992K; 40 CFR 268)		No known listed or characteristic hazardous wastes are present at the Site. However, if such wastes are encountered during Site cleanup, portions of RCRA and Washington State Dangerous Waste Regulations related to hazardous disposal would be applicable to this project. State dangerous waste is defined more broadly than Federal hazardous waste. • The Site Management Plan to be developed at later stages of design will include Contingency Plan to address these regulations.
Solid Waste Disposal	Requirements for solid waste handling management and disposal	Solid Waste Disposal Act (42 U.S.C. 6901- 6992K; 40 CFR 257-258)	Solid Waste Handling Standards (RCW 70.95; WAC 173-350)	Covers nonhazardous waste generated during remedial activities unless wastes meet recycling exemptions. • Dredged material and debris will be disposed to permitted disposal and recycling facilities that are compliant with the solid waste disposal regulations and are permitted to accept impacted materials.
Dredge/Fill and Other In-water Construction Work	Discharge of dredged/fill material into navigable waters or wetlands	Clean Water Act (33 U.S.C. 1341, 1344, 40 CFR 121.2, 230, 231; 33 CFR 320, 322, 323) Rivers and Harbor Appropriations Act (33 U.S.C. 403, 33 U.S.C. 408)	Hydraulic Code Rules (RCW 77.65; WAC 220-110)	Requirements for in-water dredging, filling, or other in-water construction. • Project design includes coordination with Washington Department of Fish and Wildlife. This coordination will address all substantive requirements of the HPA permitting process including evaluation of potential mitigation requirements and definition of work procedures and timing. • Dredging and other in-water work activities will be performed at appropriate times of the year to comply with fisheries protection requirements. • The requirements will also be addressed by the conservation measures and best management practices (BMP) identified in the design and in the ESA Section 7 Consultation Biological Assessment. • A portion of the Site is within West Waterway. EPA will lead a Section 408 consultation to review the final depths after placement of clean sand layer within the navigation channel.
	Open-water disposal of dredged sediments	Marine Protection, Research and Sanctuaries Act (33 U.S.C. 1401-1445)	Dredged Materials Management Program (RCW 79.105.500; WAC 332-30-166 (3))	Regulates dumping of dredged material in open water. • Project does not include placement of dredged material in open water.

Table 8-1

Applicable or Relevant and Appropriate Requirements and To Be Considered Criteria (page 1 of 2)

Topic	Standard or Requirement	Regulatory Citation		Project-Specific Comments/ Substantive Compliance
		Federal	State or Local	
Discharge to Surface Water	Point source standards for new discharges to surface water	National Pollutant Discharge Elimination System 33 U.S.C. 1342 {40 CFR 122, 125)	Discharge Permit Program {RCW 90.48; WAC 173-216, 220, 226)	Remediation discharges must comply with substantive requirements of NPDES rules. If upland handling of sediment is planned, construction stormwater requirements will be addressed including development of a stormwater pollution prevention plan and implementation of best management practices. NPDES program requirements will be reviewed as part of project final design. The Contractor will prepare and implement a Stormwater Pollution Prevention Plan (SWPPP). Project BMPs are identified in the design. The SWPPP will cover Transload Transport and Disposal (TTD) facility operations.
Shoreline	Construction and development	Coastal Zone Management Act {16 U.S.C. 1451 et seq.)	Shoreline Management Act {WAC 173-16)	These regulations are applicable to construction activities within 200 feet of the shoreline. • Cleanup activities along the shoreline will be in substantive compliance with King County Shoreline Master Program through the use of dredging, water quality, and erosion control BMPs, as well as measures to protect fish, marine mammals, and other aquatic species, and implementation of both worker and community health and safety plans.
Habitat for Fish, Plants, or Birds	Conserve endangered or threatened species, consult with species listing agencies, evaluate and mitigate habitat impacts	Clean Water Act Section 404 {b}{1)) Endangered Species Act of 1973 {16 U.S.C. 1531 et seq.; 50 CFR 17, 222-224, 226.212 to 402 402); Magnuson-Stevens Fishery Conservation and Management Act {16 U.S.C. 1801-1884) Migratory Bird Treaty Act {16 U.S.C. 703-712) and 50 CFR 10, 17 Eagle Protection Act 16 U.S.C. 668, 50 CFR 22	City of Seattle Master Plan Seattle Municipal Code 23.60	Habitat mitigation will be assessed and addressed in the remedial design if necessary. Mitigation requirements will be defined in remedial design and vary with the type of work conducted if necessary. Consult and obtain Biological Opinions. • A Biological Assessment will be prepared to ensure compliance with the Endangered Species Act (ESA) by identifying the presence of threatened, endangered, proposed, or candidate species, or their habitat within the vicinity of the cleanup action. EPA will consult with the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) to obtain a Biological Opinion.
Air Quality - TBC	State implementation of ambient air quality standards. Puget Sound Clean Air Agency ambient and emission standards.	Clean Air Act (CAA). 42 U.S.C. §7401	Washington State Clean Air Act (70.94 RCW) General Requirements for Air Pollution Sources (WAC 173-400) Puget Sound Clean Air Agency (PSCAA) Regulation I, PSCAA Regulation III	Potentially applicable to the cleanup which includes sediment handling. • Off-site sediment handling and/or treatment/disposal facilities will comply with applicable air regulations and maintain appropriate permits. • BMPs to control dust. Substantive requirements will be addressed in the specifications and will be further addressed in the Remedial Action Work Plan (RAWP).
Construction Activities - TBC	Local requirements and standards for construction.		King County Codes: King County Building and Construction Standards (KCC Title 16), King County Clearing and Grading Code (KCC 16.82), Shoreline Master Program (KCC Title 25). Seattle Municipal Code: Dredging (SMC 23.60A), Grading (SMC 22.170), Noise (SMC 25.08), Light (SMC 23.50)	Applicable to design and construction. • KCC Title 16 is considered in design criteria for analysis of shoreline protection • SMC 22.170 is considered in design criteria for final grade slopes • Construction activities will be limited to normal working hours, to the extent possible, to minimize noise and light impacts. Monitoring will be conducted to verify compliance. • BMPs and TESCs to control erosion. SWPPP to control and manage stormwater.

Notes:

ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = Code of Federal Regulations
MTCA =Model Toxics Control Act
NCP = National Contingency Plan
NPDES = National Pollutant Discharge Elimination System
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
RCW = Revised Code of Washington
SMS = sediment management standards
SQS = sediment quality standards
TSCA = Toxic Substances Control Act
U.S.C. = United States Code
WAC = Washington Administrative Code
PSCAA = Puget Sound Clean Air Agency
TBC = To-be-considered criteria

Section 9
Construction Schedule, Sequence, and Cost Estimate

This section discusses the main construction elements, preliminary construction schedule, contracting strategy, construction sequence, and construction cost estimates of the project. The Contactor will outline the final schedule and sequence of work in the Remedial Action Work Plan (RAWP). The RAWP and related documents will be finalized and approved by EPA per the project schedule before on-site work begins. Prior to initiation of in-water work, coordination with the EPA will be done such as readiness review meetings and site inspections to ensure proper implementation of the approved work plans.

9.1 CONSTRUCTION SCHEDULE

At the Intermediate Design stage, it is expected that construction will be completed in two in-water construction seasons. It is possible that other project constraints or a revised approach will modify this schedule. The anticipated schedule and Lockheed Martin Corporation's (Lockheed Martin) contracting strategy is summarized below.

9.1.1 Preliminary Construction Project Schedule

The preliminary schedule is based on the in-water work window and the assumptions that all necessary approvals can be obtained prior to initiation of the work. The final in-water work window will be defined and coordinated in consultation with the resource agencies and the Tribes before implementation. Construction Seasons 1 and 2 are anticipated to occur from July 16, 2018, to February 14, 2019, and July 16, 2019 to February 14, 2020, respectively.

9.1.2 Project Contracting Strategy

Lockheed Martin is seeking to achieve a cost-effective cleanup of the Site that is protective of human health and the environment, is consistent with the National Contingency Plan (NCP), and that complies with the Record of Decision (ROD), Explanation of Significant Difference (ESD), Unilateral Administrative Order (UAO), and Statement of Work (SOW).

Lockheed Martin's contracting strategy includes developing the design to the 60 percent level and then soliciting a design/build procurement under which the successful bidder would complete the development of the design and then implement the remedial action. However, Lockheed Martin reserves the right to implement the selected remedy as a single combined design/construction contract or as separate design and construction contracts.

9.2 CONSTRUCTION SEQUENCE

The anticipated on-site construction sequence is summarized in this section. Some activities can be performed simultaneously. The sequence is subject to change per the Contractor's planned operations and the detailed construction schedule. Proper planning and successful completion of each task are essential to implement the project within the schedule. The RAWP and related documents will be finalized and approved by EPA per the project schedule before any on-site work begins. Prior to beginning in-water work, there will be coordination with the EPA such as readiness review meetings and site inspections to ensure proper implementation of the approved work plans.

It is anticipated that the remedy will be completed in two field seasons. The anticipated construction sequence is described in the following subsections.

9.2.1 Construction Season 1

Preliminary Field Work

- Mobilization: establishing the infrastructure necessary for field operations. Non-field tasks, such as contracting and procurement, along with preliminary site reconnaissance activities and site access coordination. Delivery of materials/supplies, equipment, and personnel to the project site. Coordination with transloading facility, landfill facilities and verification of rail/truck haul routes
- Removal area site preparation: installation of in-water environmental controls (water quality monitoring equipment), temporary erosion and sediment controls, and utility coordination
- Pre-removal survey: pre-removal bathymetric survey to establish baseline conditions.

Remediation

- In-water debris sweep (if needed) in dry dock areas
- Removal of subtidal sediment in dry dock areas
- Verification of dredge design elevations and confirmation sampling in dredge units
- Contingency dredging if needed

- Placement of residual management layer over dredged areas
- Post-remediation bathymetry survey
- Sediment transloading, dewatering, water treatment, disposal (some concurrency with dredging)

Site Demobilization:

- Removal of contractor's equipment and materials, removal of in-water controls, and decontamination operations

9.2.2 Construction Season 2

Preliminary Field Work

- Mobilization
- Removal area site preparation: installation of temporary erosion and sediment controls, and in-water environmental controls (water quality monitoring equipment, floating debris boom), utility coordination
- Pre-removal survey: pre-removal bathymetric survey to establish baseline conditions.

Remediation

- Removal of debris from shorelines, piling removal from the shipway
- Installation of riprap and quarry spall along shorelines at locations where large debris is removed
- Dredging shipway, dredge elevations verification, confirmation sampling, and backfill
- Dredging Pier 25 intertidal area, dredge elevations verification, confirmation sampling, and backfill
- Dredging south beach intertidal area, dredge elevations verification, confirmation sampling, and backfill
- Dredging Pier 23 and Pier 24 subtidal sediment, dredge elevations verification, confirmation sampling, and RML placement
- ENR placement through the Site
- Post-remediation bathymetry survey
- Post-ENR confirmation sampling
- Sediment transloading, dewatering, water treatment, disposal

Site Demobilization:

- Removal of contractor's equipment and materials, removal of in-water controls, and decontamination operations

9.3 DRAFT CAPITAL AND OPERATION AND MAINTENANCE COST ESTIMATE

The Pre-Final (90%) and Final Design (100%) submittals will include an updated cost estimate for completion of remedial action and long-term maintenance and monitoring. This cost estimate will refine the feasibility study cost estimate to reflect the detail presented in the Final Design, with an accuracy of plus 15 percent and minus 10 percent. The U.S. Environmental Protection Agency's (EPA) cost estimating guidance, *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (EPA 540-R-D0-002, Office of Solid Waste and Emergency Response [OSWER] No. 9355.0-75, July 2000), will be utilized.

Section 10
Institutional Controls

Institutional controls (ICs) is one of the main work elements to address contaminated sediment at the Site. The ICs will be placed in the form of a proprietary control and will require coordination with the U.S. Environmental Protection Agency (EPA) to manage any residual contamination that is disturbed or encountered in the event of future excavation or dredging within the boundaries of the Lockheed West Seattle Superfund Site (Site).

10.1 OVERVIEW OF INSTITUTIONAL CONTROLS

There are two main elements of ICs required after remediation is completed:

1. Proprietary controls (e.g., restrictive covenants) to ensure the integrity of the remedy and guide management of any residual contamination that is disturbed or encountered in the event of future dredging or construction at the Site.
2. Informational devices (e.g., fish consumption advisories) to reduce human exposure from ingestion of contaminated seafood, Elliott Bay fish consumption advisories posted at the Site.

The ICs will be consistent with the State Uniform Environmental Covenants Act (UECA) and therefore will not affect or restrict Tribal fishing rights in this area nor will they restrict pile installation, anchoring, or water-based commerce. Lockheed Martin Corporation (Lockheed Martin) will secure appropriate restrictive covenants from the Port of Seattle (Port) and Washington State Department of Natural Resources (DNR). In addition, Elliott Bay fish consumption advisories, established by the Washington State Department of Health to reduce human exposure from ingestion of contaminated seafood, will be posted at the Site.

Other than these specific ICs, the pre-remedial design investigations have identified elevated polycyclic aromatic hydrocarbons (PAH) in subsurface sediments adjacent to Pacific Sound Resources (PSR) Marine Sediment Unit (refer to Section 3.6). As discussed in Section 3.1, the Site overlaps part of the regulated navigation area (RNA) established by the U.S. Coast Guard (USCG) for the sediment cap in PSR to protect the integrity of the sediment cap by restricting activities that would disturb the cap surface, such as anchoring, grounding, or spudding. The current design within the RNA requires backfilling. The subtidal backfill planned for placement at this location may be considered by EPA as capping because of known deeper PAH contamination, which may trigger revision of the PSR boundary. USCG has confirmed that there is no buffer between the RNA and the PSR boundary (Wayne Lau, personal communication, January 27, 2017), which means no adjustment of RNA boundary would be needed after the construction, if PSR boundary needs to be adjusted. The 90% design will be reviewed by USCG and EPA, and any revisions of the PSR or RNA boundary will be determined through that review.

10.2 INSTITUTIONAL CONTROLS IMPLEMENTATION AND ASSURANCE PLAN

Lockheed Martin will draft an Institutional Controls Implementation and Assurance Plan (ICIAP) and place ICs (upon approval from the EPA) in the form of a proprietary control that runs with the property and requires coordination with the EPA to protect the remedy during future construction activities at the Site. In addition, the current fish advisory for Recreational Marine Area 10 (Elliott Bay) under the Puget Sound Fish Consumption Advisory, established by the Washington State Department of Health, or any modification thereto by the EPA, to reduce human exposure from ingestion of contaminated seafood will continue to be posted at the Site. Monitoring and reporting on the efficacy of the fish advisory will not be part of the ICIAP of the long-term monitoring program.

Refer to Section 13.3 for required content of the ICIAP as outlined in the EPA Statement of Work (SOW; EPA, 2015c). The ICIAP will be developed at later stages of design. Implementation of the ICs will be documented in the Remedial Action Construction and Completion Report.

Section 11

Long-Term Monitoring and Maintenance

To ensure the long-term effectiveness of the constructed remedy, monitoring and maintenance procedures will be required with contingency actions. A long-term monitoring and maintenance plan (LTMMP) will be developed at the 90% design. The plan may be revised in the future, including after construction in the event any remedy changes and/or new information is gathered during remedy implementation. The primary objectives of monitoring specified in the LTTMP would be to determine if major natural and anthropogenic events disrupt the remedy and distinguish sediment recontamination from off-site sources from releases from within the Site.

11.1 MONITORING AND MAINTENANCE PLAN

Monitoring will be conducted to support the U.S. Environmental Protection Agency's (EPA) 5-year reviews for the Site, including a comprehensive review at year 5, consisting of bathymetric surveys, sediment sampling, file reviews, and interviews. As noted in the Record of Decision, Elliott Bay is affected by nearby urbanization, and overall concentrations of certain contaminants of concern (COCs) in bay sediments are not at the natural background concentrations or risk-based threshold concentrations identified as being protective. Therefore, it is likely that concentrations of these COCs will increase in Site sediments after remediation as a result of the movement of sediment and surface water in Elliott Bay. The Unilateral Administrative Order (UAO) for the Site does not require prevention of releases of hazardous substances originating outside the boundaries of the Site and not attributable to Lockheed Martin (i.e., recontamination from offsite sources, as defined in the UAO). If this occurs, sediment concentrations at the Site may no longer meet Cleanup Levels. This would not constitute a failure of the Selected Remedy because the Remedial Action Objectives for this remedial action will be met through active remediation and institutional controls despite any post-remedial action recontamination from other non-Site sources.

11.2 SAMPLING METHODOLOGY

Since recontamination of the sediment surface from off-site sources may occur due to ambient conditions in Elliott Bay and the Lower Duwamish Waterway, sampling and numeric performance standards such as cleanup levels will not be the only criteria for evaluating the performance of the remedy. Sampling methodology will be used to evaluate surface sediment recontamination from off-site sources ("top-down" contamination) and to evaluate potential mixing of the clean surface sediment layer with underlying sediment that has contaminant concentrations greater than the cleanup levels ("bottom-up" contamination). The sampling will take place in the biologically active zone of the subtidal (10 cm) and intertidal (45 cm) zones. If sampling demonstrates that "top-down" contamination has occurred and commensurately, "bottom-up" contamination has not occurred, and concentrations in the sediment surface layer exceed cleanup levels, then sediment quality monitoring will be discontinued unless bathymetric surveys indicate there have been substantial changes to the surface of the Site.

In addition to sediment sampling, long-term monitoring is expected to include sitewide bathymetry and other assessment techniques to ensure that dredge residuals management/ENR layer and other components of the Selected Remedy are undisturbed and/or functioning as designed. Samples of surface water, fish, and/or shellfish tissue will not be collected as part of the long-term monitoring program. The performance standards for long-term monitoring, including sampling intervals (e.g., upper surface, interior, and bottom of layer), target analytes, and bathymetric survey resolution, will be detailed in the LTMMP. The LTMMP also will outline performance expectations and potential courses of action to be taken based on the influence of marine activities including any marine construction, passage of time, recontamination from off-site sources, or the occurrence of natural phenomena such as earthquakes or significant weather events.

11.3 DOCUMENTATION AND REPORTING

The results of the long-term monitoring program will be documented in long-term monitoring and maintenance reports prepared by the Respondent and in 5-Year Review Reports prepared by the EPA. The 5 Year Review reports will also include file reviews and interviews with the landowner(s) pertaining to any development that has occurred at the Site since remediation was completed.

Further details of the long-term monitoring will be included in the Long-Term Monitoring and Maintenance Plan to be developed.

Section 12
Environmental Sustainability

The U.S. Environmental Protection Agency (EPA) Region 10's Clean and Green Policy (EPA, 2009) and EPA Green Remediation strategy (EPA, 2010, 2012a) outline the goal of comprehensively evaluating cleanup actions to ensure protection of human health and the environment and to reduce the environmental footprint of cleanup activities to the maximum extent possible. ASTM International (ASTM) Standard Guide E2893-13 – Standard Guide for Greener Cleanups (ASTM, 2013) also provides guidance for selection of project best management practices (BMPs) to reduce the environmental footprint of cleanup. A Green and Sustainable Remediation (GSR) Plan will be developed at later stages of design to describe sustainable technologies and practices for executing the remedial action at the Site. This section describes EPA's Green Remediation strategy and GSR considerations in remedial design and during the construction.

12.1 GREEN REMEDIATION STRATEGY

Green remediation comprises a range of best practices that may be applied throughout the cleanup process. The BMPs of green remediation provide the means to potentially improve waste management; conserve or preserve energy, fuel, water, and other natural resources; reduce greenhouse gas (GHG) emissions; promote sustainable long-term stewardship; and reduce adverse impacts on local communities during and after remediation activities. EPA's green remediation strategy aims to:

- Protect human health and the environment by achieving remedial action goals
- Support sustainable human and ecological use and reuse of remediated land
- Minimize impacts to water quality and water resources
- Reduce air toxics emissions and GHG production
- Minimize material use and waste production
- Conserve natural resources and energy

For remediation projects, sustainability means implementing projects in a manner that meets traditional remediation requirements (e.g., protection of human health and the environment, compliance with regulations, and meeting contaminant-mass removal goals), while also considering sustainable practices that can minimize the overall environmental footprint of the project. Green remediation comprises a range of BMPs that can be applied throughout the cleanup. These practices offer potential means to improve waste management; conserve or preserve energy, fuel, water, and other natural resources; reduce GHG emissions; promote sustainable long-term stewardship; and reduce adverse impacts on local ecological and human communities during and after remediation.

Consistent with the EPA's Green Remediation strategy, ASTM Guidance (ASTM, 2013) categorizes the BMP core elements as follows:

- Minimize total energy use and maximize use of renewable energy – reducing total energy use while also identifying the means to increase the use of renewable energy throughout the project activities
- Minimize air pollutants and GHG emissions – reducing total air emissions, including emissions of air pollutants and GHGs, throughout the project activities
- Minimize water use and impacts to water resources – minimizing the use of water and impacts to water resources throughout the project activities
- Reduce, reuse, and recycle materials and waste – minimizing the use of virgin materials and generation of waste throughout the project activities, and maximizing the use of recycled materials
- Protect land and ecosystems – reducing impacts to the land and ecosystem services throughout the project activities

12.2 GREEN AND SUSTAINABLE CONSTRUCTION CONSIDERATIONS

To the extent practicable, renewable energy sources, locally produced/sourced materials and supplies, reduction/elimination of waste (e.g., recycling of metal debris), efficient use of resources and energy, alternative fuel sources (e.g., low sulfur fuel, biodiesel), protection of ecosystem (e.g., in-water work window, water quality monitoring), and other practices are being incorporated into the remedial design. The majority of the construction BMPs currently identified for this project, summarized in Section 7, are also consistent with the EPA's Green Remediation strategy.

A GSR Plan will be developed at later stages of design. EPA's green remediation strategy and ASTM's BMP selection guidance will be utilized to identify GSR measures and describe sustainable technologies and practices for executing the remedial action at the Site. The Contractor will also prepare a GSR Plan and detail how to implement and track GSR measures of the project.

A report will be provided at the end of the construction project as part of the closeout reports. Refer to Section 13.3.5 for the goals and the content of the GSR Plan.

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Section 13
Next Stages of Design

Remedial design documents have been developed as preliminary (30 percent) and intermediate (60 percent) packages. The design of this current document is intermediate (60 percent). Additional design documents are described below and will be developed at later stages of design (pre-final (90 percent) and final (100 percent) design).

13.1 DESIGN CHANGES IDENTIFIED DURING THE PRELIMINARY (30 PERCENT) DESIGN

The cores collected during the pre-design investigation defined the vertical extent of contamination at the Site. As discussed in Section 3.6, the cores collected at the end of the former shipway area showed a layer of cleaner sediment above a sediment layer with elevated polycyclic aromatic hydrocarbon (PAH) contamination. The deeper PAH layer is likely associated with creosote contamination originating from the Pacific Sound Resources (PSR) site adjacent to the Lockheed West Site. The PSR sediments are capped to isolate the PAH contamination that has migrated offshore from the historic PSR creosoting operations. This finding during the pre-design investigation led to a design change at the end of shipway. Neatline dredge elevations were re-established at the top of the cleaner layer.

13.2 PRE-FINAL (90 PERCENT) AND FINAL (100 PERCENT) DESIGN

Pre-Final Design will be submitted when the design effort is 90 percent (90%) complete and the Final Design will be submitted when the design effort is 100 percent (100%) complete. The Pre-Final Design will fully address all comments made to the preceding design submittal(s). The Final Design will fully address all comments made to the Pre-Final Design and will include reproducible drawings and specifications.

The Pre-Final and Final Design submittals will include those elements developed for the Intermediate Design, as well as the following:

a. Plans and specifications

b. Construction Quality Assurance Plan (CQAP)
c. Water Quality Monitoring Plan (WQMP)
d. Quality Assurance Project Plan (QAPP)/Health and Safety Plan (HASP)/Field Sampling Plan (FSP) for remedial action construction activities
e. Permitting and Site Access Plan
f. Site Management Plan (includes Contingency Plan, Pollution Control Plan, Transportation and Disposal Plan, Green and Sustainable Remediation [GSR] Plan, and Climate Change Adaptation Site Plan)
g. Institutional Control Implementation and Assurance Plan (ICIAP)
h. Long-Term Monitoring and Maintenance Plan (LTMMP)
i. Biological Assessment.
j. Capital and Operation and Maintenance Cost Estimate
k. Construction Project Schedule
l. Any required additional plans

Technical specifications developed at the 90 percent design level will identify specific requirements to achieve the cleanup goals and performance requirements for construction, but will provide flexibility to the design/build contractor to advance the design and refine the means and methods of construction to accomplish the work.

13.3 OTHER REMEDIAL DESIGN DOCUMENTS IN PRE-FINAL AND FINAL DESIGN

The Pre-Final (90%) and Final (100%) Design submittals will include the following plans.

13.3.1 Draft Construction Quality Assurance Plan

The CQAP describes the Site-specific components of the performance methods and quality assurance program that will ensure that the completed project meets or exceeds all performance standards and design criteria, plans, and specifications, including achievement of Cleanup Levels.

The CQAP will contain, at a minimum, the following elements:

- Responsibilities and authorities of all organizations and key personnel involved in the design and construction of the remedial action, including the EPA and other agencies.
- Qualifications of the Construction Quality Assurance (CQA) Official, including the minimum training and experience of the CQA Officer and supporting inspection personnel.

- A description of all performance standards and methods necessary to ensure implementation of the remedial action construction, in compliance with applicable or relevant and appropriate requirements (ARAR) and identified site-specific performance standards. Performance monitoring requirements will be stated to demonstrate that best management practices (BMP) have been implemented for dredging operations, transportation of dredged material, and proper backfill/RML/ENR placement techniques.
- The observations and tests required to monitor the construction and/or installation of the components of the remedial action. The plan will include the scope and frequency of each type of inspection to be conducted. Inspections will be required to measure compliance with environmental requirements and ensure compliance with all health and safety procedures.
- Requirements for quality assurance sampling activities including the sampling protocols, sample size, locations, frequency of testing, acceptance and rejection data sheets, problem identification and corrective measures reports, evaluation reports, acceptance reports, and final documentation.
- Means, methods and performance levels to confirm the completion of the dredging in target removal areas including collection of confirmation sediment samples from the dredge bottom to evaluate dredge residuals and undisturbed residuals. Contingency actions for dredge areas will be outlined based on confirmation sample results.
- Means and methods to confirm the placement of the ENR layer in the target areas.
- Reporting requirements for CQA activities will be described in detail in the CQAP. This shall include such items as daily summary reports, inspection data sheets, problem identification and corrective measures reports, design acceptance reports, and final documentation storage. A description of the provisions for final storage of all records consistent with the requirements of the Unilateral Administrative Order (UAO) will be included.
- Procedures for processing design changes and securing EPA review and approval of such changes to ensure changes conform to performance standards, ARARs, requirements of the UAO Statement of Work (SOW), are consistent with the Cleanup Levels and are protective of human health and the environment.
- Identification of all final CQAP documentation to be submitted to EPA in the Remedial Action Construction Report or Remedial Action Completion Report.

Development of the CQAP will follow applicable elements from the EPA guidance identified in the SOW: *Construction Quality Assurance for Hazardous Waste Land Disposal Facilities* (EPA/530(S) SW-86-301, 1987) and *Quality Assurance and Quality Control for Waste Contaminated Facilities* (EPA/600/R-93/182, 1993).

13.3.2 Draft Water Quality Monitoring Plan (WQMP)

The WQMP will detail water quality monitoring requirements to confirm compliance with water quality standards (as defined by substantive requirements of Clean Water Act Section 401 Water

Quality Memorandum) during dredging, RML/ENR placement, and backfill, dredged material dewatering and loading, removal of pilings, and other potential water disturbances during remedial action construction. The plan will describe the specific water quality monitoring requirements, sampling design and rationale, applicable water quality standards and points of compliance, team organization and responsibilities, sampling schedule, monitoring and sampling methods, data management and reporting, and procedures for responding to water quality exceedances. A QAPP and FSP specific to water quality monitoring, as well as a HASP, will be included in this deliverable. A Water Quality Memorandum which identifies the Clean Water Act, Section 401 substantive water quality requirements for the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) action will be written by the EPA.

13.3.3 Draft QAPP/HASP/FSP

Site-specific QAPPs will cover sample analysis and data handling for sampling during all phases of future Site work, including sampling during remedial construction and long-term monitoring. Development of the QAPPs will follow EPA guidance, including *Requirements for Quality Assurance Project Plans* (QA/R-5) (EPA/240/B-0l/003 March 2001 [Reissued May 2006]); *EPA Quality Manual for Environmental Programs* (EPA CIO 2105-P-01-0, May 2000); *EPA Requirements for Quality Management Plans* (QA/R-2) (EPA/240/B-01/002, March 2001); and *Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs* (American National Standard, January 5, 1995).

FSPs will describe sample collection activities associated with each QAPP. The FSP will supplement the QAPP and contain all relevant elements described in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA/540/G-89/004 OSWER Directive 9355.3-01, October 1988).

HASPs will be developed to protect on-site personnel and area residents from physical, chemical, and all other hazards posed by the remedial action and associated sampling activities. The HASPs will follow EPA guidance (*Health and Safety Roles and Responsibilities at Remedial Sites* [EPA OEER 9285.1-02, July 1991]) and all OSHA requirements as outlined in 29 Code of Federal Regulations (CFR) 1910 and 1926. When applicable, existing project HASPs or other company/contractor HASPs may be utilized, modified as necessary to sufficiently address the activities covered by the SOW.

13.3.4 Draft Permitting and Site Access Plan

The Permitting and Site Access Plan will demonstrate how the design plans will comply with the permitting requirements identified in the Design and will address any real property and easement requirements. The Plan will provide a strategy and appropriate information for obtaining agreements for access to the Site or associated areas as necessary for the implementation of the remedial action.

13.3.5 Draft Site Management Plan

The Site Management Plan will describe how access, security, contingency procedures, management responsibilities, and waste disposal are to be handled. These additional elements may be incorporated into other deliverables or delivered separately and will include, but not be limited to: (a) Contingency Plan, (b) Pollution Control and Mitigation Plan, (c) Transportation and Disposal Plan, (d) GSR Plan, and (e) Climate Change Adaptation Plan. General descriptions and relevant guidance for these plans are described below.

Contingency Plan

The Contingency Plan is intended to protect the local affected population in the event of an accident or emergency and will contain the following elements:

- Name of person responsible for responding in the event of an emergency incident;
- Plan and date for meeting with the local community, including local, state, and Federal agencies involved in the cleanup, as well as local emergency squads and hospitals;
- First aid and medical information including names of personnel trained in first aid; clearly marked map with the locations of medical facilities; all necessary emergency phone numbers; fire, rescue, local hazardous material teams; and National Emergency Response Team.

Pollution Control and Mitigation Plan

The Pollution Control and Mitigation Plan will provide contingency measures for potential spills and discharges from materials handling and/or transportation. It will describe the methods, means, and facilities required to prevent contamination of soil, water, atmosphere, uncontaminated structures, equipment or material from the discharge of wastes due to spills; provide for equipment and personnel to perform emergency measures required to contain any spillage and to remove and properly dispose of any media that become contaminated due to spillage; and provide for equipment and personnel to perform decontamination measures that may be required to remove spillage from previously uncontaminated structures, equipment, or material.

Transportation and Disposal Plan

The Transportation and Disposal Plan will describe the procedures to be followed in transporting sediment and debris removed from the Site to the selected upland disposal facility. The plan will include descriptions of the waste materials to be transported, the destinations of the wastes, transportation means and routing, on-site traffic control and loading procedures, recordkeeping requirements, health and safety considerations, and contingency plans for spills that might occur during handling, loading, and transportation.

Green and Sustainable Remediation Plan

The GSR Plan will describe sustainable technologies and practices for executing the remedial action. A report will be provided at the end of the project as part of the closeout reports. The five goals of the GSR Plan are to:

- Reduce total energy use and increase the percentage of renewable energy
- Reduce air pollutants and greenhouse gas (GHG) emissions
- Reduce water use and negative impacts on water resources
- Improve materials management and waste reduction efforts
- Protect land and ecosystems

The GSR metrics will include “materials and waste,” “water,” “energy,” “air,” and “land and ecosystem.” The methods to track GSR performance will also be identified. Use of local materials, facilities, and environmentally sustainable business practices will also be incorporated.

The GSR Plan will contain all relevant elements described in EPA’s *Methodology for Understanding and Reducing a Projects Environmental Footprint* (EPA/542/R12/002 OSWER and OSRTI Directive, February 2012).

Climate Change Adaptation Plan

The EPA is in the process of developing policies and guidelines for implementation of climate change adaptation protocols to ensure continuing protectiveness of current and future remedies. There is no current guidance detailing the expected content of Climate Change Adaptation Plans.

The Plan will be developed based on the most recent information available at the time from EPA (http://epa.gov/climatechange/impacts-adaptation/fed-programs/EPA-impl-plans.html).

13.3.6 Draft Institutional Controls Implementation and Assurance Plan

The ICIAP will establish and document the activities associated with implementing and ensuring the long-term stewardship of ICs and to specify the persons and/or organizations that will be responsible for conducting these activities. The details will include how the Uniform Environmental Covenant Act (UECA) covenant and the Elliott Bay fish consumption advisory will be specifically implemented, maintained, enforced, modified, and terminated (if applicable) at the Site. Development of the ICIAP will follow EPA guidance: *A Guide to Preparing Institutional Control Implementation and Assurance Plans at Contaminated Sites* (OSWER 9200.0-77, EPA-540-R-09-002, December 2012).

13.3.7 Draft Long-term Monitoring and Maintenance Plan

The post-remedial action LTMMP and QAPP (or amendments to the remedial design QAPP) will be developed to cover implementation, maintenance and monitoring of the remedial action. Because recontamination of the sediment surface from off-site sources may occur due to ambient conditions in Elliott Bay and the LDW, sampling and numeric performance standards such as Cleanup Levels will not be the only criteria for evaluating the performance of the remedy. Sampling methodology will be developed to evaluate surface sediment recontamination from off-site sources (“top-down” contamination) and to evaluate potential mixing of the clean surface sediment layer with underlying sediment that has contaminant concentrations greater than the Cleanup Levels (“bottom-up” contamination). The sampling will take place in the biologically active zone of the subtidal (10 centimeters [cm]) and intertidal (45 cm) zones. If sampling demonstrates that “top-down” contamination has occurred and commensurately, “bottom-up” contamination has not occurred, and concentrations in the sediment surface layer exceed Cleanup Levels, then sediment quality monitoring will be discontinued.

The LTMMP will include:

- Means and methods to assess the Cleanup Levels in the biologically active zones of the intertidal and subtidal portions of the Site.
- Means and methods for sampling in the ENR layer and dredge residuals management areas to ascertain the effectiveness of these remedial actions.

- Procedures for measuring and documenting if recontamination, if occurring, is from off-site sources (“top-down” contamination).
- Means and methods for evaluation of the bank excavation and replacement areas and areas of fish mix placement.
- Definition of triggering weather and/or seismic events that will require monitoring and/or sampling after they occur.
- Identification of monitoring measures that will be taken after a triggering weather and/or seismic events.
- Metrics and schedule for demonstrating successful implementation of the remedy and reductions in monitoring to trigger events.
- Identification of monitoring activities, including file reviews and interviews with the landowners pertaining to any development that has occurred at the Site since the remediation was complete in order to support the five-year review.
- Contingency actions to be taken as repairs, supplemental actions or maintenance to maintain the remedy.
- Note: Surface water and fish tissue samples will not be collected as part of the long-term monitoring program or for the 5-year review.

The LTMMP will evaluate and include, as appropriate and per the schedule to be developed, the following types of monitoring to achieve the monitoring objectives of each element of the remedial action, and will be used to support the EPA 5-year review:

- Bathymetry;
- Sediment chemistry;
- Sediment bioassays, if necessary;
- Sediment profile imaging cameras.

Development of the LTMMP will follow EPA guidance: *Guidance for Monitoring at Hazardous Waste Sites, Framework for Monitoring Plan Development and Implementation* (OSWER Directive No. 9355.4-28, January 2004); and *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (EPA-540-R-05-012, OSWER 9355.0-85, December 2005).

13.3.8 Draft Biological Assessment

A Biological Assessment will be prepared to ensure compliance with the Endangered Species Act (ESA) by identifying the presence of threatened, endangered, proposed, or candidate species, or their habitat within the vicinity of the cleanup action. The Biological Assessment will characterize baseline conditions of the existing habitat, address potential project impacts the remedial action may have on these species, their habitat, and food stocks. The Biological Assessment will also identify best management practices and conservation measures designed to avoid or minimize potential impacts. EPA will use the Biological Assessment to consult with the National Oceanic and Atmospheric Administration/National Marine Fisheries Service (NMFS) and with the U.S. Fish and Wildlife Service to show substantive compliance.

Development of the Biological Assessment will follow EPA guidance: *A Primer on Using Biological Assessments to Support Water Quality Management* (EPA 810-R-11-01, October 2011).

13.4 REMEDIAL ACTION

Following completion of Final Design, Lockheed Martin will complete the Remedial Action Work Plan (RAWP) and perform the construction as outlined in the project schedule.

13.4.1 Remedial Action Work Plan

The RAWP will provide a detailed description of the remediation and construction activities, including implementation of construction activities and coordination with the EPA. Per Lockheed Martin’s current contracting strategy (i.e., developing the intermediate design and then soliciting a design/build procurement), the RAWP is anticipated to be developed concurrently with the design. Further details of RAWP components are provided in Section IV.C of the SOW, Appendix B to the UAO for the Remedial Design and Remedial Action for the Site (EPA, 2015b).

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Section 14
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APPENDIX A— PRE-DESIGN CHEMISTRY DATA SUMMARY AND DREDGE EXTENT VERIFICATION

Appendix A
Pre-Design Chemistry Data Summary and Dredge Extent Verification

This appendix to the Intermediate (60 Percent) Design for the Lockheed West Seattle Superfund Site (Site) provides details on the chemistry data used for the remedial design and how the data were handled for use in the design. Included in the summary is a description of how the data for locations where multiple cores were handled to use in the design. A summary of the determination of the horizontal extents for the removal areas using a three-dimensional model is included in this appendix. In addition, the characterization of the polycyclic aromatic hydrocarbons (PAHs) detected at depth in the area of the former shipway in relation to the PAHs detected at the Pacific Sound Resources (PSR) site is also included.

A.1 REMEDY DESIGN INVESTIGATIONS

Since 1984, an extensive series of studies have been independently conducted by Lockheed Martin Corporation (Lockheed Martin) and the Port of Seattle (Port) to investigate the nature and extent of sediment contamination at the Site (Tetra Tech, 2008). Much of this information was compiled by Parametrix (1994a and b) and by Enviros (1990) to support characterization of the Lockheed Shipyard No. 2 site for the Southwest Harbor Cleanup and Redevelopment Project planning by the Port. Available historical sediment quality information in the vicinity of the Site includes samples collected prior to 1998 and in 2003 as part of a due diligence investigation (Hart Crowser, 2003). Previous work also supported studies for the Harbor Island Remedial Investigation/Feasibility Study (RI/FS; Weston, 1993), evaluation of sediments in the West Waterway of the Duwamish River, and other sediment quality evaluations. Existing studies and data are further described below.

Environmental samples from this historical work were summarized in Appendix A of the *RI/FS Work Plan* (Tetra Tech, 2008) and were compiled from the Washington State Department of Ecology (Ecology) SEDQUAL database and Hart Crowser (2003). In addition to bulk chemical analysis, sediment characterization work also included the following tests for some of the samples collected:

- Nineteen bioassay tests;
- Eight infauna sampling locations;
- Five surface samples tested using the Toxicity Characteristic Leaching Procedure;
- Forty benthic flux samples from two locations; and
- Sixty interstitial porewater samples from six squeeze core locations.

Hart Crowser (1995) also completed 24 additional subsurface geotechnical borings for the Port to assess sediment types and physical properties throughout the Site and the adjacent West Waterway (Tetra Tech, 2008). Data from these borings were used for engineering design and stability analysis for development of Terminal 5 by the Port.

In addition to the recent sediment data collected in direct support of the Lockheed West RI, data from other sediment investigation efforts was incorporated into the RI to the extent that the data were found to be valid and usable for the intended purposes. These include data from the following previous studies:

- **Sediment Quality Study in Elliott Bay (Ecology, 2009).** In 2007, Ecology conducted a sediment quality study in support of the Urban Waters Initiative. This study included collection of surface sediment samples from Elliott Bay, which were analyzed for metals, polychlorinated biphenyls (PCBs), pesticides, semivolatile organic compounds (SVOCs), conventional parameters, and grain size. The samples for this study were grouped into three general categories: Basin, Urban, and Harbor areas.
- **Lockheed Shipyard No. 2 Sediment Characterization (Hart Crowser, 2003)**. Surface sediment samples were collected to update the Site environmental status. Laboratory analyses included metals, PCBs, pesticides, SVOCs, volatile organic compounds (VOCs), dioxins, conventional parameters, and grain size.
- **Southwest Harbor Puget Sound Dredge Disposal Analysis–Related Sediment Quality Investigation (Enviros, 1992)**. This investigation included the collection of subsurface sediment core data, which were analyzed for metals, PCBs, pesticides, SVOCs, VOCs, and conventional parameter analysis.

- **Southwest Harbor RI Sediment Quality Investigation (Enviros, 1991).** Subsurface core data were collected and analyzed for metals, PCBs, SVOCs, VOCs, and conventional parameters.
- **Lockheed Shipyard No. 2 Sediment Characterization and Geochemical Study (Enviros, 1990).** This study included the collection of sediment core data for metals, PCBs, pesticides, SVOCs, VOCs, and conventional parameters analyses.

The Site RI fieldwork was conducted from 2006 through 2008 and is summarized in the RI/FS (Tetra Tech, 2012). Field activities and collected data include the following:

- Performance of a high-resolution multi-beam bathymetry survey, shoreline conditions survey, and topographic survey;
- Collection of surface sediment samples from the intertidal and subtidal areas;
- Collection of subsurface sediment samples from the subtidal area;
- Collection of pore water and surface water samples; and
- Performance of clam reconnaissance surveys and collection of clam tissue samples.

A.2 PRE-REMEDIAL DESIGN INVESTIGATION

A pre-design sampling investigation was conducted in January 2016 to support the development of the remedy design. As part of the pre- design investigation, surface and subsurface sediment samples were collected and analyzed for contaminants of concern (COC) to refine the remedial action boundaries at the Site. Six subtidal surface sediment samples were collected and 142 subsurface samples from 37 core sample locations were collected for chemical analysis. The results for these samples were reported in the Pre-Remedial Design Field Sampling Data Report (Tetra Tech, 2016).

A.3 DATA REDUCTION FOR REMEDIAL DESIGN

To support the remedy design, data were collected during the pre-remedial design investigation to determine the depth of contaminated sediment where historic cores from the remedial investigation had chemical concentrations above the Sediment Quality Standards (SQS) or Cleanup Screening Levels (CSL). Several of the proposed coring locations in the pre-remedial design investigation were collected at these locations to determine the vertical extent of chemical contamination above the SQS or CSL levels to refine removal depths in these areas of the site. For those cores, Table A-1 (at the back of this appendix) summarizes the pre-design cores and remedial investigation cores; the recent core collected to a deeper depth with intervals below the SQS and CSL levels replaces the RI core for use in the remedy design.

A.4 HORIZONTAL EXTENT OF CONTAMINATION

A summary of the chemical analyses for the risk driver COC data for all samples from the historic investigations, RI, and pre-design investigation is presented in Table A-2. Data from the RI, pre-design investigation, and for surface and subsurface samples from historic investigations were used in a three-dimensional (3-D) kriging model to determine the horizontal extent of sediment contamination above the SQS outside of the inner harbor line in the West Waterway area of the site and above the CSL inside the inner harbor area for the remainder of the Site. The 3-D kriging software (C-TECH MVS) used the easting and northing sample coordinates along with the depth/elevation of the sample intervals and contaminant concentrations for the eight risk driver chemicals (arsenic, copper, lead, mercury, zinc, PCBs, tributyltin, and carcinogenic PAHs [cPAH]) to model the sediment concentrations across the Site based on the collected data. The model honors the collected data by using a nugget, an aspect of the model for local variability, of zero. This limit of local variability results in the model output matching the collected data at the individual sample points. Adjustments to the boundaries were made to account for data deviations in the model extents at individual data points. Adjustments were made by refining the boundaries to be half the distance between a sample location with concentration above the RALs and a location with concentrations below the RALs to capture Site bathymetric features not captured by the analytical data set. These features are primarily located in the dry dock areas with suspected contamination based on similarity to the areas with known contamination based on the chemical analytical results. The remedial boundaries for the intermediate design are shown on Figure A-1 (at the back of this appendix).

Data collected in the pre-remedial design investigation were used to refine the horizontal boundaries for the following removal areas.

Cores collected in the intertidal beach and along the shoreline were used to refine the extent of removal between +4 feet and -10 feet mean lower low water (MLLW). In addition, the extent of existing rip rap/rock was used to refine areas of the shoreline removal. Cores TT-CS127 to TT-

CS132 along with the RI intertidal beach samples were used to refine the intertidal beach removal area up to the rip rap covered Florida Street storm drain outfall.

Cores collected during the pre-design survey refined the extent of contamination at the northeast corner of the Site where contamination above the cleanup goals was found during the RI (TT34). Two new cores around TT34 (i.e., TT-CS137 and TT-CS138) refined the horizontal extents of sediment contamination to be removed in this area.

In the area of former Pier 22, the pre-design investigation core TT-CS118 refined the extent of removal to the west from the dry docks area.

Cores and surface sediment samples collected in the area of former Pier 23 around RI locations TT20 and the Ecology location (Ecology 197) were used to refine the extent for removal in these two areas. The pre-design data allowed for the refinement of the areas around these two points for removal.

Along the shoreline between former Pier 23 and Pier 24, two cores (TT-CS109 and TT-CS110) were collected to refine the extent of removal. The extent of removal for this area is refined based on the contamination present in the one core (TT-CS109) and the concentrations in TT-CS110 being below the Site action levels for removal.

Eight cores (TT-CS101 to TT-CS108) were collected from the former shipway to refine the extent of contamination for removal in this area. The data from the eight cores along with the intertidal samples from the RI were used in the design to refine the extent of removal in this area.

A.5 VERTICAL EXTENT OF CONTAMINATION IN REMOVAL AREAS

Depth of contamination in areas for removal was determined from the core profiles and defined as the bottom of the deepest sample interval with any concentration for the risk-driver COC above the SQS or CSL depending on the area of the Site for the sample location. Where the collected core encountered a refusal and the deepest collected interval had concentrations above the SQS or CSL level, the estimated depth of contamination for the sample location is based on the depth of the refusal encountered where refusal was the encountering of rock or consolidated material on several attempts. For cores collected in the former shipway area (CS-103, CS-105 and CS-106) where refusal was due to the density of pilings, the design dredge depths were extended to 3 feet below the depth of the encountered refusal.

The extents of vertical contamination are extrapolated from the core data to capture the extent of contamination within a prism across the dry dock and former shipway areas expected to be contaminated based on the similarity of Site features to the sampling core locations.

Cores collected during the pre-design investigation defined the vertical extent of contamination in the northeast corner of the Site (TT34), along the western edge of the of the dry dock removal area (TT30), at the area of the intertidal beach (TT04), and in the areas along Pier 23 (TT20 and Ecology-197). In addition, the eight cores collected from the former shipway defined the vertical extents for the removal. In the cores collected at the end of the former shipway area, a gap of cleaner material appears to be present above a deeper sediment layer with elevated PAH contamination. The vertical extent of the contamination in the shipway related to the former shipyard activities is limited to the upper sediment zones (less than 5 feet below the mudline), whereas the deeper (greater than 6 feet below the mudline) PAH contamination appears to be related to other sources, as discussed below.

A.6 NATURE AND SOURCE OF PAHS IN SHIPWAY

Deeper cores in the former shipway area of the site had elevated concentrations of PAHs present at depth below intervals of lower contamination related to the former shipway activities (see Table A-2). The deeper PAHs are likely associated with creosote contamination originating from the PSR site adjacent to the Lockheed West Site. The PSR sediments are capped to isolate the PAH contamination that has migrated offshore from the creosoting operations that historically took place at this site. Data for PSR sediment samples collected from areas adjacent to the Lockheed West site are included in Table A-3.

PAHs come from many historic and ongoing sources. The source of PAH contamination can be determined using the PAH profile and PAH ratios.

The PAH profiles (Figures A-2 through A-7) show the PSR upland dense non-aqueous phase liquid (DNAPL) from the PSR RI Report (Weston, 1998), the core interval samples from locations (EB113 and EB012) nearest the former shipway on the Site, the surface samples collected from locations nearest the former shipway for the PSR RI, the shallow interval samples, and the deepest interval samples from the cores collected in the shipway as part of the pre-remedial investigation. The DNAPL sample shows a pattern for PAHs consistent with a pyrogenic source creosote material with a relatively high fraction of the total PAHs being light PAHs (naphthalene, acenaphthene, and phenanthrene). Samples from PSR locations EB113 and EB012 also show a relatively high fraction of PAHs in the light weight range. The surface samples from the PSR RI and shallow core intervals from the pre-design investigation show the mid- to heavy weight PAHs making a larger fraction of the total PAHs in the samples. The deep core interval samples with higher concentrations for PAHs from the shipway show a relatively high fraction of the acenaphthene and phenanthrene similar to that found in the samples from the PSR site sediment cores.

The ratio of heavier weight PAHs can be used to determine similarities between the sources of PAHs in samples. These PAH ratios are generally conservative in that they change little over time because there is limited degradation of the PAHs in the environment. Two common PAH ratios used for this purpose are fluoranthene/pyrene and benz(a)anthracene/chrysene (Figure A-8). The double ratio plot shows the groupings of samples based on these ratios with most of the surface samples in one area of the plot and deeper interval samples and the upland DNAPL grouped in a separate area of the plot. Of interest are the three PSR surface samples grouped with the deeper interval samples. These three locations (EB-001, EB-002, and EB-009) are all located in the PSR marine area just north of the upland area to the west of the former shipway (Figure A-9) indicating a likely similarity of contamination source for these, the deeper core sample, the deeper shipway samples, and the PSR upland DNAPL.

Based on the PAH profiles and PAH ratios, it is likely that the source for the PAHs found at depth in the former shipway is similar to that for the PAHs in the PSR marine site and potentially linked to the DNAPL in the PSR upland area. Therefore, the design set the dredging removal depth based on the clean interval above the PAHs found at depth, thereby leaving the contamination associated with PSR in place.

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Table A-1
Pre-Remedial Design Core Replacements for Remedial Investigation Cores

RI Location ID	Depth(elevation) achieved (ft)	Pre-RD Location ID	Depth(elevation) achieved (ft)	Interval Depth < SQS or CSL (ft)	Depth (elevation) Contamination (ft)
TT04-CS	10.3 (-33.8)	TT-CS136	18.5 (-45.2)	5 – 6	5 (-31.7)
TT07-CS	6.9 (-13.6)	TT-CS124	19 (-27.8)	6 – 7	6 (-14.8)
TT08-CS	9.7 (-50.1)	TT-CS104	21.5 (-61.6)	9 – 10	9 (-49.1)
TT30-CS	1.6 (-53.8)	TT-CS141	8 (-59.5)	1 – 2	1 (-55.5)
TT34-CS	0.5 (-51.8)	TT-CS138	11 (-62.3)	0 – 1	0 (-53.3)
TT18-CS	4.4 (-38.9)	TT-CS121	18.8 (-52.0)	5 – 6	5 (-39.2)

CSL = Cleanup Screening Level; ft = feet; ID = identifier; RI = remedial investigation; SQS = Sediment Quality Standards;

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)							
South Beach Dredge Area													
TT-IT-01		4/20/2007		5.0	0 (5)	0.5 (4.5)	45.4	73.5	91.5	0.032 *	0.017	0.00368	0.00081 J
TT-IT-02		4/20/2007		2.7	0 (2.7)	0.5 (2.2)	20.7	44.6	**1420**	0.046 *	0.077	0.0216	0.013
TT-IT-03		4/20/2007		1.6	0 (1.6)	0.5 (1.1)	44.6	207	152	0.16 *	0.047	0.0222	0.0038
TT-IT-04		4/20/2007		-0.7	0 (-0.7)	0.5 (-1.2)	5.86	93.6	164	0.266 *	0.028	0.0301	0.001 J
TT-IT-05		4/20/2007		-0.1	0 (-0.1)	0.5 (-0.6)	**185**	266	346	*0.423* *	0.034	0.0758	0.0026
TT-CS127-00-01		1/18/2016	-5.5	-7.6	0 (-7.6)	1 (-8.6)	13.7	98	160	0.111	0.134	*1.92*	0.18
TT-CS127-01-02		1/18/2016	-5.5	-7.6	1 (-8.6)	2 (-9.6)	20.7	86.2	103	0.179	*0.3*	*1.73*	0.28
TT-CS127-2	Dup of TT-CS127-01-02	1/18/2016	-5.5	-7.6	1 (-8.6)	2 (-9.6)	39.5	76	99.3	0.147	*0.283*	*1.56*	0.27
TT-CS128-00-01		1/18/2016	0.0	-2.3	0 (-2.3)	1 (-3.3)	20.2	17.5	199	0.048	0.0134	0.0197	0.0087
TT-CS129-00-01		1/18/2016	-9.7	-9.5	0 (-9.5)	1 (-10.5)	4.83	27.2	56.7	0.243	0.0202	**7.10**	0.00069
TT-CS129-01-02		1/18/2016	-9.7	-9.5	1 (-10.5)	2 (-11.5)	4.61	25.9	64.6	0.131	0.0167	*1.27*	0.0013
TT-CS130-00-01		1/19/2016	0.1	-2.2	0 (-2.2)	1 (-3.2)	13.6	43.8	31.1	0.06	0.046	0.0571	0.3
TT-CS130-01-02		1/19/2016	0.1	-2.2	1 (-3.2)	2 (-4.2)	5.81	56.1	62.4	*0.447*	*0.184*	0.275	0.028
TT-CS130-02-03		1/19/2016	0.1	-2.2	2 (-4.2)	3 (-5.2)	1.85	8.2	7.71	0.016	0.0021	0.0277	0.00053
TT-CS131-00-01		1/9/2016	-5.5	-7.6	0 (-7.6)	1 (-8.6)	2.19	12.2	17.6	0.105	0.0043	0.0425	0.0015
TT-CS131-01-02		1/9/2016	-5.5	-7.6	1 (-8.6)	2 (-9.6)	2.2	10.5	15.7	0.035	0.0043	0.0214	0.0013
TT-CS131-02-03		1/9/2016	-5.5	-7.6	2 (-9.6)	3 (-10.6)	2.66	14.4	13.9	0.076	0.0043	0.0751	0.0013
TT-CS132-00-01		1/9/2016	-6.8	-8.5	0 (-8.5)	1 (-9.5)	7.64	34.5	49.8	0.171	0.127	0.173	0.0052
TT-CS132-01-02		1/9/2016	-6.8	-8.5	1 (-9.5)	2 (-10.5)	16	77.5	85.6	*0.419*	*0.51*	*1.635*	0.0014
TT-CS132-02-03		1/9/2016	-6.8	-8.5	2 (-10.5)	3 (-11.5)	3.98	49.8	37.2	0.286	0.074	0.771	0.0013
TT03-SS		1/24/2007	-16.7	-27.2	0 (-27.2)	0.8 (-28)	10.6	97.1	59.2	*0.471*	*0.24*	0.680	0.38 D
TT04-SS	Replaced by TT-CS136	1/24/2007	-23.5	-22.8	0 (-22.8)	0.8 (-23.6)	9.83	79.2	56.3	*0.437*	*0.27*	0.595	0.3 D
TT92-SS	Dup of TT04-SS	1/24/2007	-23.5	-22.8	0 (-22.8)	0.8 (-23.6)	9.65	78.3	48.6	*0.443*	0.173	0.649	0.29 D
TT04-CS-B		1/22/2007	-23.5	-23.5	0.4 (-23.9)	1.2 (-24.7)	12.2	173 *	159	**1.39**	*0.57*	0.613	0.016
TT04-CS-C		1/22/2007	-23.5	-23.5	1.2 (-24.7)	2.1 (-25.6)	5.61	50.6 *	47.9	*0.425*	0.094	0.217	0.026
TT04-CS-J		1/22/2007	-23.5	-23.5	7 (-30.5)	7.9 (-31.4)	7.4	45.9 *	57.6	**0.623**	0.045	0.692	0.000082 U
TT04-CS-K		1/22/2007	-23.5	-23.5	7.9 (-31.4)	8.7 (-32.2)	6.61	33	39.3	*0.448*	0.0041 U	*3.14*	0.000087 U
TT04-CS-M		1/22/2007	-23.5	-23.5	9.5 (-33)	10.3 (-33.8)	6.1	38.9	35.8	**0.651**	0.0027 U	0.326	0.000087 U
TT-CS136-00-01	Replaces TT-04-CS	1/20/2016	-27.7	-27.3	0 (-27.3)	1 (-28.3)	10.5	78.9	55.2	0.384	*0.36*	0.593	0.72
TT-CS136-2	Dup of TT-CS136-00-01	1/20/2016	-27.7	-27.3	0 (-27.3)	0 (-27.3)	11.6	86.5	65.7	*0.534*	*0.295*	0.525	0.89
TT-CS136-01-02		1/20/2016	-27.7	-27.3	1 (-28.3)	2 (-29.3)	37.4	257	214	**1.57**	**1.93**	*1.300*	0.48
TT-CS136-02-03		1/20/2016	-27.7	-27.3	2 (-29.3)	3 (-30.3)	10.6	80.9	93.7	**1.15**	*0.236*	0.448	0.011
TT-CS136-03-04		1/20/2016	-27.7	-27.3	3 (-30.3)	4 (-31.3)	8.99	47	70.6	**0.73**	0.0546	0.393	0.0029
TT-CS136-04-05		1/20/2016	-27.7	-27.3	4 (-31.3)	5 (-32.3)	5.41	29.2	24	**0.671**	0.0021	0.243	0.00061
TT-CS136-05-06		1/20/2016	-27.7	-27.3	5 (-32.3)	6 (-33.3)	5.98	32.7	17	0.348	0.0021	0.325	0.00065
Dry Docks Dredge Area West Waterway													
TT06-SS		1/24/2007	-43.0	-42.3	0 (-42.3)	0.5 (-42.8)	15.9	146	87.6	**0.682**	*0.39*	0.996	0.86 D
TT93-SS	Dup of TT06-SS	1/24/2007	-43.0	-42.3	0 (-42.3)	0.5 (-42.8)	15.6	146	89.8	**0.685**	*0.42*	*1.24*	0.81 D
TT06-CS-A		1/17/2007	-43.0	-41.9	0 (-41.9)	0.9 (-42.8)	*88.9*	**1110**	253	**2.09**	**1.87**	*2.26*	**1.7 D**
TT06-CS-B		1/17/2007	-43.0	-41.9	0.9 (-42.8)	1.8 (-43.7)	*65.4*	**1170**	418	**9.43**	**1.56**	**8.71**	0.015
TT06-CS-C		1/17/2007	-43.0	-41.9	1.8 (-43.7)	2.6 (-44.5)	14.7	**794**	152	**9.67**	*0.77*	0.968	0.014
TT06-CS-E		1/17/2007	-43.0	-41.9	3.6 (-45.5)	4.5 (-46.4)	2.79	16.8	6.04	0.089	0.0064	0.0466	0.0012 J
TT06-CS-G		1/17/2007	-43.0	-41.9	5.4 (-47.3)	6.3 (-48.2)	2.42	12.6	4.49	0.036	0.0023 U	0.0792	0.0018
TT06-CS-I		1/17/2007	-43.0	-41.9	7.2 (-49.1)	8.1 (-50)	2.98	16.6	8.9	0.066	0.0023 U	0.0343	0.000073 U

Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
TT08-SS	Replaced by TT-CS140	1/24/2007	-40.4	-40.7	0 (-40.7)	0.5 (-41.2)	40.5	230	123	**1.46**	*0.69*	*1.93*	0.69 D
TT08-CS-B		1/16/2007	-40.4	-41.1	0.5 (-41.6)	1.3 (-42.4)	**374**	**2110**	**998**	**6.96**	**1.38**	**17.2**	**8.2 D**
TT08-CS-C		1/16/2007	-40.4	-41.1	1.3 (-42.4)	2 (-43.1)	**298**	**2620**	**982**	**3.78**	**1.13**	**8.86**	**8.6 D**
TT08-CS-I		1/16/2007	-40.4	-41.1	5.9 (-47)	6.7 (-47.8)	**148**	**1470**	**568**	**10.2**	**2.4**	**6.67**	**4.1 D**
TT08-CS-K		1/16/2007	-40.4	-41.1	7.4 (-48.5)	8.2 (-49.3)	**105**	**1530**	*527*	**14.5**	*0.96*	**5.45**	1 D
TT08-CS-M		1/16/2007	-40.4	-41.1	8.8 (-49.9)	9.7 (-50.8)	21	**1840**	232	**4.6**	*0.41*	*1.51*	**1.9 D**
TT-CS139-00-01		1/18/2016	-42.8	-40.7	0 (-40.7)	1 (-41.7)	8.3	40.4	13.4	0.161	0.0029	0.2026	0.0024
TT-CS139-01-02		1/18/2016	-42.8	-40.7	1 (-41.7)	2 (-42.7)	8.56	33.9	7.92	0.106	0.0021	0.0182	0.0008
TT-CS139-06-07		1/18/2016	-42.8	-40.7	6 (-46.7)	7 (-47.7)	1.28	6.45	0.82	0.003	0.0021	0.00632	0.00054
TT-CS140-00-01	Replaces TT08-CS	1/20/2016	-40.1	-40.5	0 (-40.5)	1 (-41.5)	**379**	**1180**	**552**	**1.14**	*0.787*	**4.20**	**29**
TT-CS140-01-02		1/20/2016	-40.1	-40.5	1 (-41.5)	2 (-42.5)	**150**	**2690**	**689**	**1.79**	**4.79**	**17.5**	**22**
TT-CS140-05-06		1/20/2016	-40.1	-40.5	5 (-45.5)	6 (-46.5)	29.4	**2170**	*520*	**12.6**	**1.27**	**3.52**	0.0016
TT-CS140-06-07		1/20/2016	-40.1	-40.5	6 (-46.5)	7 (-47.5)	56.5	**534**	210	**2.75**	*0.478*	*1.73*	**1.7**
TT-CS140-08-09		1/20/2016	-40.1	-40.5	8 (-48.5)	9 (-49.5)	7.13	37.8	15.7	**3.66**	0.031	**17.5**	0.00091
TT-CS140-09-10		1/20/2016	-40.1	-40.5	9 (-49.5)	10 (-50.5)	2.24	10.4	2.86	0.055	0.0021	0.652	0.00056
TT-CS140-10-11		1/20/2016	-40.1	-40.5	10 (-50.5)	11 (-51.5)	3.48	11.8	2.95	0.022	0.0021	0.0113	0.00058
TT-CS140-11-12		1/20/2016	-40.1	-40.5	11 (-51.5)	12 (-52.5)							
TT09-SS		1/25/2007	-40.8	-40.1	0 (-40.1)	0.5 (-40.6)	**183**	**483**	258	*0.525*	*0.48*	*1.35*	**3.5 D**
TT30-SS	Replaced by TT-CS141	1/24/2007	-52.2	-51.4	0 (-51.4)	0.5 (-51.9)	30.1	388	154	**0.754**	*0.49*	*2.46*	**4.5 D**
TT30-CS-A		1/16/2007	-52.2	-51.8	0 (-51.8)	0.7 (-52.5)	8.42	122	94.6	**1.14**	*0.66*	0.559	0.014
TT30-CS-B		1/16/2007	-52.2	-51.8	0.7 (-52.5)	1.6 (-53.4)	4.97	69.7	41.3	**0.741**	0.09	0.315	0.002
TT-CS141-00-01	Replaces TT30-CS	1/14/2016	-51.5	-51.8	0 (-51.8)	1 (-52.8)	45.1	236	152	**1.51**	*0.49*	0.781	0.93
TT-CS141-01-02		1/14/2016	-51.5	-51.8	1 (-52.8)	2 (-53.8)	5.86	61.5	36.3	0.388	0.08	0.152	0.0052
TT-CS141-03-04		1/14/2016	-51.5	-51.8	3 (-54.8)	4 (-55.8)	3.57	11.9	1.65	0.016	0.0021	0.00634	0.0012
TT-CS141-04-05		1/14/2016	-51.5	-51.8	4 (-55.8)	5 (-56.8)	3.22	14.5	2.02	0.027	0.0021	0.00632	0.0021
TT31-SS		1/26/2007	-51.8	-49.7	0 (-49.7)	0.5 (-50.2)	32	**409**	192	**0.83 ***	**1.41**	*2.54*	**4.2 D**
TT31-CS-A		1/17/2007	-51.8	-51.7	0 (-51.7)	0.7 (-52.4)	14.7	**1330**	86.9	**0.803**	**1.35**	1.07	0.48 D
TT31-CS-B		1/17/2007	-51.8	-51.7	0.7 (-52.4)	1.5 (-53.2)	2.67	18.9	11.7	0.16	0.019	0.0604	0.0016
TT10-SS		1/25/2007	-31.8	-29.2	0 (-29.2)	0.5 (-29.7)	**146**	**894**	395	**0.631**	**1.31**	*1.44*	**4 D**
TT10-CS-B		1/22/2007	-31.8	-33.1	0.2 (-33.3)	1.1 (-34.2)	6.58	35.5	23.6	0.399 *	0.0298	0.215	0.0075
TT10-CS-C		1/22/2007	-31.8	-33.1	1.1 (-34.2)	2 (-35.1)	5.97	35.4	15	0.243 *	0.0027 U	0.410	0.0014 J
TT10-CS-D		1/22/2007	-31.8	-33.1	2 (-35.1)	3 (-36.1)	5.76	40.8	5.92	0.075 *	0.003 U	0.00993	0.00045 J
TT10-CS-E		1/22/2007	-31.8	-33.1	3 (-36.1)	3.9 (-37)	8.21	46.3	9.31	0.119	0.0032 U	0.0199	0.0008 J
TT11-SS		1/26/2007	-44.5	-38.2	0 (-38.2)	0.5 (-38.7)	**204**	**514**	*483*	**1.04 ***	**1.22**	*1.35*	0.29 D
TT11-CS-B		1/19/2007	-44.5	-45.7	0.4 (-46.1)	1.3 (-47)	11.5	60.1 *	40.3	**0.622**	0.027	0.437	0.0047
TT11-CS-C		1/19/2007	-44.5	-45.7	1.3 (-47)	2.1 (-47.8)	9.28	45.2 *	17.5	0.15	0.029	0.0406	0.006
TT11-CS-D		1/19/2007	-44.5	-45.7	2.1 (-47.8)	3 (-48.7)	5.85	34.7 *	5.13	0.058	0.0027 U	0.00257	0.000087 U
TT11-CS-E		1/19/2007	-44.5	-45.7	3 (-48.7)	3.9 (-49.6)	3.26	19	3.05	0.034	0.0024 U	0.00456	0.000079 U
TT42-SS		1/26/2007	-49.7	-50.0	0 (-50)	0.5 (-50.5)	23.3	132	142	**0.998**	**1.11**	0.635	0.13
TT42-CS-B		1/23/2007	-49.7	-49.6	0.3 (-49.9)	1.1 (-50.7)	10.5	63	42.5	**1.03 ***	0.077	0.406	0.084
TT42-CS-C		1/23/2007	-49.7	-49.6	1.1 (-50.7)	2 (-51.6)	7.18	48.7	26.9	**0.656 ***	0.073	0.317	0.022
TT42-CS-D		1/23/2007	-49.7	-49.6	2 (-51.6)	2.9 (-52.5)	4.93	30.1	6.88	0.146 *	0.0156	0.0794	0.0049
TT33-SS		1/26/2007	-50.6	-47.8	0 (-47.8)	0.5 (-48.3)	13.8	101	80.9	*0.54* *	*0.49*	0.513	0.16 D
TT33-CS-A		1/23/2007	-50.6	-50.2	0 (-50.2)	0.3 (-50.5)	4.84	38.2	14.8	0.176 *	0.052	0.0691	0.016
TT33-CS-B		1/23/2007	-50.6	-50.2	0.3 (-50.5)	0.9 (-51.1)	4.47	42.6	13.5	0.118 *	0.0102	0.0282	0.0024

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)							
TT33-CS-C		1/23/2007	-50.6	-50.2	0.9 (-51.1)	1.5 (-51.7)	2.67	19.6	2.21	0.025 *	0.0023 U	0.0034 U	0.000075 U
TT-CS142-00-01		1/19/2016	-46.1	-45.6	0 (-45.6)	1 (-46.6)	37	272	150	**1.23**	**1.11**	*2.94*	**3.8**
TT-CS142-01-02		1/19/2016	-46.1	-45.6	1 (-46.6)	2 (-47.6)	*57.5*	**727**	310	**1.43**	**1.32**	**6.69**	**17**
TT-CS142-02-03		1/19/2016	-46.1	-45.6	2 (-47.6)	3 (-48.6)	**182**	**1230**	**728**	**3.73**	**5.57**	**10.3**	**3.1**
TT-CS142-04-05		1/19/2016	-46.1	-45.6	4 (-49.6)	5 (-50.6)	7.88	52.6	29.8	**0.971**	0.0683	0.321	0.0014
TT-CS142-05-06		1/19/2016	-46.1	-45.6	5 (-50.6)	6 (-51.6)	8.81	52	39.1	**0.62**	0.113	0.731	0.024
TT-CS142-06-07		1/19/2016	-46.1	-45.6	6 (-51.6)	7 (-52.6)	2.43	8.43	1.92	0.019	0.0021	0.0114	0.00047
TT34-SS	Replaced by TT-CS138	1/26/2007	-51.3	-51.4	0 (-51.4)	0.5 (-51.9)	6.38	**840**	31.1	**0.758 ***	0.062	0.251	0.022
TT34-CS-A		1/17/2007	-51.3	-50.5	0 (-50.5)	0.5 (-51)	6.96	50.2	34.7	*0.429*	*0.68*	0.201	0.063
TT34-CS-B		1/17/2007	-51.3	-50.5	0.5 (-51)	1.2 (-51.7)	3.8	25.4	9.24	0.148	0.03	0.111	0.018
TT-CS138-00-01	Replaces TT34-CS	1/11/2016	-51.3	-50.5	0 (-50.5)	1 (-51.5)	10.5	70.8	32.2	0.404	0.07	0.347	0.41
TT-CS138-01-02		1/11/2016	-51.3	-50.5	1 (-51.5)	2 (-52.5)	5.15	24.3	9.81	0.093	0.0817	0.0629	0.026
TT-CS138-02-03		1/11/2016	-51.3	-50.5	2 (-52.5)	3 (-53.5)	3.94	17.8	3.96	0.035	0.0065	0.0140	0.0079
Dry Docks Dredge Area													
SA8-A		9/1/1989	-34.4	-39.9	0 (-39.9)	2 (-41.9)	49	250 E	140 E	0.0033	**1.09**		
SA8-C		9/1/1989	-34.4	-39.9	2 (-41.9)	3.5 (-43.4)	44	110 E	32 E	0.0017	*0.235*		
SA8-D		9/1/1989	-34.4	-39.9	3.5 (-43.4)	5 (-44.9)	27	100 E	30 E	0.001	0.125		
SA9-A		9/1/1989	-40.2	-44.6	0 (-44.6)	2 (-46.6)	36	220 E	120 E	0.0038	*0.61*		
SA9-B		9/1/1989	-40.2	-44.6	2 (-46.6)	5 (-49.6)	20	93 E	20 E	0.001	0.143		
SA9-C		9/1/1989	-40.2	-44.6	9 (-53.6)	10.5 (-55.1)	23	71 E	61 E	0.001	*0.21*		
SA9-D		9/1/1989	-40.2	-44.6	10.5 (-55.1)	12 (-56.6)	20	62 E	15 E	0.0005 U	0.135 U		
D5-C	Replaced by TT09-CS	9/13/1989		-39.0	0 (-39)	4 (-43)	*64*	**1200 E**	**610 E**	0.032	**2.8**		**4.5 U**
D5-D		9/13/1989		-39.0	6 (-45)	12 (-51)	48	170 E	140 E	0.0008	*0.46*		
M1-C	Replaced by TT09-CS	9/12/1989		-36.6	0 (-36.6)	7.5 (-44.1)	**110**	**1300 E**	**2200 E**	0.011	**2.6**		
M1-D		9/12/1989		-36.6	7.5 (-44.1)	12.5 (-49.1)	*64*	100 E	71 E	0.0007	0.2 U		
SB1-A	Replaced by TT09-CS	9/12/1989		-43.2	0 (-43.2)	2 (-45.2)	**110**	**1900 E**	**550 E**	0.012	**5.9**		
SB1-C		9/12/1989		-43.2	2 (-45.2)	7.5 (-50.7)	42	110 E	**550 E**	0.011	**2.3**		
SB1-D		9/12/1989		-43.2	7.5 (-50.7)	13.5 (-56.7)	*82*	**700 E**	**680 E**	0.005	**2.16**		
TT05-SS		1/25/2007	-5.9	-30.7	0 (-30.7)	0.5 (-31.2)	12.6	118	68.4	**0.707**	*0.43*	*1.13*	0.34 D
TT94-SS	Dup of TT05-SS	1/25/2007	-5.9	-30.7	0 (-30.7)	0.5 (-31.2)	11.9	114	72.4	*0.572*	*0.3*	*1.21*	0.53 D
TT07-SS	Replaced by TT-CS124	1/25/2007	-5.7	-40.5	0 (-40.5)	0.5 (-41)	14	143	77.1	**0.796**	*0.445*	*1.45*	0.81 D
TT07-CS-B		1/16/2007	-5.7	-6.3	0.3 (-6.6)	1.3 (-7.6)	*58.4*	**1670**	401	**1.48**	**4.3**	**6.48**	**4.3 D**
TT07-CS-C		1/16/2007	-5.7	-6.3	1.3 (-7.6)	2.3 (-8.6)	47.8	**1760**	232	**0.772**	**2.4**	**4.46**	**3.2 D**
TT07-CS-D		1/16/2007	-5.7	-6.3	2.3 (-8.6)	3.3 (-9.6)	49	**1520**	236	**1.38**	**2.18**	**3.89**	**5.4 D**
TT07-CS-F		1/16/2007	-5.7	-6.3	4.2 (-10.5)	5.2 (-11.5)	48.4	**860**	**576**	**5.52**	**3.58**	**3.46**	0.2 D
TT07-CS-H		1/16/2007	-5.7	-6.3	6.2 (-12.5)	6.9 (-13.2)	14.4	223	117	**1.87**	*0.48*	**4.20**	0.36 D
TT-CS124-00-01D	Replaces TT07-CS	1/11/2016	-8.8	-11.3	0 (-11.3)	1 (-12.3)	44.8	**441**	113	*0.421*	**1.77**	*1.40*	0.85
TT-CS124-04-05D		1/11/2016	-8.8	-11.3	4 (-15.3)	5 (-16.3)	**102**	**913**	**611**	**6.23**	**4.42**	**3.25**	0.24
TT-CS124-05-06D		1/11/2016	-8.8	-11.3	5 (-16.3)	6 (-17.3)	22.1	110	143	0.394	*0.562*	0.478	0.028
TT-CS124-06-07D		1/11/2016	-8.8	-11.3	6 (-17.3)	7 (-18.3)	3.93	19.6	2.72	0.026	0.0021	0.00632	0.00059
TT-CS135-00-01-C		1/11/2016	-40.1	-26.1	0 (-26.1)	1 (-27.1)	42.4	250	79.1	*0.491*	*0.3721*	0.222	0.9
TT-CS135-01-02-C		1/11/2016	-40.1	-26.1	1 (-27.1)	2 (-28.1)	53.9	**575**	94.2	**0.874**	*0.3701*	**3.38**	**2.1**
TT-CS135-02-03-C		1/11/2016	-40.1	-26.1	2 (-28.1)	3 (-29.1)	*60.7*	**659**	142	*0.541*	*0.4151*	*1.86*	1.1
TT-CS135-2	Dup of TT-CS135-02-03	1/11/2016	-40.1	-26.1	0 (-26.1)	0 (-26.1)	*77.5*	**965**	248	0.332	*0.3611*	*1.95*	**1.7**
TT-CS135-04-05-C		1/11/2016	-40.1	-26.1	4 (-30.1)	5 (-31.1)	**367**	**1280**	**889**	**4.95**	**2.19**	**4.04**	0.33

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)							
TT-CS135-05-06-C		1/11/2016	-40.1	-26.1	5 (-31.1)	6 (-32.1)	**274**	**460**	446	**2.95**	**1.21**	*3.07*	0.0088
TT-CS135-08-09-C		1/11/2016	-40.1	-26.1	8 (-34.1)	9 (-35.1)	**134**	**1560**	**774**	**4.83**	**6.1**	**16.2**	**6.6**
TT-CS135-10_5-11_5B		1/11/2016	-39.3	-26.1	10.5 (-36.6)	11.5 (-37.6)	3.69	21.6	2.3	0.022	0.0021	0.00642	0.0016
TT-CS135-12_5-13_5B		1/11/2016	-39.3	-26.1	12.5 (-38.6)	13.5 (-39.6)	2.62	12.4	1.74	0.018	0.0042	0.00632	0.0021
TT09-CS-B		1/16/2007	-40.8	-39.8	0.2 (-40)	1.2 (-41)	29.9	**1240**	264	**7.33**	*0.82*	*2.19*	**9.1 D**
TT09-CS-C		1/16/2007	-40.8	-39.8	1.2 (-41)	2.1 (-41.9)	56.4	**707**	306	**2.41**	*0.49*	0.996	**1.7 D**
TT09-CS-E		1/16/2007	-40.8	-39.8	3.3 (-43.1)	4 (-43.8)	30.5	**640**	292	**4.74**	**1.34**	**9.1**	0.51 D
TT09-CS-G		1/16/2007	-40.8	-39.8	5.3 (-45.1)	6 (-45.8)	5.36	42.2	15.8	0.231	0.075	0.117	0.011
TT09-CS-I		1/16/2007	-40.8	-39.8	6.9 (-46.7)	7.9 (-47.7)	2.4	27.6	23.3	0.166	0.03	0.0310	0.00078 J
TT09-CS-K		1/16/2007	-40.8	-39.8	8.8 (-48.6)	9.8 (-49.6)	10	312	96.5	**2.44**	**1.3**	0.989	0.00008 U
TT09-CS-L		1/16/2007	-40.8	-39.8	9.8 (-49.6)	10.4 (-50.2)	26.8	**865**	266	**8.51**	*0.182*	**3.36**	0.00052 J
TT09-CS-M		1/16/2007	-40.8	-39.8	10.4 (-50.2)	11.7 (-51.5)	6.25	33.3	11.5	0.188	0.0052	0.0437	0.000082 U
TT13-SS		1/26/2007	-45.2	-44.5	0 (-44.5)	0.5 (-45)	14.7	107	83.9	**0.71 ***	*0.311*	0.644	0.11
TT15-SS		1/25/2007	-46.2	-44.6	0 (-44.6)	0.5 (-45.1)	*74.1*	**1900**	132	**0.675**	*0.52*	*1.18*	**2.8 D**
TT15-CS-B		1/18/2007	-46.2	-45.3	0.5 (-45.8)	1.3 (-46.6)	**117**	**2280**	**577**	**17.1**	**8.89**	**6.35**	**8.1 D**
TT15-CS-C		1/18/2007	-46.2	-45.3	1.3 (-46.6)	1.9 (-47.2)	**94.7**	**699**	207	**4.43**	**9.62**	*3.01*	0.23 D
TT15-CS-G		1/18/2007	-46.2	-45.3	4.3 (-49.6)	4.8 (-50.1)	41.1	153	155	**0.933**	*0.215*	0.304	0.00064 J
TT15-CS-H		1/18/2007	-46.2	-45.3	4.8 (-50.1)	5.5 (-50.8)	18.1	61.3	56.7	0.315	0.03	0.383	0.0053
TT16-SS		1/25/2007	-38.6	-38.1	0 (-38.1)	0.5 (-38.6)	21.4	222	128	**0.993**	*0.47*	1.03	**1.9 D**
TT16-CS-B		1/22/2007	-38.6	-37.8	0.5 (-38.3)	1.3 (-39.1)	13.1	43.8	35.4	**2.74 ***	*0.29*	0.857	0.88 D
TT16-CS-C		1/22/2007	-38.6	-37.8	1.3 (-39.1)	2.2 (-40)	19	43.5	44.1	0.063 *	0.0204	0.0393	0.0062
TT16-CS-D		1/22/2007	-38.6	-37.8	2.2 (-40)	3.1 (-40.9)	2.26	15.8	2.35	0.021 *	0.0023 U	0.0034 U	0.001 J
TT16-CS-I		1/22/2007	-38.6	-37.8	6.8 (-44.6)	7.7 (-45.5)	2.32	16.2	1.86	0.025 *	0.0023 U	0.0034 U	0.000076 U
TT17-SS		1/25/2007	-41.8	-43.7	0 (-43.7)	0.5 (-44.2)	*71.5*	**661**	248	**2.94**	**2.24**	*2.91*	**4.1 D**
TT17-CS-B		1/12/2007	-41.8	-42.3	1.1 (-43.4)	2.09 (-44.4)	*83*	**2350**	**616**	**2.88**	**2**	**7.66**	**5.3 D**
TT17-CS-C		1/12/2007	-41.8	-42.3	2.1 (-44.4)	2.9 (-45.2)	**108**	**1160**	371	**3.45**	**1.8**	*2.93*	**2.3 D**
TT17-CS-D		1/12/2007	-41.8	-42.3	2.9 (-45.2)	4 (-46.3)	**123**	**1730**	410	**6.96**	**2.1**	*2.12*	0.28 D
TT17-CS-F		1/12/2007	-41.8	-42.3	4.9 (-47.2)	5.89 (-48.2)	**130**	**1040**	*522*	**8.95**	**3.6**	**5.02**	0.037
TT17-CS-H		1/12/2007	-41.8	-42.3	6.8 (-49.1)	7.79 (-50.1)	5.15	27.8	9.07	0.225	0.023	0.0709	0.0014
TT17-CS-J		1/12/2007	-41.8	-42.3	8.7 (-51)	9.5 (-51.8)	3.43	24.2	4.49	0.09	0.015	0.0260	0.0055
TT18-SS	Replaced by TT-C121	1/25/2007	-34.5	-10.1	0 (-10.1)	0.8 (-10.9)	4.87	66.6	20.3	0.117	0.114	0.325	0.028
TT18-CS-B		1/15/2007	-34.5	-34.6	0.5 (-35.1)	1.5 (-36.1)	**224**	**666**	*513*	**9.74**	**2.55**	*1.71*	0.39 D
TT18-CS-C		1/15/2007	-34.5	-34.6	1.5 (-36.1)	2.4 (-37)	*59.7*	349	232	**4.42**	*0.88*	*1.94*	0.13 D
TT18-CS-D		1/15/2007	-34.5	-34.6	2.4 (-37)	3.4 (-38)	4.54	20.9	8.98	0.082	0.029	0.0459	0.012
TT18-CS-E		1/15/2007	-34.5	-34.6	3.4 (-38)	4.4 (-39)	4.69	66.2	17.6	*0.564*	0.044	0.199	0.0023
TT-CS121-00-01	Replaces TT18	1/18/2016	-34.2	-34.9	0 (-34.9)	1 (-35.9)	*61.4*	**915**	402	**5.57**	**2.83**	*3.19*	**7.5**
TT-CS121-01-02		1/18/2016	-34.2	-34.9	1 (-35.9)	2 (-36.9)	**428**	**696**	**853**	**4.08**	**3.02**	*2.55*	0.0084
TT-CS121-04-05		1/18/2016	-34.2	-34.9	4 (-38.9)	5 (-39.9)	4.9	25.1	11.4	0.067	0.0423	0.0382	0.0047
TT-CS121-05-06		1/18/2016	-34.2	-34.9	5 (-39.9)	6 (-40.9)	11	**396**	83.1	*0.559*	0.0587	0.289	0.046
TT-CS121-2	Dup of TT-CS121-05-06	1/18/2016	-34.2	-34.9	0 (-34.9)	0 (-34.9)	10.2	157	33.8	*0.495*	0.056	0.259	0.032
TT-CS121-06-07		1/18/2016	-34.2	-34.9	6 (-40.9)	7 (-41.9)	2.44	9.41	1.77	0.052	0.0021	0.0104	
TT-CS121-07-08		1/18/2016	-34.2	-34.9	7 (-41.9)	8 (-42.9)	4.06	17.7	3.33	0.047	0.0021	0.00632	
TT-CS121-08-09		1/18/2016	-34.2	-34.9	8 (-42.9)	9 (-43.9)	3.23	15.8	3.29	0.043	0.0021	0.0143	
TT40-SS		1/26/2007	-31.2	-31.2	0 (-31.2)	0.8 (-32)	**114**	**442**	350	**1.57 ***	**2.05**	*1.16*	1.2 D
TT41-SS		1/25/2007	-32.2	-32.2	0 (-32.2)	0.8 (-33)	21.1	148	80.5	**0.837**	*0.866*	0.505	0.47 D

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location													
TT-CS120-00-01		1/19/2016	-28.9	-23.5	0 (-23.5)	1 (-24.5)	14.1	75.5	68.7	0.144	0.092	0.315	0.35
TT-CS120-01-02		1/19/2016	-28.9	-23.5	1 (-24.5)	2 (-25.5)	18.6	73.6	34.7	0.049	0.0342	0.131	0.15
TT-CS120-2	Dup of TT-CS120-01-02	1/19/2016	-28.9	-23.5	0 (-23.5)	0 (-23.5)	20.7	59.1	36.3	0.038	0.0389	0.137	0.15
TT-CS120-06-07		1/19/2016	-28.9	-23.5	6 (-29.5)	7 (-30.5)	2.84	13.3	1.84	0.015	0.0021	0.00632	0.00056
TT-CS122-00-01		1/15/2016	-30.3	-29.5	0 (-29.5)	1 (-30.5)	30.8	281	141	**0.671**	**1.154**	*1.76*	**2.1**
TT-CS122-01-02		1/15/2016	-30.3	-29.5	1 (-30.5)	2 (-31.5)	**123**	**886**	**542**	**2.44**	**3.47**	**9.02**	1.2
TT-CS122-02-03		1/15/2016	-30.3	-29.5	2 (-31.5)	3 (-32.5)	*79.1*	**508**	364	**4.83**	**3.231**	*2.40*	0.0052
TT-CS122-2	Dup of TT-CS122-02-03	1/15/2016	-30.3	-29.5	0 (-29.5)	0 (-29.5)	**106**	**476**	352	**4.97**	**5.24**	**3.31**	0.0041
TT-CS122-04-05		1/15/2016	-30.3	-29.5	4 (-33.5)	5 (-34.5)	4.13	50.7	11.5	**0.712**	0.0202	0.477	0.00056
TT-CS122-05-06		1/15/2016	-30.3	-29.5	5 (-34.5)	6 (-35.5)	4.65	88.4	7.62	0.267	0.0249	0.0696	
TT-CS122-06-07		1/15/2016	-30.3	-29.5	6 (-35.5)	7 (-36.5)	3.92	26.9	4.21	0.057	0.0021	0.0158	
TT-CS122-07-08		1/15/2016	-30.3	-29.5	7 (-36.5)	8 (-37.5)	2.8	11.6	1.73	0.017	0.0021	0.00632	
TT-CS123-00-01		1/12/2016	-18.0	-24.8	0 (-24.8)	1 (-25.8)	6.22	34.2	6.88	0.071	0.0551	0.133	0.16
TT-CS123-01-02		1/12/2016	-18.0	-24.8	1 (-25.8)	2 (-26.8)	5.17	15.4	6.69	0.023	0.0063	0.006391	0.00064
TT-CS123-02-03		1/12/2016	-18.0	-24.8	2 (-26.8)	3 (-27.8)	3.43	10.3	1.35	0.013	0.0063	0.006321	0.00067
TT-CS123-09-10		1/12/2016	-18.0	-24.8	9 (-33.8)	10 (-34.8)	2.99	10.8	2.13	0.011	0.0021	0.006321	0.00055
TT-CS123-2	Dup of TT-CS-123-09-10	1/12/2016	-18.0	-24.8	0 (-24.8)	0 (-24.8)	4.54	12.2	2.51	0.014	0.0021	0.006321	0.00056
TT-CS119-00-01		1/19/2016	-25.2	-22.6	0 (-22.6)	1 (-23.6)	**143**	338	**605**	**1.08**	**4.29**	*1.53*	0.018
TT-CS119-01-02		1/19/2016	-25.2	-22.6	1 (-23.6)	2 (-24.6)	22.3	157	306	**0.895**	**3.93**	0.854	0.0081
TT-CS119-02-03		1/19/2016	-25.2	-22.6	2 (-24.6)	3 (-25.6)	4.74	31.1	24.3	0.24	0.0641	0.304	
TT-CS119-03-04		1/19/2016	-25.2	-22.6	3 (-25.6)	4 (-26.6)	9.12	23.9	12.5	0.068	0.0085	0.00785	
TT-CS119-04-05		1/19/2016	-25.2	-22.6	4 (-26.6)	5 (-27.6)	1.89	7.43	1.46	0.009	0.0021	0.0219	
TT-CS133-00-01		1/15/2016	-36.5	-36.9	0 (-36.9)	1 (-37.9)	**630**	**968**	**1580**	**1.14**	**3.44**	*1.30*	0.68
TT-CS133-01-02		1/15/2016	-36.5	-36.9	1 (-37.9)	2 (-38.9)	**255**	**474**	*495*	**0.992**	**1.06**	*1.61*	0.2
TT-CS133-2	Dup of TT-CS133-01-02	1/15/2016	-36.5	-36.9	0 (-36.9)	0 (-36.9)	**498**	**717**	**620**	**6.11**	**1.08**	*1.27*	0.11
TT-CS133-02-03		1/15/2016	-36.5	-36.9	2 (-38.9)	3 (-39.9)	32.9	73.8	63.4	**0.833**	0.0445	0.408	0.025
TT-CS133-03-04		1/15/2016	-36.5	-36.9	3 (-39.9)	4 (-40.9)	6.61	30.6	13.4	0.254	0.0438	0.288	0.00059
TT-CS133-04-05		1/15/2016	-36.5	-36.9	4 (-40.9)	5 (-41.9)	1.92	9.9	3.92	0.029	0.0021	0.00931	0.00054
TT-CS133-05-06		1/15/2016	-36.5	-36.9	5 (-41.9)	6 (-42.9)	4.58	11.1	4.79	0.007	0.0021	0.00632	0.00056
TT-CS134-00-01		1/19/2016	-26.3	-25.8	0 (-25.8)	1 (-26.8)	**114**	**1600**	*474*	**1.83**	**4.31**	**9.94**	**17**
TT-CS134-01-02		1/19/2016	-26.3	-25.8	1 (-26.8)	2 (-27.8)	**493**	**658**	**1140**	**3.99**	**6.3**	**3.56**	0.47
TT-CS134-02-03		1/19/2016	-26.3	-25.8	2 (-27.8)	3 (-28.8)					**3.1**	**3.75**	
TT-CS134-04-05		1/19/2016	-26.3	-25.8	4 (-29.8)	5 (-30.8)					**3.06**	*2.87*	
TT-CS134-05-06		1/19/2016	-26.3	-25.8	5 (-30.8)	6 (-31.8)	53.2	319	204	**2.82**	*0.257*	**5.33**	0.0058
TT-CS134-06-07		1/19/2016	-26.3	-25.8	6 (-31.8)	7 (-32.8)	8.15	140	39.7	**1.7**	0.07	*1.51*	0.00061
TT-CS134-07-08		1/19/2016	-26.3	-25.8	7 (-32.8)	8 (-33.8)	3.89	22.9	4.79	0.099	0.041	0.0215	0.00058
TT-CS134-10-11		1/19/2016	-26.3	-25.8	10 (-35.8)	11 (-36.8)	3.47	15.9	2.57	0.025	0.0021	0.00632	0.00057
Former Shipway Dredge Area													
TT-CS101-0-3		1/7/2016		9.8	0 (9.8)	3 (6.8)	*71.9*	211	53.4	0.006	0.0021	0.0343	0.021
TT-CS102-0-3		1/7/2016		9.7	0 (9.7)	3 (6.7)	*71*	258	49.8	0.016	0.0025	*3.12*	0.006
TT-CS103-00-01		1/18/2016	0.7	-0.6	0 (-0.6)	1 (-1.6)	**293**	142	291	0.049	0.06	*1.73*	0.0033
TT-CS103-01-02		1/18/2016	0.7	-0.6	1 (-1.6)	2 (-2.6)	29.1	51.1	74	0.155	0.093	**36.9**	0.0007
TT-CS103-2	Dup of TT-CS103-01-02	1/18/2016	0.7	-0.6	0 (-0.6)	0 (-0.6)	31.6	62.6	72.7	0.344	0.106	**38.7**	0.00074
TT-CS104-00-01		1/18/2016	-2.2	-3.7	0 (-3.7)	1 (-4.7)	10.8	29.4	16.8	0.048	0.036	**7.25**	0.0024
TT-CS104-01-02		1/18/2016	-2.2	-3.7	1 (-4.7)	2 (-5.7)	12.5	40	14.2	0.047	0.0021	0.0414	0.00086

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)							
TT-CS105-00-01		1/14/2016	-5.6	-6.3	0 (-6.3)	1 (-7.3)	**158**	288	375	*0.481*	*0.58*	**6.54**	0.74
TT-CS105-02-03		1/14/2016	-5.6	-6.3	2 (-8.3)	3 (-9.3)	**384**	**1190**	341	0.056	*0.197*	*1.26*	0.27
TT-CS105-03-04		1/14/2016	-5.6	-6.3	3 (-9.3)	4 (-10.3)	**260**	**1190**	222	0.064	*0.211*	*1.39*	0.17
TT-CS105-04-05		1/14/2016	-5.6	-6.3	4 (-10.3)	5 (-11.3)	**143**	**1110**	173	0.102	*0.296*	*1.48*	0.21
TT-CS106-00-01		1/19/2016	-6.1	-6.0	0 (-6)	1 (-7)	*67.9*	**541**	358	0.299	*0.606*	**8.13**	0.92
TT-CS106-01-02		1/19/2016	-6.1	-6.0	1 (-7)	2 (-8)	**696**	**420**	**902**	*0.549*	**1.49**	**13.0**	0.13
TT-CS106-2	Dup of TT-CS-106-01-02	1/19/2016	-6.1	-6.0	1 (-7)	2 (-8)	**288**	309	*490*	*0.557*	**1.57**	**19.4**	0.41
TT-CS107-00-01		1/14/2016	-24.9	-26.2	0 (-26.2)	1 (-27.2)	43.2	176	172	0.309	*0.264*	**5.85**	0.33
TT-CS107-03-04		1/14/2016	-24.9	-26.2	3 (-29.2)	4 (-30.2)	5.96	25.8	11.6	0.074	0.039	0.502	0.00063
TT-CS107-06-07		1/14/2016	-24.9	-26.2	6 (-32.2)	7 (-33.2)	6.15	64.3	78.7	**0.647**	0.0024	**6.23**	0.00096
TT-CS108-00-01		1/14/2016	-23.6	-25.8	0 (-25.8)	1 (-26.8)	16.9	87.5	54.8	0.205	0.079	**5.65**	0.067
TT-CS108-03-04		1/14/2016	-23.6	-25.8	3 (-28.8)	4 (-29.8)	12.4	66	48.6	*0.495*	0.101	*1.86*	0.0011
TT-CS108-2	Dup of TT-CS108-03-04	1/14/2016	-23.6	-25.8	3 (-28.8)	4 (-29.8)	12.1	61.7	37.1	*0.444*	0.1	*1.69*	0.0007
TT-CS108-06-07		1/14/2016	-23.6	-25.8	6 (-31.8)	7 (-32.8)	7.53	40.4	60.7	**0.63**	0.0021	**6.80**	0.00078
TT-IT-07		4/20/2007		1.3	0 (1.3)	0.5 (0.8)	**152**	**975**	213	0.049 *	0.017	0.170	0.057
TT-IT-08		4/20/2007		4.7	0 (4.7)	0.5 (4.2)	**158**	**1310**	251	0.05 *	0.012	0.162	0.056
TT-IT-09		4/20/2007		6.5	0 (6.5)	0.5 (6)	**197**	**774**	268	0.022 *	0.014	0.184	0.036
Pier 25 Dredge Area													
TT-IT-06		4/20/2007		-1.2	0 (-1.2)	0.5 (-1.7)	**330**	**1060**	399	0.021 *	0.0042	0.344	0.028
Pier 24 Dredge Area													
TT-CS109-00-01		1/20/2016	-23.8	-23.3	0 (-23.3)	1 (-24.3)	44.1	153	102	0.136	*0.571*	0.904	0.47
TT-CS109-01-02		1/20/2016	-23.8	-23.3	1 (-24.3)	2 (-25.3)	*68.6*	**416**	233	0.253	*0.275*	*1.10*	1.3
TT-CS109-02-03		1/20/2016	-23.8	-23.3	2 (-25.3)	3 (-26.3)	**161**	**769**	**1270**	*0.426*	**1.44**	0.935	0.75
TT-CS109-04-05		1/20/2016	-23.8	-23.3	4 (-27.3)	5 (-28.3)	**103**	46.7	91.3	0.009	0.0088	0.00834	0.00057
Pier 23 Dredge Area													
TT-SS114-00-005		1/8/2016	-25.4	-31.4	0 (-31.4)	0.5 (-31.9)	**338**	200	277	0.118	0.0901	0.752	0.056
TT20-SS		1/25/2007	-27.7	-27.7	0 (-27.7)	0.5 (-28.2)	30.4	173	106	0.325	*0.217*	0.582	0.16 D
TT-CS112-00-01		1/7/2016	-29.2	-27.7	0 (-27.7)	1 (-28.7)	**213**	212	235	0.372	*0.2477*	0.563	0.048
TT-CS112-01-02		1/7/2016	-29.2	-27.7	1 (-28.7)	2 (-29.7)	37.2	65.8	48.1	0.289	0.0764	0.395	0.0065
TT-CS112-2	Dup of TT-CS112-01-02	1/7/2016	-29.2	-27.7	0 (-27.7)	0 (-27.7)	52.7	73.6	60.1	*0.49*	0.0879	0.512	0.011
TT-CS112-02-03		1/7/2016	-29.2	-27.7	2 (-29.7)	3 (-30.7)	8.15	21.9	14.1	0.102	0.038	0.0643	0.0021
TT-SS113-00-005		1/8/2016	-26.0	-26.8	0 (-26.8)	0.5 (-27.3)	*61.5*	238	184	0.111	*0.3491*	0.465	0.27
Shoreline Removal Areas													
TT-CS126B-00-01		1/20/2016	-5.7	-7.7	0 (-7.7)	1 (-8.7)	28.2	204	154	**1.38**	*0.184*	0.263	0.063
TT-CS126B-01-02		1/20/2016	-5.7	-7.7	1 (-8.7)	2 (-9.7)	48.3	308	227	**2.02**	*0.586*	0.283	0.12
TT-CS126B-02-03		1/20/2016	-5.7	-7.7	2 (-9.7)	3 (-10.7)	40.5	335	191	**1.82**	*0.64*	0.523	0.044
ENR Area													
D3-A		9/5/1989	-30.4	-41.6	0 (-41.6)	2 (-43.6)	46	210 E	100 E	0.0008	*0.246*		
D3-B		9/5/1989	-30.4	-41.6	2 (-43.6)	4.5 (-46.1)	50	68 E	28 E	0.0005 U	0.16		
D3-C		9/5/1989	-30.4	-41.6	10.5 (-52.1)	12.5 (-54.1)	23	26 E	11 E	0.0005 U	0.12 U		
D3-D		9/5/1989	-30.4	-41.6	13 (-54.6)	15 (-56.6)	26	22 E	6.7 E	0.0005 U	0.12 U		
D4-S		8/31/1989	-53.2	-49.0	0 (-49)	0.5 (-49.5)	21	87 E	24 E	0.0008	*0.195*		
D4-D		9/8/1989	-53.2	-49.0	0 (-49)	9.5 (-58.5)	47	43 E	14 E	0.0005 U	0.093		
SA2-S		8/31/1989	-27.8	-25.4	0 (-25.4)	0.8 (-26.2)	40	140 E	160 E	0.0013	*0.202*		
SA2-C		8/29/1989	-27.8	-25.4	0 (-25.4)	1 (-26.4)	11	150 E	150 E	0.0019	*0.329*		

Site Area/Sample Location	Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
					CSL	93	390	530	0.59	0.96	3.2	1.335
					SQS	57	390	450	0.41	0.18	1.1	1.335
					Clean up Level	7	114	11	0.41	0.002	0.009	430
SA2-D	8/29/1989	-27.8	-25.4	2 (-27.4)	5 (-30.4)	40	64 E	31 E	0.0011	0.12 U		
SA3-A	8/30/1989	-3.5	-19.7	0 (-19.7)	2 (-21.7)	*71*	150 E	160 E	0.0006	0.136		
SA3-B	8/30/1989	-3.5	-19.7	2 (-21.7)	4.5 (-24.2)	31	77 E	58 E	0.0005	0.13		
SA3-C	8/30/1989	-3.5	-19.7	5 (-24.7)	7.5 (-27.2)	3.9	38 E	38 E	0.0005 U	0.12 U		
SA3-D	8/30/1989	-3.5	-19.7	8 (-27.7)	10.5 (-30.2)	1.6	40 E	6.1 E	0.0005 U	0.12 U		
SA4-C	8/30/1989	-33.3	-29.7	0 (-29.7)	2 (-31.7)	3.6	63 E	53 E	0.0005	0.131		
SA4-D	8/30/1989	-33.3	-29.7	2 (-31.7)	4.5 (-34.2)	7.5	42 E	3.7 E	0.0005 U	0.12 U		
SA5-A	8/31/1989	-28.1	-37.7	0 (-37.7)	2 (-39.7)	37	91 E	18 E	0.0005	0.121		
SA5-C	8/31/1989	-28.1	-37.7	2 (-39.7)	4.5 (-42.2)	36	77 E	18 E	0.0005 U	0.12 U		
SA5-D	8/31/1989	-28.1	-37.7	4.5 (-42.2)	7.5 (-45.2)	38	40 E	13 E	0.0005 U	0.12 U		
SA6-S	8/31/1989	-22.9	-42.3	0 (-42.3)	0.8 (-43.1)	52	160 E	80 E	0.0005	0.132		0.19 U
SA6-C	8/31/1989	-22.9	-42.3	0 (-42.3)	1.5 (-43.8)	43	160 E	46 E	0.0005 U	0.135 U		
SA6-D	8/31/1989	-22.9	-42.3	1.5 (-43.8)	3 (-45.3)	28	50 E	6 E	0.0005	0.12 U		
SA7-A	8/31/1989	-42.3	-31.8	0 (-31.8)	2 (-33.8)	55	100 E	35 E	0.0005 U	0.125		
SA7-B/C	8/31/1989	-42.3	-31.8	2 (-33.8)	6 (-37.8)	*58*	61 E	13 E	0.0005 U	0.125		
SA7-D	8/31/1989	-42.3	-31.8	7.5 (-39.3)	9 (-40.8)	*70*	72 E	9 E	0.0006	0.12 U		
SA10-S	8/31/1989	-17.2	-21.4	0 (-21.4)	0.5 (-21.9)	33	160 E	130 E	0.0018	*0.59*		
SA10-A	9/16/1989	-17.2	-21.4	0 (-21.4)	2 (-23.4)	28	150 E	63 E	0.0039	*0.26*		
SA10-B	9/16/1989	-17.2	-21.4	2 (-23.4)	5 (-26.4)	36	38 E	13 E	0.0009	*0.23*		
SA10-C	9/16/1989	-17.2	-21.4	9 (-30.4)	10.5 (-31.9)	42	39 E	7 E	0.0005	0.12 U		
SA10-D	9/16/1989	-17.2	-21.4	10.5 (-31.9)	12 (-33.4)	28	26 E	5.8 E	0.0005 U	0.12 U		
TT01-SS	1/24/2007	-30.0	-38.1	0 (-38.1)	0.5 (-38.6)	7.88	64	39.8	0.299	0.149	0.621	0.16 D
TT01-CS-A	1/19/2007	-30.0	-33.0	0 (-33)	0.5 (-33.5)	2.3	10.9 *	3.26	0.028	0.07	0.0204	0.011
TT01-CS-B	1/19/2007	-30.0	-33.0	0.8 (-33.8)	1.6 (-34.6)	2.42	14.5 *	1.8	0.02	0.0023 U	0.0034 U	0.000075 U
TT01-CS-C	1/19/2007	-30.0	-33.0	1.6 (-34.6)	2.4 (-35.4)	2.39	15.3 *	1.76	0.018 B	0.0024 U	0.0034 U	0.000074 U
TT02-SS	1/24/2007	-38.4	-40.3	0 (-40.3)	0.8 (-41.1)	9.05	71.4	51	0.374	0.15	0.391	0.23 D
TT02-CS-B	1/18/2007	-38.4	-39.8	0.5 (-40.3)	1.3 (-41.1)	5.36	27.8 *	6.64	0.079	0.0062	0.00212	0.002
TT02-CS-C	1/18/2007	-38.4	-39.8	1.3 (-41.1)	2.2 (-42)	3.04	13.5 *	1.93	0.016 B	0.0024 U	0.0035 U	0.000077 U
TT02-CS-D	1/18/2007	-38.4	-39.8	2.2 (-42)	3 (-42.8)	2.54	13.4 *	1.9	0.02	0.0024 U	0.0034 U	0.000076 U
TT03-CS-B	1/18/2007	-16.7	-18.0	0.5 (-18.5)	1.3 (-19.3)	3.18	14.4 *	21.3	0.158	0.022	0.0692	0.0032
TT03-CS-C	1/18/2007	-16.7	-18.0	1.3 (-19.3)	1.9 (-19.9)	7.93	8.9 *	8.31	0.033	0.0119	0.0369	0.00057 J
TT03-CS-D	1/18/2007	-16.7	-18.0	1.9 (-19.9)	2.4 (-20.4)	1.39	8.6 *	6.54	0.029	0.0059	0.0295	0.00054 J
TT05-CS-A	1/12/2007	-5.9	-6.1	0 (-6.1)	0.9 (-7)	3.91	41.9	27.5	0.143	0.0896	0.367	0.036
TT05-CS-B	1/12/2007	-5.9	-6.1	0.9 (-7)	1.8 (-7.9)	4.28	55.5	31.1	0.312	0.0756	0.160	0.02
TT05-CS-C	1/12/2007	-5.9	-6.1	1.8 (-7.9)	2.6 (-8.7)	3.34	44.2	44.5	0.297	0.029	0.212	0.0022
TT05-CS-E	1/12/2007	-5.9	-6.1	3.5 (-9.6)	4.3 (-10.4)	1.9	12.7	13.2	0.087	0.0105	0.112	0.000072 U
TT05-CS-G	1/12/2007	-5.9	-6.1	5.1 (-11.2)	5.9 (-12)	1.11	10.6	5.55	0.021	0.0022 U	0.00568	0.00024 Ui
TT12-SS	1/26/2007	-42.4	-42.9	0 (-42.9)	0.8 (-43.7)	18.3	111	80.9	**0.636 ***	*0.257*	0.610	0.19 D
TT12-CS-B	1/15/2007	-42.4	-42.3	0.5 (-42.8)	1.5 (-43.8)	9.03	44	23.8	0.404	0.079	0.0984	0.013
TT12-CS-C	1/15/2007	-42.4	-42.3	1.5 (-43.8)	2.4 (-44.7)	4.92	22.1	11.1	0.091	0.036	0.0410	0.0074
TT12-CS-D	1/15/2007	-42.4	-42.3	2.4 (-44.7)	3.3 (-45.6)	2.91	16.2	3.11	0.043	0.0245	0.0162	0.0018
TT12-CS-E	1/15/2007	-42.4	-42.3	3.3 (-45.6)	4.2 (-46.5)	2.02	13.2	2.52	0.03	0.0024 U	0.00878	0.00029 J
TT13-CS-A	1/19/2007	-45.2	-45.5	0 (-45.5)	0.7 (-46.2)	6.09	63.4	15.1	0.225	0.058	0.0643	0.016
TT13-CS-B	1/19/2007	-45.2	-45.5	0.7 (-46.2)	1.2 (-46.7)	3.36	20.4	2.53	0.026	0.0025 U	0.0037 U	0.00029 J
TT13-CS-C	1/19/2007	-45.2	-45.5	1.2 (-46.7)	1.8 (-47.3)	3.07	20.2	2.38	0.03	0.0025 U	0.0037 U	0.000082 U

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)							
TT14-SS		1/25/2007	-25.2	-25.3	0 (-25.3)	0.8 (-26.1)	12.4	73.2	46.5	0.14	0.134	*1.93*	0.1
TT14-CS-B		1/13/2007	-25.2	-26.9	0.6 (-27.5)	1.5 (-28.4)	25.7	287	235	0.264	*0.38*	*1.41*	0.82 D
TT14-CS-C		1/13/2007	-25.2	-26.9	1.5 (-28.4)	2.3 (-29.2)	**112**	**558**	450	**2.28**	**2.4**	*1.59*	0.39 D
TT14-CS-J		1/13/2007	-25.2	-26.9	7.5 (-34.4)	8 (-34.9)	3.89	24.7	13.8	0.227	0.062	0.422	0.00086 J
TT14-CS-L		1/13/2007	-25.2	-26.9	8.8 (-35.7)	9.6 (-36.5)	5.27	30.2	16.8	*0.412*	0.0055 U	0.360	0.00021 Ui
TT90-CS-A	Dup of TT14-CS-B	1/13/2007	-25.2	-26.9	0.6 (-27.5)	1.5 (-28.4)	18.6	287	94.1	0.229	*0.41*	0.846	0.67 D
TT90-CS-B	Dup of TT14-CS-C	1/13/2007	-25.2	-26.9	1.5 (-28.4)	2.3 (-29.2)	**127**	**500**	**561**	**1.76**	**1.96**	*2.45*	0.44 D
TT90-CS-C	Dup of TT14-CS-J	1/13/2007	-25.2	-26.9	7.5 (-34.4)	8 (-34.9)	4.85	22.7	23	*0.44*	0.034	0.375	0.0031
TT19-SS		1/25/2007	-32.9	-33.1	0 (-33.1)	0.5 (-33.6)	12.8	115	73.5	0.306	*0.22*	*1.19*	0.25 D
TT19-CS-A		1/15/2007	-32.9	-33.3	0 (-33.3)	0.7 (-34)	17.6	114	72.1	0.252	0.17	0.750	0.16 D
TT19-CS-B		1/15/2007	-32.9	-33.3	0.7 (-34)	1.3 (-34.6)	18.5	146	80.8	0.255	*0.251*	0.701	**1.4 D**
TT19-CS-C		1/15/2007	-32.9	-33.3	1.3 (-34.6)	1.65 (-35)	15.4	72.3	94.1	0.163	*0.192*	0.185	0.046
TT19-CS-D		1/15/2007	-32.9	-33.3	1.7 (-35)	2.5 (-35.8)	7.22	40.8	40.1	0.058	0.131	0.0650	0.047
TT19-CS-E		1/15/2007	-32.9	-33.3	2.5 (-35.8)	3.1 (-36.4)	2.64	15.8	2.59	0.1	0.0023 U	0.00561	0.003
TT91-CS-A	Dup of TT19-CS-A	1/15/2007	-32.9	-33.3	0 (-33.3)	0.7 (-34)	21.2	119	78.3	0.294	*0.23*	0.825	0.18 D
TT91-CS-B	Dup of TT19-CS-B	1/15/2007	-32.9	-33.3	0.7 (-34)	1.3 (-34.6)	20.1	165	167	0.27	*0.34*	0.554	0.77 D
TT21-SS		1/25/2007	-32.1	-32.1	0 (-32.1)	0.5 (-32.6)	23.6	127	76.8	0.215	*0.205*	0.671	0.18 D
TT22-SS		1/25/2007	-43.4	-46.5	0 (-46.5)	0.5 (-47)	7.23	64.7	32.7	0.308	*0.46*	0.417	0.2 D
TT22-CS-B		1/12/2007	-43.4	-43.6	0.5 (-44.1)	1.4 (-45)	7.31	44.7	8.81	0.083	0.003 U	0.00970	0.0016 J
TT22-CS-C		1/12/2007	-43.4	-43.6	1.4 (-45)	2.3 (-45.9)	3.99	24.3	4.17	0.088	0.0026 U	0.00771	0.0016
TT22-CS-D		1/12/2007	-43.4	-43.6	2.3 (-45.9)	3.2 (-46.8)	3.12	19.4	2.93	0.041	0.0024 U	0.00643	0.00021 Ui
TT23-SS		1/26/2007	-42.9	-45.3	0 (-45.3)	0.5 (-45.8)	4.66	33.4	15.9	0.138 *	0.054	0.188	0.042
TT23-CS-B		1/10/2007	-42.9	-44.8	0.8 (-45.6)	1.58 (-46.4)	3.63	26.8	5.1	0.03	0.0046	0.0112	0.0018
TT23-CS-C		1/10/2007	-42.9	-44.8	1.6 (-46.4)	2.33 (-47.1)	2.77	23.4	3.23	0.018 B	0.0022 U	0.0033 U	0.0004 Ui
TT23-CS-H		1/10/2007	-42.9	-44.8	5.3 (-50.1)	6.2 (-51)	2.34	16.1	2.05	0.018	0.0023 U	0.0033 U	0.000074 U
TT24-SS		1/25/2007	-26.3	-27.0	0 (-27)	0.5 (-27.5)	5.58	33.5	17	0.22	0.048	0.384	0.0089
TT24-CS-B		1/10/2007	-26.3	-28.7	0.6 (-29.3)	1.9 (-30.6)	2.49	23.5	6.64	0.074	0.0258	0.0491	0.0015
TT24-CS-C		1/10/2007	-26.3	-28.7	1.9 (-30.6)	3 (-31.7)	7.96	81	52	*0.451*	*0.58*	0.700	0.0088
TT24-CS-E		1/10/2007	-26.3	-28.7	3.7 (-32.4)	4.7 (-33.4)	3.58	27.5	10.5	0.13	0.013 U	0.118	0.00098 J
TT24-CS-H		1/10/2007	-26.3	-28.7	6.4 (-35.1)	7.2 (-35.9)	5.21	38.6	16	0.22	0.014 U	0.131	0.000087 U
TT25-SS		1/25/2007	-24.6	-26.3	0 (-26.3)	0.5 (-26.8)	11.1	90.1	50.7	0.094	*0.202*	*1.75*	0.14
TT25-CS-B		1/12/2007	-24.6	-26.0	0.3 (-26.3)	0.9 (-26.9)	19.1	105	123	**0.712**	*0.223*	*1.55*	0.019
TT25-CS-C		1/12/2007	-24.6	-26.0	0.9 (-26.9)	1.5 (-27.5)	12.6	77.9	62.5	*0.577*	0.122	*1.61*	0.003
TT25-CS-J		1/12/2007	-24.6	-26.0	5.3 (-31.3)	6 (-32)	4.57	32	14.1	0.162	0.0041	0.0861	0.000079 U
TT25-CS-L		1/12/2007	-24.6	-26.0	6.6 (-32.6)	7.2 (-33.2)	10	64.7	80.9	**0.733**	*0.211*	**6.73**	
TT26-SS		1/25/2007	-30.1	-23.7	0 (-23.7)	0.5 (-24.2)	13	114	61.3	0.094	0.071	*2.6*	0.052
TT26-CS-B		1/12/2007	-30.1	-27.6	0.7 (-28.3)	1.4 (-29)	38.7	200	115	0.156	0.162	0.950	0.71 D
TT26-CS-C		1/12/2007	-30.1	-27.6	1.4 (-29)	2.1 (-29.7)	**316**	335	360	0.139	*0.183*	*1.48*	0.29 D
TT26-CS-G		1/12/2007	-30.1	-27.6	4.3 (-31.9)	5.1 (-32.7)	**123**	194	281	0.317	*0.69*	1.03	0.05
TT26-CS-I		1/12/2007	-30.1	-27.6	5.8 (-33.4)	6.5 (-34.1)	3.02	14.1	3.7	0.022	0.0023 U	0.00330	0.00043 J
TT27-SS		1/24/2007	-28.8	-17.6	0 (-17.6)	0.5 (-18.1)	9.45	75.1	45.9	0.343	*0.217*	0.365	0.24 D
TT27B-CS-B		1/23/2007	-28.8	-32.4	0.2 (-32.6)	1.1 (-33.5)	3.69	18.9	19.1	0.181 *	0.0203	0.0577	0.0053
TT27B-CS-C		1/23/2007	-28.8	-32.4	1.1 (-33.5)	2 (-34.4)	4.43	27.3	18	0.364 *	0.0112	0.157	0.0036
TT27B-CS-D		1/23/2007	-28.8	-32.4	2 (-34.4)	2.9 (-35.3)	6.23	36.1	9.75	0.186 *	0.0027 U	0.130	0.0032
TT28-SS		1/24/2007	-52.7	-52.7	0 (-52.7)	0.5 (-53.2)	8.58	34.5	22.5	0.178	0.072	0.144	0.052

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

						Parameter	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
						CSL	93	390	530	0.59	0.96	3.2	1.335
						SQS	57	390	450	0.41	0.18	1.1	1.335
						Clean up Level	7	114	11	0.41	0.002	0.009	430
Site Area/Sample Location		Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)							
TT29-SS		1/24/2007	-41.0	-44.2	0 (-44.2)	0.5 (-44.7)	6.08	28.2	19.8	0.376	0.104	0.144	0.13 D
TT29-CS-A		1/18/2007	-41.0	-45.1	0 (-45.1)	0.5 (-45.6)	1.65	7.2 *	37.7	0.018 B	0.0023 U	0.0114	0.00047 J
TT29-CS-B		1/18/2007	-41.0	-45.1	0.8 (-45.9)	1.5 (-46.6)	1.56	6.7 *	6.94	0.014 B	0.0022 U	0.00629	0.00023 Ui
TT29-CS-C		1/18/2007	-41.0	-45.1	1.5 (-46.6)	2.2 (-47.3)	2.47	15.5 *	19.5	0.099	0.04	0.10	0.00007 U
TT32-SS		1/26/2007	-41.7	-43.7	0 (-43.7)	0.5 (-44.2)	8.58	54.5	26.5	0.253 *	0.139	0.157	0.071
TT32-CS-B		1/13/2007	-41.7	-42.7	0.2 (-42.9)	0.9 (-43.6)	3.29	19	2.78	0.023	0.0025 U	0.0036 U	0.00055 J
TT32-CS-C		1/13/2007	-41.7	-42.7	0.9 (-43.6)	1.5 (-44.2)	3.17	21.7	2.83	0.026	0.0025 U	0.000022	0.00008 U
TT32-CS-H		1/13/2007	-41.7	-42.7	4.3 (-47)	5.2 (-47.9)	2.95	20.3	2.96	0.022	0.0024 U	0.0035 U	0.00026 Ui
TT39-SS		1/25/2007	-42.8	-44.1	0 (-44.1)	0.5 (-44.6)	6.41	34.6	20.5	0.158	0.085	0.146	0.061
TT39-CS-A		1/12/2007	-42.8	-44.0	0 (-44)	1.1 (-45.1)	10.3	71.5	45.1	0.332	*0.321*	0.511	0.063
TT39-CS-B		1/12/2007	-42.8	-44.0	1.1 (-45.1)	2.02 (-46)	8.79	75.1	51.5	*0.446*	*0.432*	0.404	0.052
TT39-CS-C		1/12/2007	-42.8	-44.0	2 (-46)	2.94 (-47)	4.88	31.2	14.1	0.151	0.047	0.0926	0.0067
TT-CS110-00-01		1/15/2016	-30.4	-26.5	0 (-26.5)	1 (-27.5)	43.3	118	271	0.129	0.044	0.299	0.025
TT-CS110-01-02		1/15/2016	-30.4	-26.5	1 (-27.5)	2 (-28.5)	24.6	95.6	40.1	0.027	0.0087	0.0307	0.0034
TT-CS110-02-03		1/15/2016	-30.4	-26.5	2 (-28.5)	3 (-29.5)	2.37	9.83	5.46	0.01	0.0021	0.00632	0.00054
TT-CS110-05-06		1/15/2016	-30.4	-26.5	5 (-31.5)	6 (-32.5)	3.34	19.1	2.93	0.022	0.0021	0.0063	0.00059
TT-CS116-00-01		1/6/2016	-26.2	-28.7	0 (-28.7)	1 (-29.7)	30.1	63.1	34.9	0.196	0.056	0.261	0.023
TT-CS116-01-02		1/6/2016	-26.2	-28.7	1 (-29.7)	2 (-30.7)	21	43.2	19.6	0.061	0.0101	0.019	0.00081
TT-CS116-02-03		1/6/2016	-26.2	-28.7	2 (-30.7)	3 (-31.7)	2.29	9.27	2.86	0.016	0.0021	0.195	0.00053
TT-CS118-00-01		1/20/2016	-22.9	-26.1	0 (-26.1)	1 (-27.1)	14.1	51	135	0.143	0.089	0.591	0.0053
TT-CS118-2	Dup of TT-CS118-00-01	1/20/2016	-22.9	-26.1	0 (-26.1)	0 (-26.1)	14	44	56	0.332	0.088	0.491	0.01
TT-CS118-01-02		1/20/2016	-22.9	-26.1	1 (-27.1)	2 (-28.1)	3.01	12.9	2.79	0.046	0.0026	0.0366	0.0006
TT-CS118-04-05		1/20/2016	-22.9	-26.1	4 (-30.1)	5 (-31.1)	2.61	9.74	2.05	0.007	0.0021	0.00985	0.00056
TT-CS125-00-01		1/11/2016	-6.2	-6.6	0 (-6.6)	1 (-7.6)	3.23	12.7	2.62	0.007	0.0033	0.00632	0.0015
TT-CS125-01-02		1/11/2016	-6.2	-6.6	1 (-7.6)	2 (-8.6)	2.47	8.34	1.18	0.007	0.0021	0.00632	0.0012
TT-CS125-02-03		1/11/2016	-6.2	-6.6	2 (-8.6)	3 (-9.6)	1.9	6.7	1.03	0.006	0.0021	0.00632	0.00053
TT-CS137-00-01		1/11/2016	-47.4	-48.0	0 (-48)	1 (-49)	3.6	15.4	43.5	0.037	0.0021	0.01219	0.0013
TT-CS137-01-02		1/11/2016	-47.4	-48.0	1 (-49)	2 (-50)	3.86	18.3	2.43	0.032	0.0021	0.00634	0.00059
TT-CS137-2	Dup of TT-CS-01-02	1/11/2016	-47.4	-48.0	0 (-48)	0 (-48)	4.1	19.1	2.52	0.028	0.0021	0.00632	0.00059
TT-CS137-02-03		1/11/2016	-47.4	-48.0	2 (-50)	3 (-51)	3.99	18.7	2.37	0.027	0.0021	0.00632	0.00058
TT-SS111-00-005		1/8/2016	-21.7	-28.3	0 (-28.3)	0.5 (-28.8)	54.5	165	79.7	0.201	0.1311	0.617	0.11
TT-SS115-00-005		1/8/2016	-28.9	-30.1	0 (-30.1)	0.5 (-30.6)	26.6	333	34.5	0.08	0.0304	0.192	0.064
TT-SS117-00-005		1/8/2016	-34.9	-37.6	0 (-37.6)	0.5 (-38.1)	21.2	40.9	22.9	0.043	0.0204	0.298	0.0097
TT-SS161-00-005		1/8/2016	-27.7	-28.6	0 (-28.6)	0.5 (-29.1)	22	179	72.2	0.124	0.1107	*2.14*	0.061
TT-SS162-00-005		1/8/2016	-31.9	-33.5	0 (-33.5)	0.5 (-34)	19	63	23.9	0.041	0.0035	0.0541	
Outside Remedy Area													
C5 (0 - 2)		12/1/1991		-63.0	0 (-63)	2 (-65)	2.5	17.9 J	4	0.1 U	0.0785 U		
C5 (2 - 5)		12/1/1991		-63.0	2 (-65)	5 (-68)	2.03	14.4 J	3 U	0.07 U	0.0798 U		
C5 (5 - 8)		12/1/1991		-63.0	5 (-68)	8 (-71)	2.1	12.9 J	3 U	0.05 U	0.0781 U		
C6 (0 - 2)		12/1/1991		-42.2	0 (-42.2)	2 (-44.2)	12.2	61.8 J	32	0.34	0.177		
C6 (2 - 5)		12/1/1991		-42.2	2 (-44.2)	5 (-47.2)	8.44	46.3 J	18	0.27	0.0821 U		
C6 (5 - 8)		12/1/1991		-42.2	5 (-47.2)	8 (-50.2)	3.19	20.9 J	3	0.06 U	0.000787 U		
C7 (0 - 2)		12/1/1991		-72.0	0 (-72)	2 (-74)	1.36	10.1 J	3 U	0.06 U	0.0792 U		
C7 (2 - 5)		12/1/1991		-72.0	2 (-74)	5 (-77)	1.68	9.2 J	3 U	0.05 U	0.0770 U		
C7 (5 - 8)		12/1/1991		-72.0	5 (-77)	8 (-80)	1.64	8.1 J	2 U	0.05 U	0.0804 U		

Table A-2 Risk Driver Chemical Concentrations
Lockheed West Seattle Superfund Site

Site Area/Sample Location	Date	Field Mudline	2015 Bathy Mudline	Top Depth (Elev) (ft)	Bottom Depth (Elev) (ft)	Arsenic	Copper	Lead	Mercury	PCBs (total)	Total cPAH	Tributyltin
					CSL	93	390	530	0.59	0.96	3.2	1.335
					SQS	57	390	450	0.41	0.18	1.1	1.335
					Clean up Level	7	114	11	0.41	0.002	0.009	430
D2-S	8/31/1989		-39.1	0 (-39.1)	0.5 (-39.6)	31	97 E	69 E	0.0018	*0.19*		
D2-C	9/7/1989		-39.1	0 (-39.1)	4 (-43.1)	55	35 E	6.1 E	0.001	0.06 U		
D2-D	9/7/1989		-39.1	4 (-43.1)	10.5 (-49.6)	50	45 E	5.9 E	0.0005 U	0.06 U		
TT35-SS	1/25/2007	-49.4	-44.9	0 (-44.9)	0.5 (-45.4)	4.56	39.3	20.5	0.176	0.06	0.0868	0.52 D
TT35-CS-B	1/15/2007	-49.4	-50.7	0.3 (-51)	0.8 (-51.5)	6.53	39.6	32.5	*0.456*	0.099	0.167	0.0054
TT35-CS-C	1/15/2007	-49.4	-50.7	0.8 (-51.5)	1.3 (-52)	4.79	30.7	16.6	0.296	0.0072	0.0783	0.003
TT35-CS-D	1/15/2007	-49.4	-50.7	1.3 (-52)	1.8 (-52.5)	3.85	23.7	7.64	0.139	0.0025 U	0.0498	0.0014 J
TT36-SS	1/25/2007	-57.7	-57.7	0 (-57.7)	0.5 (-58.2)	5.08	28.3	18.5	0.084	0.047	0.0576	0.03
TT37-SS	1/25/2007	-40.9	-49.2	0 (-49.2)	0.5 (-49.7)	7.37	39.8	22.4	0.121	0.121	0.116	0.033
TT37-CS-A	1/13/2007	-40.9	-43.4	0 (-43.4)	0.7 (-44.1)	7.75	23.6	15.6	0.032	0.085	0.0411	0.0063
TT37-CS-B	1/13/2007	-40.9	-43.4	0.7 (-44.1)	1.3 (-44.7)	2.38	10	4.76	0.019	0.027	0.0222	0.0043
TT37-CS-C	1/13/2007	-40.9	-43.4	1.3 (-44.7)	1.9 (-45.3)	2.59	13.4	4.87	0.075	0.0054	0.0171	0.0015
TT38-SS	1/25/2007		-64.0	0 (-64)	0.5 (-64.5)	8.76	31.2	25.4	0.122	0.106	0.0908	0.018

Concentrations in mg/kg
U - non detect result
J - estimated result
Elevations feet MLLW
Depths in feet below mudling
MLLW - Mean Low Lower Water
Bold - Concentration above the CSL
italic - Concentration above the SQS
Sample intervals in the dredge prism

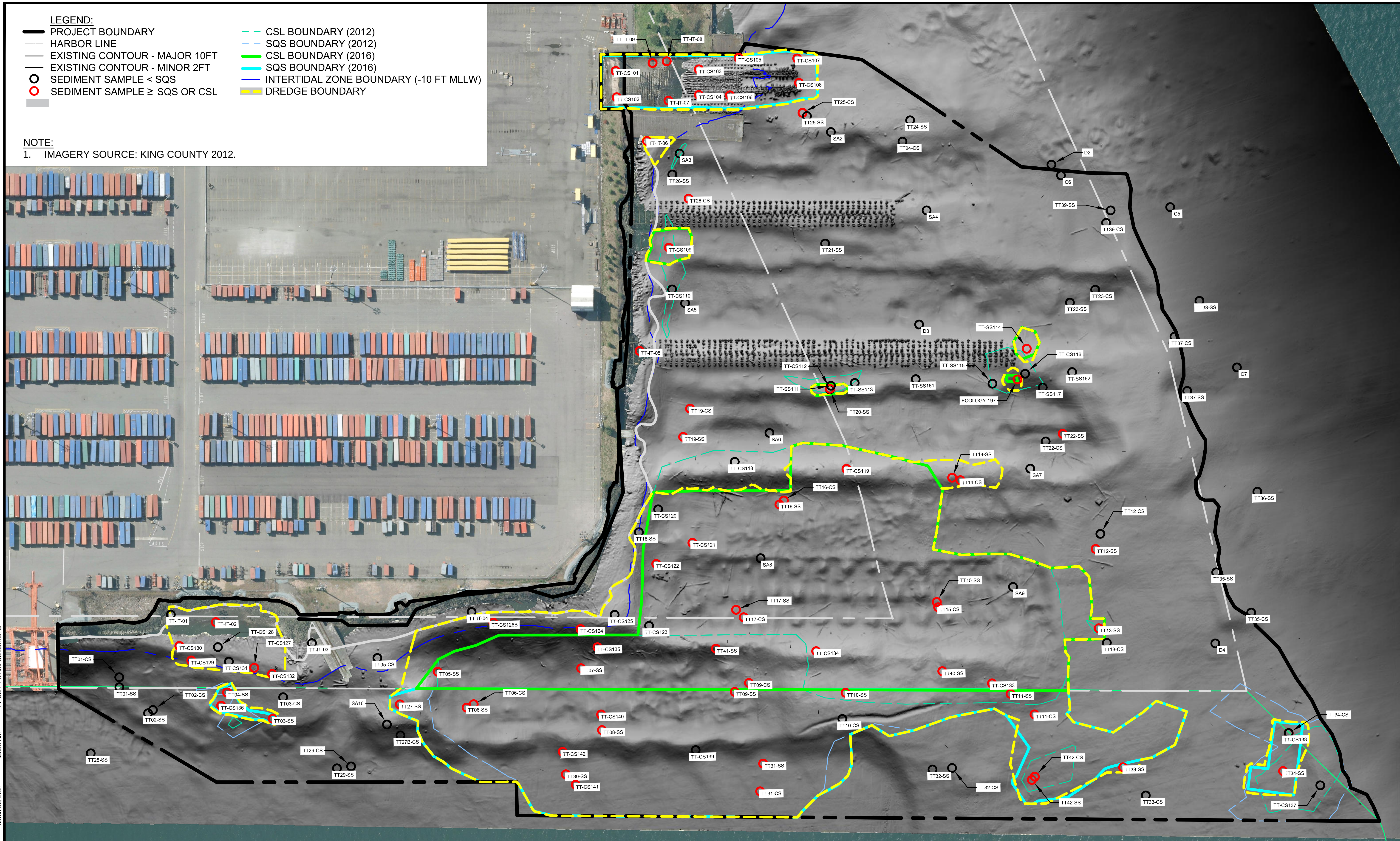
Table A-3

Pacific Sound Resources Sediment Data Adjacent to the Lockheed West Site

Parameter	Upland PSR DNAPL (PSR RI)	PSR EB012 0-4	PSR EB012 4-8	PSR EB012 8-12	PSR EB113 0-4	PSR EB113 4-7		PSR EB001	PSR EB002	PSR EB009	PSR EB012	PSR EB018	PSR EB116
PAHs (ug/kg)													
2-Methylnaphthalene	18000	6100	7600	3840	96400	40500		1540	3100	20000	1350	5460	777
Acenaphthene	22000	626	39200	13000	633000	178000		2990	12600	32700	3400	11300	1260
Acenaphthylene	ND	16100	1520	499	6120	2160		676	2040	4390	1060	1590	222
Anthracene	7000	13800	29500	6680	659000	143000		5040	60800	451000	5010	10900	1630
Benzo(a)anthracene	4200	10400	18000	4020	93800	34600		14300	28600	134000	3220	10500	2900
Benzo(a)pyrene	1130	6170	6140	1020	13600	6320		3630	12000	38600	6490	7570	4250
Benzo(b)fluoranthene	1350	13500	10400	2000	30700	13400		6970	22300	67600	16100	13600	6960
Benzo(ghi)perylene	310	2290	2160	368	1580	1280		914	3640	9620	2010	2220	1020
Benzo(k)fluoranthene	1200	6670	4420	765	11900	4800		2080	4380	29000	6010	4850	912
Benzofluoranthenes (total)	2550	20170	14820	2765	42600	18200		9050	26680	96600	22110	18450	7872
Chrysene	2750	14500	23300	4450	91000	40100		16400	44300	186000	7870	14400	4580
Dibenzo(a,h)anthracene	150	913	504	92.6	950	491		391	1400	3840	807	932	276
Fluoranthene	19500	64100	121000	34500	972000	311000		68500	124000	712000	9150	37700	7710
Fluorene	16000	13100	24800	12300	344000	96200		3260	21800	49100	3060	12600	1380
Indeno(1,2,3-cd)pyrene	310	2730	1800	319	1860	1330		1220	4450	11800	2490	2850	1070
Naphthalene	60000	34000	26800	12000	407000	216000		7010	5550	85700	5380	42100	4650
Phenanthrene	53500	26800	59700	30000	1970000	413000		8100	111000	119000	7640	35900	7080
Pyrene	11500	74600	68600	19300	545000	171000		54100	79200	439000	57000	82000	11500
Total HPAH	22900	131773	135324	32334.6	790390	273321		100005	200270	919460	101997	138922	33468
Total LPAH	176500	110526	189120	78319	4115520	1088860		28616	216890	761890	26900	119850	16999
Total PAH	218900	306399	445444	145153.6	5877910	1673181		197121	541160	2393350	138047	296472	58177
Mercury (mg/kg)	NA	NA	NA	NA	NA	NA		0.29	0.28	1.32	4.24	1.39	NA

NA - Not analyzed

ND - Non-detect



TETRA TECH

0' 80' 160' 320'

LOCKHEED WEST SEATTLE SUPERFUND SITE
SEATTLE, WA

FIGURE A-1
CSL AND SQS BOUNDARY

Z:\PROJECTS\194-8650 LOCKHEED WEST\FIGURES\SHEET FILES\DREDGE PLAN FIGURE.DWG
TT-BOTH-MAIN-COLOR.CTB
10:38 AM
March 30, 2017
PLOT DETAILS: MATHIS, TOM

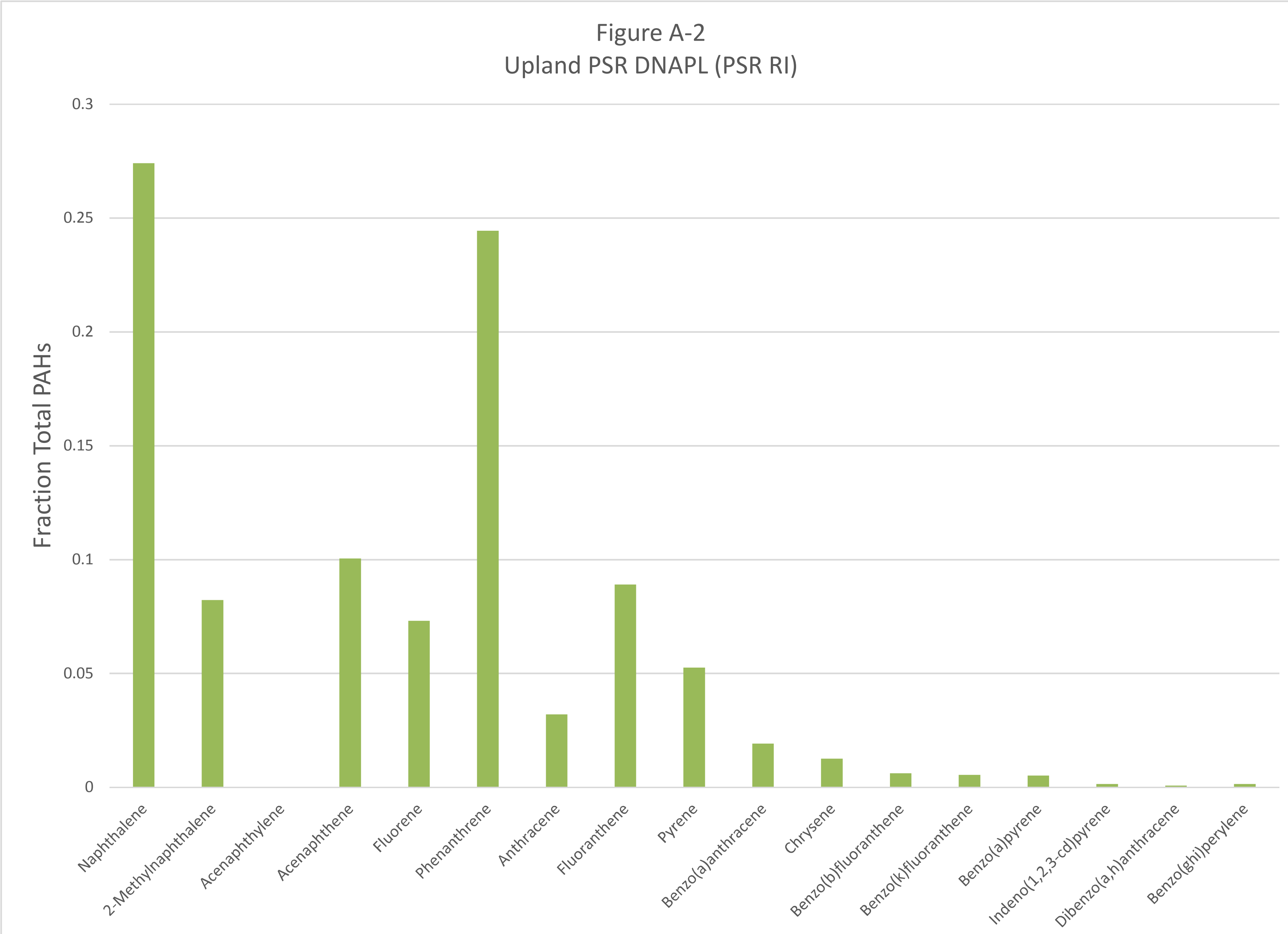


Figure A-2
Upland PSR DNAPL (PSR RI)
Fraction Total PAHs
0.3
0.25
0.2
0.15
0.1
0.05
0
Naphthalene
2-Methylnaphthalene
Acenaphthylene
Acenaphthene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene

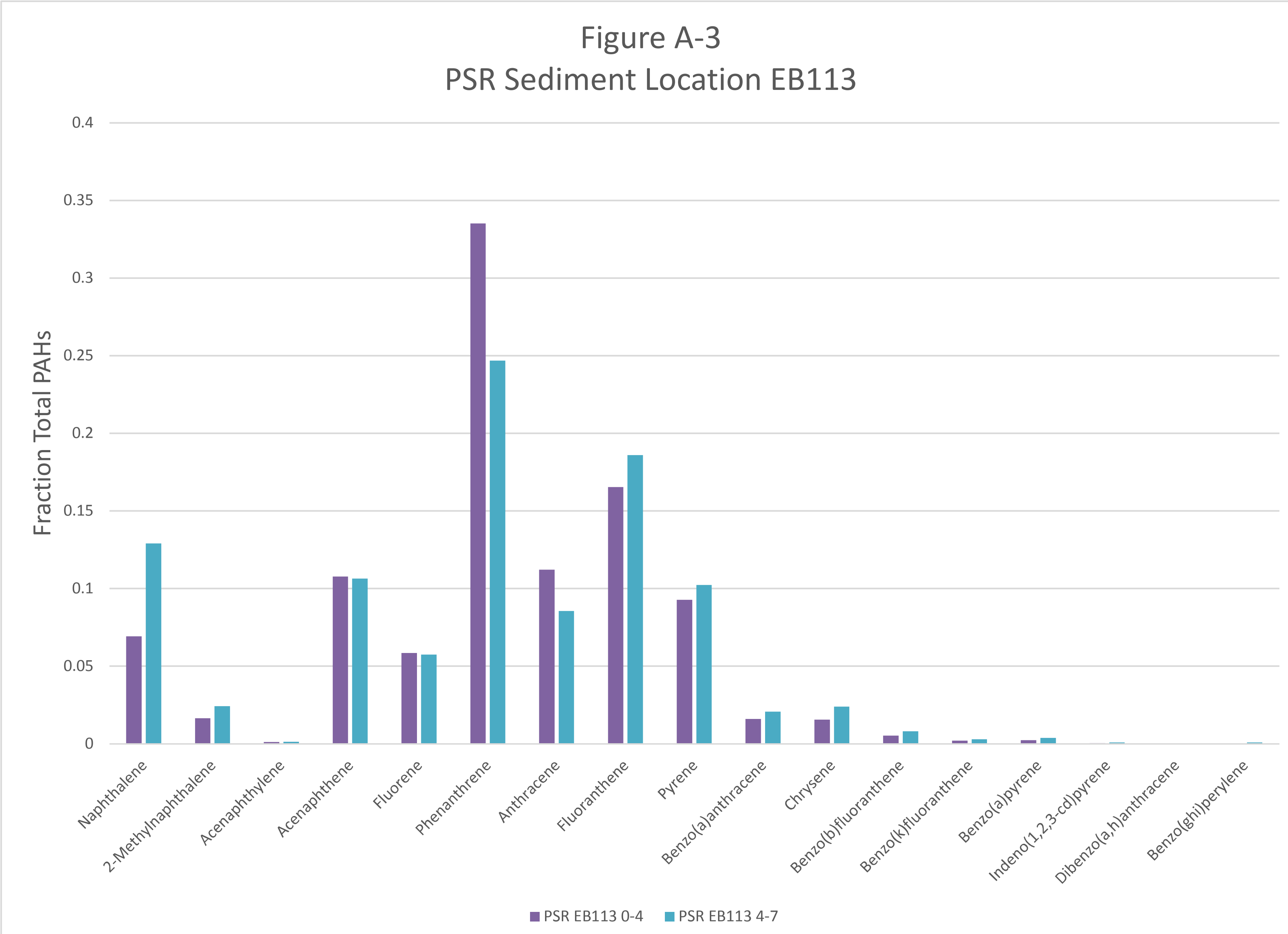


Figure A-3
PSR Sediment Location EB113
Fraction Total PAHs
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Naphthalene
2-Methylnaphthalene
Acenaphthylene
Acenaphthene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene
PSR EB113 0-4
PSR EB113 4-7

Figure A-4
PSR Sediment Location EB012

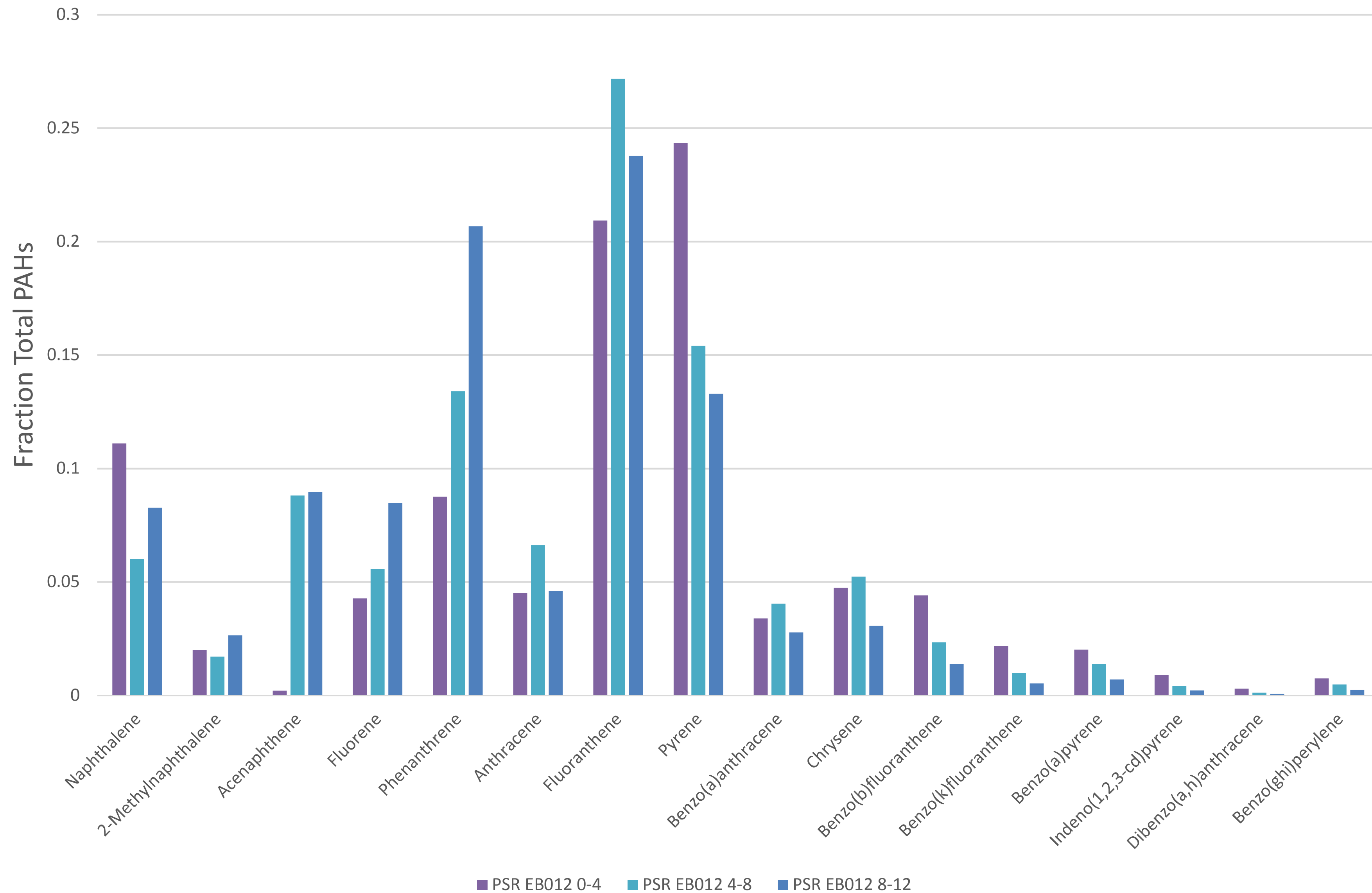
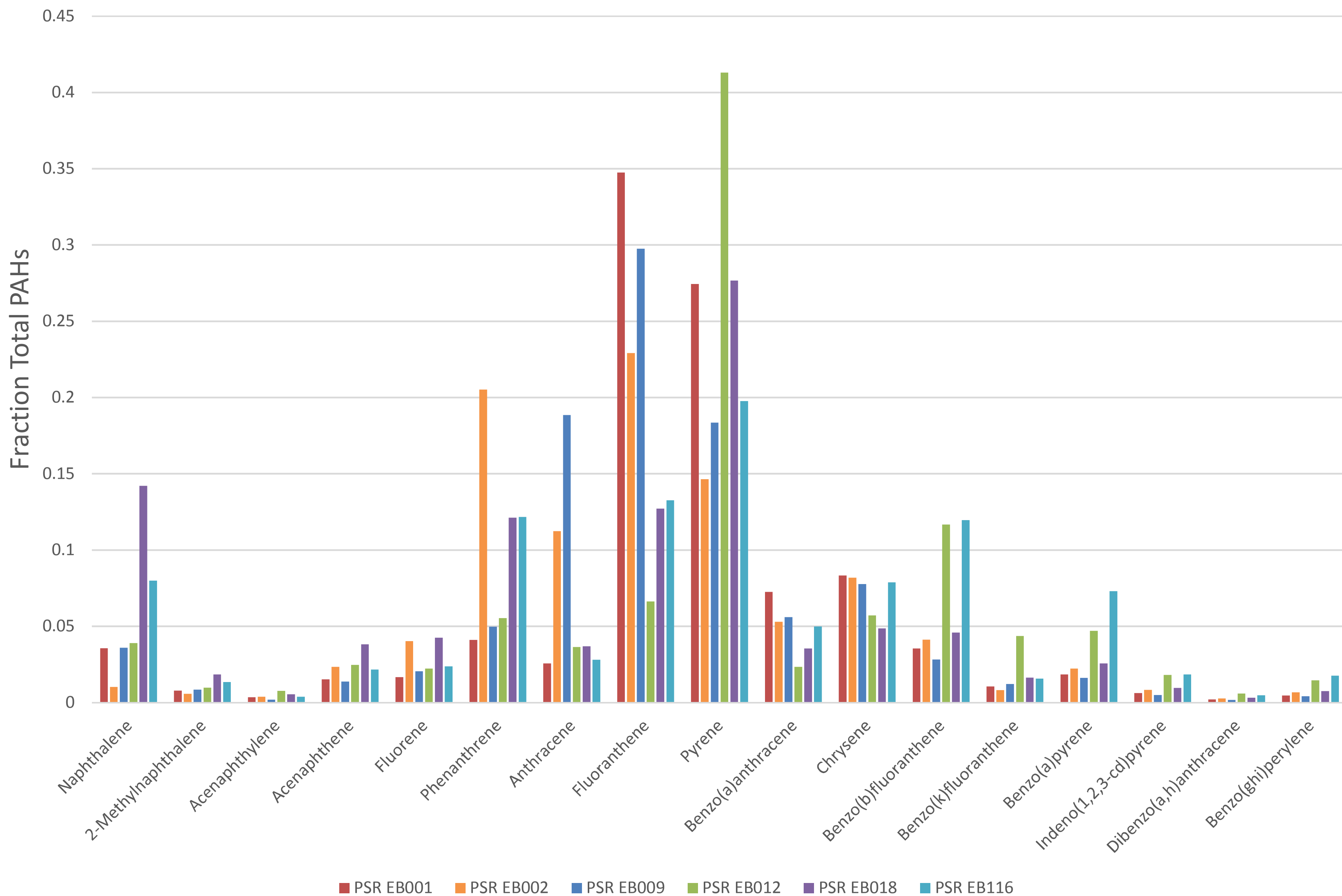


Figure A-5
PSR Surface Sediment Samples



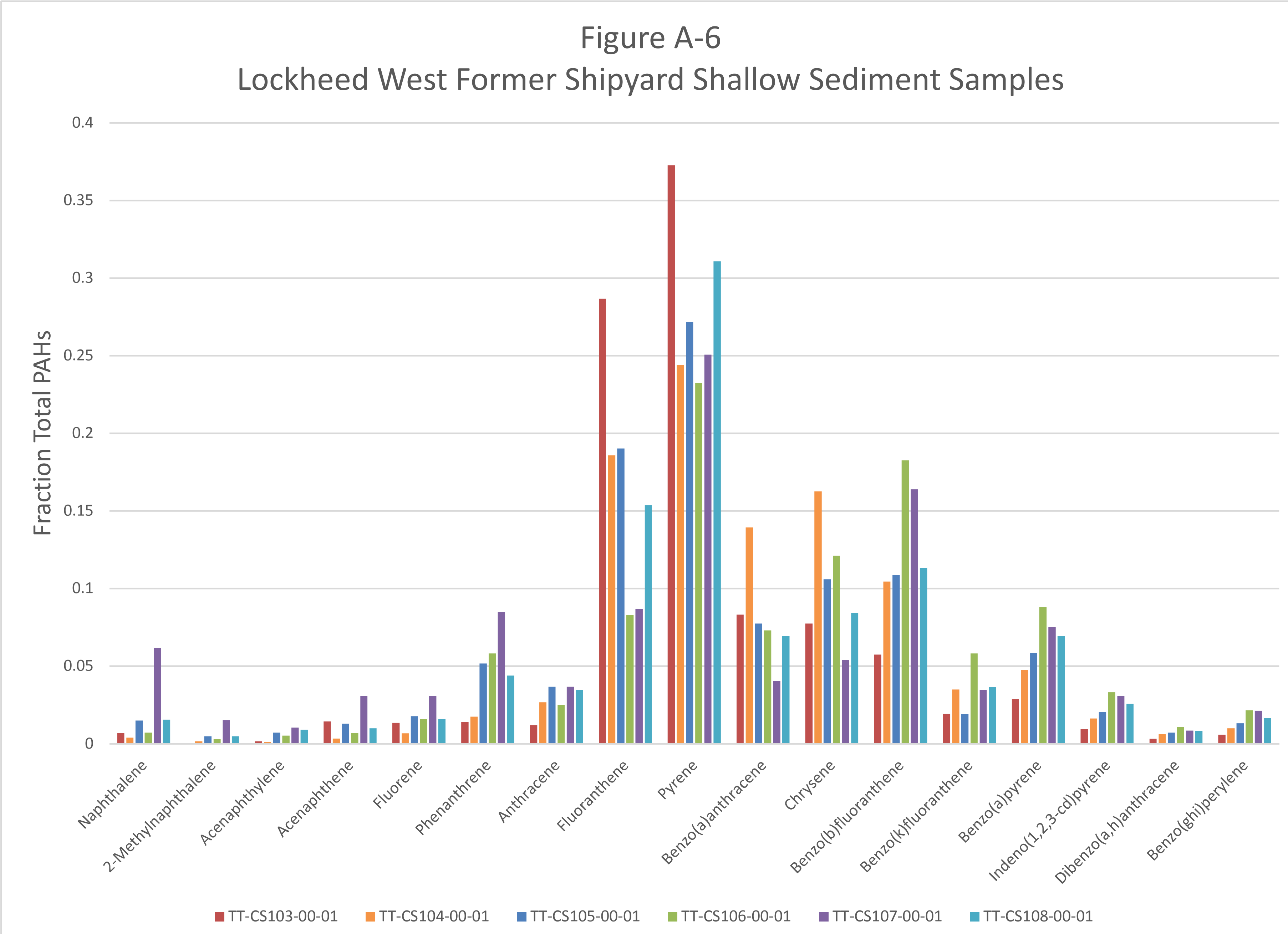


Figure A-6
Lockheed West Former Shipyard Shallow Sediment Samples
Fraction Total PAHs
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Naphthalene
2-Methylnaphthalene
Acenaphthylene
Acenaphthene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene
TT-CS103-00-01
TT-CS104-00-01
TT-CS105-00-01
TT-CS106-00-01
TT-CS107-00-01
TT-CS108-00-01

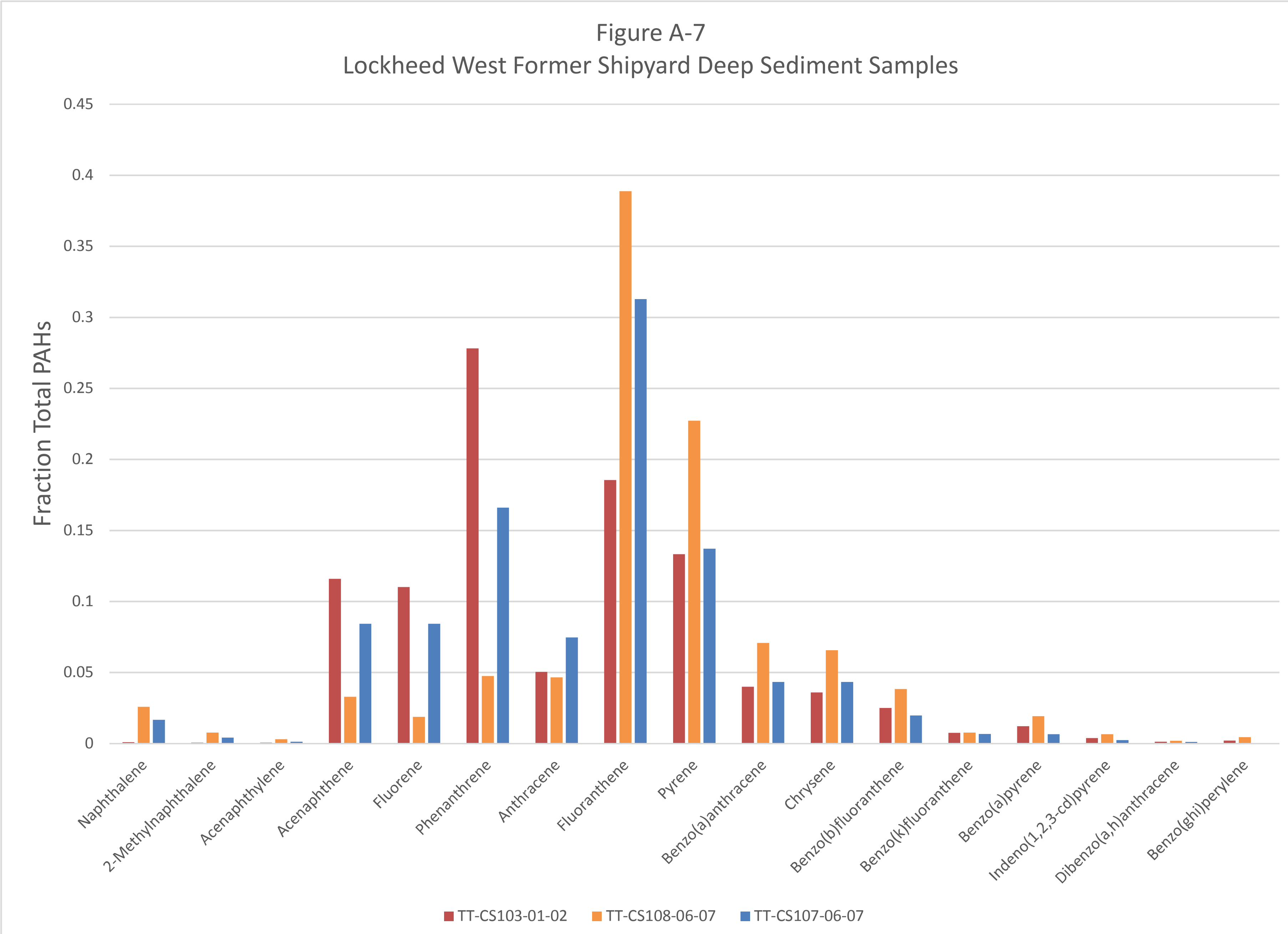
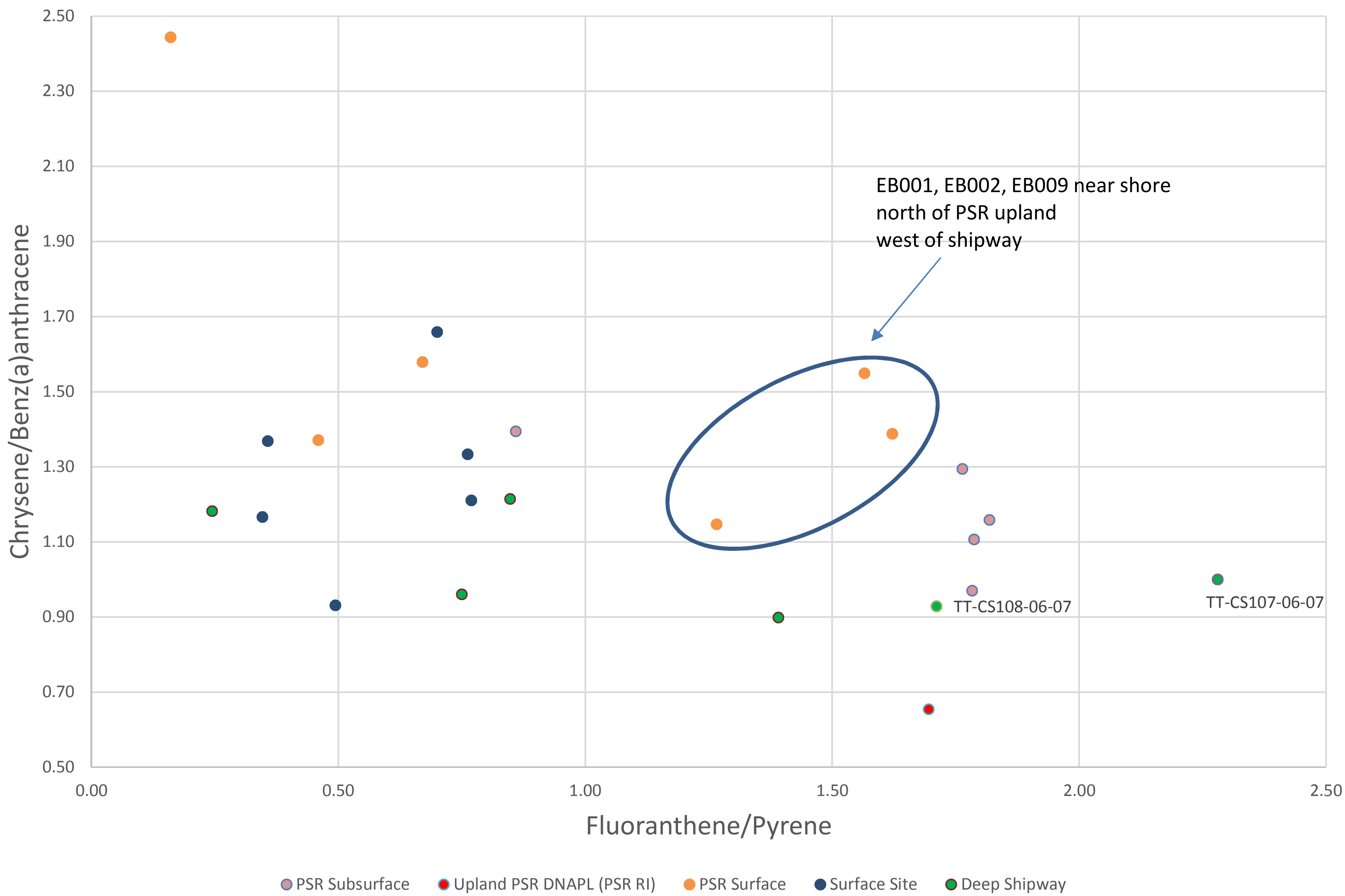


Figure A-7
Lockheed West Former Shipyard Deep Sediment Samples
Fraction Total PAHs
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Naphthalene
2-Methylnaphthalene
Acenaphthylene
Acenaphthene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(ghi)perylene
TT-CS103-01-02
TT-CS108-06-07
TT-CS107-06-07

Figure A-8
PAH Characteristic Ratios



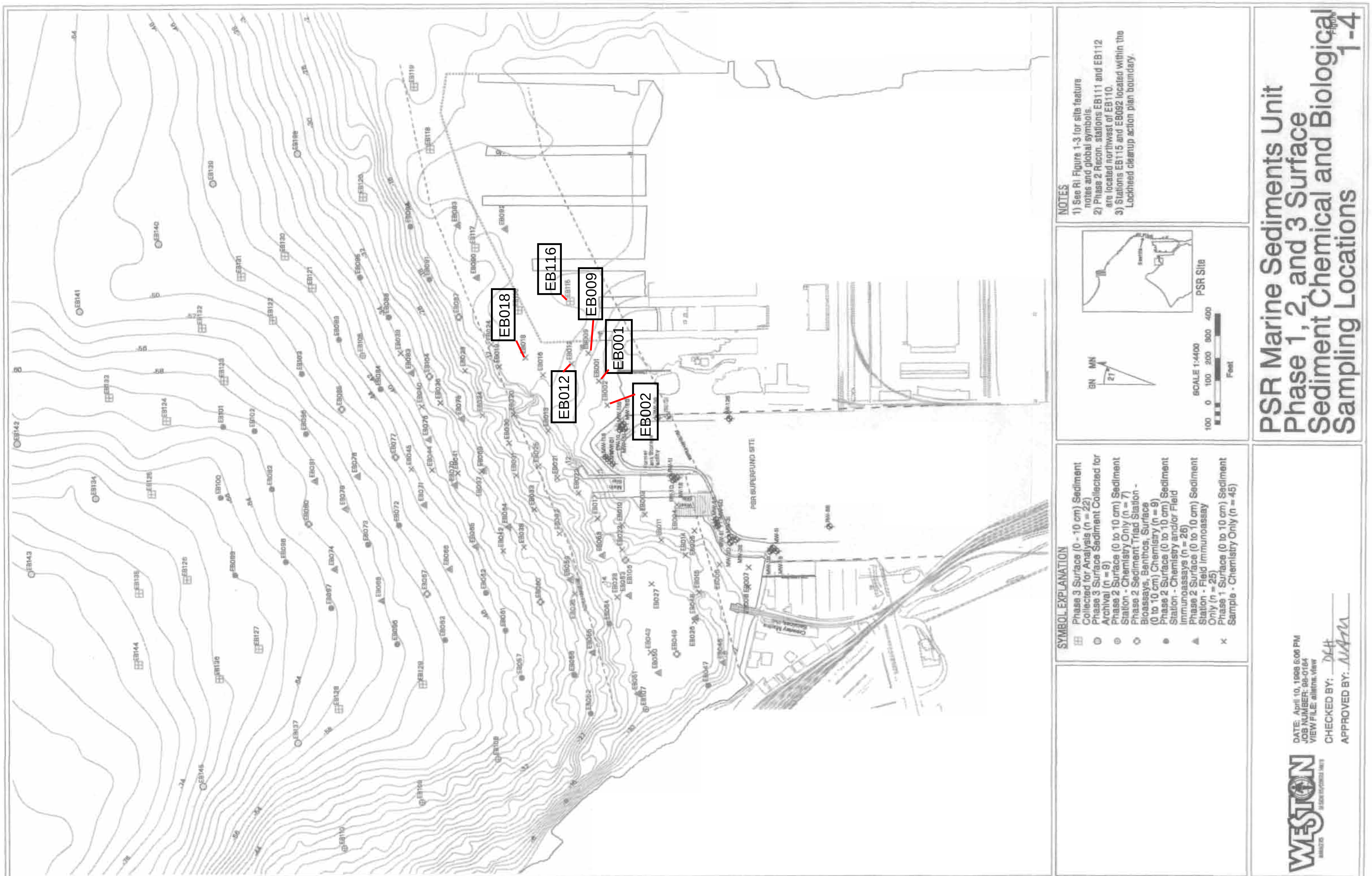


Figure A-9
PSR sample Locations
(Figure 1-4, PSR Remedial Investigation Report)

APPENDIX B— INTERMEDIATE (60 PERCENT) DESIGN DRAWINGS

(Provided separately)

APPENDIX C— PRELIMINARY OUTLINE OF TECHNICAL SPECIFICATIONS

DIVISION 01 - GENERAL REQUIREMENTS

01 11 00	Summary of Work
01 31 19	Project Meetings and Coordination
01 33 00	Submittal Procedures
01 35 29	Health, Safety, and Emergency Response Procedures
01 45 00	Quality Control
01 50 00	Temporary Facilities
01 57 13	Temporary Erosion and Sediment Control
01 57 19	Environmental Protection
01 77 00	Closeout Requirements

DIVISION 02 – EXISTING CONDITIONS

02 21 13	Site Survey
02 41 00	Debris Removal
02 41 16	Former Shipway Demolition
02 61 23	Off-site Waste Disposal

DIVISION 35 – WATERWAY AND MARINE CONSTRUCTION

35 20 23	Dredging and Dewatering
35 31 00	Shoreline Protection
35 42 00	Backfill
35 43 00	Residual Management Layer and Enhanced Natural Recovery Layer Placement

APPENDIX D— BASIS OF DESIGN CALCULATIONS

(Provided on CD)

EXISTING CONDITIONS

8650-01	Wind and Water Levels
8650-02	Wave Conditions

CIVIL

8650-03	Remediation Volumes
8650-04	Debris Quantity

GEOTECHNICAL

8650-05	Slope Stability Analysis

STRUCTURAL

8650-06	Sheet Pile Wall Stability Analysis

COASTAL

8650-07	Gravel Beach
8650-08	Shoreline Protection
8650-09	Submerged Slope Protection

CLIENT: **Lockheed Martin**		CONTRACT NUMBER: **194-8650**
SUBJECT: **CALCULATION WAVE-01 (8650-01)** **WIND & WATER LEVELS** **Lockheed West – Seattle, WA**		
BASED ON: N/A CALC. REV: REV A – 27/10/16 - DRAFT		DRAWING NUMBER: N/A
BY: JWD DATE: 15 September 16	CHECKED BY: SO DATE: 20 September 16	APPROVED BY: SO DATE: 27 October 16

REFERENCES:

1. American Society of Civil Engineers (ASCE), 2013. Minimum Design Loads for Buildings and Other Structures, ASCE Standard ASCE/SEI 7-10, American Society of Civil Engineers, Reston, VA.

2. American Technology Council (ATC), Wind Speed by Location Website, URL: http://windspeed.atcouncil.org/, accessed 20 July 2016.

3. USACE, 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes). URL: http://chl.erdc.usace.army.mil/cem.

4. National Oceanographic and Atmospheric Administration (NOAA), Center for Operational Oceanographic Products and Services (CO-OPS), Tides and Currents website, URL: http://tidesandcurrents.noaa.gov/ , accessed 20 July 2016.

5. Jamestown S'Klallam Tribe. 2013. Climate Change Vulnerability Assessment and Adaptation Plan – Appendices. Petersen, S., Bell, J., (eds.) A collaboration of the Jamestown S'Klallam Tribe and Adaptation International.

6. National Ocean Survey (NOS), 2014. Puget Sound Seattle to Bremerton, Nautical Chart 18449, 20th Edition, August 2014, last correction 5/12/2016 URL: http://www.charts.noaa.gov/PDFs/18449.pdf , accessed 20 July 2016.

7. Port of Seattle. 2016. Terminal 5 Cargo Wharf Rehabilitation and Berth Deepening Draft Environmental Impact Statement. http://www.portseattle.org/Environmental/Environmental-Documents/SEPA-NEPA/Pages/default.aspx , accessed 22 July 2016.

8. Tetra Tech. 2007. Topographic/Bathymetric Survey File. '0703201_TOPO.dwg'. Provided by Nich VanBuecken, Tetra Tech, Bothell, WA via email on 7/21/16.

PURPOSE: The purpose of this calculation is to establish the wind and water level conditions associated with the occurrence of a 50-year mean recurrence interval (MRI) design basis event at the Lockheed West Project site in Seattle, WA. The wind and water levels will provide input into the design wave calculations that are provided in Calculation WAVE-02, Design Wave Conditions.

SITE: Lockheed West is located on the southern shoreline of Elliott Bay in Seattle's Industrial District. The project's geographic coordinates are 47^{0} 35' 6.60"N, 122^{0} 21' 50.29"W. Bainbridge Island lies to the west of the site with the city of Seattle to its NE. Figure 1 shows the Lockheed West project location.

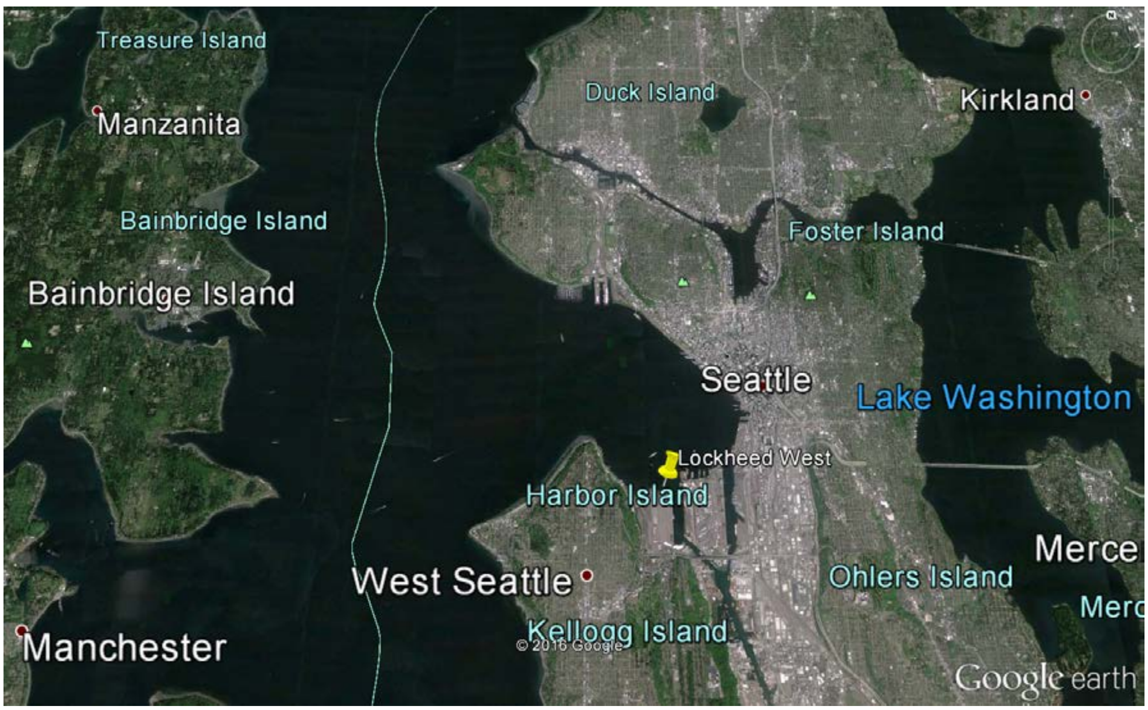


Figure 1 – Lockheed West Project Site, Seattle, WA

Source: Google Earth (19 Apr 15 image)

BACKGROUND: Former shipyard operations in the project area resulted in contamination of the sediments. Remediation efforts will dredge the contaminated sediments and backfill the shoreline/intertidal areas with a habitat mix of gravel and possibly riprap. Gravel beaches will be installed at two location within the project area. Calculations WAVE-01 and WAVE-02 provide the design wind and wave data necessary to design a dynamically stable gravel beach profile. Calculation GRAVEL-01 provides the equilibrium gravel beach slopes, median grain size, and slope thicknesses required for each shoreline installation area.

GRAVEL BEACH SITES: The first shoreline requiring stabilization through a dynamic gravel beach installation is shown in Figure 2. It is approximately 100 feet in length and located directly on Elliott Bay between two former pile supported dock structures.

Figure 2 – Gravel Beach Installation Area #1 (~100 linear ft)

The second shoreline is located in a more sheltered location along the West Waterway OU. It is approximately 285 feet in length and located within a crenulated bay that is bordered on the north by an existing outfall and to the south by a riprap revetment adjacent to Port of Seattle Terminal 5.

Figure 3 – Gravel Beach Installation Area #2 (~285 linear ft)

DESIGN CONDITIONS: The design basis event for the shoreline protection work at Lockheed West is an MRI of 50 years. The site and environmental conditions that influence wave conditions at the site include:

- overwater wave generation distance or fetch;
- average water depth over the fetch; and
- wind speed

The following sections present the development of these site conditions.

WAVE FETCH: The length of open water over which the wind blows and generates waves is known as the wave fetch. Gravel Beach Area #1 is located along the southern shoreline of Elliott Bay with Harbor Island shielding waves from the east. The NW fetch is the controlling fetch for Gravel Beach Area #1. It has a length of 73,000 feet and is shown in Figure 4.

Gravel Beach Area #2 is located along the more sheltered West Waterway OU and not in Elliott Bay. It has a fetch length of 1,975 feet as shown in Figure 5.

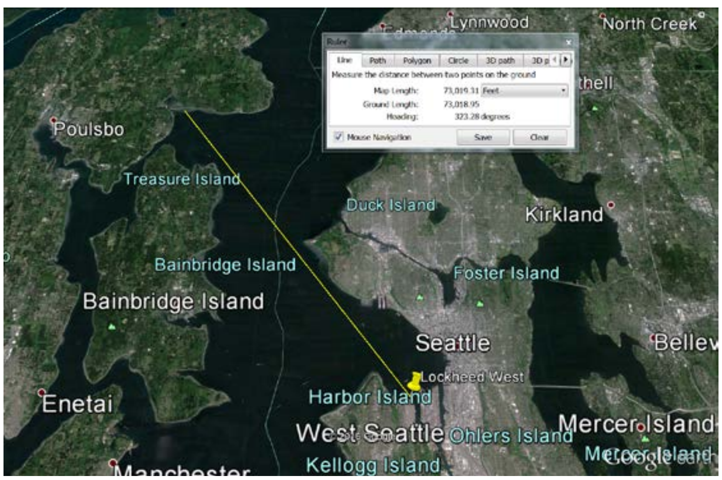


Figure 4 - Wave Generation Fetch for Gravel Beach Area #1

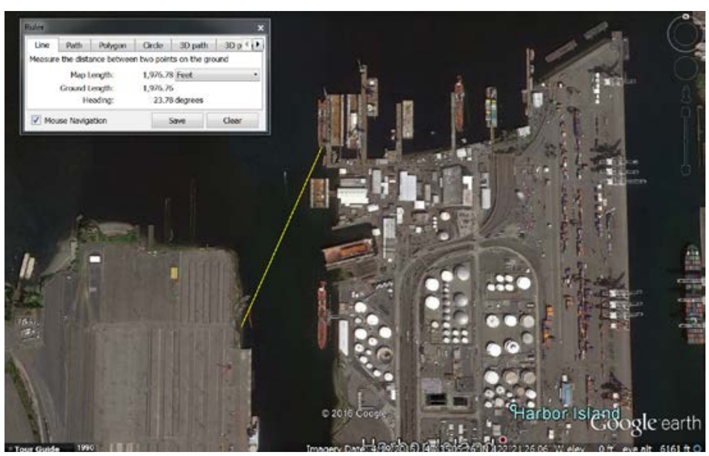


Figure 5 - Wave Generation Fetch for Gravel Beach Area #2

DESIGN WATER LEVEL: Figure 6 shows the location of the NOAA tide station (#9447130) in the vicinity of the project site. The station is located approximately 1.5 miles NE of the site and is adjacent to the city of Seattle.

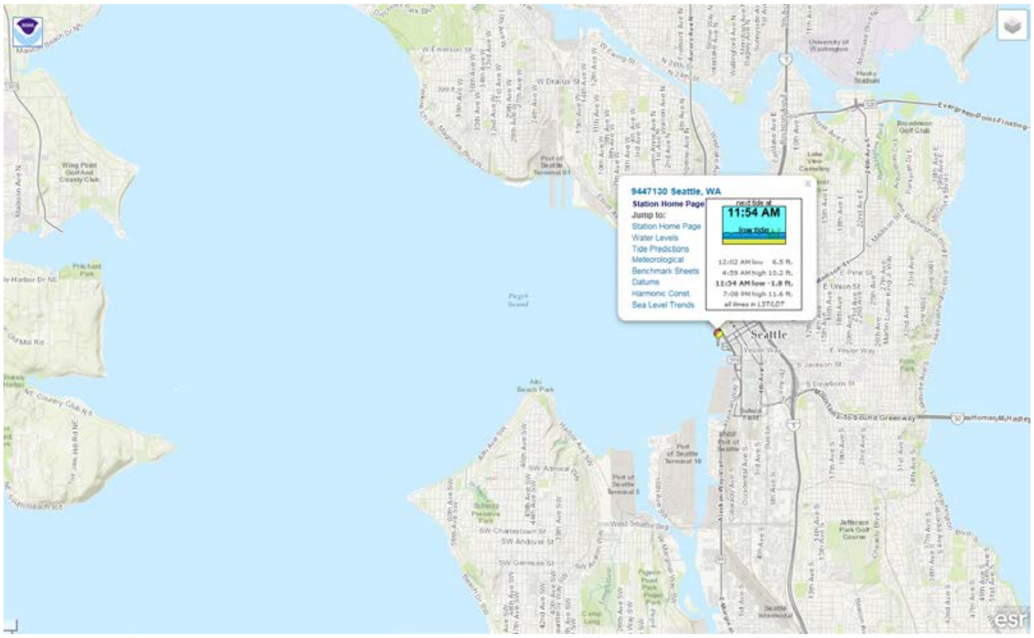


Figure 6 – National Ocean Service Tide Station Seattle, WA

Source: Reference 4

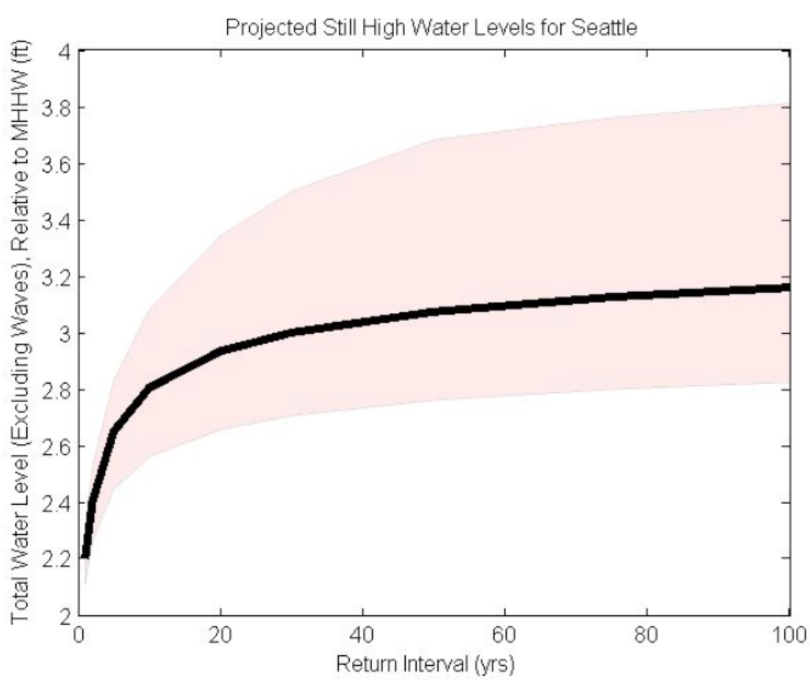


Figure 7 – Storm Surge Return Intervals for Seattle, WA

Source: Reference 5

Table 1 provides the various datum levels with respect to NAVD 88. Jamestown estimated storm surge flood elevations for Seattle, WA based on NOAA's Seattle water level gauging station (See Figure 7). Table 1 includes these extreme water levels as well.

Table 1 – Water Levels and Datum Levels at Seattle WA Tide Station (NOS 9447130)

Water Level/Datum	Elevation, ft NAVD 88	Data Source
100-yr stillwater	12.21	NOAA
Highest observed water level (1983)	12.14	Jamestown
50-yr stillwater	12.11	Jamestown
10-yr stillwater	11.81	Jamestown
Mean higher high water (MHHW)	9.01	NOAA
Mean High Water (MHW)	8.14	NOAA
Mean tide level (MTL)	4.32	NOAA
Mean sea level (MSL)	4.29	NOAA
Mean low water (MLW)	0.49	NOAA
North American Vertical Datum (NAVD 88)	0.00	NOAA
Mean lower low water (MLLW)	-2.35	NOAA
Lowest observed water level (1916)	-7.38	NOAA

Sources: NOAA (reference 4) and Jamestown (Reference 5)

Relative sea level change should also be considered for a 50-yr MRI design. The Port of Seattle is currently drafting its 2015 Climate Change Adaptation Plan that includes the Lockheed West site area. The Terminal 5 Cargo Wharf Rehabilitation and Berth Deepening Draft Environmental Impact Statement includes a reference to the document and states that the most likely level of sea level rise that the Port will experience over the next 50 years is 9 inches, or 0.75 feet.

Table 2 – 50-yr Relative Sea Level Change for Seattle

Relative Sea Level Change	Value	Data Source
50-yr	0.75 ft	NOAA

Sources: Port of Seattle (Reference 7)

DESIGN WATER DEPTHS: The water depth over the wave fetch length may limit the wave height and wave period of the design wave if the water is relatively shallow. Figures 8 & 9 are excerpts of the navigation chart for Puget Sound near Seattle, WA (reference 6) that shows the water depths relative to MLLW along the wave fetch lines. For Area #1, the average water depth along the fetch is approx. 400 ft, MLLW with the shallowest being 86 ft, MLLW (See Figure 8). For Area #2, the average water depth is approximately -50 ft, MLLW (See Figure 9). The resulting average water depth is calculated as:

- Area #1 Fetch Water Depth = 86ft, MLLW + 50-yr Design Water Elevation + Relative Sea Level Change
- Area #1Fetch Water Depth = 86ft, MLLW + (12.11ft, NAVD88 + 2.35' conversion to MLLW) + 0.75 ft
- <u>Area #1 Fetch Water Depth</u> = 101 feet
- <u>Area #2 Fetch Water Depth</u> = 50ft + 15ft = 65ft

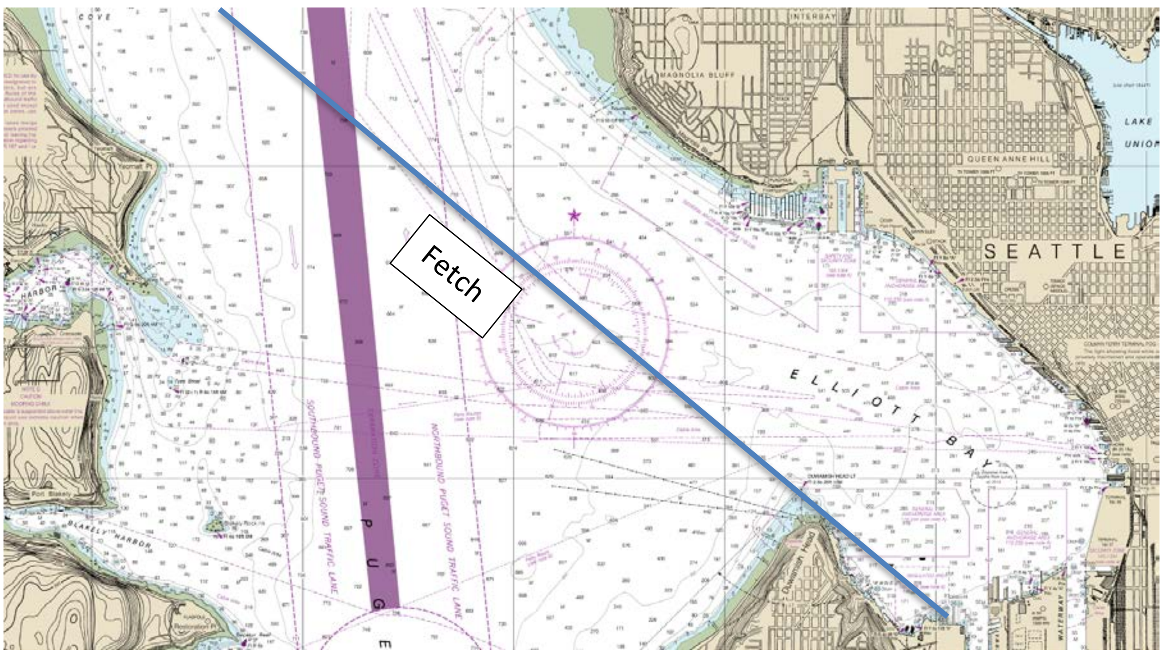


Figure 8 - Water Depths along Wave Fetch Line (Area #1)

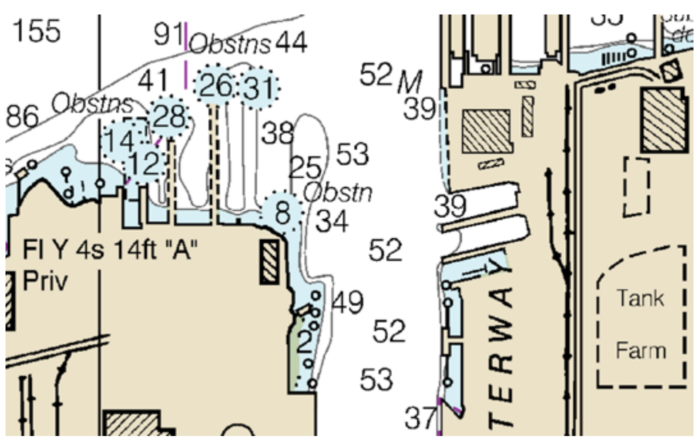


Figure 9 - Water Depths along Wave Fetch Line (Area #2)

WATER DEPTH AT TOE OF GRAVEL BEACH: The water depth at the toe of the gravel beach areas may also limit the wave height and wave period of the design wave if the water is relatively shallow. Figure 10 depicts typical sections of each gravel beach area with elevations relative to MLLW (Reference 8). For each gravel beach area, the toe of the structure terminates at approximately -10 ft, MLLW. This depth corresponds to the seaward terminus of the dry dock structures located at Gravel Beach Area #1. The resulting water depth is calculated as:

- Water Depth at Toe = 10ft, MLLW + 50-yr Design Water Elevation + Relative Sea Level Change
- Water Depth at Toe = 10ft, MLLW + (12.11ft, NAVD88 + 2.35' conversion to MLLW) + 0.75 ft
- <u>Water Depth at Toe</u> = 25.21 ft

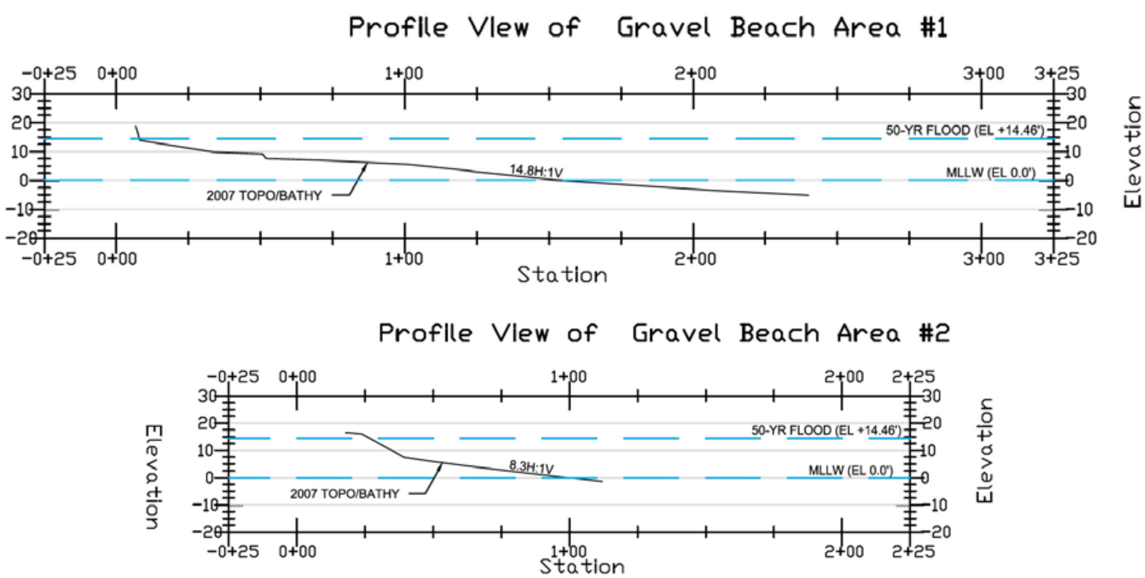


Figure 10 – Existing Topography/Bathymetry at Gravel Beach Areas (Typical Section)

DESIGN WIND SPEED: ASCE/SEI 7-10 (Reference 3) is a nationally recognized standard for environmental and service loading and serves as the basis of the 50-year MRI wind conditions. The American Technology Council (Reference 4) provides a web site that yields site specific wind speed using the GPS coordinate system. The reason this utility is needed is that the spatial resolution of the wind speed maps that are displayed in ASCE 7 are not sufficient to determine a site specific wind speed. There are no reference city or town locations on the ASCE 7 maps and, while county boundaries are shown, the resolution is affected when the maps are expanded large enough to distinguish the boundaries and approximate the city locations. Figure 11 shows the 3-second peak gust wind speeds specific to the Lockheed West site as provided by the ATC website.

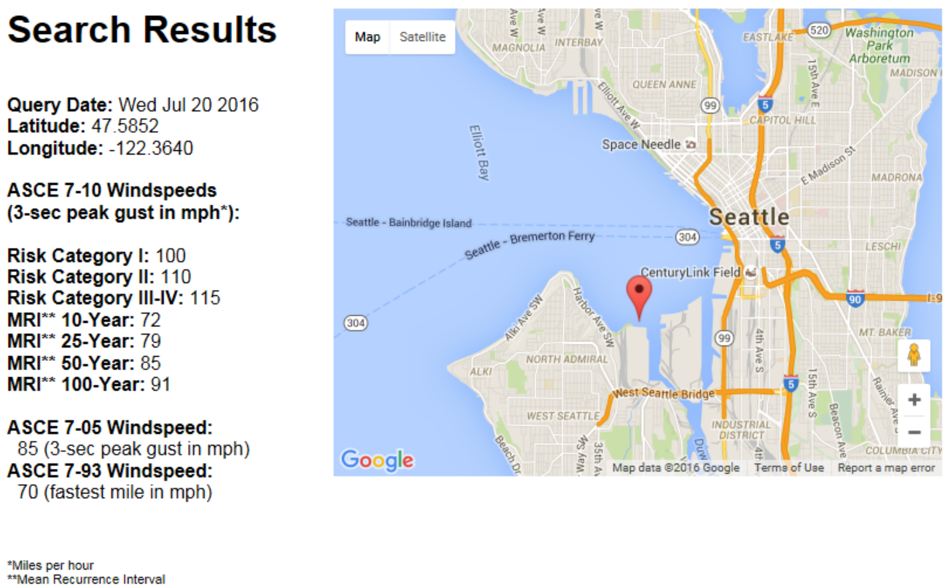


Figure 11 - ASCE 7-10 Wind Speeds

Source: Reference 2

The basic ASCE 7-10 50-year MRI, 3-second gust wind speed at both sites is 85 mph. The 50-year, 3-second gust average wind speed requires adjustment for duration, overland/overwater boundary layer differences and atmospheric boundary layer stability in accordance with the logic chart of Figure 12 from the Coastal Engineering Manual (Reference 3).

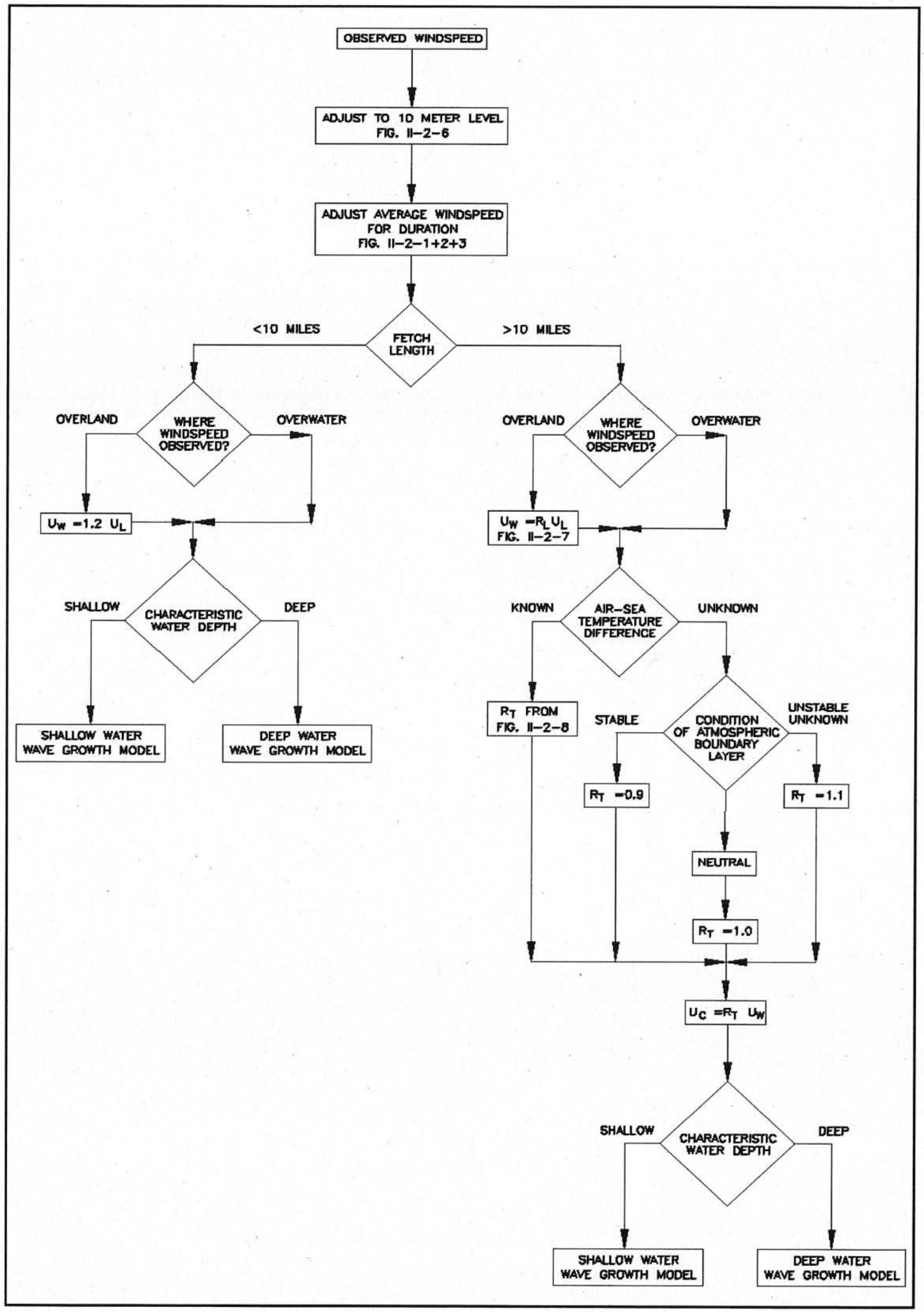


Figure 12 - Wind Speed Adjustments for Wave Hindcasting

Source: Figure II-2-20 from Reference 3

AREA #1 WIND SPEED CALCULATION

Duration Correction Calculation:

The duration correction factor is determined from ASCE 7-05 Figure C6-4 (pg. 308). In order to correct from 3-sec to 1-hr, a correction factor of 1.525 is required. ***If ASCE version is updated, check for revised graph and update equations below.***

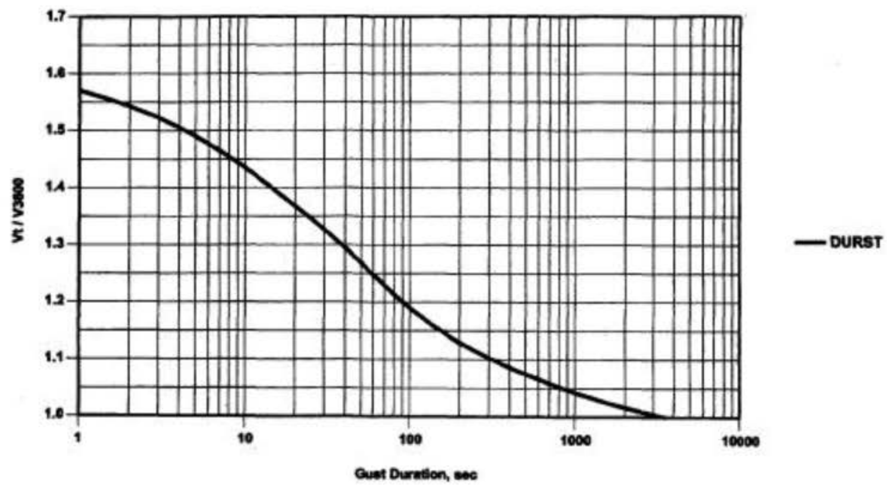


FIGURE C6-4 MAXIMUM SPEED AVERAGED OVER t_s TO HOURLY MEANS SPEED

$$wind\_speed\_50 := \frac{wind\_speed\_50}{1.525}$$

$$\boxed{wind\_speed\_50 = 24.9\,\frac{m}{s}}$$

AREA #1 WIND SPEED CALCULATION

Fetch Limited Correction Calculation:

The average wind speed can now be adjusted for duration using the CEM. Please refer to EQ II-2-35 and Figure II-2-1 from the *Coastal Engineering Manual (Part II)*.

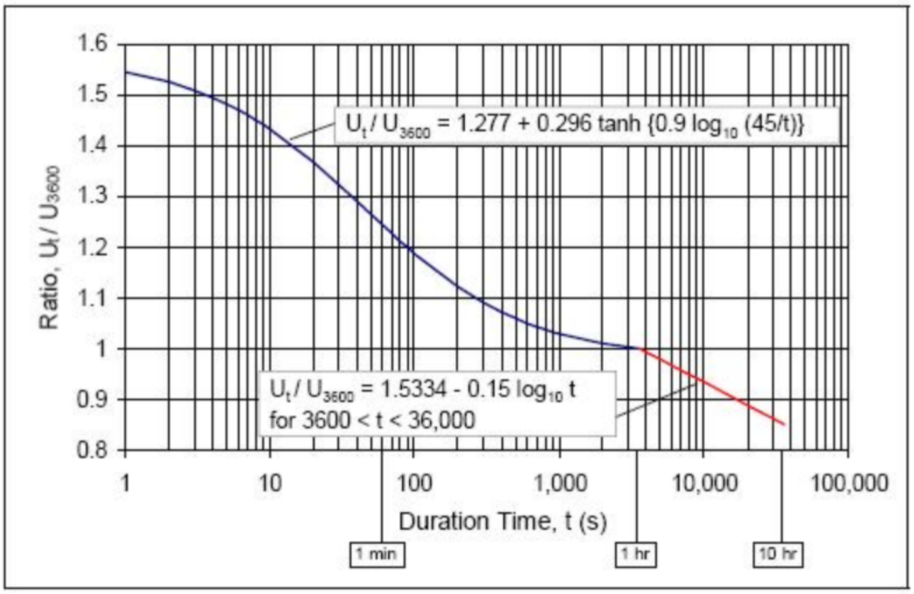


Figure II-2-1. Ratio of wind speed of any duration U_t to the 1-hr wind speed U_{3600}

$$t\_fetch\_50 := 77.23 \cdot \frac{Fetch^{0.67}}{wind\_speed\_50^{0.34} \cdot g^{0.33}}$$

$$\boxed{t\_fetch\_50 = 9964.1\ s}$$

$$duration\_correction\_50(t\_fetch\_50) := \left[\begin{array}{ll} \left(1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45 \cdot s}{t\_fetch\_50}\right)\right)\right) & \text{if } t\_fetch\_50 < 3600 \cdot s \\ 1.5334 - 0.15 \cdot \log\left(\frac{t\_fetch\_50}{s}\right) & \text{otherwise} \end{array} \right]$$

$$wind\_speed\_50 := wind\_speed\_50 \cdot duration\_correction\_50(t\_fetch\_50)$$

$$\boxed{wind\_speed\_50 = 23.3\ \frac{m}{s}}$$

AREA #1 WIND SPEED CALCULATION

Overwater Correction Calculation:

The wind speed must be corrected from an overland measurement to an overwater measurement. Please refer to Figure II-2-7 and page II-2-36 from the *Coastal Engineering Manual (Part II)*.

CEM page II-2-36 Excerpt

(c) Overland or overwater. When the observation was collected overwater (within the marine boundary layer), this adjustment is not needed. When the observation was collected overland and the fetch is long enough for full development of a marine boundary layer (longer than about 16 km or 10 miles), the observed wind speed should be adjusted to an overwater wind speed using Figure II-2-7 (see Example Problem II-2-4). Otherwise (for overland winds and fetches less than 16 km), wave growth occurs in a transitional atmospheric boundary layer, which has not fully adjusted to the overwater regime. In this case, wind speeds observed overland must be increased to better represent overwater wind speeds. A factor of 1.2 is suggested here, but no simple method can accurately represent this complex case. In relation to all of these adjustments, the term overland implies a measurement site that is predominantly characterized as inland. If a measurement site is directly adjacent to the water body, it may, for some wind directions, be equivalent to overwater.

$$\text{overwater\_correction\_50} := \begin{cases} 0.9 & \text{if } \text{Fetch} \geq 16000 \cdot \text{m} \wedge \text{wind\_speed\_50} > 18.5 \cdot \frac{\text{m}}{\text{s}} \\ 1.2 & \text{if } \text{Fetch} < 16000 \cdot \text{m} \end{cases}$$

$$\text{wind\_speed\_50} := \text{overwater\_correction\_50} \cdot \text{wind\_speed\_50}$$

$$\boxed{\text{wind\_speed\_50} = 20.9 \frac{\text{m}}{\text{s}}}$$

Temperature Correction Calculation:

If the fetch is sufficiently large, the wind speed shall be corrected due to an air-sea temperature difference. Please refer to an excerpt from page II-2-36 from the *Coastal Engineering Manual (Part II)*.

(d) Stability. For fetches longer than 16 km, an adjustment for stability of the boundary layer may also be needed. If the air-sea temperature difference is known, Figure II-2-8 can be used to make the adjustment. When only general knowledge of the condition of the atmospheric boundary layer is available, it should be categorized as stable, neutral, or unstable according to the following:

Stable - when the air is warmer than the water, the water cools air just above it and decreases mixing in the air column ($R_T = 0.9$).

Neutral - when the air and water have the same temperature, the water temperature does not affect mixing in the air column ($R_T = 1.0$).

Unstable - when the air is colder than the water, the water warms the air, causing air near the water surface to rise, increasing mixing in the air column ($R_T = 1.1$).

When the boundary layer condition is unknown, an unstable condition, $R_T = 1.1$, should be assumed.

$$\text{temperature\_correction} := \left(\begin{cases} 1.1 & \text{if } \text{Fetch} > 16000 \cdot \text{m} \\ 1.0 & \text{otherwise} \end{cases} \right)$$

$$\text{wind\_speed\_50} := \text{temperature\_correction} \cdot \text{wind\_speed\_50}$$

$$\boxed{\text{wind\_speed\_50} = 23.0 \frac{\text{m}}{\text{s}}}$$

AREA #2 WIND SPEED CALCULATION

Duration Correction Calculation:

The duration correction factor is determined from ASCE 7-05 Figure C6-4 (pg. 308). In order to correct from 3-sec to 1-hr, a correction factor of 1.525 is required. ***If ASCE version is updated, check for revised graph and update equations below.***

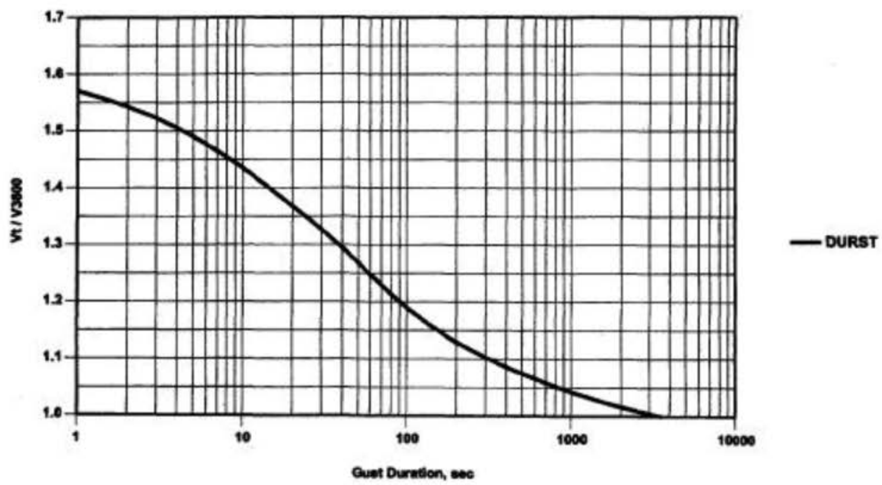


FIGURE C6-4 MAXIMUM SPEED AVERAGED OVER t_s TO HOURLY MEANS SPEED

$$wind\_speed\_50 := \frac{wind\_speed\_50}{1.525}$$

$$\boxed{wind\_speed\_50 = 24.9\,\frac{m}{s}}$$

AREA #2 WIND SPEED CALCULATION

Fetch Limited Correction Calculation:

The average wind speed can now be adjusted for duration using the CEM. Please refer to EQ II-2-35 and Figure II-2-1 from the *Coastal Engineering Manual (Part II)*.

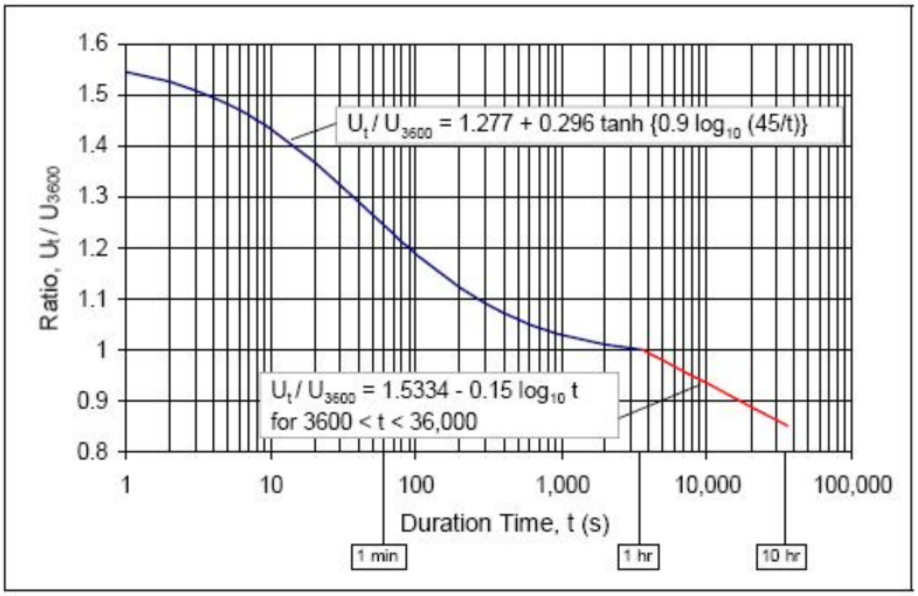


Figure II-2-1. Ratio of wind speed of any duration U_t to the 1-hr wind speed U_{3600}

$$t\_fetch\_50 := 77.23 \cdot \frac{Fetch^{0.67}}{wind\_speed\_50^{0.34} \cdot g^{0.33}}$$

$$\boxed{t\_fetch\_50 = 887.2\,s}$$

$$duration\_correction\_50(t\_fetch\_50) := \left[\begin{array}{ll} \left(1.277 + 0.296 \cdot \tanh\left(0.9 \cdot \log\left(\frac{45 \cdot s}{t\_fetch\_50}\right)\right)\right) & \text{if } t\_fetch\_50 < 3600 \cdot s \\ 1.5334 - 0.15 \cdot \log\left(\frac{t\_fetch\_50}{s}\right) & \text{otherwise} \end{array} \right]$$

$$wind\_speed\_50 := wind\_speed\_50 \cdot duration\_correction\_50(t\_fetch\_50)$$

$$\boxed{wind\_speed\_50 = 25.8\,\frac{m}{s}}$$

AREA #2 WIND SPEED CALCULATION

Overwater Correction Calculation:

The wind speed must be corrected from an overland measurement to an overwater measurement. Please refer to Figure II-2-7 and page II-2-36 from the *Coastal Engineering Manual (Part II)*.

CEM page II-2-36 Excerpt

(c) Overland or overwater. When the observation was collected overwater (within the marine boundary layer), this adjustment is not needed. When the observation was collected overland and the fetch is long enough for full development of a marine boundary layer (longer than about 16 km or 10 miles), the observed wind speed should be adjusted to an overwater wind speed using Figure II-2-7 (see Example Problem II-2-4). Otherwise (for overland winds and fetches less than 16 km), wave growth occurs in a transitional atmospheric boundary layer, which has not fully adjusted to the overwater regime. In this case, wind speeds observed overland must be increased to better represent overwater wind speeds. A factor of 1.2 is suggested here, but no simple method can accurately represent this complex case. In relation to all of these adjustments, the term overland implies a measurement site that is predominantly characterized as inland. If a measurement site is directly adjacent to the water body, it may, for some wind directions, be equivalent to overwater.

$$\text{overwater\_correction\_50} := \begin{cases} 0.9 & \text{if Fetch} \geq 16000 \cdot m \wedge \text{wind\_speed\_50} > 18.5 \cdot \frac{m}{s} \\ 1.2 & \text{if Fetch} < 16000 \cdot m \end{cases}$$

$$\text{wind\_speed\_50} := \text{overwater\_correction\_50} \cdot \text{wind\_speed\_50} \qquad \boxed{\text{wind\_speed\_50} = 30.9 \frac{m}{s}}$$

Temperature Correction Calculation:

If the fetch is sufficiently large, the wind speed shall be corrected due to an air-sea temperature difference. Please refer to an excerpt from page II-2-36 from the *Coastal Engineering Manual (Part II)*.

(d) Stability. For fetches longer than 16 km, an adjustment for stability of the boundary layer may also be needed. If the air-sea temperature difference is known, Figure II-2-8 can be used to make the adjustment. When only general knowledge of the condition of the atmospheric boundary layer is available, it should be categorized as stable, neutral, or unstable according to the following:

Stable - when the air is warmer than the water, the water cools air just above it and decreases mixing in the air column ($R_T = 0.9$).

Neutral - when the air and water have the same temperature, the water temperature does not affect mixing in the air column ($R_T = 1.0$).

Unstable - when the air is colder than the water, the water warms the air, causing air near the water surface to rise, increasing mixing in the air column ($R_T = 1.1$).

When the boundary layer condition is unknown, an unstable condition, $R_T = 1.1$, should be assumed.

$$\text{temperature\_correction} := \left(\begin{cases} 1.1 & \text{if Fetch} > 16000 \cdot m \\ 1.0 & \text{otherwise} \end{cases} \right)$$

$$\text{wind\_speed\_50} := \text{temperature\_correction} \cdot \text{wind\_speed\_50} \qquad \boxed{\text{wind\_speed\_50} = 30.9 \frac{m}{s}}$$

SUMMARY:

The design input conditions for gravel beach installation Area #1 are:

1. 50 year MRI wind speed, 3-second duration = 85 mph (38 m/s)
2. Locally adjusted wind speed, 60-second duration = 51.4 mph (23 m/s)
3. Wave fetch length = 73,000 ft
4. Average water depth along fetch = 101 ft
5. Water depth at toe = 25.26 ft

The design input conditions for gravel beach installation Area #2 are:

1. 50 year MRI wind speed, 3-second duration = 85 mph (38 m/s)
2. Locally adjusted wind speed, 60-second duration = 51.4 mph (30.9 m/s)
3. Wave fetch length = 1,975 ft
4. Average water depth along fetch = 65 ft
5. Water depth at toe = 25.26 ft

--End of Calculation --

CLIENT: **Lockheed Martin**		CONTRACT NUMBER: 194-8650
SUBJECT: **CALCULATION WAVE-02 (8650-02)** **WAVE CONDITIONS** **Lockheed West – Seattle, WA**		
BASED ON: N/A CALC. REV: REV A – 27/10/16 - DRAFT		DRAWING NUMBER: N/A
BY: JWD DATE: 15 September 16	CHECKED BY: REC DATE: 20 September 16	APPROVED BY: SO DATE: 27 October 16

REFERENCES:

1. Tetra Tech, Inc., 2016. Calculation WAVE-01, Gravel Beach Design – Wind & Water Levels, Shipyard No. 2 – Seattle, WA, 21 July 2016.

2. USACE, 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes). URL: http://chl.erdc.usace.army.mil/cem.

PURPOSE: The purpose of this calculation is to establish the design wave conditions associated with the occurrence of the 50-year mean recurrence interval (MRI) design basis event at Shipyard No. 2 of the Lockheed West Project in Seattle, WA. These design wave conditions serve as the partial basis to evaluate the stability of two gravel beach installations at the project site. Calculation WAVE-01 (Reference 1) provides the wind and water levels that are inputs to the calculation of the design wave conditions.

SITE: Lockheed West is located on the southern shoreline of Elliott Bay in Seattle's Industrial District. The project's geographic coordinates are 47^0 35' 6.60"N, 122^0 21' 50.29"W. Bainbridge Island lies to the west of the site with the city of Seattle to its NE. Figure 1 shows the Lockheed West project location.

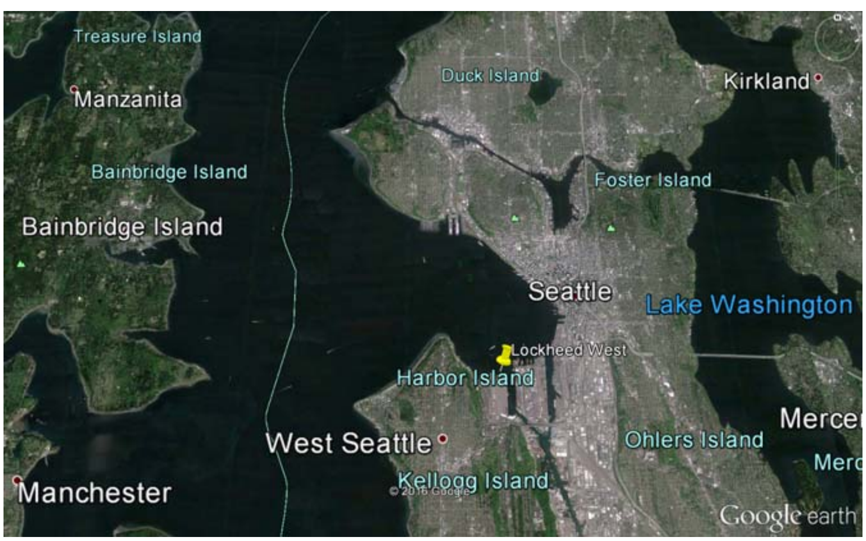


Figure 1 – Lockheed West Project Site, Seattle, WA

BACKGROUND: Former shipyard operations in the project area resulted in contamination of the sediments. Remediation efforts will dredge the contaminated sediments and backfill the shoreline/intertidal areas with a habitat mix of gravel and possibly riprap. Gravel beaches will be installed at two location within the project area. Calculations WAVE-01 and WAVE-02 provide the design wind and wave data necessary to design a dynamically stable gravel beach profile. Calculation GRAVEL-01 provides the equilibrium gravel beach slopes, median grain size, and slope thicknesses required for each shoreline installation area.

GRAVEL BEACH SITES: The first shoreline requiring stabilization through a dynamic gravel beach installation is shown in Figure 2. It is approximately 100 feet in length and located directly on Elliott Bay between two former pile supported dock structures.

Figure 2 – Gravel Beach Installation Area #1 (~100 linear ft)

The second shoreline is located in a more sheltered location within the West Waterway OU. It is approximately 285 feet in length and located within a crenulated bay that is bordered on the north by an existing outfall and to the south by a riprap revetment adjacent to Port of Seattle Terminal 5.

Figure 3 – Gravel Beach Installation Area #2 (~285 linear ft)

DESIGN CONDITIONS: Calculation WAVE-01 provides the design input conditions for the 50-yr MRI design waves for each gravel beach site. These are outlined below.

Area #1

1. 50 year MRI wind speed, 3-second duration = 85 mph (38 m/s)
2. Locally adjusted wind speed, 60-second duration = 51.4 mph (23 m/s)
3. Wave fetch length = 73,000 ft
4. Average water depth along fetch = 101 ft
5. Water depth at toe = 25.26 ft

Area #2

1. 50 year MRI wind speed, 3-second duration = 85 mph (38 m/s)
2. Locally adjusted wind speed, 60-second duration = 51.4 mph (30.9 m/s)
3. Wave fetch length = 1,975 ft
4. Average water depth along fetch = 65 ft
5. Water depth at toe = 25.26 ft

50-yr MRI DESIGN WAVE CALCULATION

The wave calculation procedures follow those outlined in the Coastal Engineering Manual (Reference 2). Specific references to pages or figures are included in the calculations at the appropriate locations.

Area #1 – 50-yr MRI Design Wave

Design Wave Height and Period Calculation:
Drag Coefficient and Friction Velocity

Please refer to Equations II-2-36 on page II-2-44 of the *Coastal Engineering Manual (Part II)*.

Drag Coefficient

$$CD\_50 := 0.001 \cdot \left(1.1 + 0.035 \cdot \frac{wind\_speed\_50}{\frac{m}{s}}\right)$$

Friction Velocity

$$u\_50 := \sqrt{CD\_50 \cdot (wind\_speed\_50)^2}$$

$$\boxed{u\_50 = 1.0\,\frac{m}{s}}$$

Energy Based Significant Wave Height

$$H_{mo\_50} := \frac{\left(0.0413 \cdot u\_50^2\right)}{g} \cdot \sqrt{\frac{(g \cdot Fetch)}{u\_50^2}}$$

$$\boxed{H_{mo\_50} = 2.0\,m}$$

Peak Wave Period

$$T_{p\_50} := 0.751 \cdot \sqrt[3]{\frac{(g \cdot Fetch)}{u\_50^2}} \cdot \left(\frac{u\_50}{g}\right)$$

$$\boxed{T_{p\_50} = 4.6\,s}$$

Area #1 – 50-yr MRI Design Wave

Design Wave Height and Period Calculation (Cont'd):
Determine Limiting Wave Period and Final Period

Please refer to Equations II-2-39 on page II-2-46 of the *Coastal Engineering Manual (Part II).*

$$Limiting_{period} := 9.78 \cdot \sqrt{\frac{ave\_water\_depth}{g}}$$

$$\boxed{Limiting_{period} = 17.3\,s}$$

$$T_{p\_50} := \begin{cases} Limiting_{period} & \text{if } Limiting_{period} < T_{p\_50} \\ T_{p\_50} & \text{otherwise} \end{cases}$$

$$\boxed{T_{p\_50} = 4.6\,s}$$

Design Wave Height and Period Calculation (Cont'd):
Determine New Fetch Length and Recalculate Energy Based Significant Wave Height

Please refer to Equations II-2-36 on page II-2-44 of the *Coastal Engineering Manual (Part II).*

New Fetch Length

$$new_{Fetch\_50} := \begin{cases} \frac{u\_50^2}{g} \cdot \left(\frac{g \cdot T_{p\_50}}{0.651 \cdot u\_50}\right)^3 & \text{if } Limiting_{period} < T_{p\_50} \\ Fetch & \text{otherwise} \end{cases}$$

$$\boxed{new_{Fetch\_50} = 22250.4\,m}$$

Energy Based Significant Wave Height

$$H_{mo\_50} := \frac{\left(0.0413 \cdot u\_50^2\right)}{g} \cdot \sqrt{\frac{\left(g \cdot new_{Fetch\_50}\right)}{u\_50^2}}$$

$$\boxed{H_{mo\_50} = 2.0\,m}$$

Design Wave Height and Period Calculation (Cont'd):
Determine Depth Limited Wave Height

$$H_{depth\_limited} := 0.6 \cdot structure\_depth$$

$$\boxed{H_{depth\_limited} = 4.6\,m}$$

Final Wave Height Determination

$$H_{mo\_50} := \begin{cases} H_{depth\_limited} & \text{if } H_{depth\_limited} < H_{mo\_50} \\ H_{mo\_50} & \text{otherwise} \end{cases}$$

$$\boxed{H_{mo\_50} = 2.0 \cdot m} \qquad \boxed{H_{mo\_50} = 6.5 \cdot ft}$$

Area #2 – 50-yr MRI Design Wave

Design Wave Height and Period Calculation:
Drag Coefficient and Friction Velocity

Please refer to Equations II-2-36 on page II-2-44 of the *Coastal Engineering Manual (Part II)*.

Drag Coefficient

$$CD\_50 := 0.001 \cdot \left(1.1 + 0.035 \cdot \frac{wind\_speed\_50}{\frac{m}{s}}\right)$$

Friction Velocity

$$u\_50 := \sqrt{CD\_50 \cdot (wind\_speed\_50)^2}$$

$$\boxed{u\_50 = 1.4\,\frac{m}{s}}$$

Energy Based Significant Wave Height

$$H_{mo\_50} := \frac{\left(0.0413 \cdot u\_50^2\right)}{g} \cdot \sqrt{\frac{(g \cdot Fetch)}{u\_50^2}}$$

$$\boxed{H_{mo\_50} = 0.5\,m}$$

Peak Wave Period

$$T_{p\_50} := 0.751 \cdot \sqrt[3]{\frac{(g \cdot Fetch)}{u\_50^2}} \cdot \left(\frac{u\_50}{g}\right)$$

$$\boxed{T_{p\_50} = 1.6\,s}$$

Area #2 – 50-yr MRI Design Wave

Design Wave Height and Period Calculation (Cont'd):
Determine Limiting Wave Period and Final Period

Please refer to Equations II-2-39 on page II-2-46 of the *Coastal Engineering Manual (Part II)*.

$$Limiting_{period} := 9.78 \cdot \sqrt{\frac{ave\_water\_depth}{g}}$$

$$\boxed{Limiting_{period} = 13.9\,s}$$

$$T_{p\_50} := \begin{cases} Limiting_{period} & \text{if } Limiting_{period} < T_{p\_50} \\ T_{p\_50} & \text{otherwise} \end{cases}$$

$$\boxed{T_{p\_50} = 1.6\,s}$$

Design Wave Height and Period Calculation (Cont'd):
Determine New Fetch Length and Recalculate Energy Based Significant Wave Height

Please refer to Equations II-2-36 on page II-2-44 of the *Coastal Engineering Manual (Part II)*.

New Fetch Length

$$new_{Fetch\_50} := \begin{cases} \frac{u\_50^2}{g} \cdot \left(\frac{g \cdot T_{p\_50}}{0.651 \cdot u\_50}\right)^3 & \text{if } Limiting_{period} < T_{p\_50} \\ Fetch & \text{otherwise} \end{cases}$$

$$\boxed{new_{Fetch\_50} = 602.0\,m}$$

Energy Based Significant Wave Height

$$H_{mo\_50} := \frac{\left(0.0413 \cdot u\_50^2\right)}{g} \cdot \sqrt{\frac{\left(g \cdot new_{Fetch\_50}\right)}{u\_50^2}}$$

$$\boxed{H_{mo\_50} = 0.5\,m}$$

Design Wave Height and Period Calculation (Cont'd):
Determine Depth Limited Wave Height

$$H_{depth\_limited} := 0.6 \cdot structure\_depth$$

$$\boxed{H_{depth\_limited} = 4.6\,m}$$

Final Wave Height Determination

$$H_{mo\_50} := \begin{cases} H_{depth\_limited} & \text{if } H_{depth\_limited} < H_{mo\_50} \\ H_{mo\_50} & \text{otherwise} \end{cases}$$

$$\boxed{H_{mo\_50} = 0.5 \cdot m} \qquad \boxed{H_{mo\_50} = 1.5 \cdot ft}$$

SUMMARY

The design wave characteristics for the 50-year MRI event are:

50-yr MRI Design Waves		
Location	Wave Height (ft)	Wave Period (s)
Area #1	6.5	4.6
Area #2	1.5	1.6

--End of Calculation --

CALCULATION COVER SHEET

PROJECT Lockheed West Seattle - Superfund Site Remediation **CLIENT** Lockheed Martin

SUBJECT Remediation Volume Estimates

CALCULATION NO 8650-03 **REVISION NO** C

TOTAL NO OF PAGES 10

Computer Program Used in Calculation: AutoCAD Civil 3D 2015

Rev No.	***Date***	***Prepared By***	***Checked By***	***Revision***
A	9/27/16	Nich VanBuecken, PE	Alex Strom, PE	30% Design - Internal draft
B	10/27/16	Nich VanBuecken, PE	Alex Strom, PE	30% Design - Draft
C	03/27/17	Alex Strom, PE	Senda Ozkan, PE	60% Design

TABLE OF CONTENTS

1.0 PURPOSE

This calculation documents the remediation volume estimates (dredge, residual management layer, enhanced natural recovery layer, and backfill) at the Lockheed West Superfund Site. In this project, contaminated sediment will be removed to meet the remedial design objectives. Following removal, backfill will be placed in strategic locations to restore habitat, provide stability and to leave a clean cover on the exposed surfaces. Refer to the design report and design drawings for further details. These volumes are developed at a 60% design stage, may need to be refined at 90% design.

2.0 INPUTS

2.1 SURFACE DEVELOPMENT

Tetra Tech completed a bathymetric survey using a multibeam sonar system (Tetra Tech, 2016). Hydrographic images including elevation contour lines and hillshade three-dimensional representation of the mudline surface were developed. The extent of shoreline riprap was determined by the site survey conducted at low-tide and using data from the high-resolution bathymetry survey and the sidescan sonar survey. For the shorelines and upland, Pacific Geomatic Services conducted a topographic survey generally from the Port of Seattle Terminal 5 fence line down to an elevation of -2 feet MLLW. To supplement the upland survey, LiDAR collected by the Puget Sound LiDAR Consortium was added. These three surveys were all adjusted as needed to the horizontal coordinate system of NAD83 Washington State Planes, North Zone, US Foot and vertical datum of MLLW feet (Epoch 1983-2001).

A combined existing surface was created by adding the three data sets, with minor adjustments based on field knowledge, to create an overall combined surface for the entire site utilizing AutoCAD Civil 3D 2015 (C3D). “Breaklines” were added as needed to consistently join together the three surfaces. The bathymetry data was used to the greatest extent possible due to the quantity and quality of raw data collected. Figure 1 below depicts a 3-dimensional view of the combined surface.

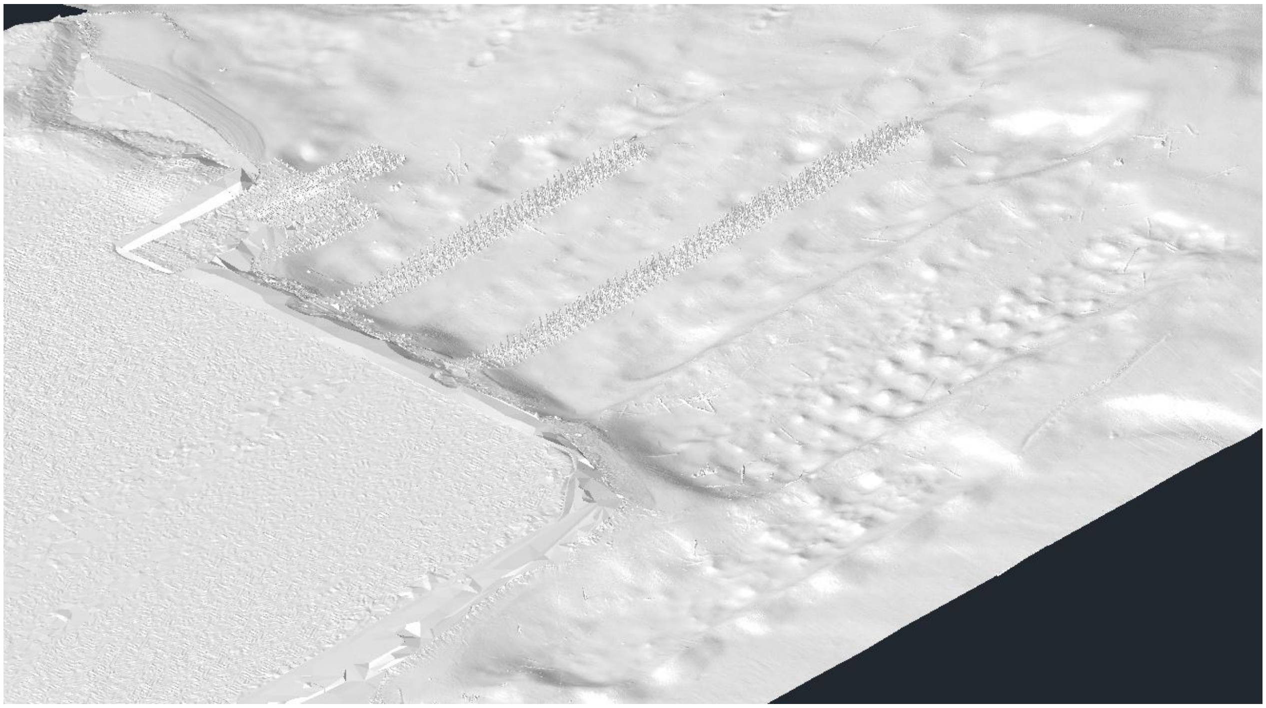


Figure 1. Combined Surface

2.2 SURVEY DATA

AutoCAD files created by Tetra Tech and property boundaries provided by Washington Department of Natural Resources, and the Port of Seattle provided background base file for the design. Historical and pre-design sediment sample core information was added into C3D. Chemistry data was evaluated against the cleanup levels in the Sediment Quality Standards (SQS) and cleanup screening level (CSL) areas. This information guided the design to determine depths and extents for removal of contaminated sediment.

3.0 METHODOLOGY

In general, the removal slopes varied from 2H:1V to 3H:1V (horizontal run to vertical rise) at the removal depths until "daylighting" to existing grade was reached. Dredging began generally at the edge of rock on the upland and continued to the edge of SQS or CSL boundaries. The dredging depths vary from 1-foot to 12-feet deep and backfill depths vary from 1-foot to 13-feet. An example of dredge neatline determination is shown in Figure 2 at sample TT-06CS. The elevation of contamination (EOC) was found to reach elevation -44.54 feet MLLW therefore the neatline elevation was set at -45.0 feet MLLW. In some areas a minimum 1-foot dredge was designed to scrape the surface and meet removal requirements of SQS and CSL (note Figure 2 labeled area "See Note 3").

Figure 2 below displays an example cross section showing the existing grade as dashed and the dredge neatline boundary as solid.

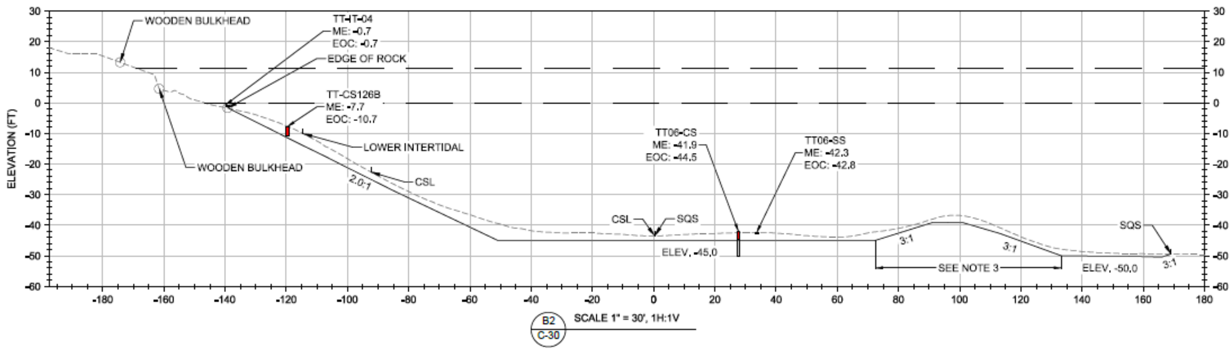


Figure 2. Example Cross Section

3.1 DREDGE

To meet the design criteria, the site will be dredged to remove all contaminated sediment to the design cleanup levels. The -10 foot MLLW elevation is the lower boundary of intertidal zone separating the intertidal zone from the subtidal zone. Volumes were calculated using C3D by comparing the combined existing conditions surface with the dredge prism neatline surfaces, as seen in Figure 3. The design was separated into 20 removal areas (see Figure 4). Figure 3 is an example screen shot from C3D for the South Beach Area where grey dashed lines represent existing contours, green and brown lines represent dredge neatline contours, blue colors represents depth of cut with brighter colors being greater depths, and the yellow line represents the dredge boundary. Table 1 below summarizes the volume of dredge to neatline:

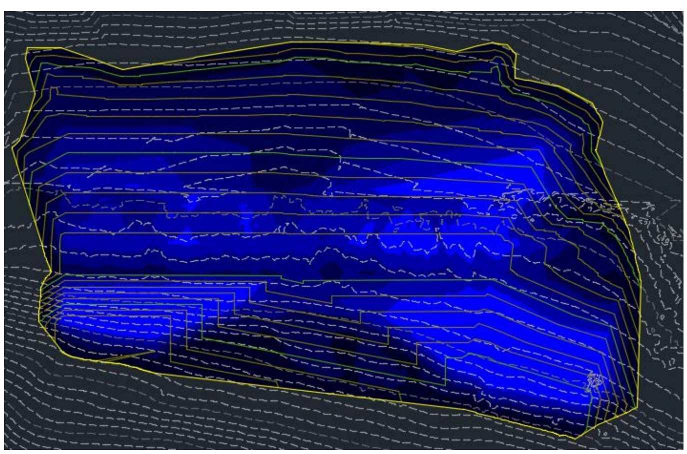


Figure 3. Volume Calculation

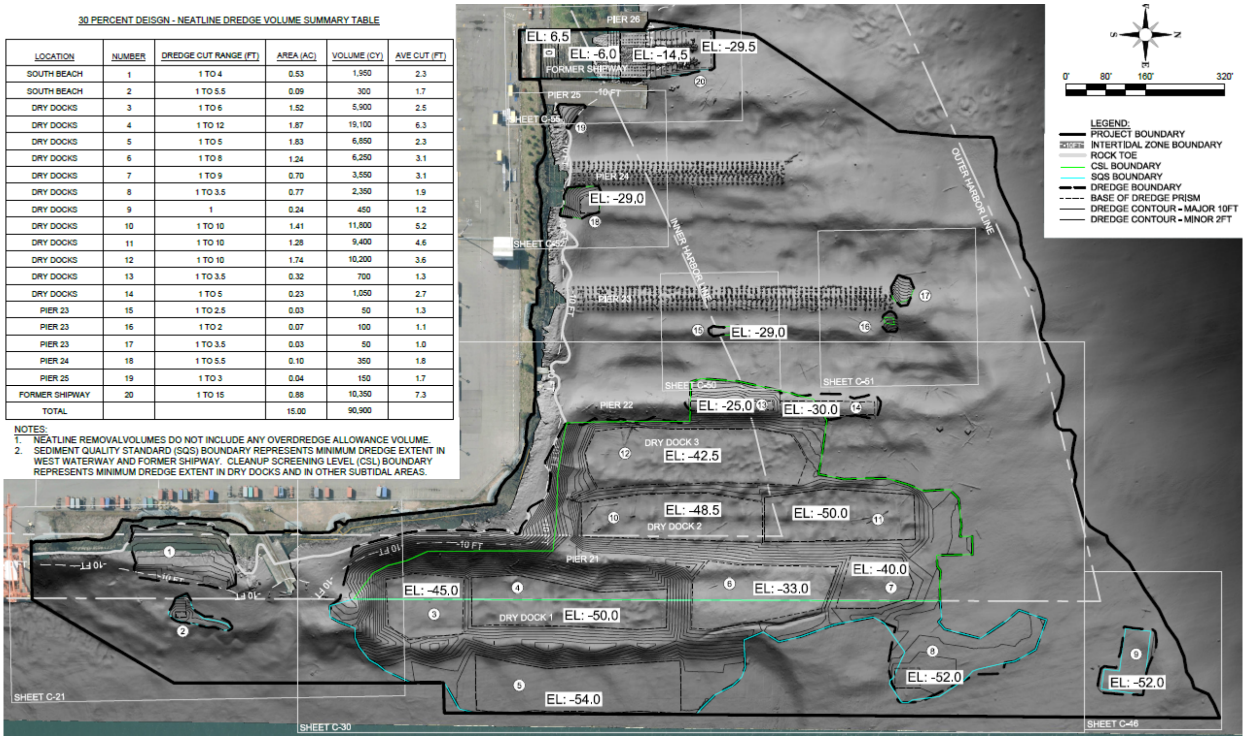


Figure 4. Dredge Removal Overview

Table 1. Estimated dredge volume

Depth	Area (ac)	Volume (cy)
Intertidal	1.5	11,730
Subtidal	13.5	79,170
Total	15.0	90,900

3.2 OVERDREDGE

An overdredge allowance (6-inch to 12-inch) was added to the design to allow the contractor flexibility in the removal process. These volume estimates were calculated using the proposed removal boundary areas multiplied by the associated depths. Table 2 below summarizes the quantities:

Table 2. Estimated overdredge volume

Number	Location	Area (AC)	Overdredge (CY, 6-IN)	Overdredge (CY, 12-IN)
1	SOUTH BEACH	0.53	430	860
2	SOUTH BEACH	0.09	80	150
3	DRY DOCKS	1.52	1,230	2,450
4	DRY DOCKS	1.87	1,520	3,030
5	DRY DOCKS	1.83	1,480	2,950
6	DRY DOCKS	1.24	1,000	2,000
7	DRY DOCKS	0.70	570	1,140
8	DRY DOCKS	0.77	620	1,240
9	DRY DOCKS	0.24	200	390
10	DRY DOCKS	1.41	1,140	2,280
11	DRY DOCKS	1.28	1,030	2,060
12	DRY DOCKS	1.74	1,400	2,800
13	DRY DOCKS	0.32	260	520
14	DRY DOCKS	0.23	190	380
15	PIER 23	0.03	30	50
16	PIER 23	0.07	60	120
17	PIER 23	0.03	30	50
18	PIER 24	0.10	90	170
19	PIER 25	0.04	30	60
20	FORMER SHIPWAY	0.88	710	1,420
	TOTAL	**15.00**	**12,100**	**24,120**

3.3 RESIDUAL MANAGEMENT LAYER

Once the sediment has been removed, a 6- to 9-inch residual management layer (RML) will be placed over the dredge areas where other backfills or stabilization techniques are not utilized. RML volume was calculated with a 12-inch thickness material placement including overplacement allowance. Table 3 below summarizes the quantities:

Table 3. Estimated RML volume

Residual Management Sand Layer (12.0 acres)		
Location	**Area (AC)**	**Volume - with 12-inch placement (CY)**
South Beach	0.09	147
Dry Docks	11.77	18,990
Piers 23, 24, & 25	0.18	291
Former Shipway	0	-
Total	12.04	19,428

3.4 ENHANCED NATURAL RECOVERY LAYER

In areas within the project area that are not receiving backfill, RML, or other stabilization techniques, the ENR layer will be placed at a depth of 6- to 9-inches. ENR volume was calculated with a 12-inch thickness material placement including over-placement allowance. Table 4 below summarizes the quantities:

Table 4. Estimated ENR volume

Area (AC)	Depth (IN)	Volume (CY)
23.1	12	37,230

3.5 BACKFILL

In areas above the intertidal boundary (-10 ft MLLW), specifically in the South Beach (area 1), near Pier 25 (area 19), and in the Former Shipway (area 20), various backfills will be placed after dredging occurs to return the elevations to near existing grades. The backfill will include three types: gravel beach mix, fish mix, and sand.

In the South Beach (area 1) and near Pier 25 (area 19), gravel beach mix with average 2 feet depth and median material size (D50) of 1.5-inch rock will be placed at locations above -10 ft MLLW.

In the Former Shipway (see Figure 5) gravel beach mix at average 3-ft depth and D50 of 1.5-inch rock will be placed to -10 ft MLLW. Sand backfill will be placed over dredge neatline below the gravel beach mix.

In all three areas (area 1, area 19, and area 20) fish mix will be placed as the final 6 to 9-inch layer over the gravel beach mix.

These volume estimates were calculated using the proposed removal boundaries and associated depths. Table 5 below summarizes the quantities:

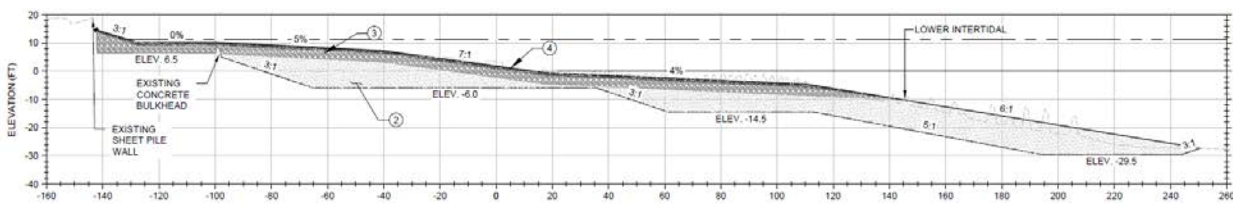


Figure 5. Former Shipway Intertidal Backfill

Table 5. Estimated backfill volume

Depth	South Beach	Pier 25	Former Shipway	Volume (cy)
Gravel Beach Mix	1,400	90	3,000	4,490
Fish Mix	860	60	1,030	1,950
Sand	-	-	8,980	8,980

‘

4.0 SUMMARY AND DISCUSSION

For the entire site, the resulting dredge volume was determined based on cleanup levels of contaminants of concern. Table 6 below summarizes the estimated removal quantities including overdredge allowance:

Table 6. Total Dredge Volume

Removal Type	Area (ac)	Volume (cy)
Dredging	15.0	90,900
Dredging with 6-Inch overdredge	15.0	103,000
Dredging with 12-Inch overdredge	15.0	115,000

Refer to Section 3 for estimated quantities of RML, ENR, and backfill.

5.0 REFERENCES

- Bathymetric survey was conducted by Tetra Tech, December 2015.
- Upland survey was performed by PGS 2007.
- LiDAR survey was completed by PSLC 2002.
- Washington Department of Natural Resources GIS files were provided for background information of property boundaries.
- Tetra Tech (Tetra Tech, Inc.), 2016. Predesign field investigation data report, Lockheed Martin Middle River Complex.

TETRA TECH

CALCULATION COVER SHEET

PROJECT **Lockheed West Seattle - Superfund Site Remediation** **CLIENT** **Lockheed Martin**

SUBJECT **Debris Quantity – Shorelines, Former Shipway, Dredge Areas**

CALCULATION NO **8650-04** **REVISION NO** **D**

TOTAL NO OF PAGES **8**

Computer Program Used in Calculation: **AutoCAD Civil 3D 2015**

Rev No.	*Date*	*Prepared By*	*Checked By*	*Revision*
A	9/27/16	Nich VanBuecken, PE	Alex Strom, PE	30% Design - Internal draft
B	10/27/16	Nich VanBuecken, PE	Alex Strom, PE	30% Design - Draft
C	1/18/17	Senda Ozkan, PE	Alex Strom, PE	30% Design – Revised draft
D	03/27/17	Senda Ozkan, PE	Alex Strom, PE	60% Design

TABLE OF CONTENTS

1.0 PURPOSE

This calculation documents the debris removal estimates at Lockheed West. In this project, debris will be removed prior to dredging in the shoreline, Former Shipway, and in-water areas. Various site visits and surveys have been conducted to inventory and quantify this debris. See the design report and design drawings for further details.

2.0 INPUTS

2.1 SHORELINE DEBRIS

Within the project area along the shoreline debris existing in various forms ranging from metal refuse, to obsolete metal or wooden structures, to chunks of concrete or slag which will impede dredging operations, as seen in Figure 1 below. Riprap will be placed to preserve shoreline stability along the shoreline of the Dry Dock and Pier 24 removal areas.

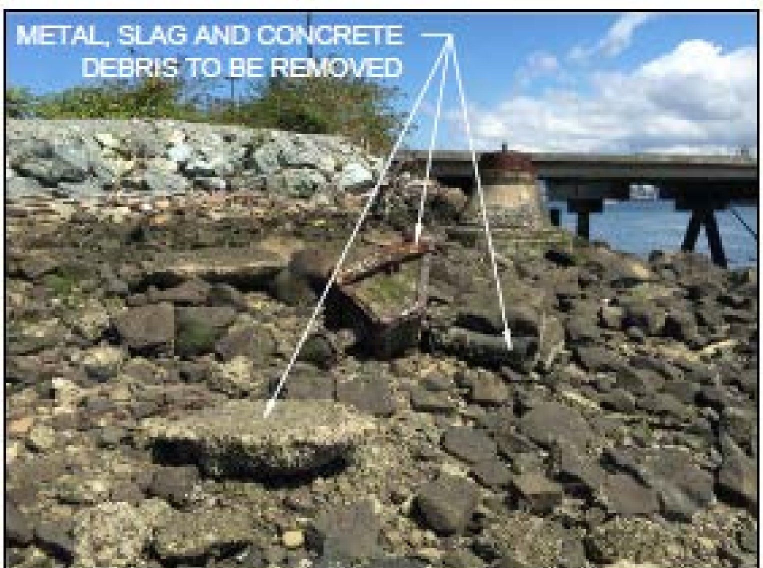


Figure 1. Shoreline Debris – Example

2.2 FORMER SHIPWAY DEBRIS

Within the Former Shipway area, wooden piles remain from the shipway dock structure that will be removed prior to dredging operations. The wood exists in a few forms: vertical round piles the protrude from the ground, flat rectangular wooden timber beams that run laterally between piers 25 and 26, and flat rectangular wooden timber beams that run longitudinally from the beach out into the open water. Additionally portions of an existing sheet pile wall (called out as No.1) will need to be removed in order to reach the sediment to be dredged. Figure 2 depicts the approximate locations of the wood and walls. Refer to the design drawings for detailed information.

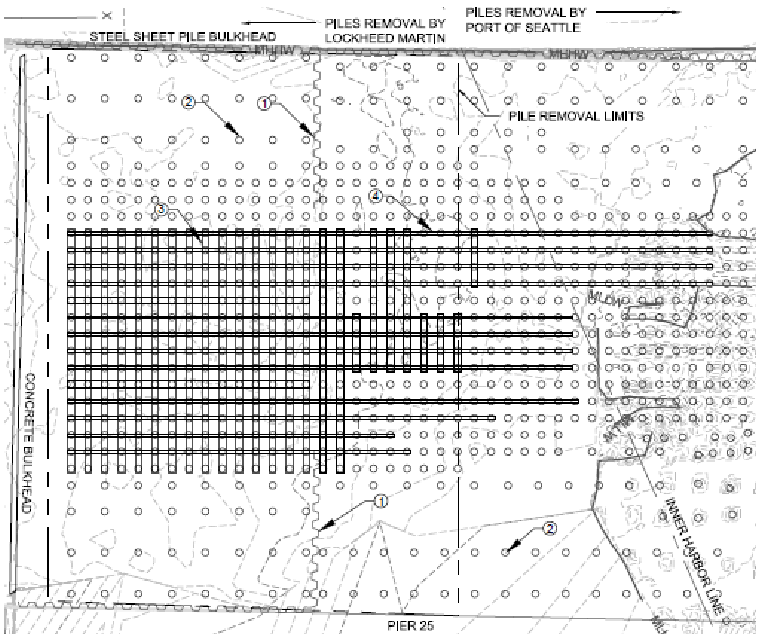


Figure 2. Former Shipway debris

2.3 IN-WATER DEBRIS IN SUBTIDAL DREDGE AREAS

The geophysical survey included side scan sonar and magnetometer to inventory metal and non-metal debris over mudline within the dredge areas. Figure 3 below illustrates a portion the survey results, with orange as metal and blue as non-metal debris. Detailed survey report is included in Pre-remedial Design Field Sampling Data Report (Tetra Tech, 2016).

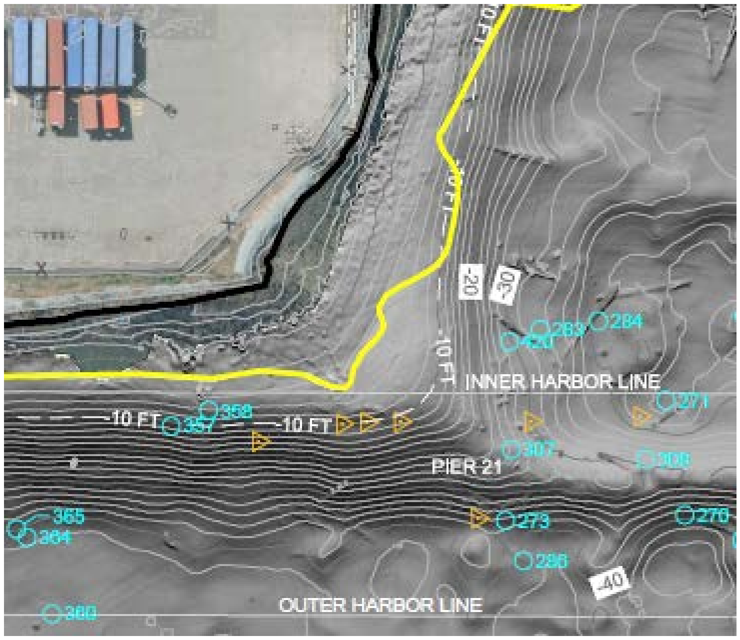


Figure 3. Example In-water debris findings

2.4 DEBRIS IN INTERTIDAL DREDGE AREAS

In addition to the in-water debris, the South beach dredge area includes buried woody debris and wood piles. The wood piles were measured as 15" diameter, typical vertical wood piles located along shorelines and in former shipway. Few photos from the site is compiled in Figure 4. The debris was not quantified during the site visit conducted at 5/5/15. It is recommended that the Contactor should review the site and make an estimate of debris to be handled during dredging this area.

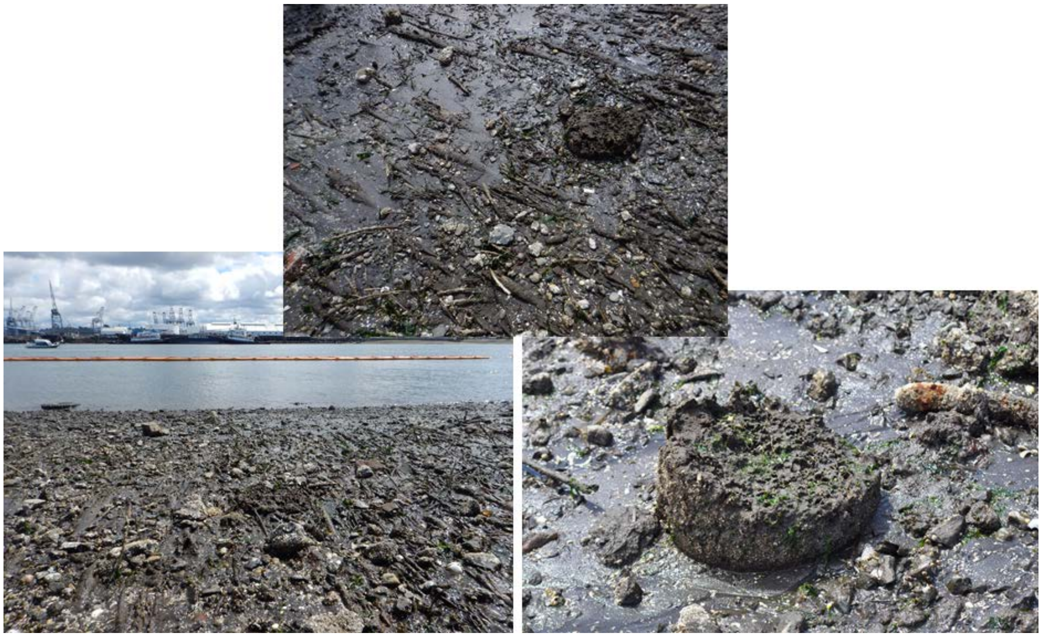


Figure 4. Buried woody debris and wood piles in south beach dredge area

3.0 METHODOLOGY

Volumes and weights for the debris located in each area were determined applying the survey data, aerial imagery, field survey with engineering judgement.

Shoreline debris estimates are based on the following measurements and assumptions:

Item	Area (SF)	Depth (ft)	Number	Volume (cy)	Density (pcf)	Weight (ton)
C-12						
Metal Slag and Concrete	16	1	11	7	150	13.2
Concrete Block	80	4	1	12	150	24.0
Concrete Block	20	2	4	6	150	12.0
Slag Asphalt/Fallen Concrete	4840	5	1	896	150	1815.0
Metal Pipes	25	0.5	20	9	490	61.3
Wooden Bulkhead	75	3	1	8	53	6.0
Wooden Bulkhead	290	5	1	54	53	38.4
C-13						0.0
Concrete Keel Blocks	1200	3	1	133	150	270.0
Fallen Pilings	65	1	1	2	53	1.7

Slag	600	3	1	67	150	135.0
Metal Pipe	10	0.5	1	0	490	1.2
C-14						0.0
Metal	10	0.5	1	0	150	0.4
Metal Structure	10	10	1	4	490	24.5
Metal Debris	10	1	1	0	490	2.5

Gray shaded volumes are assumed to be replaced by riprap/quarry spall to keep integrity of shorelines. Note that the “Number” column does not necessarily represent the number of individual debris but represent the debris type with an estimated area and depth.

Shipway piles removal quantity estimates within Lockheed Martin’s pile removal footprint are as follows:

Elements to be Removed	Quantity	Length (ft)	Volume (ft3)	Density (pcf)	Weight (lbs)	Notes	Volume (cy)	Weight (tons)
Wood Piles	514	30	18,923	53	1,002,929		710	510
Wood Timbers on top of Piles (longitudinal)	42	85	5,578	53	295,641	3 layers	210	150
Wood Timbers on top of Piles (lateral)	51	45	3,586	53	190,055	3 layers	150	110
	9	25	352	53	18,633	3 layers		
	3	10	47	53	2,484	1 layer	**1,070**	**770**

Remnant of sheet pile wall is estimated as 30 tons (20 ft high, 120 ft length, 0.5 inch thick, 490 pcf).

4.0 SUMMARY AND DISCUSSION

Results are summarized above in Tables 1 through 3. Refer to the design drawings and design report for debris handling details.

Table 1. Estimated Shoreline Debris

Type	Volume (cy)	Weight (ton)
Wood	70	50
Metal	20	90
Concrete/Rock	1,130	2,270
Total	1,220	2,410

*Estimated density: wood - 53 pcf, concrete/rock -150 pcf, metal - 490 pcf

It is estimated that about 1,200 cy or 3,000 ton of riprap/quarry spall will be placed after debris removal. Refer to Calculation 8650-08 for rock size estimates.

Table 2. Estimated Former Shipway Debris

Type	Volume (cy)	Weight (tons)
Wood Piles	710	510
Wood Timber (Lateral)	210	150
Wood Timber (Longitudinal)	150	110
Sheet Pile Wall	10	30

Table 3. Estimated In-water Debris

Type	Volume (cy)	Weight (ton)
Metal	265	1,800
Non-Metal	845	700
Total	1,110	2,500

5.0 REFERENCES

- Tetra Tech. 2015. Bathymetric multibeam and geophysical survey. November.
- Tetra Tech. 2016. Pre-remedial Design Field Sampling Data Report. May.
- Shoreline Site walks by Tetra Tech 2006 and 2016.
- Shoreline Revetment Calculation 8650-08 - Shoreline Revetment

CALCULATION COVER SHEET

PROJECT Lockheed West Seattle **CLIENT** Lockheed Martin

SUBJECT Slope Stability Analysis

CALCULATION NO 8650-05 **REVISION NO** C

TOTAL NO OF PAGES 12

Computer Program Used in Calculation: SLOPE/W 2012

Rev No.	*Date*	*Prepared By*	*Checked By*	*Revision*
A	09/01/16	Trever Gatto	Ali Azizian	30% Design - Internal draft
B	10/26/16	Antone Dabeet	Ali Azizian	30% Design - Draft
C	03/27/17	Antone Dabeet	Ali Azizian	60% Design

TABLE OF CONTENTS

1.0 PURPOSE

This calculation package outlines the slope stability analysis of shoreline and submerged dredge slopes at Lockheed West Seattle Site.

2.0 ACCEPTANCE CRITERIA

In slope stability analyses, a Factor of Safety (FoS) is calculated, which is defined as the ratio of resisting (stabilizing) forces to the driving forces. A FoS greater than 1 implies that the slope is theoretically stable. A FoS less than 1 implies that the slope is not stable and slope displacement can occur.

Geotechnical design criteria is to maintain the stability of slopes the same or improved after the construction under both static and seismic conditions. For seismic conditions, a seismic event of 50 percent probability of exceedance in 75 years, which corresponds with a return period of 108 years (nominal 100 years) was analyzed.

3.0 ANALYSIS INPUTS

Soil parameters were derived from the sonic drilling and Cone Penetration Test (CPT) results. Dredge depths were derived from sediment cores.

The drilling work was completed in two phases with a sonic drill rig provided by Holocene Drilling Inc. under the supervision of Tetra Tech and HWA GeoSciences Inc. The first phase of drilling was carried out on land, and the second phase was over water. Both phases of work included CPT (with shear wave velocity measurement at some locations) performed by Holocene Drilling Inc. and In Situ Engineering Inc.

Further information regarding the investigation can be found in the geotechnical data report titled *Geotechnical Data Report, Lockheed West Superfund Site, Seattle Washington* (April 19, 2016). Additionally, the CPT data plots are shown in Appendix A.

The CPT data were corrected for tidal variations (based on information provided by In Situ Engineering). Due to the complex sediment layering of the site, an average friction angle of 32° was chosen for the silty sand, with a unit weight of 115 pcf.

Slope/W Geotechnical Input Parameters

Material	Model Type	Unit Weight	Friction Angle	Cohesion
Silty Sand	Mohr-Coulomb	115 pcf	32°	0 psf

4.0 METHODOLOGY

Conventional two-dimensional limit-equilibrium analyses were performed using the computer program, SLOPE/W (GeoStudio 2012). The Morgenstern-Price method was used for the analysis.

Plots illustrating the slope model and critical failure planes for each of the analyses are presented in Section 6.

The dredge cut cross-sections were chosen at representative locations, and imported into the Slope/W model. Three dredge cut sections were selected at the following locations:

- along the shorelines where both static and seismic stability analyses were conducted,
- typical submerged dredge slope (2H:1V) mostly to address sloughing of submerged dredge cuts, and
- along the profile of shipway after backfilling to check the stability.

Soil was modelled as a Mohr-Coulomb material with parameters described in earlier section. Water level was taken as the Mean Lower Low Level (MLLW). Entry and exit ranges were specified for the failure surface.

FoS values were calculated for minimum slip surface depths of 3 and 5 feet. Shallow sloughing and erosion protection will be provided by a riprap layer.

Pseudo-static seismic analyses were performed using:

- Peak Ground Acceleration (PGA) = 0.144g for a 108 year return period (Appendix B)
- Site coefficient, F_{PGA} = 2.15 (as per ASCE 7-10) for Site Class E
- Multiplier for slope stability analysis = 50% (as per ASCE 61-14)
- Resulting acceleration: 0.144g x 2.15 x 50% = 0.155g

Because seismic FoS is less than 1.1, displacement analysis, e.g. using Newmark method is recommended be performed in later stages of design. Effects of amplification/de-amplification of shaking and potential liquefaction (depending on seismic return period) should also be considered in detailed design stage.

5.0 RESULTS SUMMARY

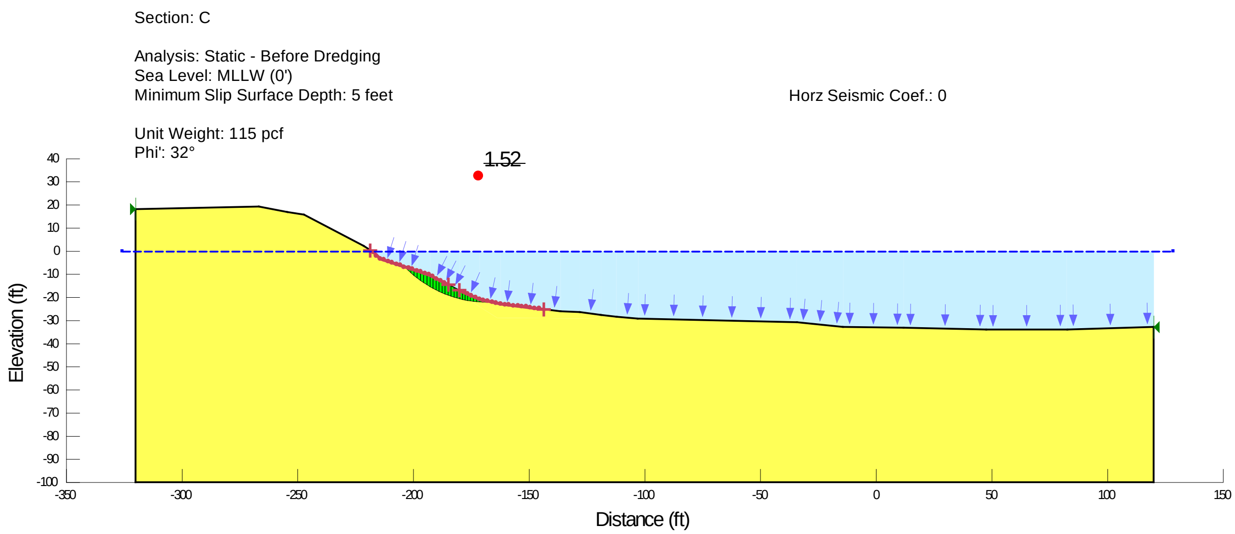
The FoS values are summarized below:

Location	Corresponding Calculation Figures	Condition	FoS (3')	FoS (5')
Dry docks (B4) 2H:1V	A	Current, Static	1.28	1.32
		Post-dredge and after placing riprap, Static	1.39	1.39
		Current, Seismic	0.64	0.66
		Post-dredge and after placing riprap, Seismic	0.77	0.77
Dry docks (B19) 2.5H:1V	B	Current, Static	1.42	1.52
		Post-dredge and after placing riprap, Static	1.61	1.61
		Current, Seismic	0.70	0.75
		Post-dredge and after placing riprap, Seismic	0.85	0.85
Pier 24 (C5) 2H:1V	C	Current, Static	1.39	1.52
		Post-dredge and after placing riprap, Static	1.46	1.46
		Current, Seismic	0.70	0.75
		Post-dredge and after placing riprap, Seismic	0.86	0.86

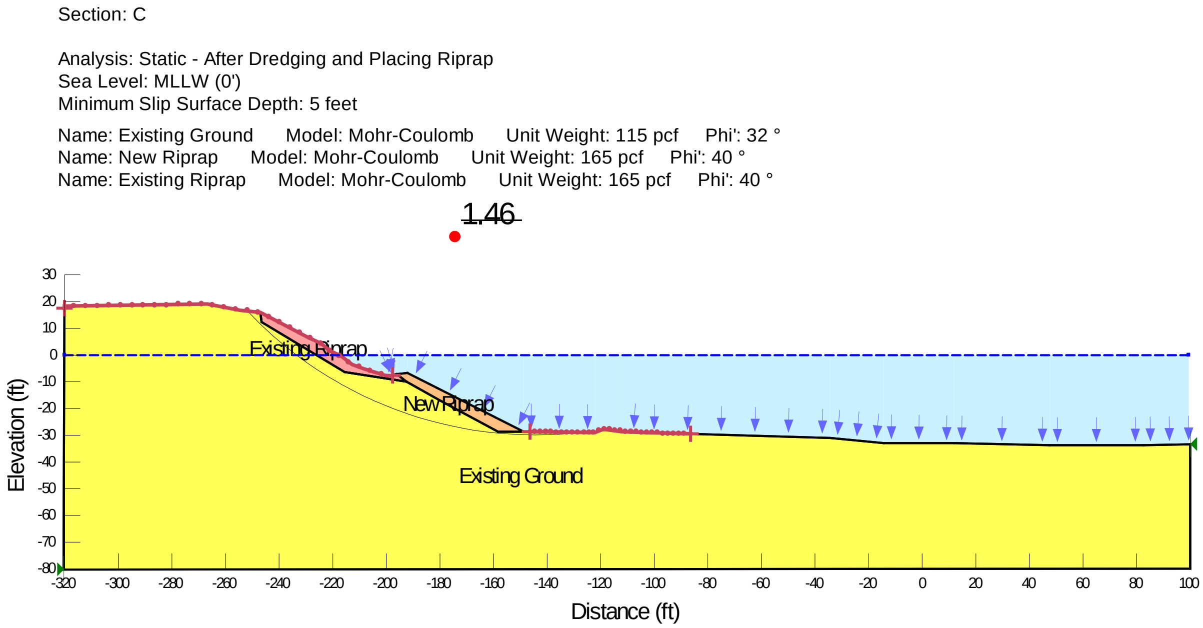
Section B6 2H:1V	B6	Post-dredge submerged slope, Static	1.48	1.63
Section D2	E3	Post-backfill with gravel and fish mix, Static	3.94	3.96

6.0 CALCULATION FIGURES

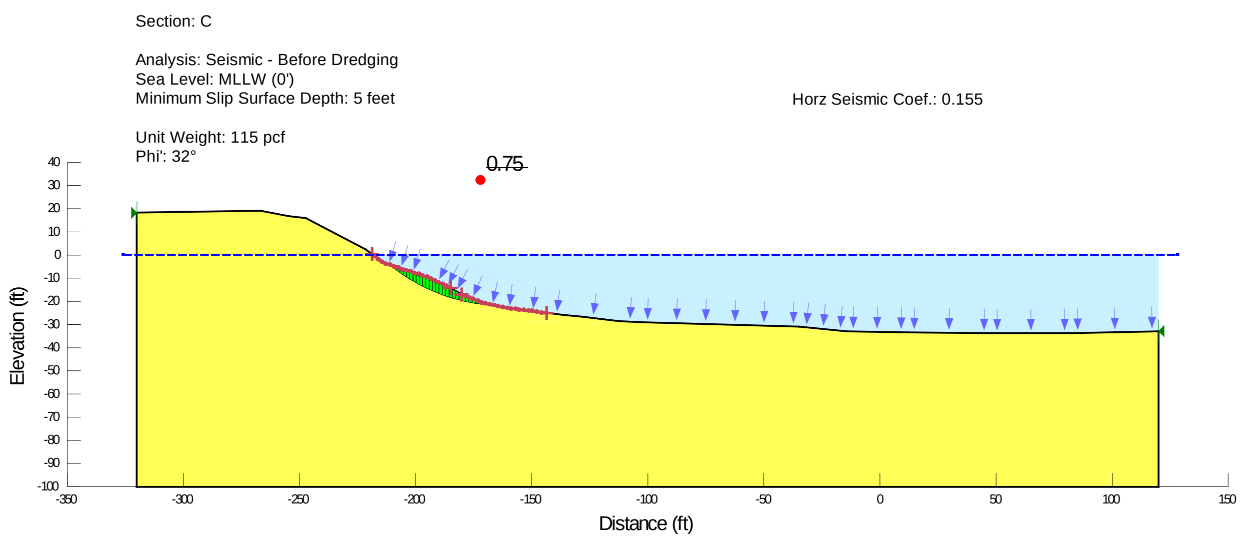
Examples of the calculation results are shown below for one section:



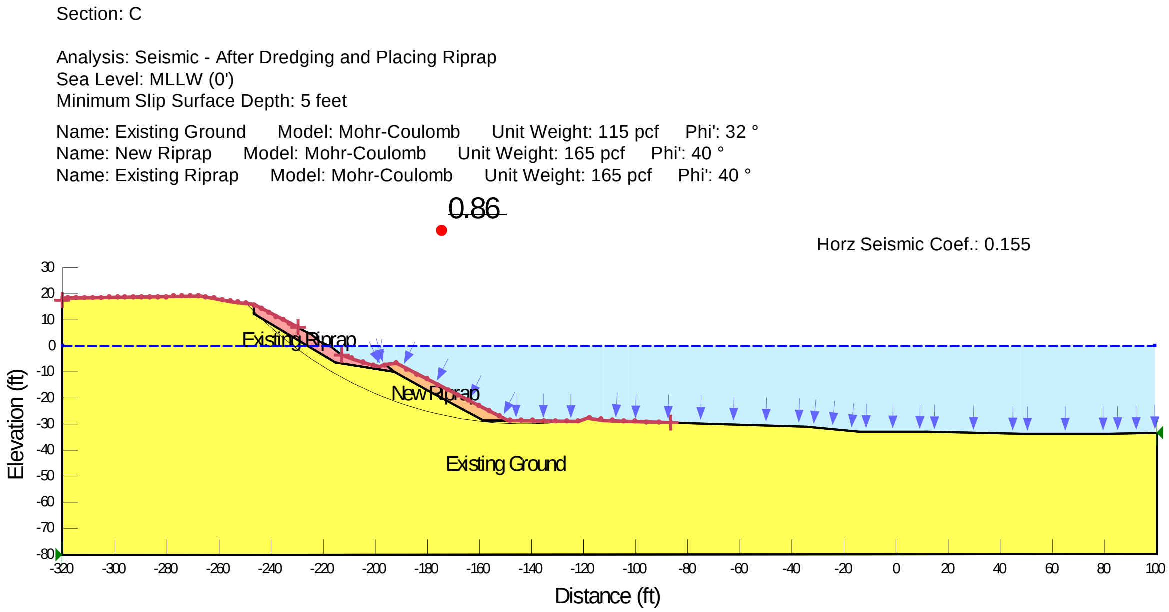
Static - Before Dredging – 5 foot minimum slip surface



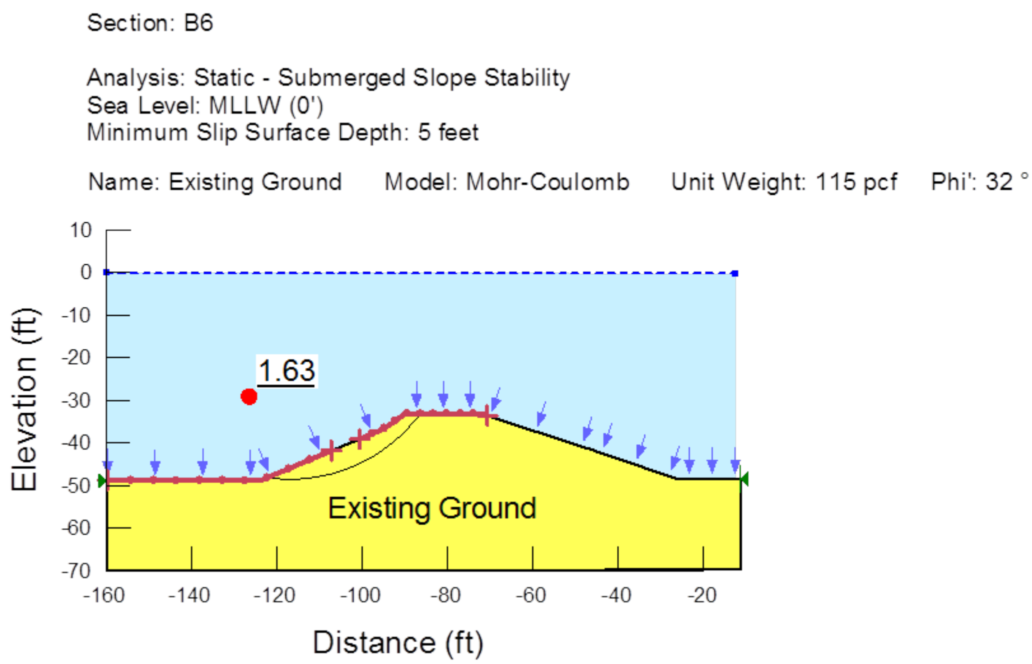
Static - After Dredging – 5 foot minimum slip surface



Seismic - Before Dredging – 5 foot minimum slip surface



Seismic - After Dredging – 5 foot minimum slip surface

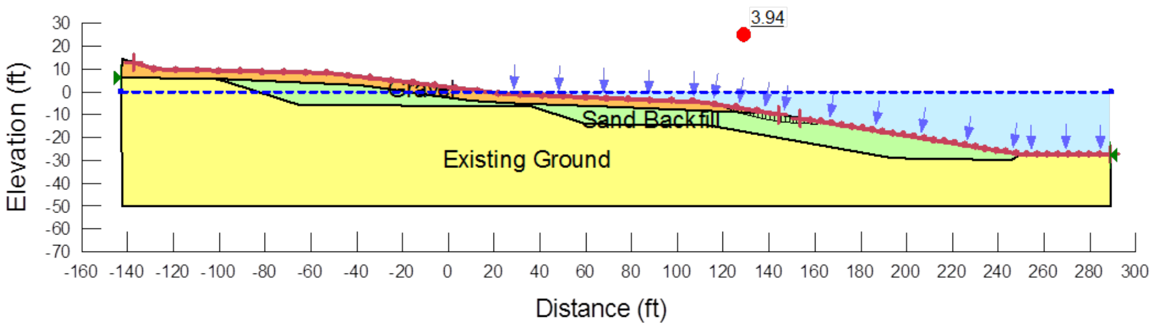


Static - After Dredging – submerged slope - 5 foot minimum slip surface

Section: E3

Analysis: Static - After Placement of Gravel and Fish Mix
Sea Level: MLLW (0')
Minimum Slip Surface Depth: 3 feet

Name: Sand Backfill Unit Weight: 115 pcf Cohesion': 0 psf Phi': 33 ° Piezometric Line: 1
Name: Existing Ground Unit Weight: 115 pcf Cohesion': 0 psf Phi': 32 ° Piezometric Line: 1
Name: Gravel Unit Weight: 125 pcf Cohesion': 0 psf Phi': 36 ° Piezometric Line: 1

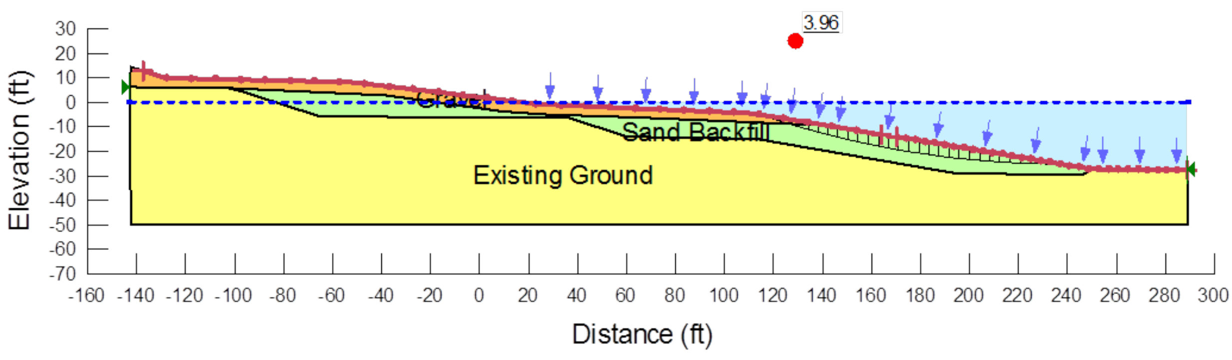


Static - After Backfill – 3 foot minimum slip surface

Section: E3

Analysis: Static - After Placement of Gravel and Fish Mix
Sea Level: MLLW (0')
Minimum Slip Surface Depth: 5 feet

Name: Sand Backfill Unit Weight: 115 pcf Cohesion': 0 psf Phi': 33 ° Piezometric Line: 1
Name: Existing Ground Unit Weight: 115 pcf Cohesion': 0 psf Phi': 32 ° Piezometric Line: 1
Name: Gravel Unit Weight: 125 pcf Cohesion': 0 psf Phi': 36 ° Piezometric Line: 1

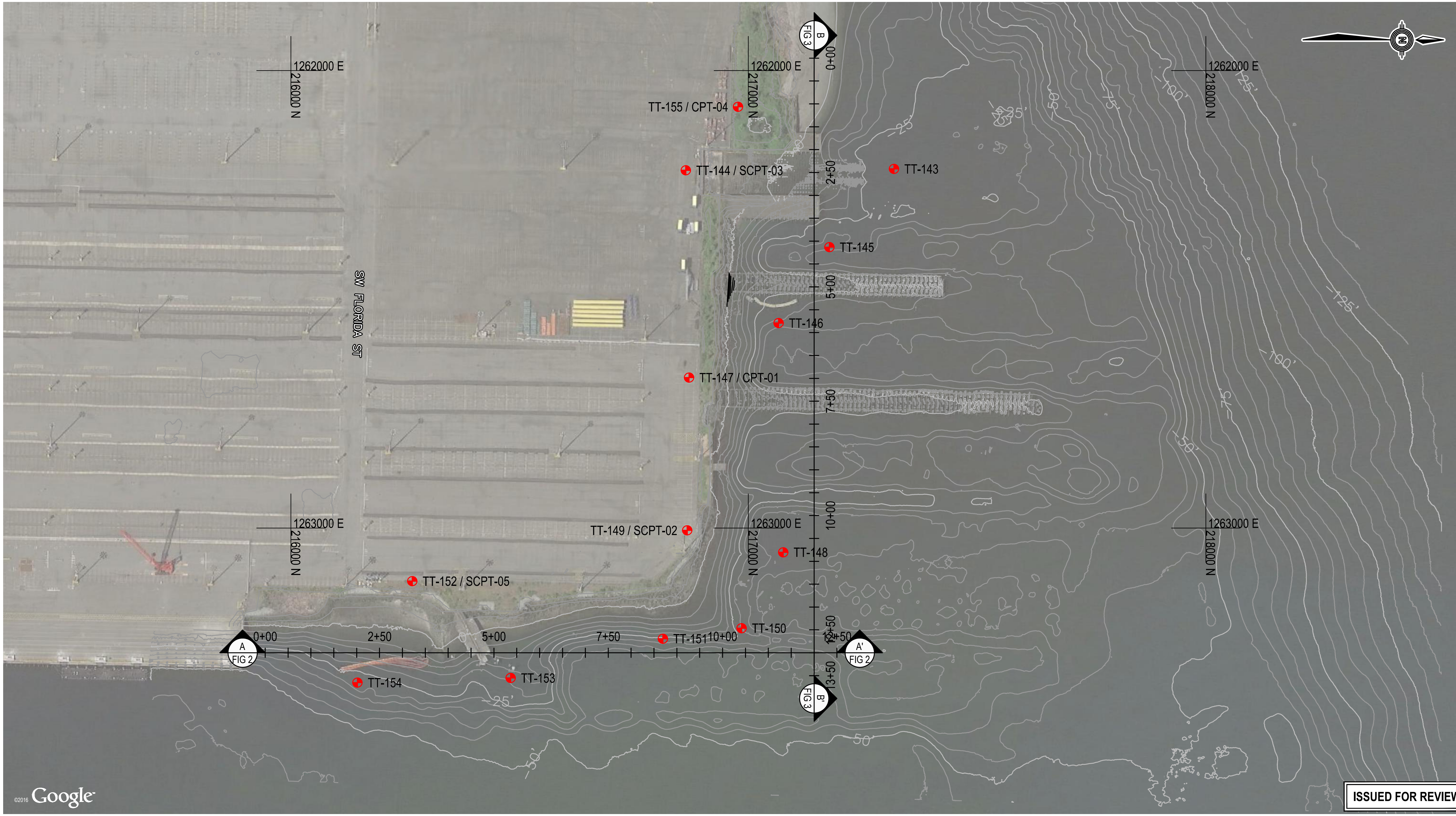


Static - After Backfill – 5 foot minimum slip surface

7.0 REFERENCES

- HWA GeoSciences Inc., 2016. Geotechnical Data Report, Lockheed West Superfund Site, Seattle Washington. Prepared for Tetra Tech. April, 2016.
- Holocene Drilling Inc. and In Situ Engineering Inc., 2016. CPT Data Plots. Prepared for Tetra Tech. April, 2016.
- GeoStudio 2012. SLOPE/W 2012.

ATTACHMENT A – GEOTECHNICAL SITE PROFILES



ISSUED FOR REVIEW

LEGEND

NOTES

1. Based on pre-design field investigations conducted by Tetra Tech in November 2015 and January 2016.
2. Surface provided by Tetra Tech on June 01, 2016 combined from 2015 Bathymetry, Topography survey data from 2007, and LiDAR from 2002 to supplement the gaps.
3. Coordinates are NAD83 Washington State Planes, North Zone, US Foot for horizontal and MLLW for vertical.
4. Imagery from Google Earth Pro.

SCALE 1" = 8'

100 0 100 200 400

CLIENT

LOCKHEED MARTIN

TETRA TECH EBA

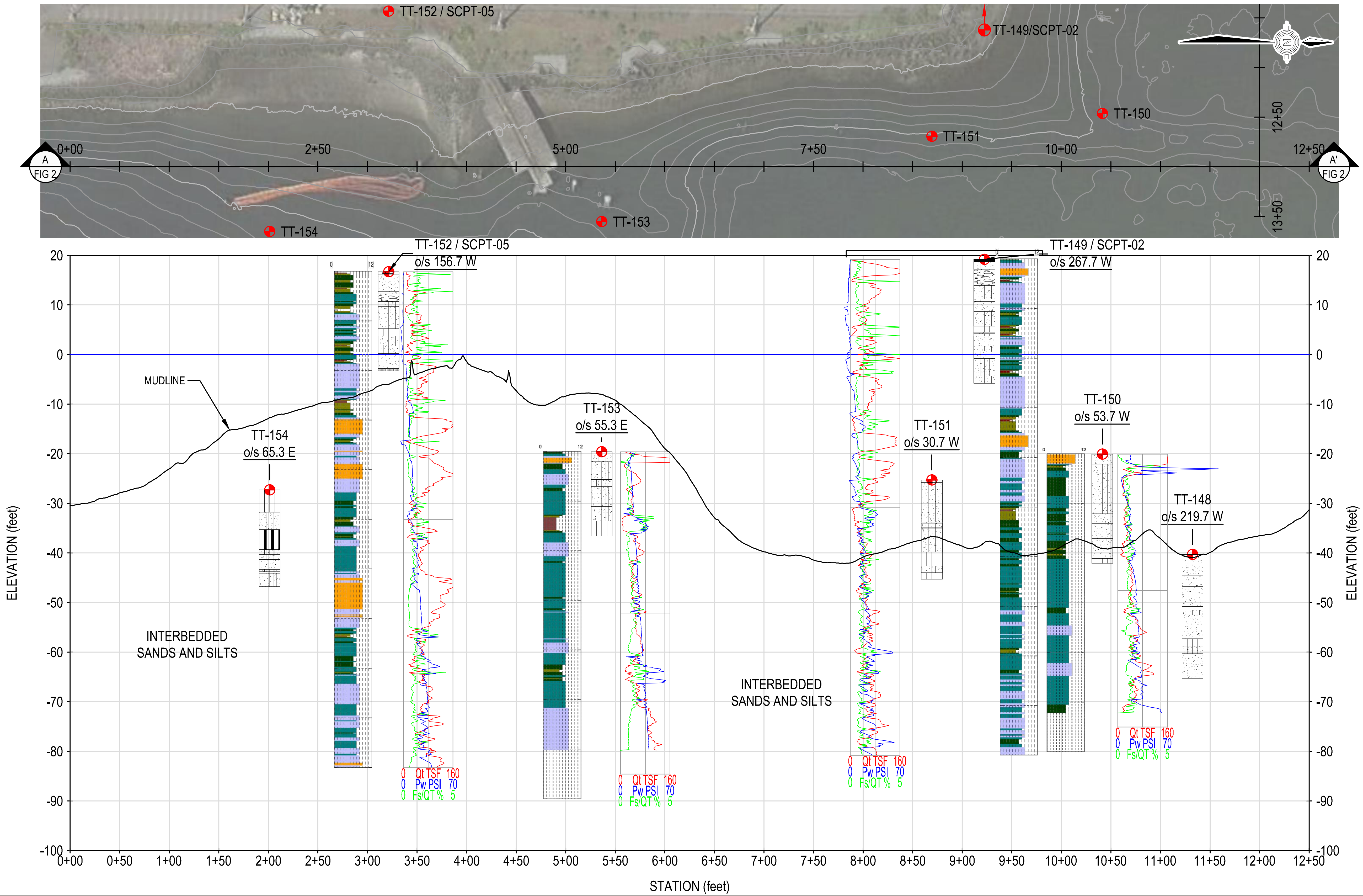
LOCKHEED WEST SEATTLE
SEATTLE, WA

GEOTECHNICAL TEST LOCATIONS

PROJECT NO.	DWN	CKD	REV
V13103373-01	RH	AA	0

OFFICE	DATE
VANC	September 23, 2016

Figure 1



TESTHOLE STICK LOGS

- Asphalt
- Sand
- Silt
- Silty Sand or Sandy Silt
- Silt and Sand
- Concrete
- Silty Gravel
- High Plasticity Silt
- Clay

CPT DATA

- Tip Resistance (Qt TSF)
- Pore Pressure (Pw PSI)
- Friction Ration (Fs/Qt %)

CPT SOIL BEHAVIOR TYPE

- Sensitive fine grained
- Organic Material
- Clay
- Silty Clay to Clay
- Clayey Silt to Silty Clay
- Sandy Silt to Clayey Silt
- Silty Sand to Sandy Silt
- Sand to Silty Sand
- Sand
- Gravelly Sand to Sand
- Very stiff fine grained
- Sand to Clayey Sand

NOTES

1. Based on testhole logs by HWA Geosciences Inc. dated April 19, 2016 and CPT data by In Situ Engineering received February 03, 2016.

ISSUED FOR REVIEW

1" = 0.8' VERTICAL SCALE (5x EXAGGERATION)

10 0 10 20 40

1" = 4' HORIZONTAL SCALE

50 0 50 100 200

CLIENT

LOCKHEED MARTIN

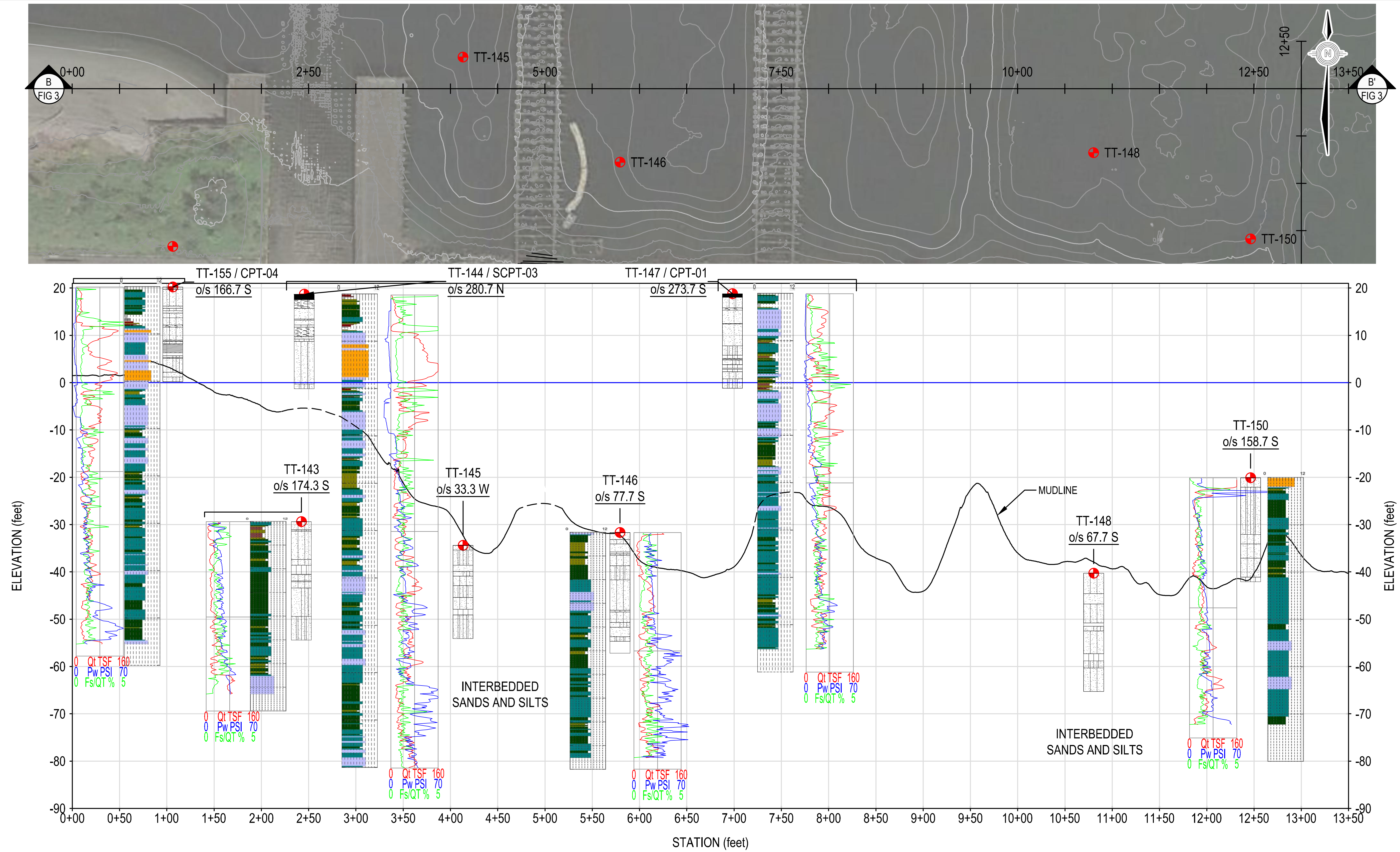
TETRA TECH EBA

LOCKHEED WEST SEATTLE
SEATTLE, WA

GEOTECHNICAL PROFILES
SECTION A-A'

PROJECT NO.	DWN	CKD	REV
V13103373-01	RH	AA	0
OFFICE	DATE		
VANC	September 23, 2016		

Figure 2



TESTHOLE STICK LOGS
- Asphalt
- Sand
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- Silty Sand or Sandy Silt
- Silt and Sand
- Concrete
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- Clay

CPT DATA
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- Friction Ration (Fs/Qt %)

CPT SOIL BEHAVOIR TYPE
- Sensitive fine grained
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- Clay
- Silty Clay to Clay
- Clayey Silt to Silty Clay
- Sandy Silt to Clayey Silt
- Silty Sand to Sandy Silt
- Sand to Silty Sand
- Sand
- Gravelly Sand to Sand
- Very stiff fine grained
- Sand to Clayey Sand

NOTES
1. Based on testhole logs by HWA Geosciences Inc. dated April 19, 2016 and CPT data by In Situ Engineering received February 03, 2016.

ISSUED FOR REVIEW

1" = 0.8' VERTICAL SCALE (5x EXAGGERATION)
10 0 10 20 40

1" = 4' HORIZONTAL SCALE
50 0 50 100 200

CLIENT
LOCKHEED MARTIN

TETRA TECH EBA

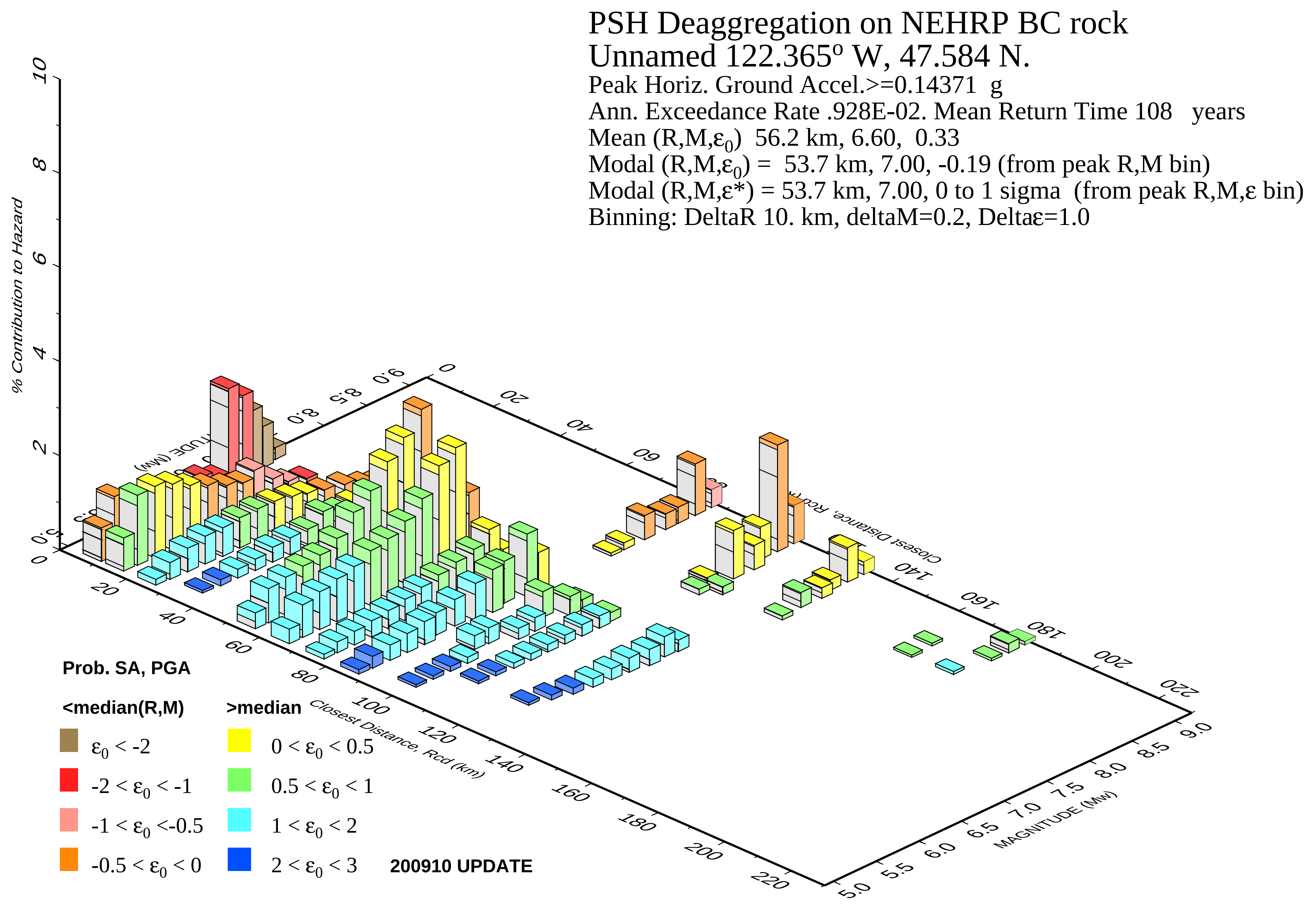
LOCKHEED WEST SEATTLE
SEATTLE, WA

GEOTECHNICAL PROFILES
SECTION B-B'

PROJECT NO.	DWN	CKD	REV
V13103373-01	RH	AA	0
OFFICE	DATE		
VANC	September 23, 2016		

Figure 3

ATTACHMENT B – PGA FOR 108 YEAR RETURN PERIOD



GMT 2016 Aug 19 22:38:24 Distance (R), magnitude (M), epsilon (E0,E) deaggregation for a site on rock with average vs= 760. m/s top 30 m. USGS CGHT PSHA2008 UPDATE Bins with lt 0.05% contrib. omitted

CLIENT: Lockheed Martin		CONTRACT NUMBER: 194-8650
SUBJECT: CALCULATION 8650-06 SHEET PILE WALL STABILITY ANALYSIS Lockheed West – Seattle, WA – 60% Design		
BASED ON: See below CALC. REV: REV A – 27/10/16 - DRAFT REV B – 03/27/17		DRAWING NUMBER: See below
BY: Antone Dabeet and Laura Quiroz DATE: Sept. 29, 2016	CHECKED BY: Ali Azizian DATE: Sept. 29, 2016	REVIEWED BY: SO DATE: October 27, 16; March 27, 17

1.0 DOCUMENTS REVIEWED

The following documents were reviewed in preparation of this report:

- HWA GeoSciences Inc. report titled “Geotechnical Data Report, Lockheed West Superfund Site, Seattle, Washington”, dated April 19, 2016.
- Holocene Drilling Inc. and In Situ Engineering Inc. CPT Data, April 2016.
- Tetra Tech Drawing C-55 through C-57 titled “Dredge Plan, Former Shipway, Plan View” and “Dredge Plan, Former Shipway, Cross Sections”, internal draft, dated September 27, 2016.
- Norton Corrosion Limited, LLC titled “Structural Condition Assessment, Lockheed West Superfund Site, Seattle, Washington”, dated January 29, 2016.

2.0 SHEET PILE WALL DEFORMATION ANALYSIS

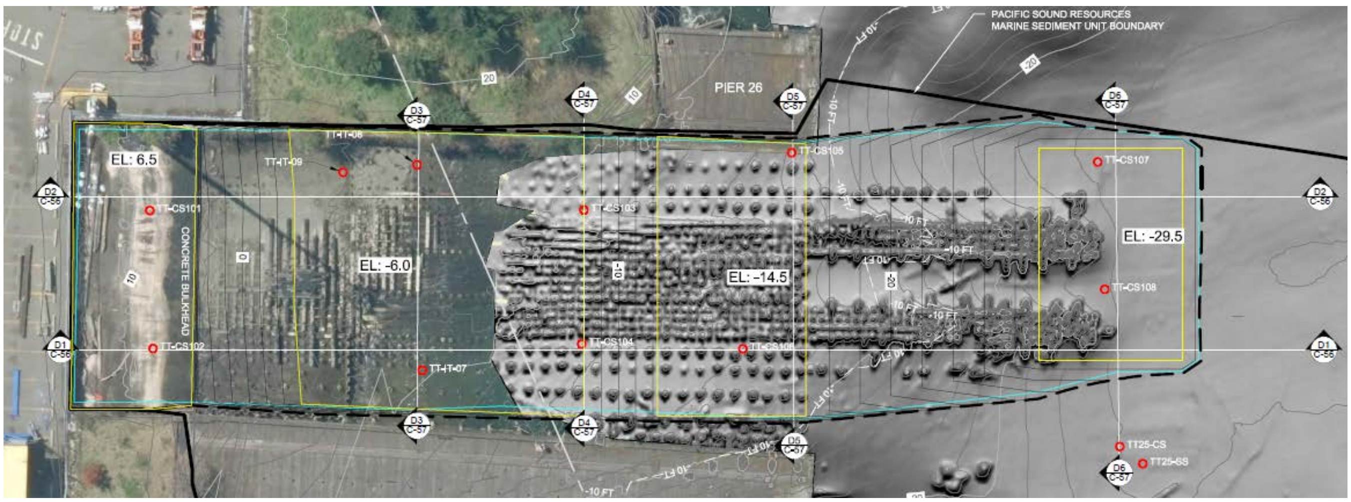
2.1 ANALYSIS METHODOLOGY

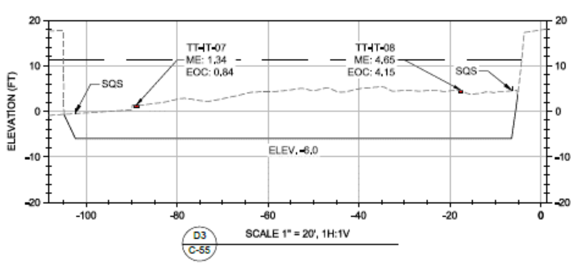
The analysis was performed using the commercially available software PYWALL (Version 2013) by ENSOFT, INC. The software uses the commonly used p-y analysis (soil-sheet pile reaction vs. deflection) method. PYWALL analysis captures soil-structure interaction using a beam column model to represent the sheet pile section and springs to represent soil resistance. Soil resistance was modelled using non-linear soil-resistance curves also known as p-y curves. The programs provides computed deformation, shear force and bending moment profiles.

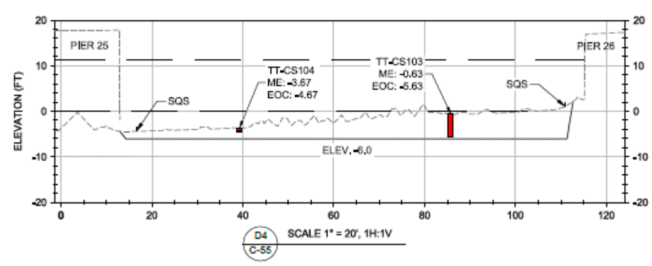
2.2 ANALYSIS CASES

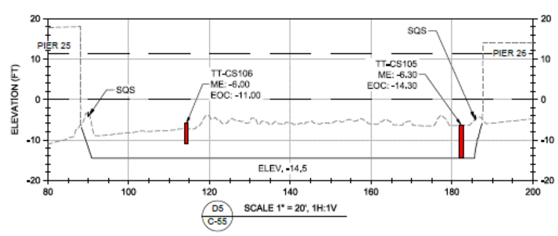
PYWALL analysis was performed at sheet pile sections D3, D4 and D5 along Pier 26, as shown in Drawing C-55 and C-57. The following analysis cases were considered:

- **Existing Conditions:** Existing sheet pile free heights were obtained from Tetra Tech Drawing C-57.
- **After Removal of Timber Piles:** Given the close proximity of the sheet piles to the timber piles, removal of timber piles is expected to result in soil subsidence in front of the wall. It was estimated that free height will increase by up to 3 ft due extracting the timber piles.
- **After Dredging:** Sheet pile free heights after dredging were based on dredging elevations obtained from Tetra Tech Drawing C-57.









2.3 SOIL AND GROUNDWATER CONDITIONS

Interpreted soil conditions were based on the drilling works consisting of cone penetration tests (CPTs) and Sonic drilling performed by Holocene Drilling Inc. For the purpose of the PYWALL modeling, the soil stratigraphy and PYWALL input parameters shown in Table 1 were considered in the analysis. These parameters were derived based on interpretation of the CPT data using the commercially available software CPeT-IT (version 1.7.6.42) and the recommended PYWALL model input parameters according to the PYWALL software manual.

Worst case scenario water table level, assigned at ground level in front of the wall, was considered in the analysis. However, when ground level in front of the wall was below the mean lower low water (MLLW) level, MLLW level was used in the analysis.

Table 1: Representative Soil Input Parameters for PYWALL Analysis

Soil Layer Description	Layer Top Depth (ft)	Layer Bottom Depth (ft)	PYWALL Soil Model	Total Unit Weight (lbs/cu. ft)	Friction Angle (Degree)	*$K_{(py)}$ (lbs/cu. in)	Cohesive Strength (lbs/ sq. ft)	**E_{50}
Loose to compact silty SAND to sandy SILT	0	30	Sand	115	32	40	N/A	N/A
Soft remolded sandy SILT	30	45 (Sheet pile tip)	Soft Clay	110	N/A	30	450	0.02

* k_{py} is soil-modulus parameter (refer to PYWALL Technical Manual). It was derived based on interpretation of CPT data and PYWALL User Manual.

** E50 is the value of strain corresponding to 50% of maximum stress derived based on interpretation of CPT data and PYWALL User Manual for “Soft” consistency. Applicable for the PYWALL Soft Clay model only.

2.4 SHEET PILE WALL SECTION

The following sheet pile section inputs were used in the PYWALL analysis based on the Norton Corrosion Limited (NCL) report, dated January 29, 2016:

- estimated flexural stiffness (EI) of 3.02×10^9 lb.in^2 per foot of the wall, calculated using section dimensions along with estimated 63% section remaining due to corrosion;
- yield strength of 54 ksi.

Given the deteriorated condition of the walers, the contribution of the tiebacks to the stability of the sheet pile was not considered in the analysis and the wall was modelled as a cantilevered wall.

For this evaluation, the analyses were performed using unfactored demand and capacity for estimating displacements. Demand capacity ratio of less than 1 indicates that the sheet pile wall has bending capacity to resist the lateral loads.

2.5 RESULTS

The results of the PYWALL analysis are presented in Table 2.

Table 2: PYWALL Analysis Results

Section	Conditions	Free height /Embedment Depth (ft)	Total Deflection (Including Current) (in)	Deflection on Top of Current (in)	Demand Capacity Ratio (Bending)	Notes
D5	Current	12/33	3.5	0.0	0.32	-
	After removal of piles	15/30	8.1	4.6	0.60	-
	After dredge	25/20	See notes	See notes	See notes	Analysis does not converge which suggests instability
D4	Current	10/35	1.7	0.0	0.19	-
	After removal of piles	13/32	4.6	2.9	0.40	-
	After dredge	16/29	10.4	8.7	0.71	-
D3	Current	5/40	0.3	0.0	0.05	-
	After removal of piles	8/37	0.9	0.6	0.12	-
	After dredge	11/34	2.4	2.1	0.24	-

Note that free height vs. embedment depths have been refined after Port of Seattle's topographic survey conducted in January, 2017. A revised set of calculations were not performed at 60% design due to Port of Seattle's new design as of March, 2017. Refer to Section 2.6.

2.6 DISCUSSIONS

The following is a summary of analysis results shown in Table 2:

Section D5: Analysis results suggest that sheet pile instability is likely to occur if the proposed dredging is undertaken.

Sections D3 & D4: Although the results in Table 2 do not suggest instability, significant deformations of up to 10.4 in at the top of the sheet pile wall are anticipated if proposed dredging is undertaken. As computed demand to capacity ratios were less than 1, the sheet pile walls will likely have bending capacity to resist the lateral loads,

Mitigation approaches are being investigated. As of March, 2017, Port of Seattle plans to pursue a mitigation project at this location. Port of Seattle plans to cut off the sheet pile wall at the mudline and excavate upland behind the wall to reduce the lateral pressure. The wall may need to be strengthen by adding tiebacks to keep the stability of the remaining wall after dredging. Further analysis and design is being performed by the Port of Seattle, which will be finalized in mid- 2017 before Lockheed West remediation design is completed.

CLIENT: **Lockheed Martin**		CONTRACT NUMBER: **194-8650**
SUBJECT: **CALCULATION GRAVEL-01 (8650-07)** **GRAVEL BEACH DESIGN** **Lockheed West – Seattle, WA**		
BASED ON: N/A CALC. REV: REV A – 27/10/16 - DRAFT REV B – 27/03/17 – Reference to drawings and other calculations were added.		DRAWING NUMBER: C-60 and C-61
BY: JWD DATE: 15 September 16	CHECKED BY: REC DATE: 16 September 16	REVIEWED BY: SO DATE: 27 October 16 ; 27 March 2017

REFERENCES:

1. Tetra Tech, Inc., 2016. Calculation WAVE-01, Gravel Beach Design – Wind & Water Levels, Lockheed West – Seattle, WA, 22 July 2016.

2. Tetra Tech, Inc., 2016. Calculation WAVE-02, Gravel Beach Design – Wave Conditions, Lockheed West – Seattle, WA, 26 July 2016.

3. Finlayson, D. 2006. The geomorphology of Puget Sound beaches. Puget Sound Nearshore Partnership Report No. 2006-02. Published by Washington Sea Grant Program, University of Washington, Seattle, Washington. Available at http://pugetsoundnearshore.org.

4. Powell, K.A. 1993. Dissimilar Sediments: Model Tests of Replenished Beaches Using Widely Graded Sediments. Report SR 350. HR Wallingford.

5. Van der Meer, 1998. Rock Slopes and Gravel Beaches Under Wave Attack. Thesis submitted 1998. Also published as Delft Hydraulics Communication No. 396.

PURPOSE: The purpose of this calculation is to determine a dynamically stable gravel beach profile for two locations at the Lockheed West Project site. The design wind, wave, and water level parameters necessary to develop this calculation were provided in Calculation WAVE-01 & WAVE-02.

SITE: Lockheed West is located on the southern shoreline of Elliott Bay in Seattle's Industrial District. The project's geographic coordinates are 47^0 35' 6.60"N, 122^0 21' 50.29"W. Bainbridge Island lies to the west of the site with the city of Seattle to its NE. Figure 1 shows the Lockheed West project location.

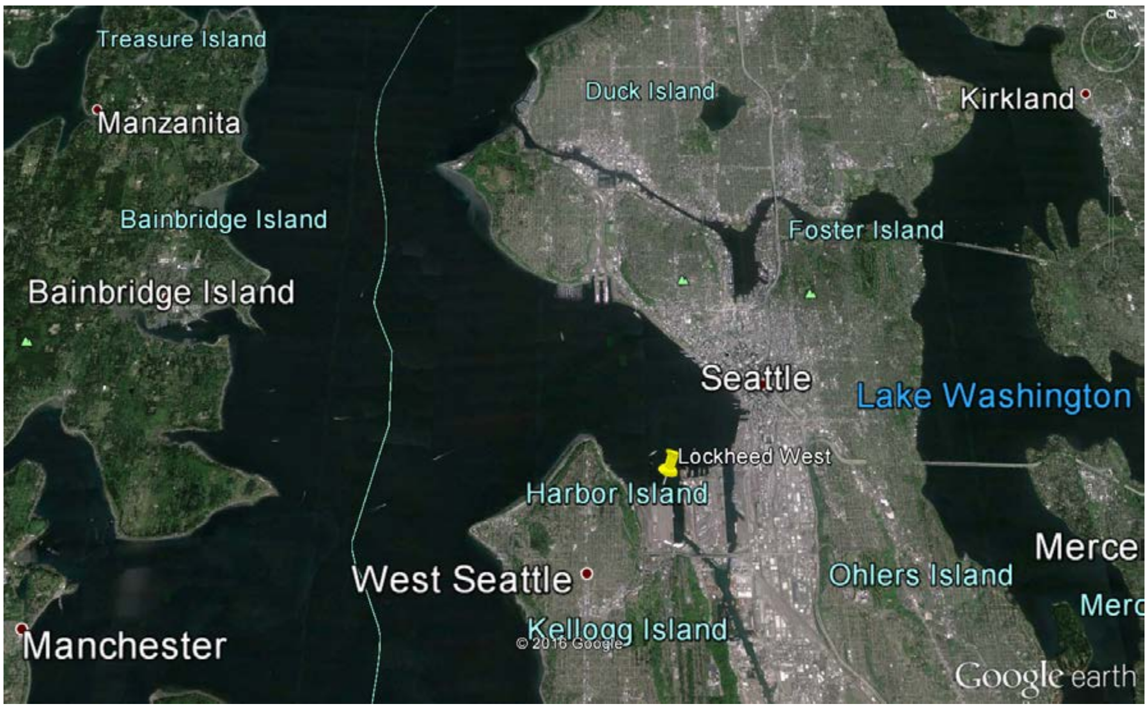


Figure 1 – Lockheed West Project Site, Seattle, WA

Source: Google Earth (19 Apr 15 image)

BACKGROUND: Former shipyard operations in the project area resulted in contamination of the sediments. Remediation efforts will dredge the contaminated sediments and backfill the shoreline/intertidal areas with a habitat mix of gravel and possibly riprap. Gravel beaches will be installed at two location within the project area. Calculations WAVE-01 and WAVE-02 provide the design wind and wave data necessary to design a dynamically stable gravel beach profile. This calculation, GRAVEL-01, provides the equilibrium gravel beach slopes, median grain size, and slope thicknesses required for each shoreline installation area.

GRAVEL BEACH SITES: The first shoreline requiring stabilization through a dynamic gravel beach installation is shown in Figure 2. It is approximately 100 feet in length and located directly on Elliott Bay between two former pile supported dock structures. Note that the Port will demolish the short pier (Pier 26) and a portion of the long pier (Pier 25) before dredging and backfill of the shipway by Lockheed Martin.

Figure 2 – Gravel Beach Installation Area #1 (~100 linear ft)

The second shoreline is located in a more sheltered location along the West Waterway OU. It is approximately 285 feet in length and located within a crenulated bay that is bordered on the north by an existing outfall and to the south by a riprap revetment adjacent to Port of Seattle Terminal 5.

Figure 3 – Gravel Beach Installation Area #2 (~285 linear ft)

BASIS OF DESIGN: 50-yr MRI and daily design wave conditions were used to determine the equilibrium profiles for the gravel beach sites. These site conditions are outlined below:

50-yr MRI Design Waves		
Location	Wave Height (ft)	Wave Period (s)
Area #1	6.5	4.6
Area #2	1.5	1.6

Source: Reference 2

Daily Wave Conditions		
Location	Wave Height (ft)	Wave Period (s)
Area #1/#2	0.8	2.0

Source: Reference 3

SELECTION OF GRAVEL BEACH GRADATION: The gravel beach gradation was selected based on the following:

1. Availability and price of gravel gradations at quarries within close proximity of the project location.
2. Iterative design process using various median gravel sizes to determine which would produce an equilibrium beach profile closest to the natural foreshore slope.
3. Being mindful that selecting a median gravel size that is too small may result in longshore transport of the gravel beach to locations outside of the project area.

Local quarries provide readily available gravel sizes of 0.5”, 1”, and 1.5” stone. Equilibrium beach slopes for all three median gravel stone sizes were tested using the daily and 50-year design wave conditions.

DETERMINATION OF EQUILIBRIUM PROFILE: The Powell method determines the equilibrium slope for a range of wave periods and for a range of sediment gradation (Powell, 1993). Powell recommends the following approach.

(i) Identify possible sources of replenishment material and undertake surveys in sufficient detail to establish the extent of variations in material size and grading within the resource area.

(ii) Determine wave climate at the replenishment site and calculate design wave conditions corresponding to a range of appropriate return periods.

(iii) Use Equation 5.3 to establish an 'equilibrium' slope envelope using all likely combinations of wave conditions and sediment characteristics.

(iv) Select an appropriate slope from within the derived envelope. The selection procedure may make use of probabilistic techniques to assess the most cost-effective or lowest risk option, or may simply result in a mean or extreme lower slope being employed. If the latter option is adopted it should be recognised that if the design 'equilibrium' slope is too shallow it will result in a very costly scheme and one which may, under mild conditions, also suffer a pronounced onshore movement of material, resulting in a beach that is much wider at the shoreline than originally intended.

(v) Calculate a design crest level which will usually be set at or above the 2% wave run-up exceedance level. This level could be obtained by the application of suitable formulae such as those set out in Reference 20.

(vi) Select an appropriate beach width either to provide the standard of defence required taking account of maintenance commitments or to meet amenity or recreational requirements.

(vii) Calculate and cost the volumes of material required per metre run of scheme.

$$\text{Sin}\ \theta = 0.206 \left[(H_s/L_m)^{-0.220}\ (D_{84}/D_{16})^{-0.394}\ (H_s/D_{50})^{-0.306}\right]^{0.567}$$

$$\text{or Sin}\ \theta = 0.206 \left(\frac{H_s}{L_m}\right)^{-0.124} \left(\frac{D_{84}}{D_{16}}\right)^{-0.223} \left(\frac{H_s}{D_{50}}\right)^{-0.174}$$

Equation 5.3

Where,

H_s : Significant wave height
L_m : Wave length
D_{84} : Representative sediment size of the 84% passing according to the gradation curve
D_{50} : Representative sediment size of the 50% passing according to the gradation curve
D_{16} : Representative sediment size of the 16% passing according to the gradation curve

EQUILIBRIUM SLOPE RESULTS: The equilibrium slopes were calculated for the three readily available gravel sizes; utilizing the daily wave conditions and 50-yr MRI wave conditions. The results are provided below for each Gravel Beach Area.

Gravel Beach Area #1		
D_{50}	Slope (daily)	Slope (50-yr)
0.5"	7.4	11.4
1.0"	6.1	9.4
1.5"	5.1	7.9

Gravel Beach Area #2		
D_{50}	Slope (daily)	Slope (50-yr)
0.5"	7.4	9.6
1.0"	6.1	7.9
1.5"	5.1	6.6

DESIGN CREST LEVEL: According to Powell, the design crest is typically set at or above the 2% wave run-up exceedance level. ACES was used to determine the wave runup for each Gravel Beach Area utilizing the 50-yr MRI design waves. The results are outlined below.

Case: Gravel Beach Area #1

Irregular Wave Runup on Smooth Slope Linear Be

Deepwater significant wave height:	6.50	ft
Peak energy wave period:	4.60	
Cotangent of beach slope:	14.80	
Maximum wave runup:	5.59	ft
Runup exceeded by 2% of runups:	4.85	ft
Average of highest 1/10 of runups:	4.43	ft
Average of highest 1/3 of runups	3.64	ft
Average wave runup:	2.35	ft

Case: Gravel Beach Area #2

Irregular Wave Runup on Smooth Slope Linear Be

Deepwater significant wave height:	1.50	ft
Peak energy wave period:	1.60	
Cotangent of beach slope:	8.30	
Maximum wave runup:	1.57	ft
Runup exceeded by 2% of runups:	1.34	ft
Average of highest 1/10 of runups:	1.23	ft
Average of highest 1/3 of runups	1.00	ft
Average wave runup:	0.65	ft

The 2% wave run-up elevation is determined as;

- 2% Wave Run-up Elevation = 50-yr Flood Elevation + Wave Run-up
- 2% Wave Run-up Elevation$_{\text{Area \#1}}$ = 14.46 ft, MLLW + 4.85 ft = <u>19.31 ft, MLLW</u>
- 2% Wave Run-up Elevation $_{\text{Area \#2}}$ = 14.46 ft, MLLW + 1.57 ft = <u>16.03 ft, MLLW</u>

EXISTING SHORELINE CREST ELEVATION: Gravel Beach Area #1 has a crest elevation of approximately 18.5 feet, MLLW. This corresponds to the top of the concrete wall depicted in Figures 1, 2 & 3.

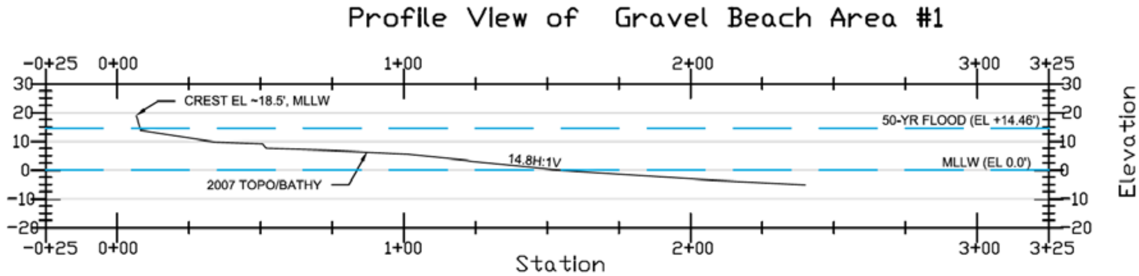


Figure 1 – Existing Topography/Bathymetry at Gravel Beach Area #1 (2007 Survey)

Figure 2 –Gravel Beach Area #1 Site Photo (July 6th, 2016)

Figure 3 –Gravel Beach Area #1 Site Photo (July 6th, 2016)

Gravel Beach Area #2 has a crest elevation of approximately 16.5 feet, MLLW. This corresponds to the top of a riprap bluff depicted in Figures 4, 5 & 6.

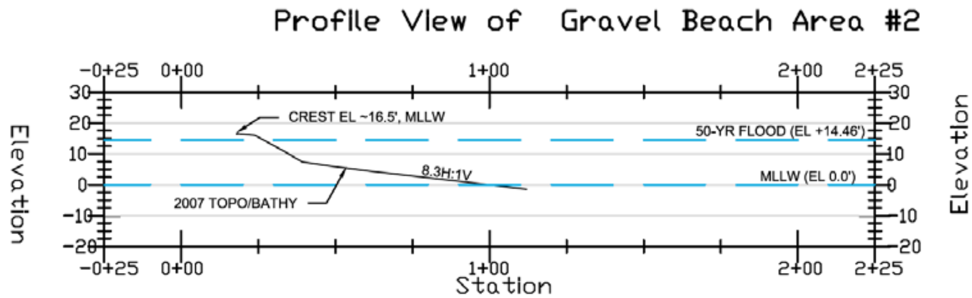


Figure 4 – Existing Topography/Bathymetry at Gravel Beach Area #2 (2007 Survey)

Figure 5 –Gravel Beach Area #2 Site Photo (July 6th, 2016)

Figure 6 –Gravel Beach Area #2 Site Photo (July 6th, 2016)

DESIGN CREST LEVEL (CONT'D): For Gravel Beach Area #1, the 2% wave runup elevation exceeds the existing bluff elevation. For this initial, 30% design, the gravel beach will be aligned with the existing bluff elevation. However, it should be noted that gravel will likely be deposited on the uplands during the 50-yr storm event and maintenance will be required. A berm that exceeds the 2% wave runup is one option that will minimize the maintenance requirements resulting from a 50-yr storm event and can be designed for the 60% submittal if authorized. The 30% design gravel beach crest elevations are selected as follows.

Gravel Beach Crest Elevations		
Beach Area	Crest EL (ft, MLLW)	Notes
#1	18.5	Beach crest < 2% Wave Runup
#2	16.5	Beach crest > 2% Wave Runup

CREST WIDTH: The gravel beach crest width and resulting layer thickness was selected by ensuring that the anticipated beach storm profile did not erode below the existing bathymetry (in this case, the newly dredged slope). Post storm profiles were determined using Van der Meer (see Figure 7) for a range of initial beach profiles that was determined above using Powell.

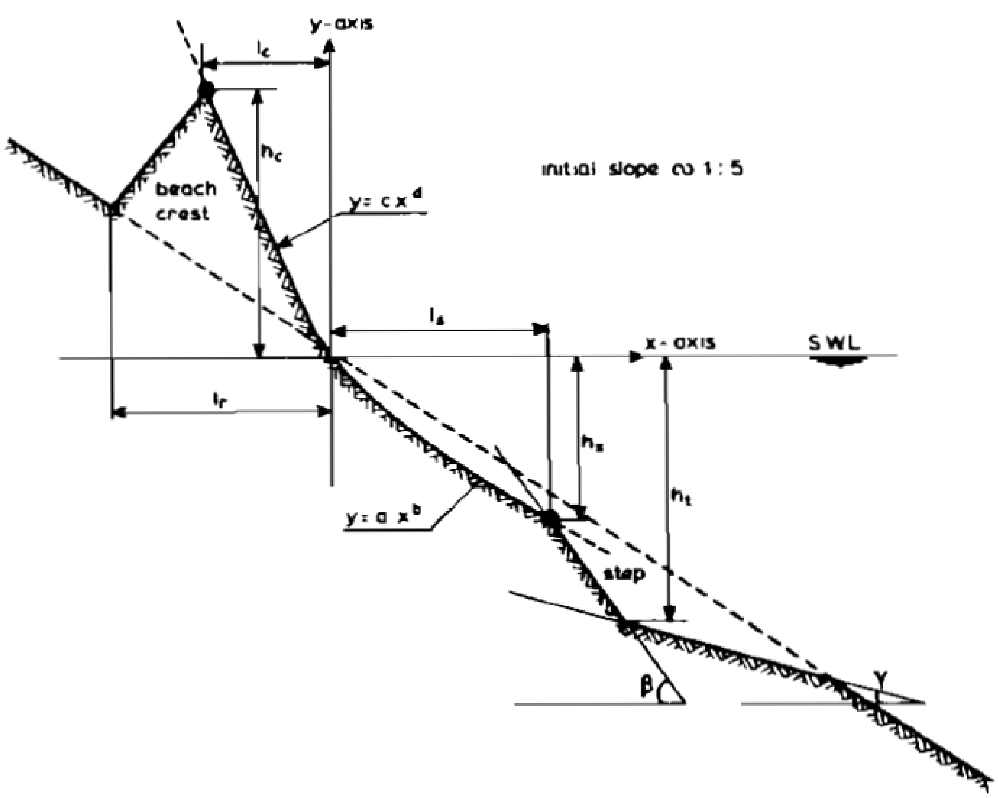


Figure 7 – Schematized Post Storm Dynamic Beach Profile (Reference 5)

CREST WIDTH (CONT'd): The volume required to maintain gravel beach fill over the existing bathymetry during a 50-yr storm event is outlined below for the range of initial beach profiles determined using Powell above. Attachment #1 provides cross sections depicting the results for Gravel Beach Area #1. Attachment #2 provides cross sections depicting the results for Gravel Beach Area #2.

Gravel Beach Area #1 Volume Requirements		
D50	Initial Slope	Minimum Volume Required (cy/lf)
0.5"	8H:1V	145
	9H:1V	200
	10H:1V	Slope does not close.
1.0"	6H:1V	117
	7H:1V	157
	8H:1V	208
	9H:1V	Slope does not close.
1.5"	5H:1V	121
	6H:1V	148
	7H:1V	194

Gravel Beach Area #2 Volume Requirements		
D50	Initial Slope	Minimum Volume Required (cy/lf)
0.5"	7H:1V	Slope does not close. Large volume would be required due to shallow initial slope and steep existing bathymetry.
	8H:1V	
	9H:1V	
	10H:1V	
1.0"	6H:1V	
	7H:1V	
	8H:1V	
1.5"	5H:1V	58
	6H:1V	95

RECOMMENDED DESIGN: We recommend using 1.5" gravel at a slope of 7H:1V for beach area #1 and at a 6H:1V slope for beach #2.

Refer to the design drawings for placement of gravel beach. For quantities, refer to Calc. No. 8650-03 Remediation Volume Estimates.

--End of Calculation --

<table>
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Lockheed Martin</td><td colspan="2">CONTRACT NUMBER:
194-8650</td></tr>
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SHORELINE PROTECTION
Lockheed West – Seattle, WA</td></tr>
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REV B – 27/03/17 – Quantity added</td><td>DRAWING NUMBER: N/A</td></tr>
<tr><td>BY: JWD
DATE: 23 Sept 2016</td><td>CHECKED BY: REC
DATE: 23 Sept 2016</td><td>REVIEWED BY: SO
DATE: 27 October 16; 27 March 17</td></tr>
</table>

REFERENCES:

1. Tetra Tech, Inc., 2016. Calculation WAVE-01, Gravel Beach Design – Wind & Water Levels, Shipyard No. 2 – Seattle, WA, 15 September 2016.

2. Tetra Tech, Inc., 2016. Calculation WAVE-02, Gravel Beach Design – Wind & Water Levels, Shipyard No. 2 – Seattle, WA, 15 September 2016.

3. USACE, 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes). URL: http://chl.erdc.usace.army.mil/cem.

PURPOSE: The purpose of this calculation is to establish the stable riprap size required to withstand the design wave conditions associated with the occurrence of the 50-year mean recurrence interval (MRI) design basis event at Shipyard No. 2 of the Lockheed West Project in Seattle, WA. Large concrete blocks and asphalt debris will be removed from portions of the existing shoreline. Riprap is proposed to stabilize the newly excavated slopes.

SITE: Lockheed West is located on the southern shoreline of Elliott Bay in Seattle's Industrial District. The project's geographic coordinates are 47^0 35' 6.60"N, 122^0 21' 50.29"W. Bainbridge Island lies to the west of the site with the city of Seattle to its NE. Figure 1 shows the Lockheed West project location.

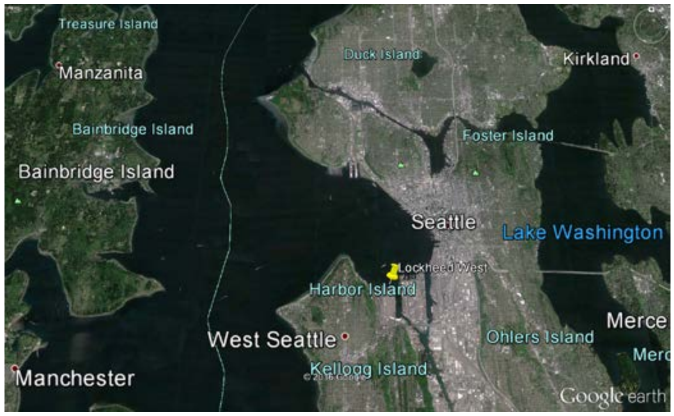


Figure 1 – Lockheed West Project Site, Seattle, WA

BACKGROUND: Former shipyard operations in the project area resulted in contamination of the sediments. Remediation efforts will dredge the contaminated sediments and backfill the shoreline/intertidal areas with a habitat mix of gravel and possibly riprap.

RIPRAP PLACEMENT SITES: The first shoreline area where local stabilization may be necessary is located east of Pier 26. This shoreline is located directly on Elliott Bay and extends to the Western Waterway OU. See Figures 2 & 3 for the draft debris removal plan.

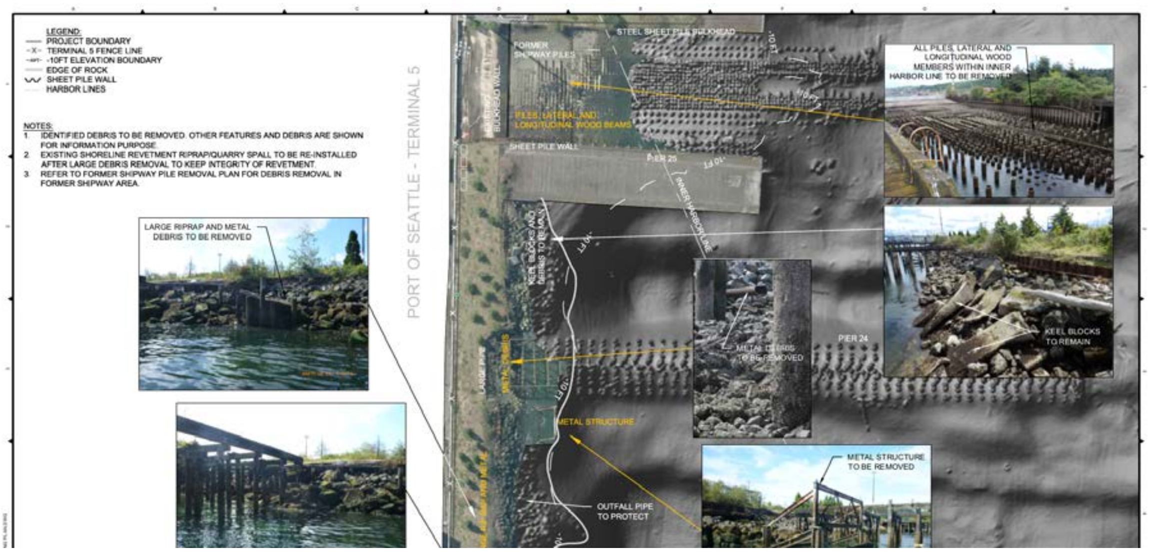


Figure 2 – Draft Debris Removal Plan East of Pier 26

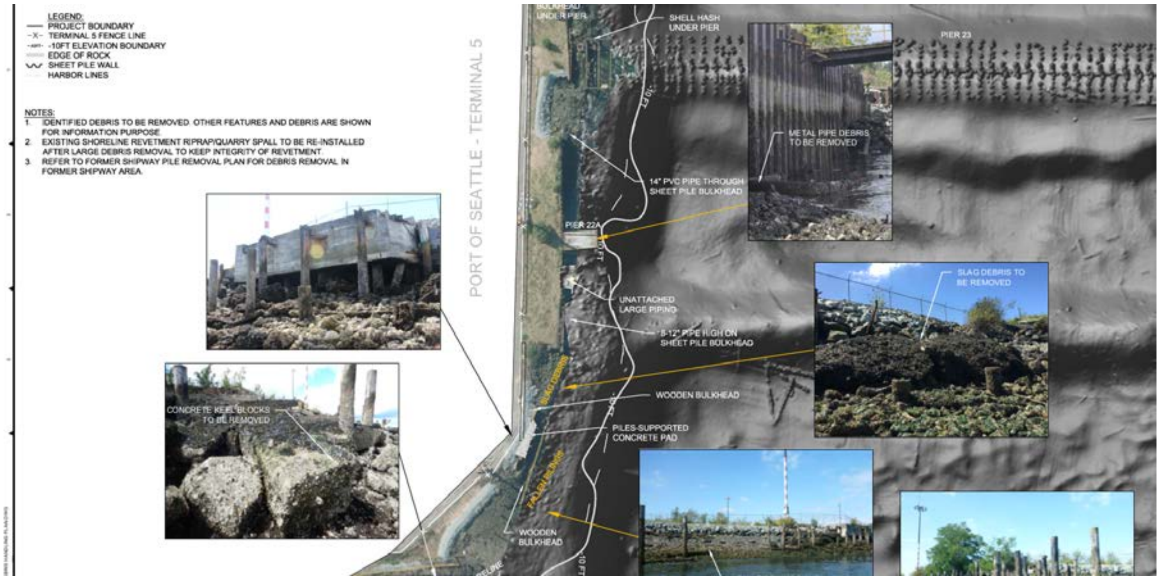


Figure 3 – Draft Debris Removal Plan East of Pier 26

The second shoreline is located in a more sheltered location within the West Waterway OU and adjacent to Gravel Beach Area #2. See Figure 4 for the draft debris removal plan.

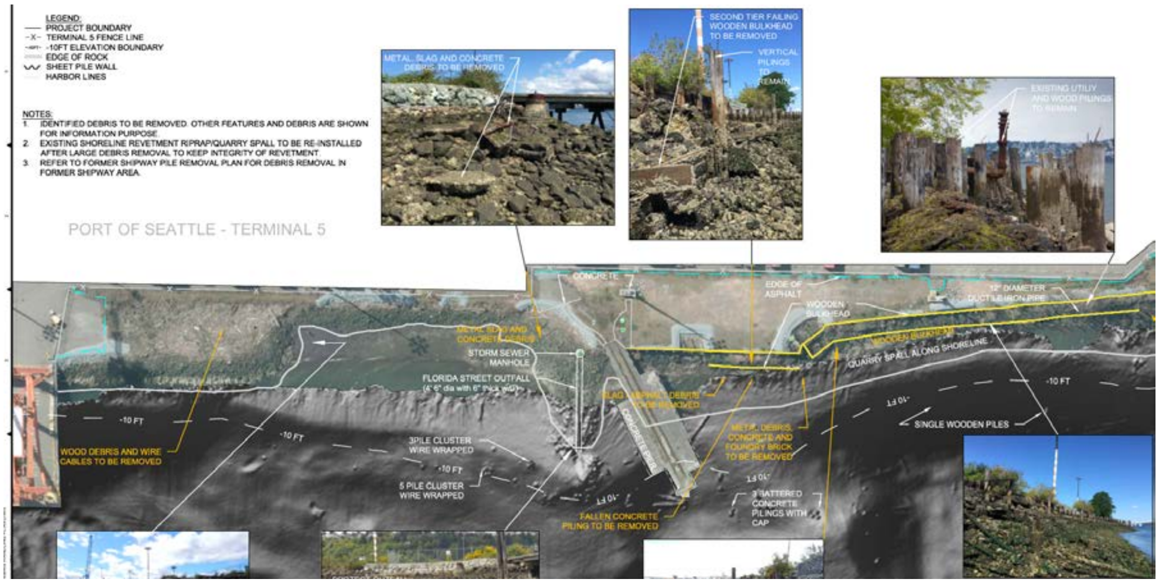


Figure 4 – Draft Debris Removal Plan Adjacent to Gravel Beach Area #2

DESIGN CONDITIONS: Calculation WAVE-01 and WAVE-02 provide the design wave conditions for the 50-yr MRI design waves for two areas immediately adjacent to the riprap placement shoreline sites. These are outlined below.

<u>Area #1 – Exposed Shoreline along Elliott Bay</u>

1. 50-yr Design Wave Height = 6.5 ft
2. 50-yr Design Wave Period = 4.6 sec
3. Water depth at toe = 25.26 ft

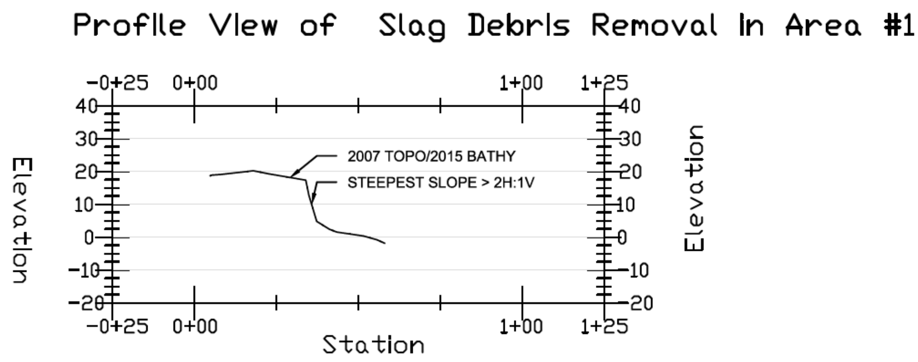
<u>Area #2 – Sheltered Shoreline along West Waterway OU</u>

1. 50-yr Design Wave Height = 1.5 ft
2. 50-yr Design Wave Period = 1.6 sec
3. Water depth at toe = 25.26 ft

ASSUMPTIONS: The exact quantity, location, and area of debris removal is likely to be refined during future design efforts. Therefore, the steepest shoreline slopes in Area #1 and Area #2 have been approximated using a single cross section from each area (See Figure 5).

1. Area #1 Steepest Existing Slope >2H:1V (near vertical)
2. Area #2 Existing Slope ~2H:1V

For this calculation it is assumed that the riprap will not be placed on a slope greater than 2H:1V (i.e. if debris is removed from a slope that is steeper than 2H:1V, the slope will be regraded).



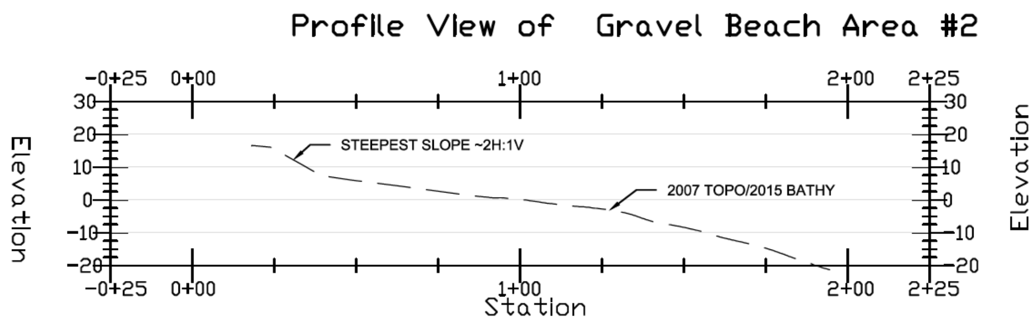


Figure 5 – Existing Sections near Area #1 & Area #2

STABLE STONE SIZE CALCULATION: The stable rock size was determined for a 2H:1V slope using ACES. See below for results for each area of interest.

Area #1

Case: Area #1 - 50-yr MRI

Rubble Mound Revetment Design

Significant wave ht (Hs):	6.50 ft
Significant wave period (Ts):	4.60 sec
Cotan of nearshore slope (cot phi):	100.00
Water depth at toe of revetment (ds):	25.26 ft
Cotan of structure slope (cot theta):	2.00
Unit weight of rock (wr):	165.00 ft
Permeability coefficient (P):	0.10
Damage level (S):	2.00
Breaking criteria:	0.60

Stone Size Gradation

Armor Layer			Filter Layer		
Thickness:	4.70435 ft		Thickness:	1.17609 ft	
% less than by weight	Weight	Dimension	% less than by weight	Weight	Dimension
	lb	ft		lb	ft
0 (min)	225.31	1.11	0 (min)	0.59	0.15
15	720.98	1.63	15	0.99	0.18
50	1802.46	2.22	50	3.34	0.27
85	3532.82	2.78	85	11.27	0.41
100 (max)	7209.84	3.52	100 (max)	18.96	0.49

Irregular wave runup (ft)

Expected maximum:	10.25 ft	Conservative:	12.90 ft
Surf Parameter:	1.71		
CERC Stability Number:	1.28	Dutch Stability Number:	1.78

Area #2

Case: Area #2 - 50-yr MRI

Rubble Mound Revetment Design

Significant wave ht (Hs):	1.50 ft
Significant wave period (Ts):	1.60 sec
Cotan of nearshore slope (cot phi):	100.00
Water depth at toe of revetment (ds):	25.26 ft
Cotan of structure slope (cot theta):	2.00
Unit weight of rock (wr):	165.00 ft
Permeability coefficient (P):	0.10
Damage level (S):	2.00
Breaking criteria:	0.60

Stone Size Gradation

Armor Layer			Filter Layer		
Thickness:	0.87141 ft		Thickness:	1.00000 ft	
% less than by weight	Weight	Dimension	% less than by weight	Weight	Dimension
	lb	ft		lb	ft
0 (min)	1.71	0.22	0 (min)	0.00	0.03
15	5.46	0.32	15	0.01	0.04
50	13.65	0.44	50	0.03	0.05
85	26.75	0.55	85	0.09	0.08
100 (max)	54.59	0.69	100 (max)	0.14	0.10

Irregular wave runup (ft)

Expected maximum:	1.94 ft	Conservative:	2.44 ft
Surf Parameter:	1.24		
CERC Stability Number:	1.28	Dutch Stability Number:	2.09

SUMMARY: Large concrete blocks and other debris that provide erosion protection to the Lockheed West shoreline will be removed during remedial actions. The riprap size necessary to stabilize these sections of shoreline have been approximated by grouping the debris removal into two areas; the exposed shoreline located directly on Elliott Bay and the sheltered shoreline located within the West Waterway OU. The median riprap sizes necessary to stabilize each of these areas is shown below.

50-yr MRI Riprap		
Location	W_{50}	D_{50}
Area #1	1,800 lb	2.2 ft
Area #2	14 lb	6”

It is estimated that about 1,200 cy or 3,000 ton of riprap/quarry spall will be placed after debris removal. Refer to Calculation 8650-04 for quantity estimates.

--End of Calculation --

CLIENT: **Lockheed Martin**		CONTRACT NUMBER: 194-8650
SUBJECT: **CALCULATION RIPRAP-02 (8650-09)** **SUBMERGED DREDGE SLOPE STABILIZATION** **Lockheed West – Seattle, WA**		
BASED ON: N/A CALC. REV: REV B – 01/18/16 – Revised Draft Riprap quantity included REV C - 03/27/17 – Riprap quantity revised		DRAWING NUMBER: Referenced below
BY: JWD DATE: 19 Oct 2016	CHECKED BY: REC DATE: 19 Oct 2016	REVIEWED BY: SO DATE: 18 Jan 2017; 27 MARCH 2017

REFERENCES:

1. Tetra Tech, Inc., 2016. Calculation WAVE-01, Gravel Beach Design – Wind & Water Levels, Shipyard No. 2 – Seattle, WA, 15 September 2016.

2. Tetra Tech, Inc., 2016. Calculation WAVE-02, Gravel Beach Design – Wind & Water Levels, Shipyard No. 2 – Seattle, WA, 15 September 2016.

3. Tetra Tech, Inc., 2016. Calculation RIPRAP-01, Riprap Shoreline Stabilization, Shipyard No. 2 – Seattle, WA, 23 September 2016.

4. USACE, 2002. Coastal Engineering Manual. Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes). URL: http://chl.erdc.usace.army.mil/cem.

PURPOSE: The purpose of this calculation is to establish the stable riprap size required to stabilize the submerged (dredged) slopes at Shipyard No. 2 of the Lockheed West Project in Seattle, WA. The main purpose of submerged slope stabilization is to improve slope stability conditions after dredging. The submerged slopes are designed to withstand the wave conditions associated with the occurrence of a 50-year mean recurrence interval (MRI) event to be consistent with riprap calculations on upper slopes (RIPRAP-01). Calculation RIPRAP-01 determined the stable riprap size required to protect exposed pockets of shoreline after large concrete blocks and asphalt debris are removed from the upper portions of the slope. This calculation determines the riprap size required to protect the dredged slopes.

SITE: Lockheed West is located on the southern shoreline of Elliott Bay in Seattle's Industrial District. The project's geographic coordinates are 47^0 35' 6.60"N, 122^0 21' 50.29"W. Bainbridge Island lies to the west of the site with the city of Seattle to its NE. Figure 1 shows the Lockheed West project location.

BACKGROUND: Former shipyard operations in the project area resulted in contamination of the sediments. Remediation efforts will dredge the contaminated sediments and backfill the shoreline/intertidal areas with a habitat mix of gravel and riprap.

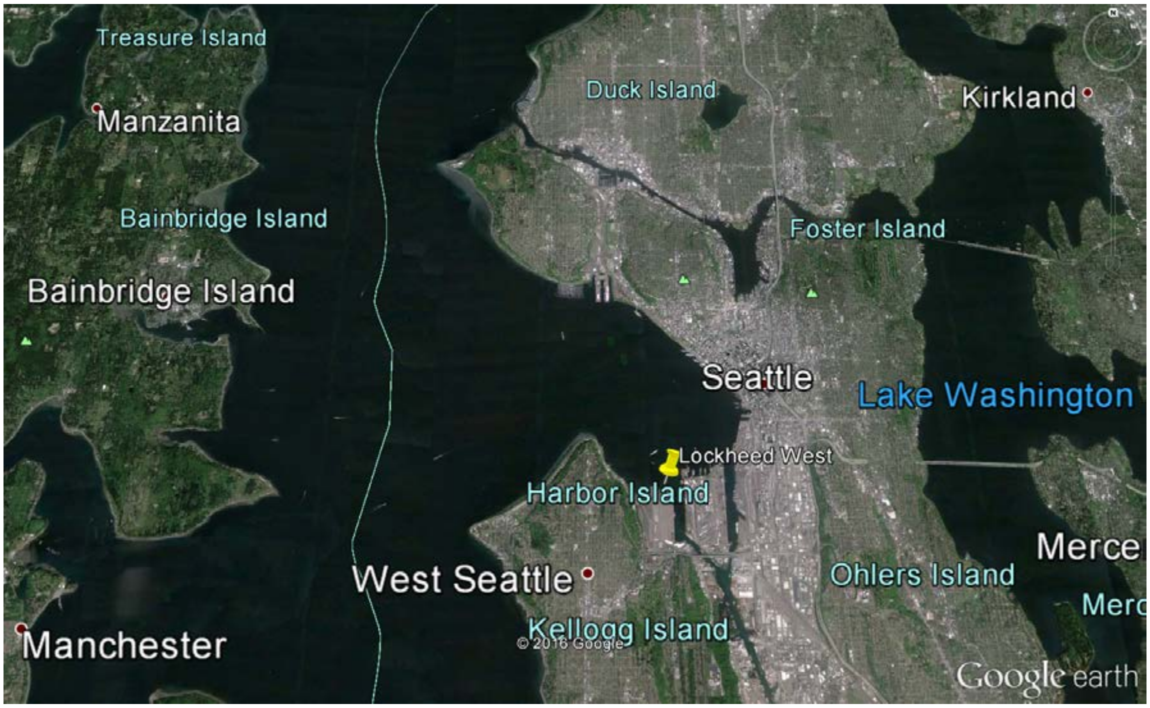


Figure 1 – Lockheed West Project Site, Seattle, WA

RIPRAP PLACEMENT SITES: Dredging will occur from the toe of the existing riprap along the slope and proceed to various target depths (See Figures 2 thru 7). Riprap stabilization has been proposed to protect the submerged shoreline slopes below the existing riprap adjacent to dredge areas #3, 4, 10 & 12 in Figure 2 and dredge area #18 in Figure 3. A majority of these areas are located directly on Elliott Bay with dredge areas 3 & 4 extending slightly into the more sheltered Western Waterway OU.

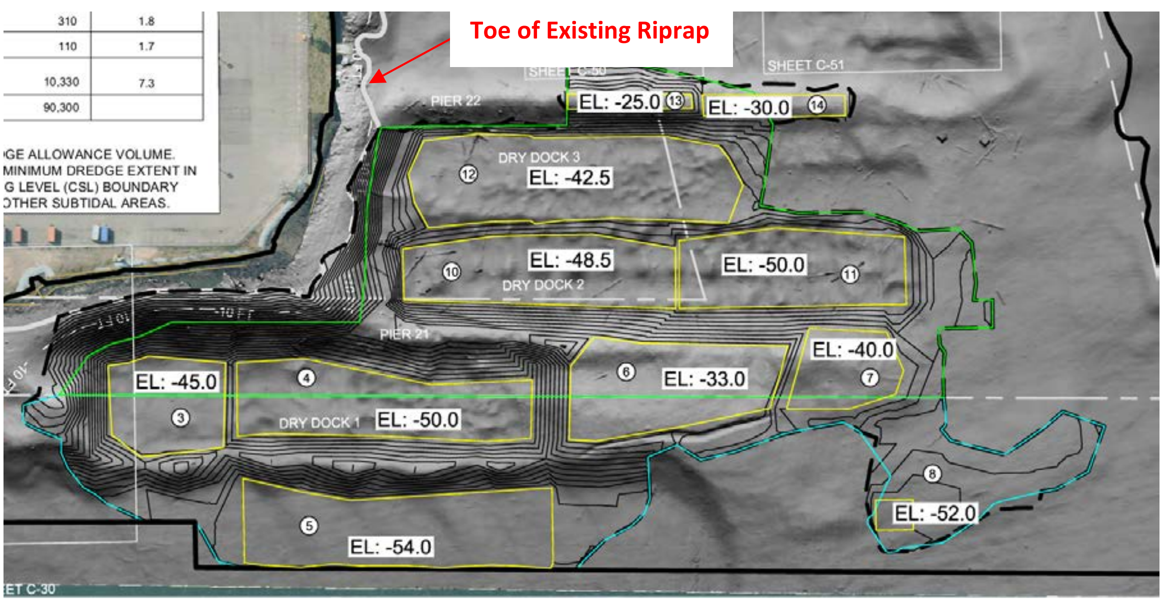


Figure 2 – Draft Dredge Plan near Pier 21 & 22

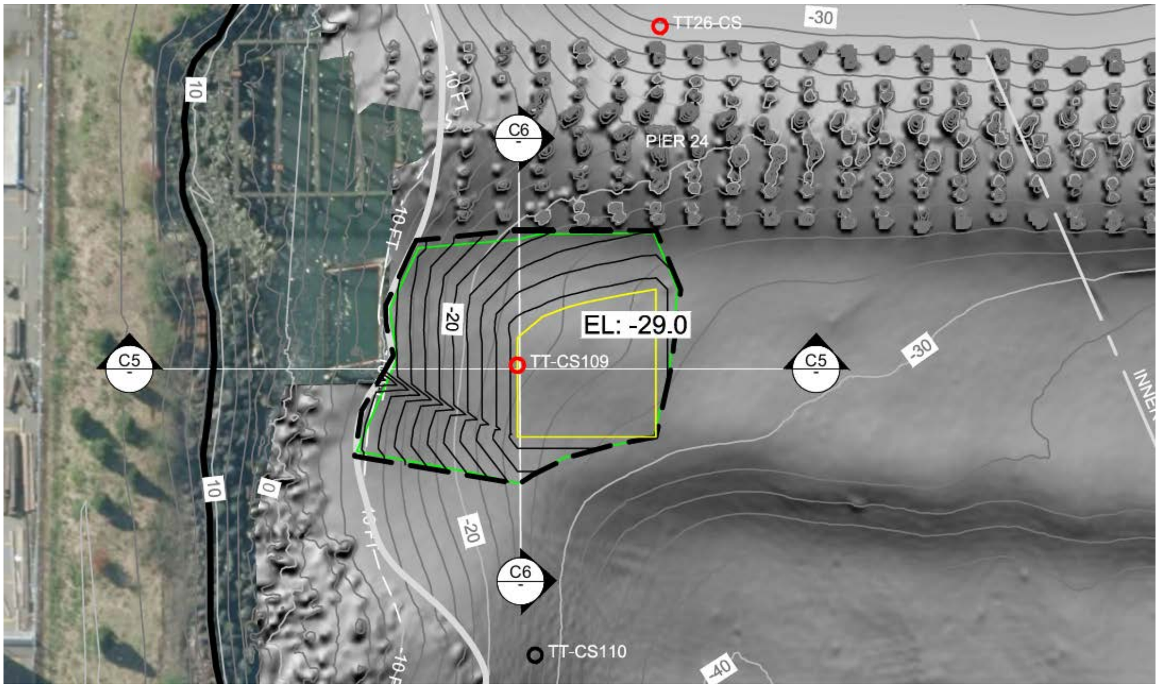


Figure 3 – Draft Dredge Plan East of Pier 24

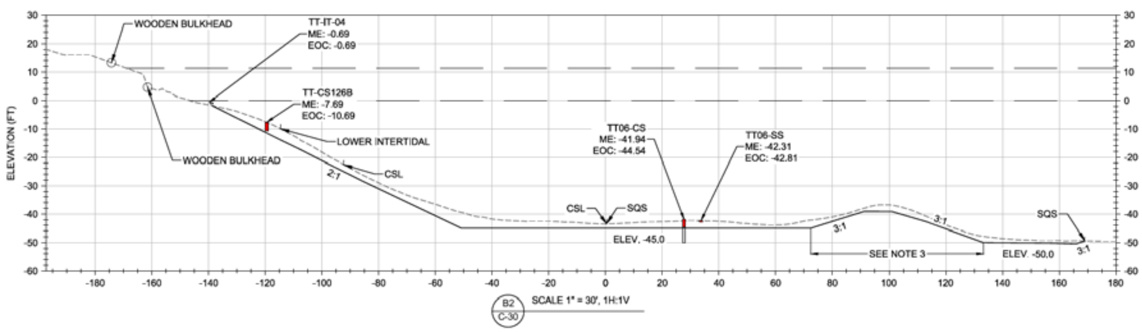
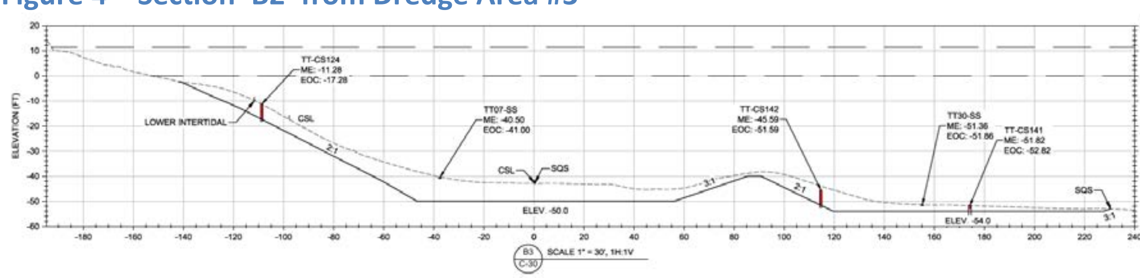


Figure 4 – Section 'B2' from Dredge Area #3



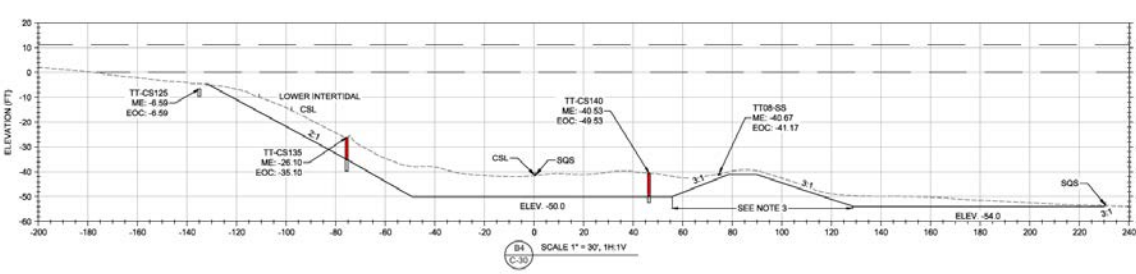


Figure 5 – Section 'B3 & B4' from Dredge Area #4

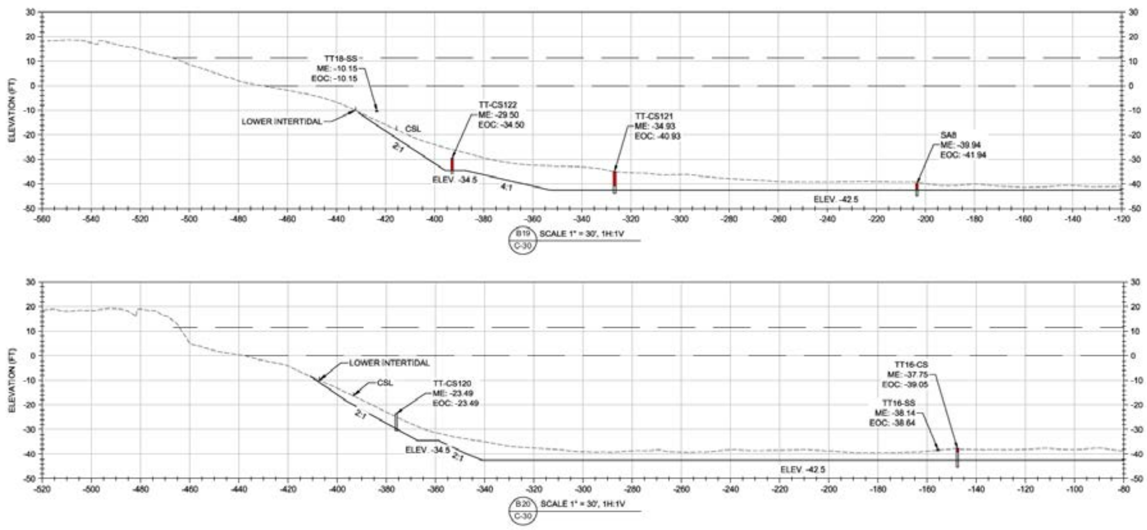


Figure 6 – Section 'B19 & B20' from Dredge Area #12

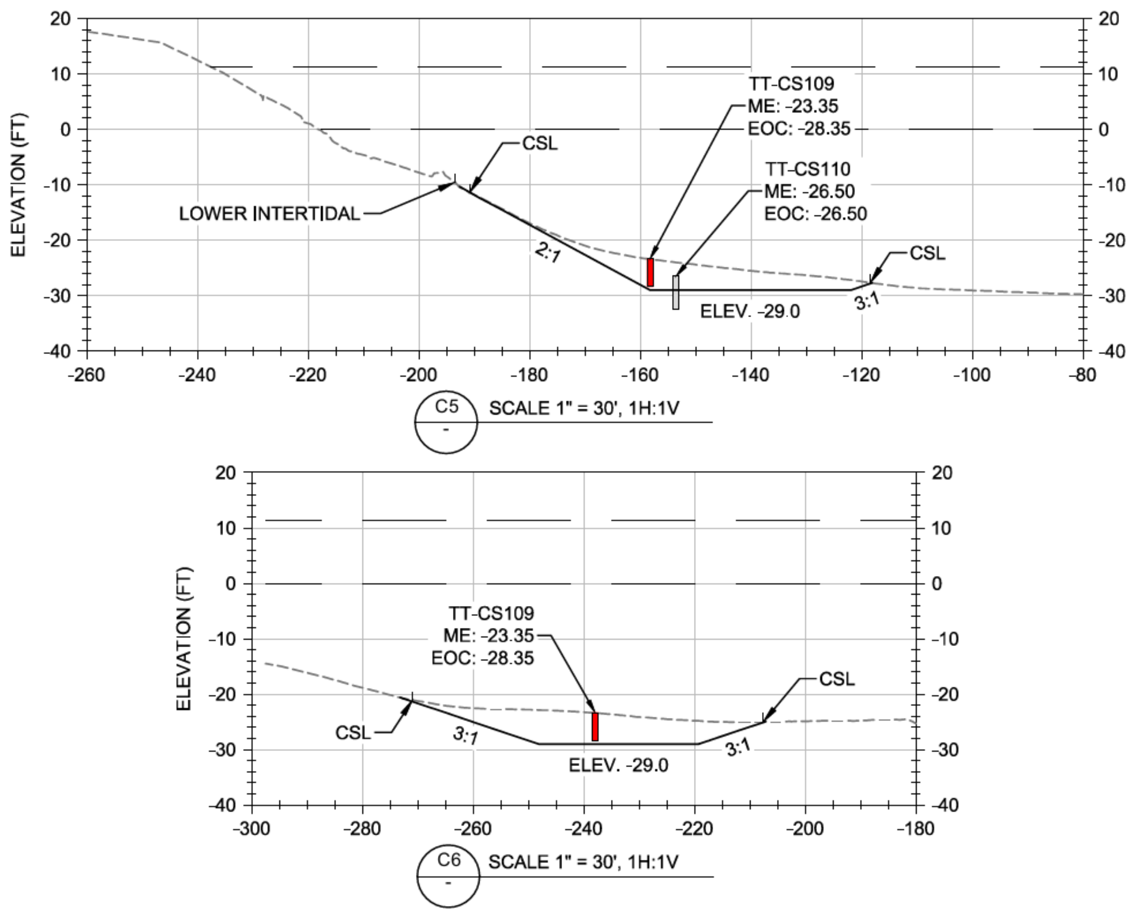


Figure 7 – Section 'C5 & C6' from Dredge Area #18

DESIGN CONDITIONS: The design conditions are outlined below.

1. 50-yr Design Wave Height = 6.5 ft (Reference: Calculation WAVE-01 & WAVE-02)
2. 50-yr Design Wave Period = 4.6 sec (Reference: Calculation WAVE-01 & WAVE-02)
3. Slopes = 2H:1V (Reference: Figures 2 thru 7)
4. Slope Toe Elevation varies from -50’ MLLW (Dredge Area #4) to -29.5’ MLLW (Dredge Area #18). (Reference: Figures 2 thru 7).
5. Existing Riprap Toe Elevation (top of proposed riprap) varies from approximately 0’ MLLW to -10’ MLLW. (Reference: Figures 2 thru 7).
6. Substrate: Silty sand. (Reference: Table 1)

Table 1 – Geotechnical Properties of Dredge Sediment

Sampling Location/Dredge Area	Exploration Designation	Classification	Depth (feet)	Moisture Content (%)	Organic Content (%)	Specific Gravity	PI	Gravel (%)	Sand (%)	Fines (%)
Former Shipway	TT-143,S-1	Silty sand (SM)	3.5-4.0	76.4	10.66	2.39	NP	17.8	50.4	31.8
	TT-143,S-2	Silt (ML)	9.5-10.0	50.3			NP			78.6
Between Piers 24 and 25	TT-145,S-1	Silt (ML)	3.0-4.0	38.7				0.2	29.1	70.7
	TT-145,S-2	Poorly-graded silty sand (SP-SM)	5.5-6.5	21	0.73		NP		90	10
Between Piers 23 and 24	TT-146,S-1	Poorly-graded sand (SP)	3.0-3.5	22.4				0	97.2	2.8
	TT-146,S-2	Silty sand (SM)	5.0-5.5	35	2.75	2.65				23.1
Dry Dock	TT-148,S-1	Poorly-graded sand (SP)	5.0-6.0	21.9						4.3
	TT-148,S-2	Silty sand (SM)	8.5-9.5	36	4.95	2.63		3.1	78.4	18.5
	TT-150,S-1	Silt (ML)	5.5-6.0	25.3		2.67		0.6	47.3	52.1
	TT-151,S-1	Silty sand (SM)	6.0-7.0	35.6		2.64		0	78.7	21.3
	TT-153,S-1	Poorly-graded silty sand (SP-SM)	4.0-4.5	25.6				0.1	92.5	7.3
	TT-153,S-2	Silt (ML)	6.5-7.0	29.4						54.7
South Beach and West Waterway	TT-154,S-1	Poorly-graded silty sand (SP-SM)	3.5-4.0	44	4.1	2.64	10		32.7	67.3
	TT-154,S-2	Silty sand (SM)	6.0-7.0	68.1				0.9	49.7	49.4
	TT-154,S-3	Elastic silt (MH)	8.0-9.0	77.7	7.86	2.87	13	7.9	6.1	85.9

PI = Plasticity Index; NP = Non-plastic

STABLE STONE SIZE CALCULATION: The stable rock size was determined using two different methodologies;

- For elevations below -10' MLLW, Van der Meer's submerged breakwater equation is used to determine the stable rock size (Reference 4: Table VI-5-25).
- For elevations above -10' MLLW, both the Hudson and Van der Meer equations are used for a non-overtopped revetment slope. Equations for a uniform armor layer design were selected since a riprap gradation is not recommended for revetment slopes exposed to wave conditions of greater than 5 feet (Reference 4: CEM VI-5-89). These equations are also conservative since a reduction factor can be applied to overtopped slopes (Reference 4: CEM Table VI-5-24).

An elevation of -10' MLLW was selected as the transition point between rock sizes since it is approximately 1.5 times the wave height (Reference 4: page VI-5-137).

Elevations Above -10' MLLW: Hudson Armor Stone Size Calculation

Case: Hudson - Two Layer Armor

Breakwater Design Using
Hudson and Related Equations

Armor unit weight (Wr):	165.000	lb/ft³
Wave height (Hi):	6.500	ft
Stability coefficient (KD):	4.000	
Layer coefficient (k delta):	1.000	
Average porosity (P):	37.000	%
Cotan of structure slope (cot theta):	2.000	
No. of units comprising thickness of layer (n):	2.000	

Single armor unit weight (w):	1439.621	lb
Minimum crest width (B):	6.17603	ft
Average layer thickness (r):	4.11735	ft
No single armor units per unit surface area (Nr):	297.300	per 1000 ft²

Elevations Above -10' MLLW: Van der Meer Armor Stone Size Calculation

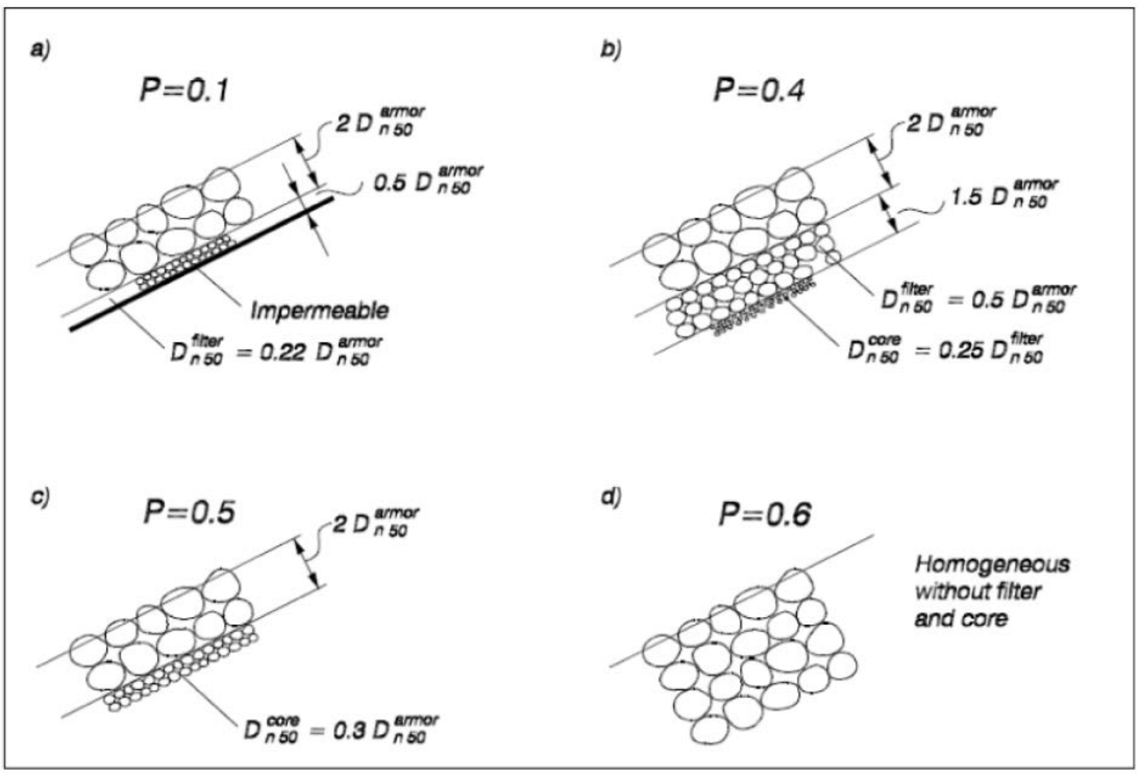
The damage level is determined using Table VI-5-21 from (USACE, 2006). The permeability coefficient is determined from Figure VI-5-11 from (USACE, 2006).

$S := 2$

Damage level by S for two-layer armor (van der Meer 1988)

Unit	Slope	Initial damage	Intermediate damage	Failure
Rock	1 : 1.5	2	3–5	8
Rock	1 : 2	2	4–6	8
Rock	1 : 3	2	6–9	12
Rock	1 : 4 – 1 : 6	3	8–12	17

$P := 0.5$



The median armor stone size is found using EQ VI-5-68 and EQ VI-5-69 from (USACE, 2006). Thornton and Kane, 2007, page PDH 3 state that stone armor is graded between 0.91 and 1.08 the median stone size.

$$\xi_m := (s_m)^{-0.5}\left(\frac{1}{structure\_slope}\right) \qquad \xi_m = 1.9$$

$$\xi_{mc} := \left[\left(6.2\cdot P^{0.31}\right)\cdot\left(\left(\frac{1}{structure\_slope}\right)\right)^{0.5}\right]^{\frac{1}{(P+0.5)}} \qquad \xi_{mc} = 3.5$$

$$D_{n50\_V} := \begin{cases} \left(\dfrac{H_s}{\Delta\cdot 6.2\cdot S^{0.2}\cdot P^{0.18}\cdot N_z^{-0.1}\cdot \xi_m^{-0.5}}\right) & \text{if } \xi_m < \xi_{mc} \\ \left[\left[\dfrac{H_s}{\Delta\cdot 1.0\cdot S^{0.2}\cdot P^{-0.13}\cdot N_z^{-0.1}\cdot (structure\_slope)\ \xi_m^{P}}\right]\right] & \text{if } \xi_m > \xi_{mc} \end{cases}$$

Plunging Waves

Surging Waves

$$D_{n0\_V} := 0.91\cdot D_{n50\_V}$$

$$D_{n100\_V} := 1.08\cdot D_{n50\_V}$$

$$W_{n0\_V} := \rho_{stone}\cdot\left(D_{n0\_V}\right)^3\cdot g \qquad \boxed{W_{n0\_V} = 5720.9\,N} \qquad \boxed{W_{n0\_V} = 1286.1\cdot lbf}$$

$$W_{n50\_V} := \rho_{stone}\cdot\left(D_{n50\_V}\right)^3\cdot g \qquad \boxed{W_{n50\_V} = 7591.7\,N} \qquad \boxed{W_{n50\_V} = 1706.7\cdot lbf}$$

$$W_{n100\_V} := \rho_{stone}\cdot\left(D_{n100\_V}\right)^3\cdot g \qquad \boxed{W_{n100\_V} = 9563.4\,N} \qquad \boxed{W_{n100\_V} = 2149.9\cdot lbf}$$

$$\boxed{D_{n0\_V} = 0.6\,m} \qquad \boxed{D_{n0\_V} = 2.0\cdot ft} \qquad \boxed{D_{n0\_V} = 23.8\cdot in}$$

$$\boxed{D_{n50\_V} = 0.7\,m} \qquad \boxed{D_{n50\_V} = 2.2\cdot ft} \qquad \boxed{D_{n50\_V} = 26.1\cdot in}$$

$$\boxed{D_{n100\_V} = 0.7\,m} \qquad \boxed{D_{n100\_V} = 2.4\cdot ft} \qquad \boxed{D_{n100\_V} = 28.2\cdot in}$$

In summary, the D_{50} stable armor rock size determined by Hudson and Van der Meer are shown below.

50-yr MRI Uniform Armor Size		
Method	W_{50}	D_{50}
Hudson	1,440 lb	2.1 ft
Van der Meer	1,700 lb	2.2 ft

Elevations Below -10' MLLW: Van der Meer Submerged Breakwater Calculation

Table VI-5-25
Rock, Submerged Breakwaters with Two-Layer Armor on Front, Crest and Rear Slope
(van der Meer 1991)

Irregular, head-on waves

$$\frac{h'_c}{h} = (2.1 + 0.1\ S)\ \exp(-0.14\ N_s^*) \qquad \text{(VI-5-72)}$$

where h Water depth

h'_c Height of structure over seabed level ($h - h'_c$ is the water depth over the structure crest).

S Relative eroded area

N_s^* Spectral stability number, $N_s^* = \frac{H_s}{\Delta D_{n50}} s_p^{-1/3}$

Where,

h = 64.5 ft (-50ft, MLLW + 12.11ft, NAVD88 + 2.35' conversion to MLLW)
$h - h'_c$ = 12.11ft, NAVD88 + 2.35' conversion to MLLW – (-10' MLLW) = 24.5 ft
h'_c = 64.5 ft – 24.5 ft = 40 ft
S = 2

In summary, the submerged slope uniform armor stone size gradation (for slopes below an elevation of -10' MLLW) is shown below.

Submerged Slope Uniform Armor Stone Size		
Stone	Weight (lbs)	Dimension (ft)
D_0	330	1.3
D_{50}	450	1.4
D_{100}	560	1.5
Minimum Layer Thickness		2.8 ft

Under layer and core layer rock requirements will be re-evaluated at 90% design depending on the refinement of the design, and geotechnical slope stability conditions of the slopes. At 60% design, the rock slope along the north shore of dry docks was determined to be at 2.5H:1V, where core layer rock will be placed under armor rock to construct this slope. At other locations (i.e., eastern slope of dry docks, and adjacent to Pier 24), the required riprap rock face slope of 2H:1V based on the geotechnical slope stability evaluations can be constructed with two layers of armor stone. Refer to the design drawings.

SUMMARY: Remediation efforts will dredge contaminated sediments and backfill with riprap in order to provide erosion protection to the identified shorelines during a 50-yr MRI event. The submerged slope armor stone will be a minimum of two stones at 2.8 feet thick. A summary of required armor rock and core layer rock size is provided below.

Submerged Slope Uniform Armor Stone Size		
Stone	Weight (lbs)	Dimension (ft)
D_0	330	1.3
D_{50}	450	1.4
D_{100}	560	1.5
Minimum Layer Thickness		2.8 ft

Core Layer Rock Size		
Stone	Weight (lbs)	Dimension (in)
D_0	0.2	1.0
D_{50}	0.4	1.5
D_{100}	0.6	2.0

Total volume of riprap along the dry dock slopes and adjacent to Pier 24 areas:

Riprap		
Location	Area (AC)	Volume (CY)
Dry Docks	1.40	7,297
Pier 24	0.10	231

Considering the possibility of adding a toe berm and overplacement, total riprap volume along dredge slopes is estimated as 9,000 CY (20,000 TN).

--End of Calculation --