Remedial Investigation/Feasibility Study Work Plan for

Lockheed West Seattle Superfund Site

Final

June 2008

Revision 3

Prepared for LOCKHEED MARTIN

Prepared by TETRA TECH

REMEDIAL INVESTIGATION/ FEASIBILITY STUDY WORK PLAN FOR LOCKHEED WEST SEATTLE SUPERFUND SITE

Final

Prepared for

Lockheed Martin Corporation

Prepared by

TETRA TECH

June 2008
Revision 3

ISO 14001
GREEN DOVE AWARD
SGS

CONTENTS

CONTENTS (CONTINUED)

CONTENTS (CONTINUED)

CONTENTS (CONTINUED)

CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (CONTINUED)

ACRONYMS AND ABBREVIATIONS

AKART	all known, available, and reasonable technologies
ANSI	American National Standards Institute
ARAR	applicable or relevant and appropriate requirements
ASAOC	Administrative Settlement Agreement and Order on Consent
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWQC	Ambient Water Quality Criteria
BCF	bioconcentration factor
BEHP	bis(2-ethylhexyl)phthalate
BSAF	biota-sediment accumulation factor
BW	body weight
CAP	Cleanup Action Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFS	cubic feet per second
CHE	Coast and Harbor Engineering, Inc.
COC	chemical of concern
COI	chemical of interest
COPC	chemical of potential concern
CPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
CSM	Conceptual Site Model
CST	Column Settling Test
CWA	Clean Water Act
CY	cubic yard
DFC	daily food consumption
DMMP	Dredged Material Management Program
DNR	Washington State Department of Natural Resources
DQO	Data Quality Objective

ACRONYMS AND ABBREVIATIONS (CONTINUED)

DRET	Dredging Elutriate Test
DSC	daily sediment consumption
dw	dry weight
DW/HW	dangerous waste/hazardous waste
Ecology	Washington State Department of Ecology
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ER	exceedance ratio
ERA	Ecological Risk Assessment
Framework	tribal framework
FWM	food web model
g/cm^3	grams per cubic centimeter
g/day	grams per day
GIS	Geographic Information System
GRA	general response actions
GWCMP	Groundwater Confirmation Monitoring Program
H	horizontal
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	hazard index
HPAH	high-molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
IRIS	Integrated Risk Information system
LAET	lowest apparent effects threshold
LDW	Lower Duwamish Waterway
LMC	Lockheed Martin Corporation
LOAEL	lowest-observed-adverse-effect-level
LPAH	low-molecular weight polycyclic aromatic hydrocarbon

ACRONYMS AND ABBREVIATIONS (CONTINUED)

LSSOU	Lockheed Shipyard Sediment Operable Unit
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
MCUL	minimum cleanup level
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mg/kg-OC	milligrams per kilogram organic carbon normalized
mg/L	milligrams per liter
mL	milliliters
MLLW	mean lower low water
MNR	monitored natural recovery
MS/MSD	matrix spike/matrix spike duplicate
MTCA	Model Toxics Control Act
NAD	North American Datum
NAPL	non-aqueous phase liquid
NCP	National Contingency Plan
NOAA	National Oceanic Atmospheric Association
NOAEL	no-observed-adverse-effect-level
NPL	National Priorities List
O&M	operation and maintenance
OC	organic carbon
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PAH	polycyclic aromatic hydrocarbons
Pb	lead
PCB	polychlorinated biphenyls
Port	Port of Seattle
ppm	part per million
PRG	preliminary remediation goal
PROPWASH	propeller wash modeling

ACRONYMS AND ABBREVIATIONS (CONTINUED)

PSAMP	Puget Sound Ambient Monitoring Program
PSDDA	Puget Sound Dredge Disposal Analysis
PSEP	Puget Sound Estuary Program
PSR	Pacific Sound Resources
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
QSAR	Qualitative Structure Information System
RA	risk assessment
RAO	remedial action objective
RBACG	risk-based analytical concentration goal
RBC	risk-based concentration
RBG	risk-based goal
RBTC	risk-based threshold concentration
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RfD	reference dose
RG	remediation goal
RI/FS	Remedial Investigation/Feasibility Study
RL	reporting limit
RM	river mile
RME	reasonable maximum exposure
ROC	receptor of concern
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SEDQUAL	Sediment Quality Information System
SHIPWAVE	ship-induced waves
Site	Lockheed West Seattle Superfund Site
SMS	Washington State Sediment Management Standards
SMU	sediment management unit

ACRONYMS AND ABBREVIATIONS (CONTINUED)

SOW	statement of work
SQS	sediment quality standard
SRI	Supplemental Remedial Investigation
SVOC	semivolatile organic compound
SWAC	spatially weighted average concentration
SWH	Southwest Harbor
SWHCRP	Southwest Harbor Cleanup and Redevelopment Project
TBC	to be considered
TBT	tributyltin
TCLP	toxicity characteristic leaching procedure
TEQ	toxic equivalency quotient
TM	Technical Memorandum
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
UST	underground storage tank
VOC	volatile organic compound
WAC	Washington Administrative Code
WDFW	Washington Department of Wildlife
WDOH	Washington State Department of Health

1. INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) Work Plan describes the procedures and activities that will be completed by the Lockheed Martin Corporation (LMC) for the RI/FS of sediment areas at the Former Lockheed Shipyard No. 2, located in Seattle, Washington (henceforth referred to as the Lockheed West Site or Site). This Work Plan was prepared as required by the Administrative Settlement Agreement and Order on Consent (ASAOC) (U.S. Environmental Protection Agency [EPA] Docket No. CERCLA-10-2006-0321/Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]) and accompanying Statement of Work (SOW) for the Lockheed West Seattle Superfund Site.

The RI/FS described in this Work Plan will be completed in accordance with the ASAOC. The RI/FS process for the Lockheed West Site described in this Work Plan and diagramed on Figure 1-1 is based on flexible and cooperative effort between EPA and LMC. This effort aims to produce a protective, timely, and cost-effective remediation strategy for the Site.

EPA approval of this Work Plan will fulfill the requirements specified in Section II, Task I of the SOW. During the development of this Work Plan, EPA approved the Site Characterization Sampling and Analysis Plan (Appendix C) and Quality Assurance Project Plan (Appendix D) in January 2007 to allow LMC to expedite investigation of the site, including: sediment sampling, site surveying, and reconnaissance activities. Sampling plans for these activities are referred to as proposed, including those that will have been completed by the time of EPA's final approval. Data resulting from implementation of these activities are described in the past tense in Chapter 8 of this Work Plan.

1.1 PURPOSE OF THE LOCKHEED WEST RI/FS

The purposes of completing an RI/FS for the Lockheed West Site are to (a) determine the nature and extent of contamination (i.e., define the site cleanup boundary) and any threat to the public health, welfare, or the environment caused by the release or threatened release of hazardous substances, pollutants or contaminants at or from the Site, by conducting an RI; and (b) identify and evaluate remedial alternatives to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a FS. The Lockheed West RI/FS will be conducted in accordance with the provisions of the ASAOC, SOW, CERCLA, National Contingency Plan (NCP), and EPA guidance, including, but not limited to, the "Interim

Final Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (Office of Solid Waste and Emergency Response [OSWER] Directive #9355.3-01, October 1988 or subsequently issued guidance), "Guidance for Data Usability in Risk Assessment" (OSWER Directive #9285.7-05, October 1990 or subsequently issued guidance) and guidance referenced therein, and guidance referenced in the SOW, as may be amended or modified by EPA. A project roadmap, diagramming the primary project phases, key considerations, and SOW is presented in Figure 1-1.

1.2 DESCRIPTION OF THE LOCKHEED WEST SEATTLE SUPERFUND SITE

The area of investigation for this RI/FS (henceforth referred to as the Site) is located in the southwest corner of Elliott Bay, and consists of the areal extent of sediment contamination (as determined by environmental sampling) and sources thereto from the former shipyard facility also known as Lockheed Shipyard No. 2, which was located at 2330 Southwest Florida Street in West Seattle, Washington. For purposes of illustration, the historical property boundaries are shown on the figures but are not intended to represent the cleanup boundary which will be determined following the completion of the RI/FS and based on extent of historical shipyard contamination. The area of investigation includes both the property occupied by the former shipyard and the areas of Elliott Bay and the West Waterway immediately adjacent to the former shipyard property.

The Site is bounded by Elliott Bay on the north, Harbor Island West Waterway on the east, and Pacific Sound Resources (PSR) Superfund Site on the west (Figure 1-2). It includes approximately 7 acres of aquatic land now owned by the Port of Seattle (Port) (formerly owned by LMC) and approximately 20 acres owned by Washington Department of Natural Resources (DNR) and historically leased to LMC.

LMC discontinued operations at Lockheed Shipyard Number 2 in 1987 after approximately 45 years of continuous operations by Lockheed and others that included shipbuilding, ship repair, and ship maintenance. Past industrial practices at or adjacent to the facility have resulted in contamination of aquatic sediments. The contaminants found in the aquatic area include hazardous substances associated with shipbuilding, repair, and maintenance activities, consistent with the historical uses of the facility. Other contaminants not directly associated with shipyard activities may be present at the Site.

Historical shipyard contaminants of potential concern (COPCs) include, but are not limited to, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), mercury, other metals, and other organic compounds.

Associated sediments are habitat to numerous fish and other aquatic species, and are within a migratory corridor for endangered, threatened, and other anadromous fish.

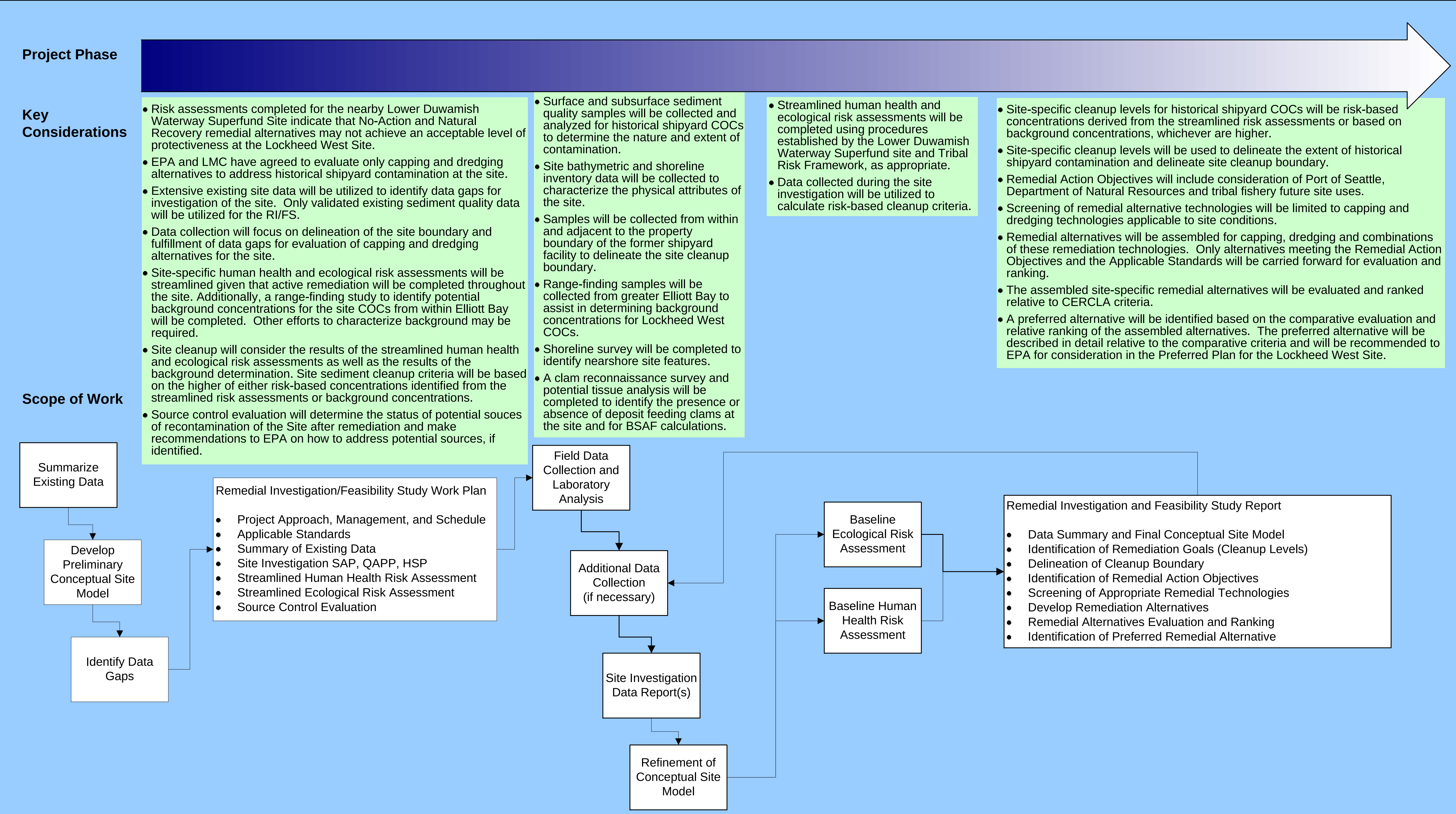
Pursuant to Section 105 of CERCLA, 42 U.S.C. § 9605, EPA proposed the Site for inclusion on the National Priorities List (NPL) on September 26, 2006. The Lockheed West Seattle Site was listed on the NPL on March 7, 2007.

1.3 WORK PLAN ORGANIZATION

This Work Plan is organized into the following sections:

- Section 1 – Introduction
- Section 2 – Project Approach, Team, Deliverables, and Schedule
- Section 3 – Listing of Applicable Standards
- Section 4 – Summary of Existing Information
- Section 5 – Preliminary Identification of Remedial Action Objectives and Potential Remedial Alternatives
- Section 6 – Preliminary Remediation Goals
- Section 7 – Sediment Stability
- Section 8 – Sampling and Analysis
- Section 9 – Data Management
- Section 10 – Field Data Collection and Data Reporting
- Section 11 – Risk Assessment Work Plan
- Section 12 – Source Control Evaluation
- Section 13 – Remedial Investigation and Feasibility Study
- Section 14 – Community Involvement Activities
- Section 15 – References

This page is intentionally left blank.



TETRA TECH

Lockheed West Shipyard No. 2 Seattle, WA

Figure 1-1
Project Roadmap:
Lockheed West Remedial Investigation and Feasibility Study

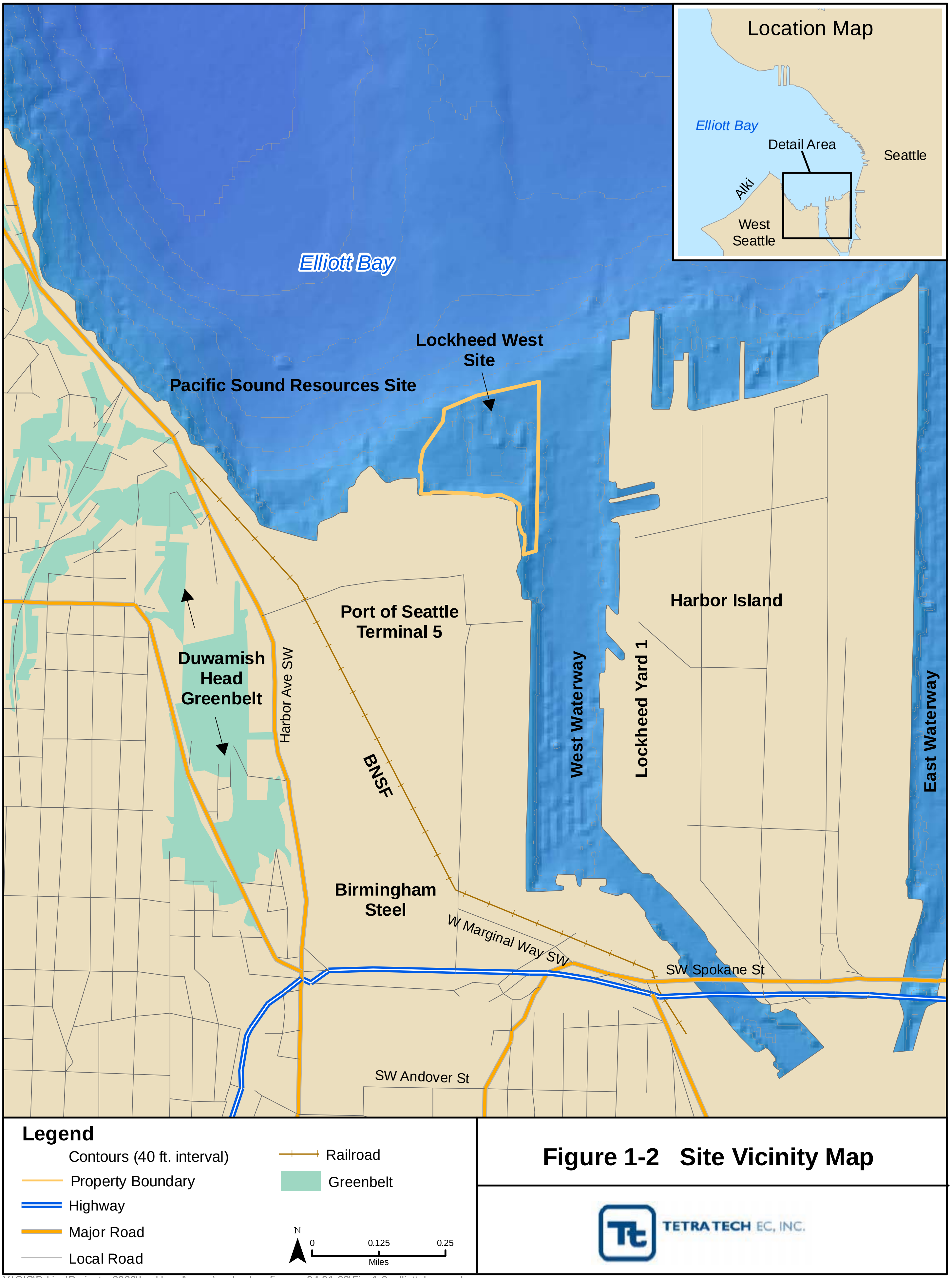


Figure 1-2 Site Vicinity Map

TETRA TECH EC, INC.

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\work_plan_figures_04-01-08\Fig_1-2_elliott_bay.mxd

2. PROJECT APPROACH, TEAM, DELIVERABLES, AND SCHEDULE

This section provides information on the project approach, team, deliverables, and schedule for completion of the Lockheed West RI/FS.

2.1 STREAMLINING THE RI/FS PROCESS

Authority for the cleanup of the Lockheed West Site was transferred from the Washington Department of Ecology (Ecology) to EPA Region 10 in September 2006. Since this time, EPA and LMC have held several planning meetings for the purposes of finding acceptable ways to streamline the RI/FS process. Given that a significant body of data is available for the Site, both EPA and LMC desire to expedite cleanup of the Site. The existing data and precedents at nearby EPA cleanup sites have allowed for efficiencies that will streamline the Lockheed West RI/FS and allow cleanup of the Site to be implemented in a protective and time-efficient manner.

Prior to the transfer of the Site, Lockheed West (then referred to as Lockheed Shipyard No. 2) was listed as a sediment cleanup priority by Ecology who had developed a Cleanup Action Plan (CAP) for the Site in 1996 after completion of a cleanup investigation. The Ecology CAP was never implemented. However, the studies supporting the Ecology CAP produced a significant amount of data that are useful in developing and understanding the nature and extent of sediment contamination at the Site prior to implementation of the investigation that is the subject of this Work Plan.

In addition to the Ecology CAP and supporting studies, other information relevant to completion of Lockheed West RI/FS is available from EPA Superfund sites nearby and adjacent to Lockheed West. To the immediate west of Lockheed West is the PSR Superfund Site. Sediment area remedial actions were implemented at the PSR Site in 2002. East of Lockheed West is the West Waterway Operable Unit (OU) of the Harbor Island Superfund Site. The West Waterway OU is subject to a No-Action Record of Decision (ROD). Upstream of the West Waterway OU is the Lower Duwamish Waterway (LDW) Superfund Site. The LDW Site is currently undergoing an RI/FS to address sediment contamination.

Sediment remediation goals will be established for the Lockheed West Site as part of the RI/FS. These numbers will be derived from baseline human health and ecological risk assessments (ERAs) that will identify sediment contaminants of concern (COCs) and from evaluation of background concentrations of COCs. Baseline risk assessments completed for the nearby LDW Site have shown that the sediment cleanup criteria for aquatic organisms established by Ecology's Sediment Management Standards (WAC 173-204) may not meet cleanup levels based on EPA human health risk thresholds for PCBs and other COCs and site-specific exposures including the tribal framework for tribal seafood consumption (the Framework). Similarly, based on the risk assessments, it has been recognized that risk-based sediment cleanup levels for PCBs at the LDW Site may be below background concentrations for the LDW. LMC and EPA recognized, without completing baseline risk assessments for the Lockheed West Site, that similar risk assessment outcomes are likely to result for some of the historical shipyard COCs.

Because of the likelihood that the in-situ chemical concentrations in Lockheed West sediment will result in exceedances of human health or ecologically based thresholds, LMC recognized that No Action and Natural Recovery as primary remedial alternatives at the Site would not likely meet CERCLA criteria for remedy selection. LMC therefore committed to elimination of these non-active remedial technologies. At the minimum, remediation of the Site will consist of placing caps over all contaminated sediments. Dredging, capping or some combination of dredging and capping are the only remedial alternatives under consideration at this time.

Limiting the remediation technologies for the Lockheed West Site allows the RI/FS process to be streamlined in that:

- Data collection can be focused on delineation of the cleanup boundary and filling of data gaps for completion of risk assessments and evaluation of capping and dredging technologies;
- Baseline human health and ecological risk assessments will be completed as applicable, consistent with the procedures established at the LDW Superfund Site and the draft Framework (EPA 2007d), as appropriate, and will use data collected during the site investigation to identify COCs and to determine risk-based cleanup criteria;
- Risk-based cleanup criteria will be identified for COCs identified in the risk assessments, and will be derived largely from the upstream LDW site;
- Background concentrations for COCs (to be determined in coordination with EPA, Muckleshoot and Suquamish tribes, and other stakeholders) will be considered as cleanup criteria if risk-based cleanup criteria are lower and, therefore, not practically achievable; and
- Remedial alternatives will be assembled for capping, dredging, and combinations of these remediation technologies. Only alternatives meeting the cleanup criteria,

remedial action objectives (RAOs), and the applicable standards will be carried forward for evaluation and ranking.

2.2 LOCKHEED WEST RI/FS SCOPE OF WORK

The RI/FS process includes several steps. RI activities are any activities necessary to develop sufficient information to support the development of remedial options, assess the potential human health and ecological risks from site contamination, and assess the potential for sediment recontamination. FS activities are those activities that evaluate and assemble remedial alternatives in support of the selection of the preferred remedial option. To implement the Lockheed West RI/FS, the following SOW will be completed;

- Compile and assess existing site data to identify potential data gaps for evaluation of remedial alternatives;
- Identify chemicals of interest (COIs) resulting from historical shipyard activities;
- Characterize the nature and delineate the extent of historical shipyard COIs by collection and analysis of environmental samples (as identified by data gaps) and completion of physical surveys of the project area and shoreline;
- Delineate a cleanup boundary for the Lockheed West Site based on the Site investigation data;
- Refine the Conceptual Site Model (CSM) based on interpretation of the site investigation data;
- Complete baseline human health and ecological risk assessments to identify site COCs and risk-based cleanup criteria, and background sediment sampling to identify appropriate cleanup levels for remediation of the Site;
- Identify site-specific RAOs for remediation of the Site;
- Identify appropriate remedial technologies and assemble applicable remediation alternatives for cleanup of the Site;
- Evaluate assembled remedial alternatives against CERCLA criteria; and
- Recommend a preferred remedial alternative based on the comparative evaluation and relative ranking of the assembled alternatives. The preferred alternative will be recommended to EPA for consideration in the Preferred Plan for the Lockheed West Site.

Descriptions of the approaches and procedures for completion of each of these project steps are detailed in the following sections of this Work Plan.

2.3 EXPEDITED SITE CHARACTERIZATION SAMPLING AND ANALYSIS PLAN

Both EPA and LMC recognized that collection of site data early in the RI/FS would assist in streamlining the evaluation of remedial alternatives for the Site. Sampling and analysis was carried out in January 2007. To facilitate efficient review and approval by EPA, the Site Characterization Sampling and Analysis Plan (SAP) was submitted as a stand-alone document and is a component of this RI/FS Work Plan. The Site Characterization SAP describes a sampling and analysis plan approach for the Lockheed West Site and was prepared as a stand-alone document to expedite collection of site data. EPA comments on the site investigation approach were incorporated into the study design; however, rangefinding sampling locations were not approved by EPA. As agreed with EPA, collection of additional site data early in the site cleanup process will lead to better informed decision making and determination of appropriate cleanup measures.

2.4 PROJECT TEAM

Tetra Tech, Inc. (Tetra Tech) is the primary contractor to LMC represented by Gene Matsushita, Program Manager. Mr. Matsushita or his designee, Mr. Bill Bath (Project Coordinator), will be responsible for coordination with regulatory agencies and overall implementation of the ASAOC and SOW. Tetra Tech will be responsible for project management, and conducting RI and FS tasks. Tetra Tech will also be responsible for preparing project deliverables, team resources, project budget and financial controls, scheduling, coordination, and communications. Tetra Tech is supported by John Herzog (GeoEngineers) and Gary Pascoe (Pascoe Environmental Consulting), who will provide risk assessment support. In accordance with Section VIII of the ASAOC, project team qualifications were provided to EPA. The project team organization is presented in Table 2-1 and Figure 2-1.

2.5 PROJECT DELIVERABLES

Following is a description of the planned project deliverables that will be prepared in addition to this Work Plan. All documents will be prepared in accordance with EPA guidelines for conducting an RI/FS. Further, the quality of all reports and submittals to EPA will be ensured by strict adherence to the Tetra Tech Quality Assurance (QA) program, including, but not limited to, internal technical and editorial review, independent verification of all calculations used in the RI/FS, documentation of all reviews, and the process to be used to identify and correct problems. This program has been formatted and designed to meet the requirements of the latest versions of American National Standards Institute/American Society of Mechanical Engineers, Nuclear QA (ANSI/ASME NQA-1), Ecology Order 5700.6, as well as applicable EPA QA requirements and other recognized and appropriate engineering codes, standards, requirements, and practices. Tetra Tech procedures and criteria applicable include, but are not limited to, the following:

- SCI-002 Technical Review of Scientific Documents,
- QA-3 Control of Work Process,
- QA-6 Document Control,
- ENG-7 Design Verification, and
- ENG-8 Record Drawings.

A full listing of Tetra Tech procedures will be provided to EPA upon request.

2.5.1 Progress Reports

LMC will submit monthly progress reports to the EPA Project Coordinator by the 10th of the month for the preceding reporting period. If this day is a weekend or holiday, progress reports will be submitted on the next business day. Progress reports will, at a minimum, contain the following information regarding the preceding reporting period:

- Description of actions that have been taken to comply with the ASAOC and SOW during the previous month,
- Summary of results of sampling and tests and all other data received by LMC,
- Description of all work planned for the next 2 months with schedules relating such work to the overall project schedule for RI/FS completion, and
- Description of all problems encountered and any anticipated problems, any actual or anticipated delays, and solutions developed and implemented to address any actual or anticipated problems or delays.

2.5.2 Data Collection Report

The Data Collection Report will present the results of the RI field investigation, including:

- Description of the field activities completed;
- Deviations from the approved Work Plan, SAP, Quality Assurance Project Plan (QAPP), or Health and Safety Plan (HASP);
- Tabulated chemical, physical, and biological data with comparisons to regulatory criteria (where applicable);
- Sample identification matrix;

- Sample location and sample identification information;
- Data validation reports;
- Field logs;
- Chain of custody forms; and
- Electronic data, submitted in accordance with EPA instructions for formatting digital data (EPA 1993a) and in a format compatible with software currently available within EPA Region 10 (Microsoft® Access format).

All data will be submitted to EPA in an acceptable electronic format.

2.5.3 Source Control Evaluation Report

The Source Control evaluation will identify and assess potential sources of contamination to the Lockheed West Site (Site). The purpose of the source control evaluation is to document the current status of source control and to determine whether there are sources with the potential to recontaminate the Site following its planned remediation.

The objectives of this Source Control Evaluation are to:

1. Identify potential sources and assess the potential pathways and the potential for recontamination of Lockheed West following its remediation.
2. Evaluate whether the resuspension, transport, and deposition of bottom sediments in the adjacent Elliott Bay and West Waterway are a potential ongoing source of chemical contamination that could result in recontamination of Lockheed West after remediation.
3. Qualitatively compare available source information to existing sediment quality data.
4. Identify data gaps that should be resolved so that the status of source control at Lockheed West can be confirmed.
5. Make recommendations to the EPA regarding the need for further investigation or control of identified potential sources.

The Source Control Evaluation approach will be further refined through technical workshops with EPA and the project stakeholders. Details of the Source Control Evaluation approach stemming from the technical workshops will be documented and submitted for review and approval.

2.5.4 Remedial Investigation and Feasibility Study Report

LMC will prepare and submit a draft and final Remedial Investigation/Feasibility Study (RI/FS) Report for EPA review and approval. This report will present an evaluation of the nature and extent of contamination at the Site and evaluate remedial alternatives for cleanup. The individual elements of the RI/FS Report are described below.

2.5.4.1 Remedial Investigation

The remedial investigation section will summarize all useable data into a complete evaluation of the nature and extent of contamination at and from the Site. It will also include discussions of historical data, chemical fate, sediment transport, and historical and potential ongoing sources of contamination. LMC will use EPA RI/FS guidance for an outline of the report format and required contents.

2.5.4.2 Baseline Ecological and Human Health Risk Assessments

The baseline risk assessments will be streamlined consistent with the RI approach described above. Because of the decision to actively remediate the entire Site, the no-action alternative and natural recovery alternatives will be evaluated to the extent required by CERCLA, however, these alternatives are not intended for serious consideration. Instead, the entire Site will be actively remediated to mitigate all assumed human health and ecological risks. The presence of Site contamination requires performance of a baseline risk assessment to indicate the potential extent of risk under present site conditions, and to support the remedy selection for the sediments that will mitigate the risk.

Risks to human health and ecological receptors from exposures to chemicals in Site sediments will be evaluated through streamlined approaches. The streamlined risk assessment (RA) will evaluate potential risk by structuring the assessments to use technical information from the risk assessments performed at the nearby LDW site.

The streamlined Human Health Risk Assessment (HHRA) will evaluate the potential for human health risks to adults and children from site sediments and consumption of fish/shellfish tissue. The baseline HHRA will include (at a minimum), with justification, the following exposure scenarios: 1) tribal seafood consumption and clam harvesting, 2) recreational child beach play, and 3) tribal netfishing. It will address risks to seafood-consuming tribal individuals by utilizing relevant material from the LDW HHRA, as appropriate, and applying the Framework on seafood consumption.

2.5.4.3 Remedial Action Objectives

Remedial Action Objectives (RAOs) will be identified to provide a framework for the evaluation of remedial alternatives as part of the feasibility study. The RAO section will include the following:

- List of final COCs as determined from the baseline risk assessments,
- Identification and rationale for goals and technical basis for cleanup level goals (preliminary remediation goals [PRGs], applicable or relevant and appropriate requirements [ARARs], risk assessments), and
- Identification of cleanup boundaries based on determined cleanup level goals.

2.5.4.4 Remedial Technologies Screening and Alternatives Assembly

The remedial technologies screening section will identify and screen remedial technologies and assemble representative alternatives to reduce the number of alternatives to be considered for detailed analysis in the FS. This process consists of the general steps described below.

- Develop general response actions (GRAs) for each medium of concern defining removal, containment, attenuation, or other actions, singly or in combination, which may be taken to satisfy the RAOs for the Site.
- Identify preliminary volumes or areas of media to which GRAs might be applied, taking into account the requirements for protectiveness as identified in the RAOs and the chemical and physical characterization of the Site.
- Identify and screen the technologies and process options (e.g., specific processes within each technology type) applicable to each GRA to ensure that only those technologies and process options applicable to the contaminants present, their physical matrix, and other site characteristics will be considered. Given the streamlined RI/FS approach for the Site, the technologies and process options to be screened will include:
  - In-place confinement (capping), and
  - Dredging with upland disposal in existing landfills.

    This screening will be based primarily on a technology's ability to effectively address the contaminants at the Site, but will also take into account a technology's implementability, constructability, and cost.
- Combine retained technologies and process options into media-specific or site-wide representative alternatives. The developed alternatives will be defined with respect to size and configuration of the representative process options, time for remediation,

rates of flow or treatment, spatial requirements, distances for disposal, and other factors necessary to evaluate the alternatives.

2.5.4.5 Feasibility Study

The FS section will summarize applicable results of the RI and risk assessments, and will include the results of the RAO identification and remedial alternatives screening. The results of the FS will provide the basis for remedy selection by EPA and will document the development and detailed analysis of remedial alternatives. This FS will apply CERCLA evaluation criteria to the remedial alternatives identified by the remedial alternatives screening to ensure the selected remedial alternative(s) will:

- Protect human health and the environment;
- Be in compliance with, or include a waiver of, ARARs;
- Be cost-effective;
- Utilize permanent solutions and alternative treatment technologies, or resource recovery technologies, to the maximum extent practicable; and
- Address the statutory preference for treatment as a principal element.

For each alternative described in the FS, the report will include: 1) a description of the alternative that outlines the sediment management strategy involved and identifies the degree of protectiveness and key ARARs associated with each alternative; and 2) an assessment of each alternative against each of the CERCLA criteria except Criteria 8 (state acceptance) and 9 (community acceptance) which will be addressed by EPA after the RI/FS report has been released to the public.

2.5.5 Meetings

Although not a specific project deliverable, several meetings are anticipated to ensure that planning and communication for the RI/FS is undertaken in a manner that is cost-effective and timely. LMC and EPA will hold meetings for the purpose of briefing EPA or responding to EPA comments or concerns. These meetings will be held as deemed necessary and appropriate by the parties, and may include a review of project deliverables and coordination with other agencies, such as:

- Coordination on sampling and data gap fulfillment approach,
- Coordination with EPA and other parties regarding baseline human health and ecological risk assessments,
- Coordination with EPA and other parties regarding habitat issues,

- Coordination with EPA and other parties regarding existing and future site use plans, and
- Coordination with EPA and Ecology to identify areas and activities that may require implementation of source control measures prior to remedial actions at the Site.

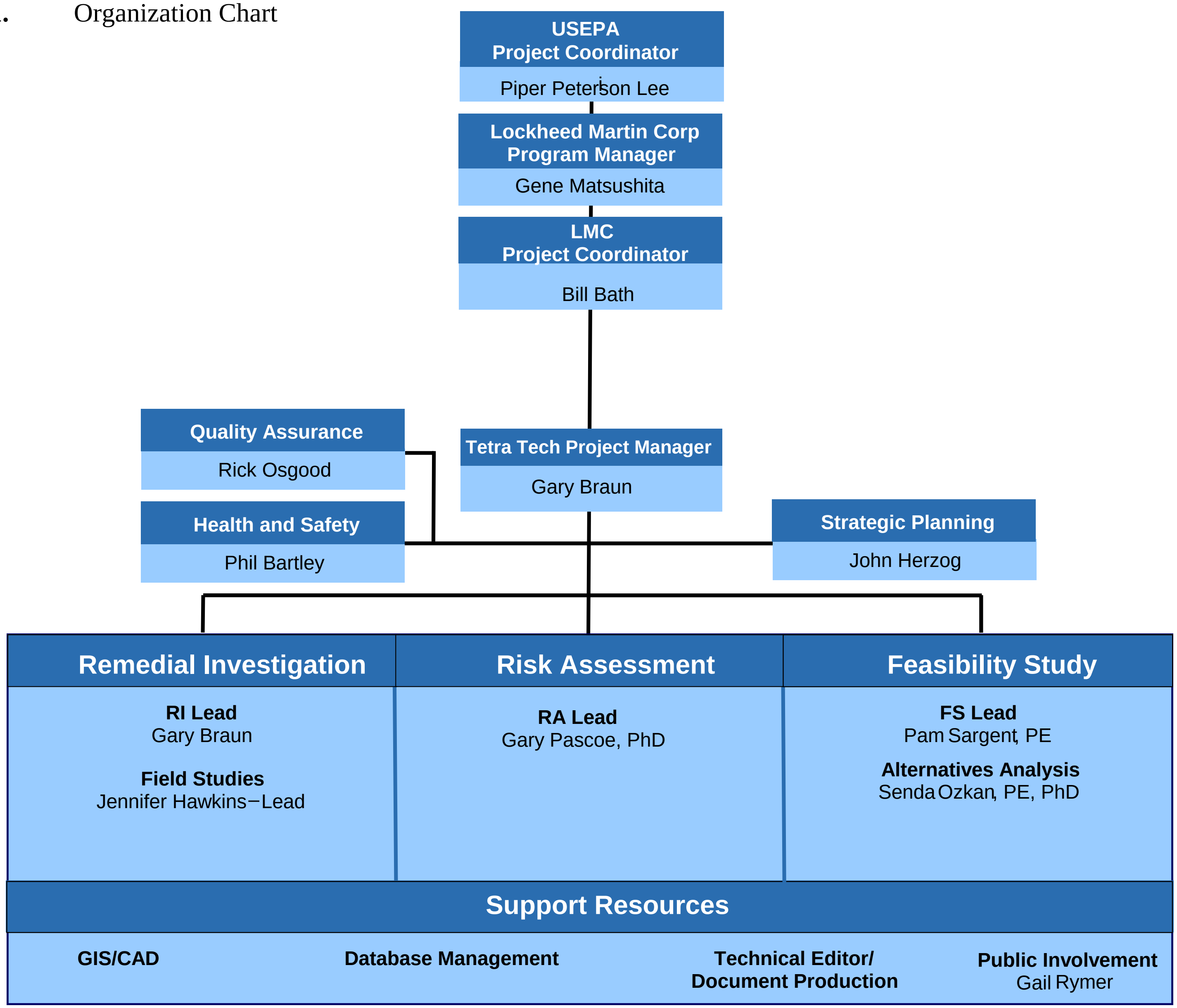
2.6 SCHEDULE OF ACTIVITIES

This section describes a schedule for the completion of the ASAOC/SOW tasks (in calendar days). The schedule for performing the RI/FS tasks, as set forth in Section III of the SOW, is presented in Figure 2-2. Initial draft deliverable due dates to EPA are listed in Section III of the SOW. Revised deliverables (including one redlined version) are due 30 days after receipt of EPA comments on the draft. Documents become final upon written approval by EPA. Days are calendar days; if due dates fall on a weekend or holiday, deliverables will be submitted to EPA on the next business day. Where the deliverable due date is triggered by notification, comments, or approval, the starting date for the period shown is the date LMC received notification, comments, or approval, unless otherwise shown. Where triggered by EPA receipt of a deliverable, the starting date for the period shown is based on the mail receipt date or EPA's signature on the hand delivered form. The completed RI/FS will be subject to public comment. After the public comment period, EPA will consider comments and select the final remediation plan. EPA will provide written notification of the final selection to LMC. EPA may modify the project schedule as necessary.

Table 2-1. Project Organization

Position	Name	Phone Number
EPA Project Coordinator/Remedial Program Manager	Piper Peterson Lee	206-553-4951
LMC Program Manager	Gene Matsushita	818-847-0197
LMC Project Coordinator	Bill Bath	303-977-3997
Project Manager	Gary Braun, Tetra Tech	425-482-7840
QA Manager	Rick Osgood, Tetra Tech	425-482-7819
Health and Safety Manager	Phil Bartley, Tetra Tech	509-372-5818
Quality Control (QC) Manager	Sheri Wunderlich, Tetra Tech	425-482-7849
RI Lead	Gary Braun, Tetra Tech	425-482-7840
RA Lead	Gary Pascoe, Pascoe Environmental	360-385-9977
FS Lead	Pamela Sargent, Tetra Tech	425-482-7615
Strategic RI/FS Consultant	John Herzog, GeoEngineers	206-406-6431
Field Operations Lead	Jennifer Hawkins, Tetra Tech	425-482-7678
Analytical Laboratory	Columbia Analytical Services	360-577-7222

Figure 2-1. Organization Chart



Lockheed West RI/FS Representative Project Schedule

ID	Task Name	Duration	Start	Finish
1	**AOC for Initial Data Review**	108 days	Tue 12/6/05	Thu 3/23/06
2	**ASAOC for Remedial Investigation/Feasibility Study**	**114 days**	**Thu 4/6/06**	**Fri 7/28/06**
3	Receive Special Notice Letter and Draft AOC/SOW	0 days	Thu 4/6/06	Thu 4/6/06
4	Good Faith Offer to EPA and Negotiation of Remedial Investigation/Feasibility Study AOC	60 days	Thu 4/6/06	Sun 6/4/06
5	ASAOC for RI/FS Effective Date	54 days	Mon 6/5/06	Fri 7/28/06
6	**Monthly Progress Reporting**	**2193 days**	**Mon 5/1/06**	**Tue 5/1/12**
80	**Remedial Investigation / Feasibility Study (RI/FS) Work Plan**	**703 days**	**Sat 7/29/06**	**Tue 7/8/08**
81	**Prepare RI/FS Work Plan**	**703 days**	**Sat 7/29/06**	**Tue 7/8/08**
82	Prepare Draft RI/FS Work Plan	30 days	Sat 7/29/06	Sun 8/27/06
83	Submit Draft Work Plan to EPA	1 day	Mon 8/28/06	Mon 8/28/06
84	EPA review of Draft RI/FS Work Plan	45 days	Tue 8/29/06	Thu 10/12/06
85	Prepare and Submit Site Characterization SAP	15 days	Wed 11/1/06	Wed 11/15/06
86	EPA review of Site Characterization SAP	6 days	Thu 11/16/06	Tue 11/21/06
87	EPA Approval of SC SAP	0 days	Mon 12/4/06	Mon 12/4/06
88	Revise and Prepare Revised Streamlined RI/FS Work Plan	78 days	Mon 12/25/06	Mon 3/12/07
89	Submit Final Streamlined RI/FS Work Plan to EPA	0 days	Mon 3/12/07	Mon 3/12/07
90	EPA Review of revised Streamlined RI/FS Work Plan	197 days	Tue 3/13/07	Tue 9/25/07
91	Resolve EPA comments	62 days	Wed 9/26/07	Tue 12/4/07
92	Revise and Prepare Draft Final Streamlined RI/FS Work Plan	51 days	Wed 12/5/07	Thu 1/24/08
93	Submit Draft Final RI/FSWork Plan to EPA	0 days	Thu 1/24/08	Thu 1/24/08
94	EPA review of Draft Final RI/FS Work Plan	53 days	Fri 1/25/08	Mon 3/17/08
95	Revise and Prepare Final Streamlined RI/FS Work Plan	99 days	Tue 3/18/08	Tue 6/24/08
96	EPA Review of Final Streamlined RI/FS Work Plan	14 days	Wed 6/25/08	Tue 7/8/08
97	EPA Approval of Final Streamlined RI/FS Work Plan	0 days	Tue 7/8/08	Tue 7/8/08
98	**Prepare Risk Assessment Work Plan**	**122 days**	**Mon 8/21/06**	**Wed 12/20/06**
107	**Remedial Investigation Field Work**	**144 days**	**Tue 12/5/06**	**Fri 4/27/07**
108	Field Work Planning	34 days	Tue 12/5/06	Sun 1/7/07
109	Field Work Implementation - Subtidal	25 days	Mon 1/8/07	Thu 2/1/07
110	Field Work Implementation - Intertidal	10 days	Wed 4/18/07	Fri 4/27/07
111	**Remedial Investigation Data Report**	**489 days**	**Fri 2/2/07**	**Thu 6/12/08**
112	Prepare Draft Remedial Investigation Data Report	100 days	Fri 2/2/07	Sat 5/12/07
113	EPA Comment on Draft Remedial Investigation Data Report	192 days	Sun 5/13/07	Tue 11/20/07
114	Prepare and Submit Addenda to Data Report for Intertidal work	60 days	Sat 4/28/07	Tue 6/26/07
115	Revise Remedial Investigation Data Report	66 days	Wed 11/21/07	Fri 1/25/08
116	EPA Review of Final Remedial Investigation Data Report	139 days	Sat 1/26/08	Thu 6/12/08
117	EPA Approval of Final Remedial Investigation Data Report	0 days	Thu 6/12/08	Thu 6/12/08
118	**Baseline Ecological and Human Health Risk Assessments**	**255 days**	**Thu 6/12/08**	**Sun 2/22/09**
119	Draft Baseline Ecological Risk Assessment	150 edays	Thu 6/12/08	Sun 11/9/08
120	Draft Baseline Human Health Risk Assessment	150 edays	Thu 6/12/08	Sun 11/9/08
121	EPA Comment on Draft Baseline ERA and HHRA	45 edays	Sun 11/9/08	Wed 12/24/08

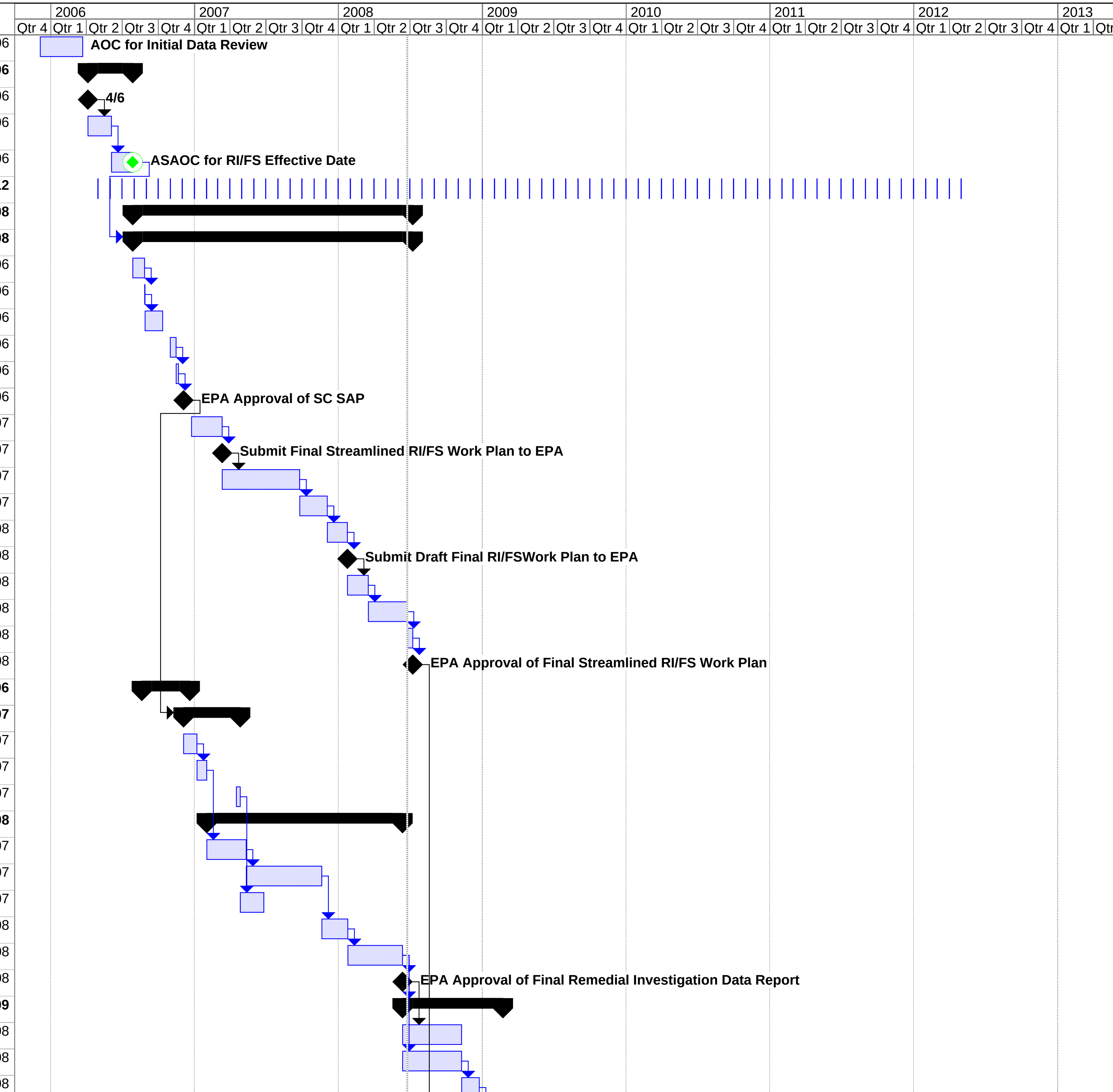


Figure 2-2 Representative Project Schedule

(6/24/08)

Task		Progress		Summary		External Tasks		Split	
Split		Milestone		Project Summary		External MileTask			

Note: This schedule is predicated on EPA review and approval within specified time periods. The schedule reflects Lockheed Martins intent to expedite site remediation; however, it does not supersede the schedule presented in the ASAOC.

Mon 6/23/08

Lockheed West RI/FS Representative Project Schedule

ID	Task Name	Duration	Start	Finish
122	Revise BERA and BHHRA	30 edays	Wed 12/24/08	Fri 1/23/09
123	EPA Review of BERA and BHHRA	30 edays	Fri 1/23/09	Sun 2/22/09
124	EPA Approval of BERA and BHHRA	0 days	Sun 2/22/09	Sun 2/22/09
125	**Source Control Evaluation Report**	**464 days?**	**Thu 5/22/08**	**Sun 9/6/09**
126	Source Control Evaluation Workshop	1 day?	Thu 5/22/08	Thu 5/22/08
127	Source Control Approach and Meeting Summary	26 edays	Thu 5/22/08	Tue 6/17/08
128	Prepare Summary of Existing Data, Conceptual Model, and Data Gap Ev	90 edays	Tue 7/8/08	Mon 10/6/08
129	EPA Comment on Draft Summary of Existing Data, Conceptual Model, a	45 edays	Mon 10/6/08	Thu 11/20/08
130	Revise and Submit Summary of Existing Data, Conceptual Model, and D	30 edays	Thu 11/20/08	Sat 12/20/08
131	EPA Review of Summary of Existing Data, Conceptual Model, and Data	30 edays	Sat 12/20/08	Mon 1/19/09
132	EPA Approval of Summary of Existing Data, Conceptual Model, and Data	0 days	Mon 1/19/09	Mon 1/19/09
133	Prepare Draft Source Control Evaluation Report	125 edays	Mon 1/19/09	Sun 5/24/09
134	EPA Comment on Draft Source Control Evaluation Report	45 edays	Sun 5/24/09	Wed 7/8/09
135	Revise and Submit Source Control Evaluation Report	30 edays	Wed 7/8/09	Fri 8/7/09
136	EPA Review of Source Control Evaluation Report	30 edays	Fri 8/7/09	Sun 9/6/09
137	EPA Approval of Source Control Evaluation Report	0 days	Sun 9/6/09	Sun 9/6/09
138	**Remedial Investigation/Feasibility Study Report**	**394 days**	**Sun 2/22/09**	**Thu 4/1/10**
139	Prepare Draft Remedial Investigation	90 edays	Sun 2/22/09	Sat 5/23/09
140	Remedial Action Objectives Technical Memorandum	30 edays	Sat 5/23/09	Mon 6/22/09
141	Submit RAO Technical Memorandum for EPA Comment	15 edays	Mon 6/22/09	Tue 7/7/09
142	Revise RAO Technical Memorandum	7 edays	Tue 7/7/09	Tue 7/14/09
143	EPA Review and Approval of RAO Technical Memorandum	7 edays	Tue 7/14/09	Tue 7/21/09
144	Remedial Alternaives Screening Technical Memorandum	30 edays	Tue 7/21/09	Thu 8/20/09
145	Submit to EPA Remedial Alternatives Screening Technical Memorandum	15 edays	Thu 8/20/09	Fri 9/4/09
146	Revise Remedial Alternatives Screening Technical Memorandum	7 edays	Fri 9/4/09	Fri 9/11/09
147	EPA Review and Approval of Remedial Alternatives Screening Technica	7 edays	Fri 9/11/09	Fri 9/18/09
148	Prepare Feasibility Study	90 edays	Fri 9/18/09	Thu 12/17/09
149	Submit Draft Remedial Investigation/Feasibility Study for EPA Review	45 edays	Thu 12/17/09	Sun 1/31/10
150	Revise RI/FS Report	30 edays	Sun 1/31/10	Tue 3/2/10
151	EPA Review of RI/FS	30 edays	Tue 3/2/10	Thu 4/1/10
152	EPA Approval of RI/FS	0 days	Thu 4/1/10	Thu 4/1/10
153	**Develop Proposed Plan and Record of Decision (EPA)**	**120 days**	**Thu 4/1/10**	**Fri 7/30/10**
157	**Consent Decree for Remedial Design**	**90 days**	**Fri 7/30/10**	**Thu 10/28/10**
160	**Remedial Design**	**445 days**	**Thu 4/1/10**	**Mon 6/20/11**
181	**Remedial Action Construction**	**239 days**	**Mon 6/20/11**	**Tue 2/14/12**
182	Construction Preparation	56 edays	Mon 6/20/11	Mon 8/15/11
183	Remedy Construction Year 1	183 edays	Mon 8/15/11	Tue 2/14/12
184				
185	**Allowable In-water Work Period**	**2010 days**	**Tue 8/15/06**	**Tue 2/14/12**

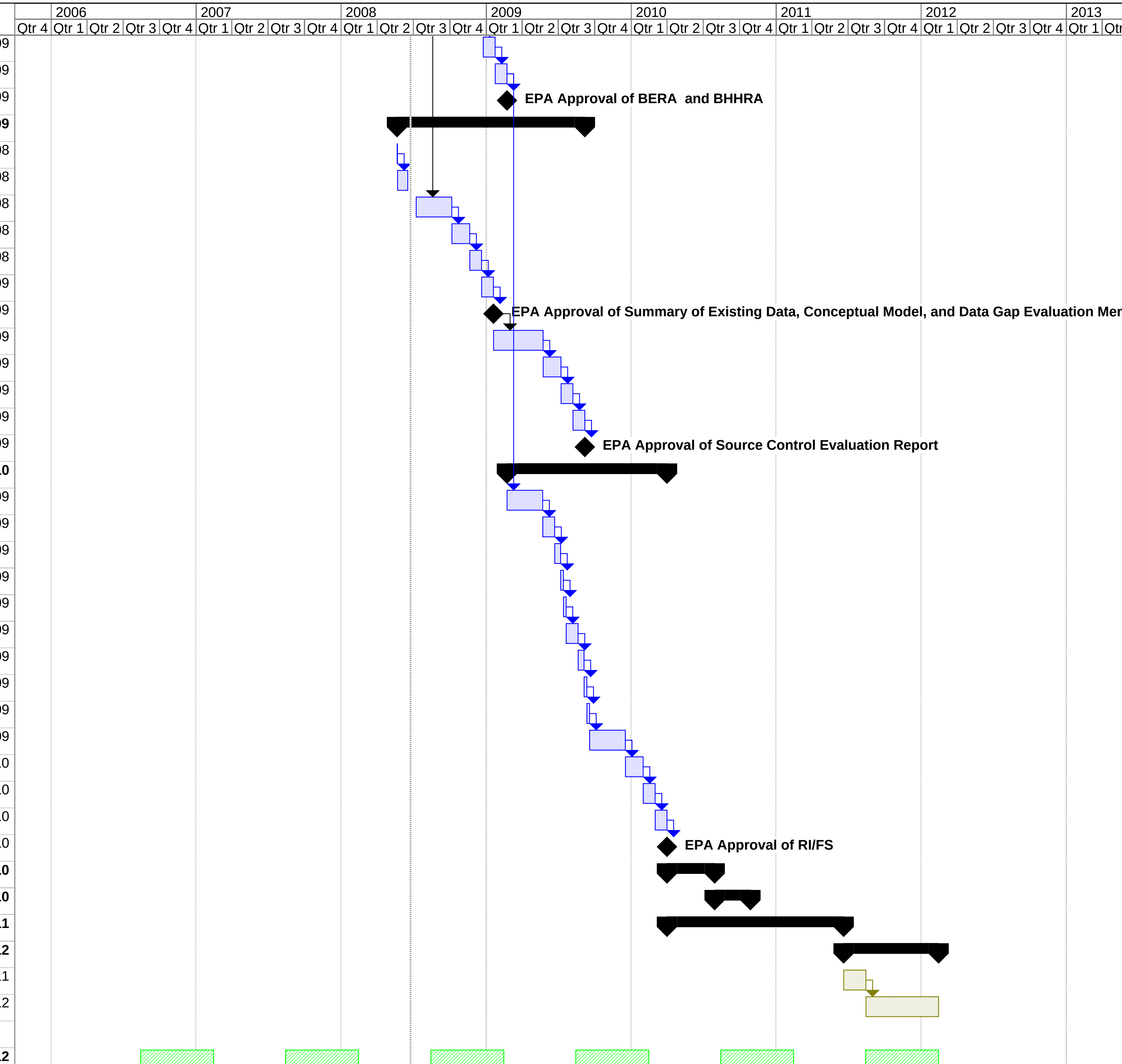


Figure 2-2 Representative Project Schedule
(6/24/08)

Task		Progress		Summary		External Tasks		Split	
Split		Milestone		Project Summary		External MileTask			

Note: This schedule is predicated on EPA review and approval within specified time periods. The schedule reflects Lockheed Martins intent to expedite site remediation; however, it does not supersede the schedule presented in the ASAOC.

Mon 6/23/08

3. POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

3.1 INTRODUCTION

This section presents potential applicable or relevant and appropriate requirements (ARARs) identified for the Lockheed West site.[1] The identification of ARARs is an iterative process. The list of ARARs is expected to change during the various phases of the remedial process and will be updated as appropriate. The ARARs could change due to identification of additional COCs during the RI or due to changes in remedial actions during the feasibility study. Final ARAR determinations will be made during the preparation of the Record of Decision (ROD).

3.1.1 Applicable Requirements

State and federal requirements can be either *applicable* or *relevant and appropriate*. Applicable requirements, as defined in 40 Code of Federal Regulations (CFR) 300.5, are

> those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

In other words, an applicable requirement is one that a private party would have to comply with by law if the situation/action was not undertaken under CERCLA or MTCA. MTCA, the state equivalent to the federal CERCLA program, has a similar definition of applicable or relevant and appropriate requirements at WAC 173-340-710.

3.1.2 Relevant and Appropriate Requirements

If a requirement is not applicable, it may still be relevant and appropriate. Relevant and appropriate requirements, also defined in 40 CFR 300.5, are

> those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state

[1] Most of the text and tables in this section were excerpted from EPA's Harbor Island RI prepared by Weston (1993).

environmental or facility siting laws, that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

While the determination of "applicability" is a legal one, the determination of "relevant and appropriate" relies on professional judgment, taking into account the circumstances of the site, the chemicals, the actions, and the location. A relevant and appropriate requirement should cover situations similar to those at the site (relevancy) and be suitable for the conditions at the site (appropriateness). Both conditions must exist in order for a requirement to be relevant and appropriate. MTCA has a similar definition of applicable or relevant and appropriate requirements at WAC 173-340-710.

3.1.3 Items to Be Considered

Unenforceable standards or guidelines may be used as items to be considered (TBCs) in developing and evaluating remedial alternatives. Proposed standards, guidance documents, and health advisories are examples of potential items to be considered. Not all items to be considered need be reported [40 CFR 300.4(g)(3)]; a small number of items to be considered are presented at the end of this section.

3.2 ARAR CATEGORIES

ARARs may be divided into the following categories: chemical-specific, action-specific, or location-specific. These different categories are defined in the sections below; potential ARARS for the Lockheed West Site are listed in Table 3-1 (chemical-specific ARARs), Table 3-2 (action-specific ARARs), and Table 3-3 (location-specific ARARs). These tables present both federal and state ARARs.

3.2.1 Chemical-Specific ARARs

Chemical-specific requirements set concentration limits or ranges in various types of environmental media. Such ARARs may set protective cleanup levels for the chemicals of concern in the designated media. Chemical-specific ARARs may also indicate an appropriate level of discharge.[2]

[2] In this instance an ARAR can be considered both chemical-specific and action-specific.

Chemical-specific requirements are health- or risk-based concentration limits such as ambient water quality criteria. Table 3-1 presents a list of potential federal and state chemical-specific ARARs identified for the various media at the Lockheed West site. These ARARs are based on current, publicly available information and do not reflect administrative discretion that may be exercised in the future by federal or state authorities.

EPA (2002b) states the following:

> "Generally, under CERCLA, cleanup levels are not set at concentrations below natural background levels. Similarly, for anthropogenic contaminant concentrations, the CERCLA program normally does not set cleanup levels below anthropogenic background concentrations (EPA 1996, 1997c, 2000b). The reasons for this approach include cost-effectiveness, technical practicability, and the potential for recontamination of remediated areas by surrounding areas with elevated background concentrations."

Therefore, when background concentrations for contaminants are above the ARAR for that contaminant, the ARAR may not be achievable and alternative ARARs or risk-based standards may dictate the appropriate action. This scenario could occur in the Lockheed West site for some chemicals. A detailed comparison of site-specific chemical concentrations with background chemical concentrations will be made during the development of remediation goals.

3.2.2 Action-Specific ARARs

Action-specific ARARs are typically technology- or activity-based requirements or limitations on actions. These requirements are not triggered by the specific contaminants identified, but by activities related to management of these contaminants. Table 3-2 presents the potential action-specific ARARs for soil, surface water, groundwater, and air that have been identified for a preliminary list of remedial actions. The final list of remedial actions will be developed during the feasibility study phase of the RI/FS. Requirements such as Occupational Safety and Health Act (OSHA) standards are excluded as action-specific ARARs because they must be adhered to under all circumstances, regardless of whether the activity is related to a CERCLA or MTCA action.

Because one activity may trigger several requirements, descriptions of the potential ARARs are provided under each activity category. In general, activities may be subject to certain limitations depending upon 1) the type of activity performed (e.g., incineration), 2) the type of waste being managed, and 3) whether the activity is conducted on-site. A discussion of the second and third limitations is provided below.

3.2.2.1 Waste Type

Requirements for treatment, storage, and disposal of hazardous wastes are provided under the federal Resource Conservation and Recovery Act (RCRA) and the Washington State Dangerous Waste Regulations. Activities may be subject to RCRA or state hazardous waste ARARs depending upon the type of waste generated at the Lockheed West site.

RCRA requirements are generally applicable for actions involving RCRA hazardous waste. RCRA hazardous waste must be a 1) solid waste or contaminated environmental media and 2) RCRA-characteristic or RCRA-listed waste. RCRA characteristic wastes exhibit at least one of four characteristics: ignitability, reactivity, corrosivity, or toxicity. Toxicity is determined by the toxicity characteristic leaching procedure (TCLP), which has threshold values for various contaminants above which a waste would be regulated. RCRA-listed wastes are listed in 40 CFR 261, Subpart D.

State dangerous waste requirements are generally applicable for activities involving either a RCRA or non-RCRA state hazardous waste. State dangerous wastes are defined in WAC 173-303-070 and include RCRA plus state-defined “criteria” waste.

Solid wastes are subject to the federal Solid Waste Disposal Act storage and disposal requirements as administered under 40 CFR 257-258 and the state Solid Waste Handling Standards in WAC 173-350.

3.2.2.2 On-site Permit Exemptions

CERCLA §121(e) provides an exemption from federal, state, or local permits for the portion of any removal/remedial action conducted entirely on-site. On-site is interpreted by the EPA to mean “the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action.”

Although a permit would not be required for on-site activities, substantive, non-administrative requirements of the permit must be met. For example, on-site discharges to the Lockheed West via a pipe, ditch, conduit, or other means of discrete conveyance would be subject to the substantive requirements of an NPDES permit issued by the state, but in itself would not require a National Pollutant Discharge Elimination System (NPDES) permit. However, discharges directly off-site (e.g., into a conveyance system leading to a Publicly Owned Treatment Works [POTW]) would be subject to both substantive and administrative permitting requirements.

3.2.3 Location-Specific ARARs

Location-specific ARARs are restrictions placed on either the concentration of hazardous substances or the conduct of activities performed in certain locations. They may restrict or preclude certain remedial actions or may apply only to certain portions of the area of contamination. Potential Lockheed West-specific ARARs are presented in Table 3-3.

3.3 PROCEDURES FOR DETERMINING ARARS

Compliance with other laws may be either applicable or relevant and appropriate, but not both, based on cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law. Thus, each evaluation of a potential ARAR will consist of a determination as to whether the requirement is applicable, relevant and appropriate, or neither.

The determination of ARARs will be ongoing throughout the RI/FS process, and will progress from the identification of regulatory programs that may impose requirements, to a determination of specific criteria and standards that will become part of the response objectives. In general, potential chemical-specific and location-specific ARARs will be identified during the RI. Later, as remedial alternatives are developed as part of the feasibility study, activity-specific ARARs will be more definitive. Final ARAR determinations will be made during preparation of the ROD.

3.4 ARAR WAIVERS OR VARIANCES

An ARAR waiver or variance may be obtained if an ARAR(s) cannot be met. Typically, the justification for these waivers must be one of the following items:

1. The measure/action that will not attain all ARARs is an interim measure, which will be followed by a complete measure that will attain ARARs.
2. Equivalent or better results can be obtained using a design or method different from that specified in the ARAR.
3. Compliance with an ARAR will cause greater risk to human health and the environment than noncompliance.
4. Achieving an ARAR(s) is technically impracticable.
5. The costs associated with meeting an ARAR in order to obtain an added degree of protection or reduction of risk would jeopardize the funds for remedial actions at other sites. This waiver is available for Fund-financed actions only.

3.5 STATE REQUIREMENTS AS POTENTIAL ARARS

For actions conducted under CERCLA, an analysis of state ARARs is required. CERCLA §121 states that in order for a state requirement to be eligible to be an ARAR, it must be both promulgated and more stringent than federal requirements. A state requirement is promulgated if it is legally enforceable (i.e., it must be issued in accordance with state procedural requirements and contain specific enforcement provisions or be otherwise enforceable under state law), and it is generally applicable. The evaluation of stringency considers two types of regulations: 1) those for which there is a federal counterpart (or program), and 2) those for which there is no federal counterpart (or program).

For most federally authorized state programs (e.g., RCRA, Clean Water Act [CWA]), state requirements are at least as stringent as federal requirements. Therefore, state requirements under these programs do not require a comparison of stringency. It must be determined, however, that the state has been authorized to administer the program and to develop regulations under the authorized program. For non-authorized state programs, the investigator must prepare a side-by-side analysis of requirements to show that the state requirement is more stringent than federal requirements. Regulations promulgated under state programs that do not have a federal counterpart, but address specific conditions within that state, represent ARARs because they are more stringent than federal law and add new or specific requirements to the body of federal environmental regulations.

In addition, state requirements must be substantive; that is, they must not impose only administrative or procedural requirements, or requirements that can be substituted effectively by established CERCLA administrative procedures. Further, EPA will consider state requirements to be an ARAR only if they are "of general applicability." That is, state requirements that apply only to one or more Superfund sites are not to be considered an ARAR. For a state requirement to be a potential ARAR it must be applicable to all remedial situations described in the requirement, not just to Superfund sites. Also, the requirement must be consistently applied to all sites. Local laws are generally not promulgated state requirements and therefore may or may not be ARARs. If the local requirement is developed under explicit state authority or if compliance is a requirement of a promulgated state statute, the local requirement may be an ARAR.

To support the inclusion of state requirements as ARARs, the following information should be provided. First, evidence should be provided that the proposed ARAR is a promulgated standard, including the statute or regulation, the date of enactment, or the effective date. Second, evidence should be provided that the proposed ARAR is broader or that it imposes a more restrictive standard of performance than federal requirements.

If a state disputes the determination by the EPA that a state requirement is not an ARAR, the state may submit its argument to the EPA Assistant Administrator for Solid and Hazardous Waste. Other dispute resolution mechanisms may be developed and presented in a State/Superfund Memorandum of Agreement. If the state's requirement is still not determined to be an ARAR after completing the dispute resolution process, the requirement may nevertheless be applied to the remedy if the state demonstrates an ability and willingness to pay for the additional incremental expense associated with its application. In this circumstance, the state may be required to take the lead in the remedial design and remedial action.

3.6 ITEMS TO BE CONSIDERED (TBCS)

State and local ordinances, advisories, and other requirements that are not ARARs may be used in determining the appropriate extent and manner of cleanup. These requirements can be TBC requirements. Generally, TBC requirements are used when no federal or state requirements exist for a particular situation. Some TBC items are presented in Table 3-4.

Table 3-1. Potential Chemical-Specific ARARs for Lockheed West[3]

Medium/ Requirement	Standard/Criteria	Prerequisite	Citation	Comments
Clean Air Act (42 USC 7401 et seq.; 40 CFR 50-69)	National primary and secondary ambient air quality standards	Site located in nonattainment area for National Ambient Air Quality Standards; treatment unit would be "significant source"	Clean Air Act (Sec.109; 40 CFR 50)	Not anticipated as ARAR; in general, emissions from site not expected to qualify as significant source.
Washington State Clean Air Act (70.94 RCW)	State implementation of ambient air quality standards		General Requirements for Air Pollution Sources (WAC 173-400)	Potential ARAR for investigative or remedial actions; site located in nonattainment zone for CO and ozone.
	Puget Sound Clean Air Agency (PSCAA) ambient and emission standards		PSCAA Regulations I and III	
Resource Conservation and Recovery Act (42 USCA 7401-7642) (40CFR 260-280)	Lists and characteristics for identifying hazardous wastes	Meets listing or characteristic definitions (includes threshold levels for Toxic Characteristic Leaching Procedure [TCLP])	Criteria for Identifying the Characteristics of Hazardous Waste and for Listing Hazardous Waste (40 CFR 261.24.10-11, Subpart B)	Using appropriate analytical methods or knowledge of the source of contamination, determination should be made whether sediments (including investigation-derived waste [IDW]) contain hazardous waste characteristic; certain requirements for management of hazardous wastes may be applicable or relevant and appropriate. Dredged sediments are excluded from RCRA Subtitle C if they are managed under the CWA Section 404 program (63 FR 65874).
Washington Dangerous Waste Regulations (WAC 173-303)	State criteria for dangerous waste which are broader than federal criteria	Meets listing or characteristic definitions, or concentrations exceed defined threshold criteria	Section -070, Designation procedures	The appropriate waste designation for state-listed or characteristic waste should be made in order to determine the applicability or relevance and appropriateness of state requirements for the management of IDW. Dredged sediments are excluded as a designated dangerous waste if they are managed under the CWA Section 404 program (WAC 173-303-071.

[3] Tables 3-1, 3-2, and 3-3 provide a menu of requirements that might be ARARs and from which ARARs will be selected in the Record of Decision.

Table 3-1. Potential Chemical-Specific ARARs for Lockheed West (continued)

Medium/ Requirement	Standard/Criteria	Prerequisite	Citation	Comments
Federal Water Pollution Control Act/Clean Water Act (CWA) (33 USCA 1251-1376; 40 CFR 100-149)	Ambient water quality criteria for the protection of aquatic organisms and human health	Discharges to surface waterbody that are sources of sediment contamination	40 CFR 131	CERCLA requires the attainment of water quality criteria where relevant and appropriate under the circumstances of the release or threatened release. Requirements are implemented differently depending on whether discharges are subject to NPDES permits. Also anticipated to be relevant and appropriate for remedial measures involving any discharges.
Toxic Substances Control Act (TSCA) (40 CFR 761)	Because PCBs are a COC at this site, regulations pertaining to “PCB remediation waste” are also potential ARAR		40 CFR 761.61	Cleanup levels may be determined based on expected exposure and proximity to sensitive environments.
Washington State Public Water Supplies (WAC 246-290)	Includes Maximum Contaminant Levels (MCLs) for drinking water	Public drinking water supply	WAC 173-290-310 Federal MCLs (40 CFR 141)	Depending on the scope of any remedial action, MCLs could be a potential ARAR for groundwater if it were a localized source of public drinking water, which is highly unlikely. MCLs are also potentially relevant and appropriate to groundwater, even if it is not a public source of drinking water, until and unless EPA determines the groundwater is Class III.
Washington State Water Quality Standards for Surface Waters (WAC 173-201a)	State Water Quality Standards; conventional water quality parameters and toxic criteria	Discharges to surface waterbody that are sources of sediment contamination	WAC 173-201a-040	Implementation of federal requirement to develop state water quality control plan. Narrative and quantitative limitations for surface water protection. Requirements are implemented differently depending on whether discharges are subject to NPDES permits. Anticipated as relevant and appropriate to control releases that create concentrations of concern in the sediment.
Model Toxics Control Act (WAC 173-340)	Requirements for establishing numeric or risk-based standards and selecting cleanup actions	State hazardous waste site and any contaminated site in Washington being cleaned up under Superfund	Section 760: Sediment	Sediment cleanup must comply with the requirements of MTCA as well as the Washington Sediment Management Standards. If the remedy involves media other than sediment, other sections of MTCA will also be ARARs.

Table 3-1. Potential Chemical-Specific ARARs for Lockheed West (continued)

Medium/ Requirement	Standard/Criteria	Prerequisite	Citation	Comments
Washington Sediment Management Standards (WAC 173-204)	Numerical and narrative criteria for sediment quality standards, cleanup screening levels (CSL), and minimum cleanup levels	Sediment remediation and source control	WAC 173-204	Anticipated to be applicable to site remediation. Anticipated as relevant and appropriate to control releases that create concentrations of concern in the sediment.

Table 3-2. Potential Action-Specific ARARs for Lockheed West

Actions	Requirement	Prerequisite	Citation	Comments
General Remediation	Requirement for use of all known available and reasonable technologies for treating wastewater prior to discharge to waters of the state	Industrial sources	State Water Pollution Control Act (RCW 90.48), Water Resources Act (RCW 90.54)	Anticipated to be applicable to remedial technologies involving discharges to surface or groundwater. See also MTCA under Pump and Treat.
Construction in state waters	Requirements for construction and development projects for the protection of fish and shellfish	State waters	Construction in State Waters, Hydraulic Code Rules (RCW 75.20; WAC 220-110) Rivers and Harbors Appropriation Act (33 USC 401 et seq.) DMMP (2000) guidelines	Substantive requirements of Army Corps of Engineers permit anticipated to be relevant and appropriate to construction, dredging, and filling below the mean high-water line. (See also Dredging/Disposal under soil action-specific ARARs.) Substantive requirements of State Hydraulic Code may apply.
Source control	Requirements for protecting sediment and surface water quality	Ongoing sources of chemicals to sediments	State Water Pollution Control Act (RCW 90.48) Clean Water Act (40 CFR 100-149) Sediment Management Standards (WAC 173-204) Model Toxics Control Act (WAC 173-340)	Applicable to chemical sources that create concentrations of concern in LDW sediments. Requirements are implemented differently depending on whether discharges are subject to NPDES permits.
Discharge to POTW (Publicly Owned Treatment Works)	Contaminated water must be pretreated to certain limits prior to discharge	Nonhazardous waste	National Pretreatment Standards (40 CFR 403); Metro District Wastewater Discharge Ordinance	Discharges to POTWs are considered off-site activities; pretreatment and permitting requirements would be applicable.

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Discharge to surface waters	Point-source standards for discharges into surface water bodies	Point-source discharge or site runoff directed to surface water body when the discharges are subject to an NPDES Permit	National Pollutant Discharge Elimination System (40 CFR 122, 125) State Discharge Permit Program; NPDES Program (WAC 173-216, 220)	Anticipated to be applicable to some discharges.
	Federal criteria for water quality to protect human health and aquatic life	Discharges to surface waterbodies	Federal Water Quality Criteria (40 CFR 131)	CERCLA requires the attainment of water quality criteria where relevant and appropriate to the circumstances of the release. Requirements are implemented differently depending on whether discharges are subject to NPDES permits. Anticipated to be relevant and appropriate for remedial measures involving this activity.
	State Water Quality Standards for Surface Water	Discharges to surface waterbodies.	WAC 173-201-045, -047	Implementation of federal requirement to develop state water quality control plan. Narrative and quantitative limitations for surface and groundwater protection, based upon beneficial uses. Requirements are implemented differently depending on whether discharges are subject to NPDES permits. Anticipated as relevant and appropriate.
Containment - Capping - Vertical barriers	(see Capping and General Excavations under Action-specific ARARS for soil)			

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Air stripping	Meet ambient air quality requirements for significant sources	Site located in nonattainment area for National Ambient Air Quality Standards; treatment unit would be major source	National Ambient Air Quality Standards (40 CFR 50)	Not anticipated as ARAR, not anticipated to qualify as major source.
Granular-activated carbon treatment	Meet design and operating standards for treatment and storage units	Treatment and storage of RCRA hazardous waste	40 CFR 264, Subpart I-Containers 40 CFR 264, Subpart J-Tanks 40 CFR 264, Subpart X-Misc. units	Anticipated to be relevant and appropriate if technology is implemented.
Treatment, storage, or disposal of hazardous wastes	Disposal of contaminated soil or debris is subject to land disposal prohibitions or treatment standards	Dangerous or hazardous waste	40 CFR 268 Federal Land Disposal Restrictions WAC 173-303-140, -141 Land Disposal Restrictions	May be ARAR if placement of hazardous or dangerous waste occurs during remediation.
Storage or disposal of solid wastes	Requirements for solid waste management	Solid waste (nonhazardous)	Solid Waste Disposal (Act 42 USC Sec. 3251-3259, 6901-6991) as administered under 40 CFR 257, 258 Solid Waste Handling Standards (WAC 173-350)	Potentially ARAR to nonhazardous waste generated during remedial activities
Noise control	Maximum noise levels		Noise Control Act of 1974 (RCW 80.107; WAC 173-60)	Potentially relevant and appropriate depending upon remedial activities selected.

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Air				
Air emissions	National Primary and Secondary Ambient Air Quality Standards for carbon monoxide, lead, nitrogen dioxide, particulate matter (PM10), ozone, and sulfur dioxides	Emissions from a “major” source	Clean Air Act (Sec. 109; 40 CFR 50)	Emissions from site not expected to qualify as major source unless activities will result in emissions of ≥100 tons/year or of a specified air contaminant.
	Regional ambient air quality standards	Emission of regulated air contaminant	Puget Sound Clean Air Agency (PSCAA) Regulation I	Not anticipated as ARAR
	National Emissions Standards for Hazardous Air Pollutants (NESHAPs)	Industrial emissions	Clean Air Act, National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61) State Emission Standards for Hazardous Air Pollutants (WAC 173-400-075)	Emission standards would need to be converted to area source standards for use at Harbor Island, if determined to be relevant and appropriate to releases of hazardous air pollutants from remedial actions.
	New Source Pretreatment Standards	New source of hazardous air pollutants	40 CFR 60	Potentially applicable to releases from remedial actions.
	Controls for New Sources of Toxic Air Pollutants	Emission of any Class A or Class B toxic air pollutant (identified in WAC 173-460-150 through -160) into ambient air	WAC 173-460	Potentially applicable to releases from remedial actions.
	Regional Emission Standards for Toxic Air Pollutants	Source of toxic air contaminant requires a notice of construction	PSCAA Regulation III	Potentially applicable depending upon remedial technology used.

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Soil/Sediment/Fill				
General remediation of hazardous waste	RCRA hazardous waste management requirements	RCRA hazardous waste management in treatment, storage, or disposal facility	Resource Conservation and Recovery Act [RCRA as amended by the Hazardous and Solid Waste Amendments (HSWA) (42 USCA 6901 et seq.)]; 40 CFR 264 for permitted TSDFs	Need to determine waste designation for IDW and remediation waste. In general, RCRA requirements are anticipated to be applicable or relevant and appropriate depending upon designation of waste, if generated. Dredged sediments are excluded from RCRA Subtitle C if they are managed under the CWA Section 404 program (63 FR 65874).
	State hazardous waste management requirements	Management of wastes that pass criteria for WA hazardous waste as specified in WAC 173-303-070	General Facility Standards (WAC 173-303-280-395)	In general, state hazardous waste requirements are broader and more stringent than federal requirements; anticipated to be relevant and appropriate. . Dredged sediments are excluded as a designated dangerous waste if they are managed under the CWA Section 404 program (WAC 173-303-071).
Closure with waste in place (capping)	RCRA design and operational requirements for closures with waste in place require the minimization of need for further maintenance and control, installation of long-term cover, elimination of free liquids, stabilization of remaining waste, post-closure care, etc.	RCRA waste in landfill placed after 19 November 1980	Federal: 40 CFR 264-110 through 117 State: WAC 173-303-610	Potentially ARAR for placement of RCRA wastes, or wastes sufficiently similar to RCRA wastes in on-site upland facility.
Clean closure	RCRA clean closure requirements; complete removal of RCRA hazardous waste	Any unit that is not closing as landfill	40 CFR 264.110 et seq.	Potentially relevant and appropriate depending upon remedial action. Clean closure requires minimization of need for further maintenance and control.
Post-closure care	Post-closure monitoring and maintenance requirements	RCRA TSD Unit	Federal: 40 CFR 264.110 et seq. State: WAC 173-303-665(6)	Requirements provided under each action or storage method (e.g., landfill, waste piles, etc.). Anticipated to be relevant and appropriate.

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Remediation of PCB-contaminated waste	Regulations pertain to PCB remediation waste	PCBs as chemical of concern	Toxic Substances Control Act (TSCA) (40 CFR 761.61)	Cleanup levels may be determined based on expected exposure and proximity to sensitive environments.
Surface impoundments	Requirements for containment system, emergency repair, contingency plans, design, etc.	New RCRA surface impoundment	Federal: 40 CFR 264.220 et seq. State: WAC 173-303-650	Not anticipated to be relevant and appropriate unless this technology is used during remediation.
Waste piles	Requirements for noncontainerized solid, non-flowing material	RCRA hazardous waste stored in pile	Federal: 40 CFR 264.254 et seq.	Potentially relevant and appropriate if employed during investigation or remediation.
		State dangerous waste stored in pile	State: WAC 173-303-660	
Landfills	Requirements for design, operation, and maintenance	New or replacement on-site landfill units for disposal of RCRA hazardous waste	Federal: 40 CFR 264.300 et seq. State: WAC 173-303-665	Potentially relevant and appropriate to extensions of existing landfill.
	Landfill design, construction, and closure standards developed to protect the water of the state	Hazardous, designated, or nonhazardous wastes and closed landfills	Federal: 40 CFR 257, 258, 264 State: WAC 173-304, 173-303-665, 173-350	Should this technology be used, anticipated to be relevant and appropriate.
Land treatment	Operating, monitoring, and closure requirements; hazardous chemicals must be degraded, transformed, or immobilized within the treatment zone; treatment efficiency must be demonstrated, design criteria must be met, and monitoring must be established. Develop fugitive and odor emission control plan for the treatment activities.	RCRA hazardous waste treatment in land farming unit	40 CFR 264, Subpart M	May be ARAR if technology is selected for remediation.

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Chemical, physical, and biological treatment	Operating, monitoring, and closure requirements	RCRA hazardous waste	Federal: 40 CFR 264 State: WAC 173-303	Potentially applicable if hazardous or state dangerous wastes are treated using any of these methods. Otherwise, anticipated to be relevant and appropriate for the treatment of nonhazardous waste.
Incineration	Requirements include monitoring and analysis of waste feed and residuals, and disposal of treatment residuals. Performance standards include: - Destruction removal efficiency of 99.99% for each principal organic hazardous chemical - Reduction of hydrogen chloride emissions to 1.8 kg/hr or 1% HCl in the stack gases prior to entering any pollution control devices - Limit maximum particulate matter to 180 mg in stack gases	RCRA hazardous waste State dangerous waste	Federal: 40 CFR 264.340 et seq. State: WAC 173-303-670	Anticipated to be relevant and appropriate should this technology be implemented. On-site operations would need to meet substantive requirements of the operating permit. State requirements would be applicable for non-RCRA hazardous wastes.
	Performance standards for incinerators	Incinerator with charging rates of more than 45 metric tons per day	Federal: CAA 42 USCA 7401-7642 State: WAC 173-303-670; PSCAA emission and ambient standards	Anticipated to be relevant and appropriate if this technology is employed.
Thermal treatment (other than incineration)	Operating, monitoring, and closure requirements	Treatment using technologies other than controlled flame combustion	Federal: 40 CFR 265, Subpart P State: WAC 173-303-680 State: WAC 173-303-680	Potentially applicable if wastes are treated using this method. Otherwise, anticipated to be relevant and appropriate for wastes sufficiently similar to hazardous or dangerous waste.

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Excavation and disposal of hazardous wastes	Disposal of contaminated soil or debris is subject to land disposal prohibitions of treatment standards	RCRA hazardous waste	Federal: 40 CFR 268 federal land disposal restrictions	May be ARAR if placement of hazardous or dangerous waste occurs during remediation.
		State dangerous waste	State: Land Disposal Restrictions (WAC 173-303-140, -141)	
Excavation and disposal of solid wastes	Requirements for solid waste management	Solid waste (nonhazardous)	Federal: Solid Waste Disposal Act (42 USC Sec. 325103259, 6901-6991), as administered under 40 CFR 257, 258 State: Solid Waste Handling Standards (WAC 173-350)	Potentially applicable to the disposal of nonhazardous waste generated during remedial activities.
Treatment of non-RCRA hazardous or state dangerous waste	Treatment requirements for non-RCRA hazardous or state dangerous wastes	Non-RCRA hazardous waste	Federal: 40 CFR 257, 258, 761	Standards for non-RCRA hazardous or non-RCRA state dangerous waste, including PCB waste, incinerator treatment residuals, etc. Anticipated to be applicable to non-RCRA hazardous and dangerous wastes, or relevant and appropriate to sufficiently similar wastes.
		Non-RCRA state-only dangerous waste	State: WAC 173-303-141	
Sediment remediation	Methods for determining allowable levels of chemicals and/or biological effects in sediment	Marine/estuarine environment	WAC 173-204; WAC 173-340-760	Marine sediment. Anticipated as ARAR.
Dredging/disposal	Requirements for the discharge of dredged/fill material into navigable waters or wetlands	Waters of the US	CWA 33 USC 401 et seq.; 33 USC 1413; 33 USC 1251-1316; 40 CFR 230, 231, 404; 33 CFR 320-330 Hydraulic Code Rules on Dredging (WAC 220-110-130, -320) Aquatic Land Management Open Water Disposal Sites (WAC 332-30-166) PSDDA (1988a,b; 1989)	Potential ARAR. Deposited materials could be considered point-source discharges under NPDES. (See also General excavation activities and Construction in state waters under Action-specific ARARs for waters.)

Table 3-2. Potential Action-Specific ARARs for Lockheed West (continued)

Actions	Requirement	Prerequisite	Citation	Comments
Noise control	Maximum noise levels	Activities which may result in exceedance of maximum noise levels	Noise Control Act of 1974 (RCW 70.107; WAC 173-60)	Potentially relevant and appropriate depending upon remedial activities selected.

Table 3-3. Potential Location-Specific ARARs for Lockheed West

Location	Requirement	Prerequisite	Citation	Comments
Within 61 m of a fault displaced in Holocene time	New treatment, storage, or disposal facilities of hazardous waste are prohibited in these areas	RCRA hazardous waste; treatment, storage, or disposal	40 CFR 264.18(a)	Not potential ARAR. Not within 61 m of Holocene fault.
Within 61 m of shoreline	Requirements for construction and development near shorelines	Shorelines of statewide significance, including marine waters and wetlands	Shoreline Management Act (RCW 90.58); Coastal Zone Management Act (16 USC 1451 et seq.).	Anticipated to be relevant and appropriate.
Within 100-year floodplain	Facility must be designed, operated, and maintained to avoid washout	RCRA hazardous waste	40 CFR 264.18(b); 40 CFR 761.75.	None
Within floodplain	Actions must be performed so as to avoid adverse impacts, minimize potential harm, restore and preserve natural and beneficial values of the floodplain	Actions that will occur in a floodplain (i.e., lowlands) and relatively flat areas adjoining inland and coastal waters and other flood-prone areas	Executive Order 11988, Protection of Floodplains (40 CFR 6, Appendix A).	None
Within/adjacent to wetlands	Action must be performed so as to minimize the destruction, loss, or degradation of wetlands. Requirement for no net loss of [illegible]	Wetland as defined by Executive Order 11990, Section 7	Executive Order 11990, Protection of Wetlands (40 CFR 6, Appendix A).	None
Critical habitat upon which endangered or threatened species depend	Actions must be performed so as to conserve endangered or threatened species, including consultation with the Department of the Interior and National Marine Fisheries Service	Determination of endangered or threatened species and the essential fish habitat on which they depend	Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR Part 200, 50 CFR Part 402 Essential Fish Habitat provisions of the Magnuson-Stevens Fishery Conservation and Management Act (50 CFR 600).	Lockheed West is used as a salmon migratory route.
State waters	Dredging and other construction must meet specific standards.	Applies to any construction activity in or near state waters	Hydraulic Code (RCW 77-55-100) Hydraulic Code Rules (WAC 220-110).	Substantive standards potentially applicable. No Hydraulic Project Approval required on-site. Dredging is explicitly considered as a construction activity.

Table 3-3. Potential Location-Specific ARARs for Lockheed West (continued)

Location	Requirement	Prerequisite	Citation	Comments
Oceans or waters of the US	Permit requirements for activities that may obstruct or alter a navigable waterway	Obstruction or alteration of a navigable waterway	Section 10 of the Rivers and Harbors Appropriations Act (33 USC 403)	None
Within state siting criteria locations for dangerous waste	Siting criteria to be used as initial screen for consideration of dangerous waste facility sites	New dangerous waste facilities	WAC 173-303-282(2)(b)(iii)	Not ARAR. Does not apply to facilities conducting CERCLA remediation.
Habitat for fish, plants, or birds subject to WDFW oversight	Prohibits water pollution with any substance deleterious to fish, plant life, or bird life	Discharges of chemicals to sediment	US Fish and Wildlife Coordination Act. 16 USC 661-667e.	Lockheed West is used as a salmon migratory route and provides habitat for other species of fish and wildlife. Requirements are implemented differently depending on whether discharges are subject to NPDES permits.
Harbors, tidelands, shorelines, or beds of navigable rivers	Siting criteria and requirements for fill operations		Constitution of the State of Washington (RCW 79.90.020; WAC 332-300-117, -118).	Potentially relevant and appropriate to remedial actions.
Native American graves	Excavation must cease if Native American burials or cultural items are inadvertently discovered	Potentially applicable to sediment removal	Native American Graves Protection and Repatriation Act (25 USC 3001 et seq.; 43 CFR Part 10).	None
Sacred Native American sites	Work must stop if sacred religious sites are discovered	Potentially applicable to sediment removal	American Indian Religious Freedom Act (42 USC 1996 et seq.).	None
Historic sites or structures	Alternatives must be evaluated to avoid, minimize, or mitigate the impact on historic sites or structures	Activities that could disturb historical sites or structures	National Historic Preservation Act (16 USC 470f; 36 CFR Parts 60, 63, and 800).	None
Archaeological Resources on public and Indian lands	Removal of archaeological resources is prohibited without a permit	Potentially applicable to sediment removal	Archaeological Resources Protection Act (16 USC 470 aa et seq.; 43 CFR Part 7).	None

Table 3-4. Potential items to be considered (TBCs) for the Lockheed West

Federal, State, and Local Criteria, Advisories, and Procedures
Guidelines developed by the Elliott Bay/Duwamish Restoration Program
Sediment Cleanup Standards Users Manual, Washington Department of Ecology (December 1991)
Dredged Material Management Program (DMMP) Guidelines (DMMP 2000)
Puget Sound Water Quality Management Plan
EPA Total Maximum Daily Load (TMDL) regulations (40 CFR 130)
Guidance Document for Discharging CERCLA Aqueous Wastes to POTWs, EPA/540/G-90/005
FDA Maximum Concentrations of Contaminants in Fish Tissues (49 CFR 10372-10442)
Water Quality Guidance Documents:
Water Quality Criteria and Standards Plan (EPA, June 1998)
Water-Related Environmental Fate of 129 Priority Pollutants (1979)
Water Quality Standards Handbook, Second Edition (August 1994)
Technical Support Document for Water Quality-based Toxics Control (1994)
Local Shoreline Substantial Development Permits
EPA Wetlands Action Plan (Jan 1989, OWWP)

4. SUMMARY OF EXISTING INFORMATION, PRELIMINARY CONCEPTUAL SITE MODEL, AND IDENTIFICATION OF DATA GAPS

This section provides a summary of the existing information on the Site, including property boundaries, current and former site uses, and environmental and other physical data. This section also describes the known or anticipated future site use assumptions to be used in the evaluation of remediation alternatives. In addition, Appendix A evaluates the existing data quality and usability for the purposes of the RI/FS and presents a summary of the nature and extent of contamination. Based on the evaluation of existing information, data gaps are identified in Section 4.7.

Much of the existing data are useful for understanding the general CSM, nature and extent of contamination, and identification of data gaps; however, the majority of the information is aged. Data collection for the RI will supersede the existing data and will provide a more comprehensive suite of information for the evaluation and selection of remedial alternatives for the Site. Given that extensive data collection will be completed as part of this Work Plan, the summary of existing data, presented in Appendix A, is intended to inform development of the RI sampling activities and to provide general background for the planned RI/FS activities and is, therefore, not validated according to EPA standards or used for making decisions at the site.

Note: at the time of approval of this Work Plan, the purposed site surveying and sediment quality sampling has been completed. These data are however, not considered to be pre-existing information and are therefore not discussed in this section.

4.1 SITE USE AND HISTORY

4.1.1 Site Development, Dredging, and Filling History

The summary of development of the Lockheed West Site is based on a review of historical areal photographs and documents of the Site as well as U.S. Army Corps of Engineers (USACE) permitting and dredging records. Dredge material areas and volumes are considered to be approximate because as-built drawings confirming actual project dimensions were not located. A summary of historical development of the Lockheed West Site is presented in Table 4-1. Prior to development in the early 1900s, Lockheed West and vicinity consisted of an intertidal deltaic environment at the mouth of the Duwamish River. Progressive dredging and filling created Harbor Island, the West Waterway, and a peninsular area (now known as Terminal 5) near the present location of the Site. The West Waterway and a defined upland peninsula near the Site were completed in 1917.

Information compiled for the 1994 South West Harbor (SWH) Project Environmental Impact Statement (EIS; Parametrix 1994a), review of USACE dredge and fill permits, review of historical shipyard documents, and review of available areal photographs indicate that shipyard activities at Lockheed West began during WWII. A moorage pier south of the Site along the West Waterway is visible in a 1946 areal photograph (Figure 4-1), along with extensive wood treatment and export operations at the current PSR Site to the west. The PSR Site features a major export dock near the location of the (existing) Lockheed West shipway.

By 1942, Lockheed West was operated by Puget Sound Bridge and Dredge Co., a predecessor of Puget Sound Bridge and Drydock Company. Puget Sound Bridge and Dredge Co. obtained permits for the dredging of the eastern portion of the Lockheed West Site and the West Waterway to allow sufficient depth for dry docks in this area. The dredged material was permitted for disposal on the adjacent tide flats in 1952 and 1954. These dredge and fill events, as well as others extended the Lockheed West uplands site to the north. Figure 4-2 shows the shoreline expansion based on historical areal photos as well as the areas where material was dredged and filled at or near Lockheed West.

The Puget Sound Bridge and Drydock Company was subsequently purchased by the Lockheed Shipbuilding and Construction Company in 1959. During the 1960s, areal photographs identify progressive construction of Piers 21 through 24 from east to west. Pier 21 and Pier 22 were in-place by 1960 (Figure 4-3), along with two large floating dry docks (one owned by Lockheed and known as the “Huff” dry dock and one owned by the U.S. Navy). Historical and existing site structures are shown in Figure 4-2. Pier 21 was used as moorage location for these dry docks for over 40 years. Until the mid-1960s, Lockheed West was bounded on the west by a major inlet and tidal area used to store logs for the PSR Site and probably other wood processing operations (Figure 4-1). This inlet was filled for expansion of Terminal 5 by 1965. Pier 23 was also constructed by that time. Further development prior to 1969 led to construction of Pier 24 and the shipway (Figure 4-4).

Later areal photographs through the 1970s and 1980 (Figures 4-5 and 4-6) show that the shipyard was in use, including dry docking at three dry docks (two owned by the U.S. Navy and one owned by Lockheed), moorage along the piers, and construction in the shipway. Upland activity is also readily apparent until closure of the shipyard in 1987 and expansion of Terminal 5 container handling for Port operations. The Port purchased the LMC shipyard property in 1988 and conducted remediation of the uplands as part of the Terminal 5 expansion in the later half of the 1990s. A more recent view of the Site is provided in Figure 4-7.

In summary, the Lockheed West Site was developed beginning in 1942 by dredging the intertidal areas located on the northern terminus of the now Port of Seattle Terminal 5. Multiple dredging events were completed to create working space for drydocks and vessel moorage. Several pier structures were constructed over-time as part of the shipyard development.

4.1.2 Historical Shipyard Activities

Lockheed West primarily served as a ship repair, maintenance, and new ship construction facility. Shipyard activities included sandblasting. Sandblasting occurred as part of routine dry dock, pierside, and shipway maintenance operation over many years. The shipway and Pier 21 and Pier 22 dry docks in particular were major work areas that were subject to spent sandblast grit. Blast grit is reported to cover the upland area near the shipway to a depth of 0.5 foot or more.

The 1994 EIS and supporting documents also describe abundant use of gasoline, diesel, and lubricating oils that led to areas of significant petroleum hydrocarbon contamination in the upland areas. In addition, elevated concentrations of PAHs, PCBs, metals, and petroleum hydrocarbons were found in sediments from former catch basins in upland areas (Tetra Tech 1988). Catch basin sediment was removed and the catch basins replaced as part of subsequent upland development for Terminal 5 in the late 1990s. The storm drains were also identified as a likely pathway for contaminant transport to the aquatic areas.

4.1.3 Southwest Harbor Project and Terminal 5 Development

In the early 1990s, the Port proposed to complete major upgrades to Terminal 5 and upland portions of Lockheed West as part of comprehensive redevelopment for the SWH Project. The proposal included constructing new 400- and 1,000-foot piers in the West Waterway south of Pier 21, and dredging of additional berths. Proposed activities for the SWH Project are described in the 1994 EIS (Parametrix 1994d).

Following the approval of the SWH Project EIS, the Port completed additional upland improvements to the Terminal 5 area, constructed one new berth, and completed the 400-foot pier extension south of the Lockheed West aquatic lease area. A proposed 1,000-foot pier extension and dredging of a second berth were described in the EIS, but have not been completed. Future plans for the developing the second berth and pier extension are uncertain.

4.1.4 Ecology Designation for Lockheed West

A key component of the SWH Project involved cleanup of sediments and upland areas at Lockheed West. Cleanup planning and design were completed under the Washington State MTCA (Chapter 173-340 WAC). The combined upland and aquatic areas are identified on Ecology's Hazardous Sites List as "Southwest Harbor Project Lockheed Yard 2." The listing includes both the upland and aquatic portions of the Site with "Remedial Action In-Progress." A Site Hazard Ranking score of "1" is assigned to the Site and represents the ranking of highest concern for listed sites. Ecology database information indicates confirmed contamination for base-neutral compounds and PAHs, metals, PCBs, and petroleum products.

The upland portions of the Site have not been proposed for inclusion on the CERCLA NPL for potential Superfund cleanup; however, pursuant to Section 105 of CERCLA, 42 U.S.C. § 9605, EPA proposed listing the aquatic portions of the Lockheed West Site on September 26, 2006. EPA concurred with the plan for Ecology to take a lead role on cleanup activities associated with the upland portions of the former shipyard. As part of the purchase agreement between the Port and LMC, the Port agreed to remediate both the upland portion of the Site, and also the aquatic areas where remedial actions were necessary for constructing new Terminal 5 facilities (see Figure 4-8). For undisturbed aquatic areas, LMC maintains the primary responsibility for sediment cleanup where contamination resulted from past site activities by the shipyard.

4.1.5 Ecology Proposed Cleanup Action Plan for Lockheed West

Parametrix prepared an RI/FS to evaluate various sediment remediation options (Parametrix 1994a,b). The documents were prepared as companion pieces to the 1994 SWH Project EIS, and to fulfill requirements of the MTCA as a state-led cleanup. Remedial alternatives for the aquatic area were further described in Ecology's Draft 1996 CAP and earlier EIS and FS documents.

The preferred option for sediment cleanup was originally tied to dredging of the second Terminal 5 berth in the West Waterway portion of the Site. The preferred remedial option called for constructing a submerged nearshore fill in the aquatic area to permanently contain sediments from dredging as well as contaminated sediments from other sites. Constructing this submerged fill would also create about 13.5 acres of intertidal habitat. If the nearshore fill could not be constructed to meet the timing of dredging the second berth, a smaller nearshore fill was planned that could be enlarged for future dredging of the second berth.

Neither remedial option nor other cleanup actions were designed or implemented because the Port decided to not expand the second berth area of Terminal 5. The 1994 EIS and FS indicate, however, that cleanup could proceed independently of the SWH Project, and would be required regardless. Cleanup of the site, independent of the SWH Project was not, however, prioritized by Ecology. Cleanup was originally expected to take 2 to 5 years.

4.1.6 Ecology Delineation of Cleanup Areas

For reference purposes, Figure 4-8 shows the Site and the five use areas that were identified by Ecology for remediation as part of the SWH Project. These areas were defined by Ecology during the FS for the SWH Project based on the interpreted lateral and vertical extent of contamination, planned dredging, and anticipated development. Ecology used the SQSs and CSLs of the Sediment Management Standards (WAC 173-204) to delineate sediment cleanup areas.

The Ecology derived Site areas include the Central Area, Lockheed West Waterway, East Dry Dock, West Dry Dock, and Ship Way site units. The Central Area is located between the Ship Way and West Dry Dock site units on the northern portion of the Site. According to Ecology's assessment, the Central Area is the only area of the Lockheed West Aquatic Area that has the potential to recover naturally and, therefore, was formed into a separate site unit (Ecology 1996). The Lockheed West Waterway unit is located north of the Terminal 5 pier including the area that was proposed to be dredged for the extension of the Terminal 5 pier. The East Dry Dock unit is located east of Pier 21, which was the former site of Lockheed's Huff dry dock and U.S. Navy drydocks. The dry dock area has been separated into an east and west portion because there are different remediation options that apply due to differences in depth of contamination, bathymetry, and because the East Dry Dock is part of the main navigation channel. The East Dry Dock portion is outside the Port's fee-owned property (the Inner Harbor line) and extends into the mouth of the West Waterway. The eastern boundary of the East Dry Dock area blends into the West Waterway, on the east side of which is located the Harbor Island Superfund Site. The West Dry Dock unit is located west of the former Huff Dry Dock (Pier 21) and is within the Port's fee-owned property at the north end of the Lockheed West aquatic area. The Ship Way unit is near the western boundary of the aquatic area and surrounds an area formerly used as a ship way (Ship Way 21). Table 4-2 provides a summary of ownership status, historical uses, and the 1996 Ecology estimated extent of contaminated sediment (as compared to the SMS) for the Lockheed West aquatic area cleanup site units.

Including planned dredging for the second Terminal 5 berth, a total of about 1,300,000 cubic yards of contaminated sediments were delineated by Ecology based on the SMS criteria (Table 4-2) for remediation. This estimated volume included the full vertical-extent of contamination based on the available (pre-1994) subsurface data. As discussed further below, uncertainty exists regarding the vertical extent of contamination in several areas of the Site. This in turn affects the accuracy of the estimated volumes of contaminated sediments. Additionally, cleanup standards will be derived as part of this RI/FS to delineate the extent of sediment contamination. Volume estimates utilized as part of the remedial alternatives evaluation will be based on the derived cleanup criteria.

Approximately half of the Ecology estimated total volume of contaminated sediments is contained within the "Central Area" with low concentrations of constituents that were recognized as being amenable to natural recovery over a 10-year period (at the time predicted to be 2004). According to Ecology, natural recovery would involve chemical degradation of constituents and natural sedimentation processes of the aquatic area and adjacent West Waterway to physically cover contaminated surface sediments.

Outside of the Central Area, contamination was considered to be above levels that would recover naturally over a 10-year time frame (the regulatory compliance period considered by Ecology). Active dredging or capping was proposed for these areas as part of the preferred nearshore fill alternative. The proposed dredging and capping included about 200,000 cubic yards associated with proposed Terminal 5 dredging in the Lockheed West Waterway Area. The estimated volume also included dredging in the West Waterway outside of the DNR lease boundary and about 80,000 cubic yards of potentially non-contaminated sediments suitable for open water disposal. The actual quantity of contaminated sediments in the Lockheed West Waterway, East Dry Dock, and West Dry Dock areas could differ under other scenarios for future site use (i.e., if the proposed Terminal 5 dredging and improvements is not constructed) and because different cleanup criteria will be used.

As noted in Section 4.1.8, a portion of the contaminated sediments within the Lockheed West Site was addressed as part of the PSR remediation (a sediment cap was placed in the southwest part of the Site adjacent to the former shipway). Remedial actions included grading (to create more favorable habitat conditions) and capping.

4.1.7 Completed Upland Cleanup Actions

Cleanup efforts for the upland portion of the former shipyard were completed by the Port in the late 1990s in conjunction with the Port's Terminal 5 expansion. The Port agreed to complete the remediation of the uplands in the purchase and sale agreement for the property, which includes source control. . There are no existing access agreements for properties within the inner harbor line (shown on Figure 4-9). The Port of Seattle remediation removed or capped contaminated soils and debris, including areas of metal slag fill. Slag fill remains in some of the shoreline areas between Pier 21 and Pier 23 (shown on Figure 4-6). The cleanup work was completed as a state-led effort under MTCA to eliminate potential threats to users of the Terminal 5 and eliminate sources of recontamination to the aquatic area.

Upland remediation actions were completed to address the media identified by various environmental investigations of the Site including the following:

- Sand blast grit with metal and metalloid contamination;
- Soil with metal and metalloid contamination;
- Soil with total petroleum hydrocarbons (TPH) and total carcinogenic polycyclic aromatic hydrocarbons (CPAH) contamination; and
- Slag with metal and TPH contamination.

Upland remediation included the following elements:

- Excavation of soils with metals and sandblast grit for incorporation into concrete,
- Excavation of soils with petroleum hydrocarbons for thermal desorption,
- Excavation of stormdrain and catch basin sediments for off-site disposal,
- Replacement of storm drain system (see Appendix A-5),
- Paving the Site with asphalt,
- Groundwater monitoring, and
- Fencing and controlled access.

Upland remedial activities included 30 excavations on the Lockheed West Site to remove and soils containing metals and TPH. The distribution of hydrocarbon contamination at the Site was generally sporadic and related to spills during past facility operations. Previous analytical data indicated elevated TPH concentrations in on-site soils were more pervasive than CPAH concentrations; thus, TPH was considered to be the primary indicator hydrocarbon compound and CPAH the secondary. TPH levels were used to guide cleanup action and CPAH concentrations were verified after achieving the TPH RAOs. Where necessary, additional cleanup action was then conducted in order to achieve CPAH RAOs. Lead (Pb) was selected as the primary indicator metal in areas outside of the sandblast grit area in the northwest portion of the Site because of its high degree of coincidence with other metals of concern. Arsenic (As) was selected as the secondary indicator metal for areas of industrial use because of its relatively high toxicity and human carcinogenicity. Arsenic was not generally coincident with other metals of concern besides lead, and, therefore was not selected as a primary indicator metal outside of the sand blast grit area. In the northwest part of the Site where sand blast grit was stockpiled by the shipyard, analytical data indicated a high degree of coincidence of metals of concern. Therefore, based on toxicity and carcinogenicity to humans, arsenic was selected as the primary indicator metal and lead as the secondary indicator metal in the sand blast grit area of the northwest portion of the Site. Groundwater data summaries are presented in the Enviros (1990) Distillation report presented in Appendix A-3.

Groundwater sampling and analysis was conducted as part of the multiple site investigations. Sampling and analysis was completed at the Site to assess the following conditions:

- Groundwater quality beneath the potential source areas;
- The direction and gradient of groundwater flow;
- Shallow aquifer transmissive properties by slug and pump testing;
- The tidal effects on the groundwater levels; and
- Likely groundwater quality upgradient of the Site.

Approximately 118 groundwater samples were collected and analyzed for the following compounds depending upon the drilling location, suspected source area contamination, and objectives of the sampling episodes:

- Priority pollutant metals;
- Cyanide;
- TPH;
- VOCs;
- Volatile aromatic compounds;
- Volatile halogenated compounds;
- SVOCs;
- PAHs; and

- Conventional analyses (pH, general minerals, ammonia, nitrate, nitrite, sulfate, sulfide, salinity, total organic carbon (TOC), dissolved organic carbon, and dissolved oxygen).

Based on the sampling and analysis results, the COCs for groundwater were identified as metals (arsenic, lead, antimony, chromium, copper, nickel) and hydrocarbons (Enviros 1993, 1994). Future groundwater quality monitoring conducted as part of the long-term evaluation of the upland remediation effectiveness is expected to include analysis of these COCs.

The upland remedial actions did not specifically address risk from exposure to site groundwater contamination because of the following:

- The groundwater is tidally influenced, brackish, and not considered to be potable;
- The Site and surrounding properties are used for industrial purposes and the aquifer is not currently used for domestic, agricultural, or industrial purposes;
- Potential exposure to contaminants in the groundwater is restricted to the potential migration of contaminants into Elliott Bay where they may directly impact the local aquatic environment and may indirectly affect human populations via ingestion of local fish; and
- Chemical concentrations representing the incremental contribution from Lockheed activities could not be discerned from off-site sources.

In 2005, the Port of Seattle completed a Phase I groundwater confirmation monitoring program for hydrologic characterization (Aspect 2005) of the uplands adjacent to the Site, including the former shipyard area. The Hydrologic Characterization Report summarized the findings of the SWH Project Phase I Groundwater Confirmation Monitoring Program (GWCMP). The Phase I GWCMP specifically addresses characterization of the post-redevelopment groundwater flow system, and forms the basis for development of a site-wide water quality monitoring program to evaluate the effectiveness of remedial actions completed in conjunction with site redevelopment. At present, the Port of Seattle is negotiating the long-term groundwater quality monitoring requirements based on the results of the hydrologic characterization. No recent groundwater quality monitoring has been performed. LMC is actively seeking to coordinate with the Port on future groundwater monitoring activities at the Site. Tidal monitoring work has concluded that mean shallow groundwater gradients are generally in the offshore direction toward the West Waterway and Elliott Bay, groundwater levels have been measured to range from 7.5 to 8.5 feet mean lower low water (MLLW) at the shoreline within the former shipyard facility (See Appendix A-4; Aspect 2005).

Reduction of potential sources of contamination as the result of closure of the former shipyard and cleanup of the upland areas is evidenced by the significant reduction in concentration of historical shipyard contaminants in the Lockheed West surface sediments between the mid 1990s and 2003 sampling events (see Appendix A).

No additional information regarding the status of the upland cleanup and final condition of the property has been obtained.

4.1.8 Pacific Sound Resources Cleanup Actions

Upland remediation efforts were also completed for the former wood treatment facilities at PSR. Documents describing details of remediation have been requested from EPA, but have not been received. It is known, however, that an underground slurry cutoff wall was constructed to control flow of contaminated groundwater and possibly non-aqueous phase liquid (NAPL) and dioxin/furan constituents sourced from the wood treatment compounds used at the Site. The current status and the effect of possible contaminant transport toward shoreline and aquatic areas of the PSR and Lockheed West Site are assumed to be effective and are subject to long-term monitoring. These assumptions will be further evaluated as part of the source control evaluation (see Section 12).

Offshore contaminated sediment and marine pilings were dredged and removed off site during the 2003 in-water construction season. Additionally, the marine sediment unit was subdivided into five distinct remedial action areas to accommodate varying capping environments (subtidal and intertidal slopes [0 to 40 percent] and depths [0 to 300 feet] vary considerably in the marine sediment unit). Construction activities in the first three remedial action areas in the marine sediment unit, including installation of the new beach in the intertidal area, were completed during the 2003 in-water construction season. Construction work in the remaining two remedial action areas in the marine sediment unit, the areas with the steepest slopes and greatest depths, were completed during the 2004 in-water construction season, ending on February 15, 2005.

4.1.9 West Waterway OU No Action Clean Up Decision

The U.S. Environmental Protection Agency (EPA) made a determination in 1999 that no action is necessary for the marine sediments in the West Waterway of the Duwamish River estuary, which is known as the West Waterway Operable Unit of the Harbor Island Superfund Site, Seattle, WA. EPA stated that a no action decision is appropriate because environmental investigations and site-specific risk assessments found that concentrations of chemicals (including PCBs, tributyltin [TBT] and mercury) in marine sediments within the West Waterway Operable Unit do not pose unacceptable risks to human health and the environment. Further, environmental investigations did not identify any "hot spots" of contaminated sediments that warranted cleanup. EPA stated that sediments with the highest concentrations of chemicals on the western side of Harbor Island are already being cleaned up under EPA's Record of Decision for the "Shipyard Sediment" (Todd and Lockheed Shipyards). Finally, EPA stated that the majority of the contamination associated with the Harbor Island Site, including contamination that could have contributed to sediment problems in the West Waterway Operable Unit, is being addressed as part of the Shipyard Sediment cleanups, upland soil and groundwater cleanups, and upland source cleanups implemented to reduce contaminant inputs into the marine environment.

The West Waterway Operable Unit (West Waterway OU) includes approximately 70 acres of marine sediments and is located in the West Waterway at the mouth of the Duwamish River estuary near Harbor Island and adjacent to Lockheed West. The West Waterway is a dredged navigable channel used extensively for industrial purposes. The waterway consists primarily of subtidal sediments, which remain under water even at low tides. The shoreline of the West Waterway is predominantly pilings, bulkhead, and riprap. Areas of intertidal sediments along the shorelines adjacent to the West Waterway OU are generally nonexistent.

EPA stated that all actions necessary to control contaminant releases from the uplands portion of the site to adjacent sediments in the West Waterway OU have been completed or will be addressed through ongoing actions.

As part of the RI/FS and supplemental investigations, EPA conducted risk assessments to evaluate the current and future effects of contaminants on the environment and human health. The conclusions from the ecological and human health risk evaluations are summarized below.

Ecological Risk Evaluation Conclusion – Chemicals in sediments within the West Waterway OU do not pose a risk to the benthic community that live in the sediments. Further, bioaccumulative chemicals (PCBs, tributyltin, and mercury) in sediments do not appear to negatively affect aquatic invertebrates or fish. Thus, based on these assessments, sediments in the West Waterway OU do not require remediation to address ecological concerns.

Human Health Risk Evaluation Conclusion – A human health risk assessment was conducted to identify potential risks posed by chemicals detected in sediments or seafood (e.g., fish, shellfish) from the West Waterway OU. Based on these assessments, the cumulative site risk to an individual based on reasonable maximum exposure for both current and future use is 1 x 10-4, and the *true* risk is likely to be less than 1 x 10-4. Further, although the hazard index is slightly greater than 1, non-cancer health effects are unlikely to result from site exposure. Given that the estimated excess cancer risk is within EPA's target risk range, and considering site-specific conditions and the conservative nature of the human health risk assessment, EPA stated that the sediments in the West Waterway OU do not pose unacceptable risks to human health and sediment cleanup is not warranted.

Summary – For the West Waterway OU, the RI/FS and supplemental investigations demonstrate that concentrations of chemicals (including the three bioaccumulative chemicals of concern, PCBs, tributyltin, and mercury) in marine sediments do not pose unacceptable risks to human health or the environment. This conclusion is based on a comparison of site data to the Washington State Sediment Management Standards, results of site-specific human health and ecological risk assessments, and results of site-specific work on tributyltin toxicity and bioaccumulation. Chemical contaminants were not found to cause toxicity to animals living in or on bottom sediments, and estimates of human health risks were within EPA's acceptable risk range. Additionally, no "hot spots" of chemical contamination were found in the sediments.

In summary, EPA stated that a no action decision is appropriate for the West Waterway Operable Unit of the Harbor Island Superfund site because the marine sediments do not pose unacceptable risks to human health and the environment.

4.2 SITE DESCRIPTION INCLUDING GEOGRAPHIC AND PROPERTY BOUNDARIES

The Lockheed West Site is located at the terminus of the West Waterway of the Duwamish River estuary and Elliott Bay (T24N, R3E). The Site is bounded on the south by Southwest Florida Street, on the east by the West Waterway, and on the north by Elliott Bay. Directly to the west is the PSR (formerly Wyckoff Industries) wood treatment facility. The aquatic property previously owned by LMC includes approximately 2,050 feet of shoreline and is approximately 26.5 acres in size. The Lockheed West aquatic area is located at the northern end of the Site, extending into Elliott Bay.

Lockheed West is located along the southwestern shoreline of Elliot Bay, adjacent to the Port's container shipping operations at Terminal 5 (Figure 4-9). A portion of the Site borders the West Waterway of the Duwamish River. The former shipyard facility included the following:

- Approximately 20 acres of land previously leased from DNR, and
- Approximately 7 acres of aquatic land south of the DNR lease areas that are owned by the Port.

The DNR lease area consists of several parcels, as identified on Figure 4-9. All current and former leases with LMC have been assumed by the Port under the September 2000 Port Management Agreement between the Port and LMC. The aquatic lands south of the DNR lease area were sold by LMC to the Port in 1992. The Port also acquired the upland portion of the former shipyard from LMC for expansion of the cargo facilities at Terminal 5.

The PSR Site is located to the west of the Lockheed DNR lease area. The PSR Site was the location of a historical wood treating and export operation. Upland portions of the PSR Site have recently been remediated under the CERCLA Superfund program as part of the Terminal 5 expansion. The offshore portion of the PSR Site was addressed by EPA under CERCLA as a Superfund-led project.

The RI for the SWH Project completed in 1994 (Parametrix 1994b) states that "…a portion of the Lockheed aquatic area that is part of the PSR Site in terms of contamination similarities, but is within the Lockheed West property boundary. This area will be cleaned up as part of the PSR Site…" Figure 4-9 shows that the remedial action area of the PSR Site extends into the western portion of Lockheed West Site. According to the PSR remedial design documents and as evidenced by low tide observations, the PSR cap does extend into the area formerly occupied by the historical shipyard.

The southern edge of Lockheed West Site is defined for this report as the mean higher high water mark (+11.35 ft MLLW) along the shoreline adjacent to Terminal 5 (Figure 4-9). The Port completed extensive redevelopment and environmental remediation of upland areas at Terminal 5 in the late 1990s. The eastern and northern boundaries of the historical shipyard use area are defined by the outer limits of the DNR aquatic lease areas (Outer Harbor Line).

Access to the shoreline, piers, and aquatic areas of the former shipyard is controlled by the Port with fencing and locked gates. During redevelopment of the upland container facilities for Terminal 5, the Port constructed a sheet pile bulkhead across the apron of the former shipway in the western portion of the Site (see Figure 4-7). The shoreline to the east consists of areas of open slope, riprap-reinforcement, and wooden or steel retaining walls in generally poor condition. Since closure of the shipyard, the Port has demolished Piers 21 and 22. In addition, the decking has been removed from Piers 23 and 24.

Cleanup boundaries will be determined using cleanup levels or based on the extent of COC's that are known to be directly related to shipyard contamination, such as copper, zinc, and TBT as part of the RI/FS. As a result, the following discussion relates to the property and geographic boundaries for the Site.

4.3 IDENTIFICATION OF POTENTIAL HISTORICAL AND ONGOING SOURCES OF CONTAMINATION TO THE LOCKHEED WEST SITE

Potential historical and ongoing sources of contamination to the Lockheed West site will be evaluated as part of the Source Control Evaluation described in Section 12. The Source Control evaluation will assess each of these potential mechanisms relative to their potential to contaminate sediments at the Lockheed West Site. The potential contamination source mechanisms will be evaluated using the available existing data from Lockheed West and the adjacent areas on sediment transport and contaminants of potential concern. The following is a summary of the identified potential sources of contamination.

Sediments at Lockheed West can be impacted by a number of potential mechanisms giving rise to elevated chemical concentrations in the sediment including:

- Surface water runoff from adjacent upland areas;
- Bank erosion;
- Outfall discharges of water and sediment to the waterway from storm and CSO drainages located in and nearby the site;
- Direct discharge from vessel leaching and overwater activities such as historical shipyard work;
- Groundwater flow and discharge to the site and within the adjacent waterway;
- Transport and deposition of sediment from adjacent Elliott Bay, West Waterway and Lower Duwamish Waterway containing higher concentrations than the Lockheed West cleanup objectives due to resuspension from both natural and vessel induced waves and currents; and
- Atmospheric deposition.

A site conceptual model, further describing these potential source mechanisms is described in Section 4.6.

4.3.1 Potential Historical Sources

Historical upland uses of the Lockheed West Site provided several potential pathways for sediment contamination. Potential contaminants from historical shipbuilding practices at the Site include petroleum hydrocarbons, solvents, metals, oil, diesel, gasoline, PCB; volatile organic chemicals, and sandblast grit.

Historically the adjacent uplands at the site included areas used for sheet metal fabrication, electrical, and pipe shops and substations; various repair and storage buildings; diesel fuel tanks and automobile shop; hazardous waste storage areas; and paint and sandblast facilities. Soils contaminated as the result of spills and other environmental releases from these facilities would have a potential pathway to the adjacent aquatic sediments from direct discharge, transfer through stormdrain systems, or groundwater transport.

Historical over-water operations at the former shipyard provided several potential pathways for sediment contamination. The historical shipyard included five major piers, drydocks and a shipway. The dry docks and shipway were used to repair, sandblast, and paint vessels. Paint chip fragments, as well as chemicals and solvents used in the construction and maintenance of vessels, would have a direct path to sediments. Most ship construction activities occurred pierside and off moorings in the vicinity of Piers 23 and 24. Chemical contamination in these areas consists of a wide range of organic compounds and metals that reflect both the types of materials used at the dry docks and ship way facilities and the length of time over which the facilities operated.

A historical wood treatment facility (Pacific Sound Resources) was historically located upland of the western portion of Lockheed West. Soils contaminated as the result of spills and other environmental releases would have had a potential pathway to the adjacent sediments from direct discharge, transfer through stormdrain systems, or groundwater transport. COCs identified for the former wood treating facility include PAHs and dioxin.

Other historical sources include nearby uncontrolled combined sewer overflows. The SW Florida Street combined sewer overflows and storm drain, which discharges into the West Waterway adjacent to the southeast corner of the property. CSOs are generally accepted as potential sources to sediment contamination, given their periodic uncontrolled and untreated discharges.

Other possible historical sources include the Duwamish River and Elliott Bay. No barriers are known to exist that would prevent free exchange of suspended sediment between Lockheed West and the adjacent waterways. Sediment exchange would most likely have been the result of suspension and transport by river and tidal currents. Multiple point and non-point sources of contamination to the adjacent Duwamish river, West Waterway, and Elliott Bay have been documented.

4.3.2 Ongoing Potential Sources of Contamination

Currently, the upland areas adjacent to Lockheed West are used by the Port for shipping container storage. Occasionally barges are temporarily moored along the existing pier structures using tug boats. In addition, non-commercial vessel traffic such as recreational boats may transit the Site. Commercial vessels operating in the vicinity of the Site are controlled by the Coast Guard and are required use the established navigational channels and berth approaches.

Potential ongoing sources of contamination from Terminal 5 may include direct groundwater discharges, and untreated discharges from the SW Florida Street CSO. Other nearby storm drains and outfalls associated with the former shipyard facility have been plugged or removed as part of the upland remediation.

The transport of sediments from the Duwamish River, West Waterway and Elliott Bay may pose a potential source of contamination at the Site. As described above, sediments are assumed to exchange between these waterways and the Site. Multiple ongoing sources of contamination may be transported by river and tidal currents. Whether this is a source of future contamination depends on the chemical concentrations associated with suspended sediments.

4.3.3 Adjacent Site Uses

Currently, both the uplands portion and the offshore portion of the former PSR Site have had remedial actions performed. These actions presumably have controlled the potential historical sources from the Site. At present, the uplands portion of the PSR Site is part of the Port's Terminal 5 operation and is subject to the source control activities conducted by the Port. The shoreline and offshore portion of the PSR Site is not currently used for a specific purpose. It also has restrictive signs and fencing that limit public access to the shoreline for recreational purposes.

The West Waterway continues to be maintained and functions as an industrial waterway for navigation and commerce. Several cleanup actions have taken place along the waterway (e.g., Lockheed Shipyard Sediment Operable Unit (LSSOU), Todd Shipyard) that are assumed to have reduced the potential sources of contaminants to Lockheed West from these locations. The West Waterway continues to be subject to influences from the Lower Duwamish River. The effectiveness of these completed remedial actions is subject to evaluation of the long-term monitoring program data for the sites.

4.3.4 Completed Source Control Activities

Several source control activities have been completed to address some of the potential historical and ongoing sources of contamination to the Site (described above).

Upland areas of the former shipyard were remediated by the Port under Ecology supervision (described above), and are subject to long-term monitoring. Remediation and redevelopment efforts for the Site included treatment and removal of contaminated soils (total petroleum hydrocarbons [TPH] and metals), paving the majority of the former shipyard area, and replacement of upland storm drains and related outfalls. Contaminated soil removal and treatment actions effectively reduced potential sources to sediment contamination resulting from direct transport from the upland areas. Paving of the Site effectively reduces surface water infiltration to groundwater at the Site. According to the available information, the historical storm drains were removed or plugged in accordance with the Port's remediation plans. Note that the storm drain lines at the north side of the facility were plugged at a point some distance inboard of the shoreline, immediately downstream of the last catch basin. Historical structures that were maintained and protected were preserved to drain the Terminal 5 yard located immediately to the south.

Upland remediation efforts were also completed for the PSR Site under the CERCLA Superfund program as part of the Terminal 5 expansion. As part of this remediation effort, an underground slurry cutoff wall was constructed to control flow of contaminated groundwater and possibly NAPL and dioxin/furan constituents sourced from the wood treatment compounds used at the Site. In addition, remediation of the offshore portion of the PSR Site was completed under CERCLA as a Superfund-led project. A portion of the PSR sediment remediation area extends into the western portion of the Lockheed West Site. Remedial design documents for the PSR Site indicate that this area was capped as part of the PSR remediation program. Based on the available data and information on the PSR remediation, it is assumed that this cleanup has addressed to the extent possible the extent of PSR derived sediment contamination. Confirmation of the remedy effectiveness will be identified by the long-term monitoring of the Site.

4.4 GEOGRAPHIC AND PHYSICAL SITE CHARACTERISTICS

Sediment descriptions, subsurface conditions, and occurrence of groundwater are described in geotechnical investigations by Enviros (1990), Hart Crowser (1995), and in the 1994 RI, FS, and EIS documents for the SWH Project (Parametrix 1994a,b,c,d). Information was also collected by McLaren-Hart for the remedial investigation of upland areas of Lockheed West, and by Converse Consultants and Pacific Groundwater Group as part of a sediment dredge disposal and containment model study (Converse Consultants and Pacific Groundwater Group 1993) for the Port.

4.4.1 Future Site Use Assumptions

Future plans for the Site are uncertain, but the development of the RI/FS will consider potential future Port plans and use of the Site for tribal fishing and shellfish harvesting. As discussed above, in the early 1990s, the Port proposed to complete major upgrades to

Terminal 5 as part of the SWH Project. Part of the proposal included constructing new 400- and 1,000-foot piers in the West Waterway south of Pier 21, and dredging of additional berths. Proposed activities for the SWH Project are described in the 1994 EIS. The proposed 1,000-foot pier extension and dredging of a second berth were described in the EIS, but have not been completed.

Future plans for the developing the second berth and pier extension are uncertain, but the Port has expressed continued interest in completing this work. The Port has provided LMC schematic drawings of the potential project’s footprint. LMC also understands that the Port may also want to use the northern portion of the Site for temporary barge moorage, with the potential construction of mooring dolphins. LMC will consider these plans, to the extent possible, in the evaluation of potential remedial options at the Site.

4.4.2 Shoreline Characteristics and Vicinity Land Use

Elliott Bay and the Duwamish Waterway are shorelines of statewide significance under the Shoreline Management Act and the Coastal Zone Management Program. They are part of Puget Sound, an estuary of national significance under the National Estuary Program. The Duwamish Estuary and Elliott Bay have experienced extensive development and urban growth during the 20th century. Dredging of the Duwamish Waterway, completed in 1921, resulted in straightening what was originally 9.3 miles of meandering estuarine channel habitat into the 5.3-mile deep-draft channel that exists today. 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. Currently, less than 2 percent of the flats, shallows, and tidal marshes remain.

The Duwamish Waterway is part of the larger south Seattle/Duwamish industrial district, the oldest of three industrial concentrations in the greater Seattle area. The Duwamish industrial district is a major transportation corridor for rail, trucking, and waterborne shipping. The primary land uses in the vicinity of the Lockheed West Site have been industrial and maritime related for over 100 years. Warehousing, commercial, and industrial distribution activities are located throughout the area (see Figure 1-2).

Land use to the south of the Lockheed West Site is primarily industrial. Birmingham Steel (formerly Salmon Bay Steel), located between SW Spokane Street and SW Andover Street, is the largest industrial facility in the area. Birmingham Steel’s property is used for open scrap storage and slag (an inorganic by-product of steel production) processing. There are also Burlington Northern rail lines south of the Lockheed West Site. To the southwest of the Site, between West Marginal Way SW and SW Spokane Street, are relatively small parcels that support various retail and commercial facilities.

Land use in the upland areas to the west of the Site is primarily single-family residential, including the residential neighborhoods of West Seattle. Also to the west, along Harbor Avenue SW, are bluffs that are part of the Duwamish Head Greenbelt, consisting of approximately 343 acres of developed, publicly owned land and undeveloped or privately owned land. Denser residential areas are located on the bluffs and have an unobstructed view of the Site. Harbor Avenue SW is considered the gateway to the Alki Beach shoreline area. Commercial land uses and park land are located along the shoreline of Elliott Bay to Duwamish Head.

The Lockheed West Site was formerly owned by the Lockheed Company and used for ship repair and ship construction; in 1987 Lockheed ceased operations. The Port currently owns the Site and the Terminal 5 to the south. Terminal 5 and a portion of the former shipyard are currently leased by American President Lines for container-handling operations. The shoreline of the former shipyard is characterized by armoring or bulkheads with the exception of a small intertidal beach located on West Waterway.

The Lower Duwamish Waterway and southern Elliott Bay provide recreational opportunities for area residents. Numerous boat ramps, parks, waterfront trails, public moorages, and open-space areas provide the public with access to the shoreline. Lower Duwamish Waterway and Elliott Bay are also usual and accustomed tribal fishing areas.

4.4.3 Watershed

The West Waterway is at the mouth of the Duwamish/Green River system, which drains an area of about 483 square miles (Grette and Salo 1986). From the mouth to river mile (RM) 11 (location of former Black River confluence), the river is referred to as the Duwamish River; above RM 11 it is called the Green River. The upper drainage is fed by rain and snowmelt, while the lower drainage and two main tributaries, Big Soos Creek and Newaukurn Creek, are fed by rain and groundwater. Flows in the main river below RM 64.5 are controlled by releases from Howard A. Hanson Dam and the City of Tacoma water diversion at RM 61. USACE has limited discharges to 12,000 cubic feet per second (cfs) at Tukwila and minimum flows to as low as 200 cfs, with an average flow of 1,500 to 1,800 cfs (Weston 1993). The West Waterway carries most of the river flow due to shoaling at the entrance of the East Waterway (USACE 1983). The upper drainage originates in the high Cascade Mountains and flows generally west and northwest through mostly narrow valleyed, steep-sloped, forested clear-cut terrain, before encountering more gentle slopes and broader valley conditions at about RM 46 (Williams et al. 1975). From this point, the river passes through upland fields, woods, and increasing residential/commercial use areas. The lower end of the river (Duwamish River section) flows through intensive commercial and industrial use areas, including the proposed project area (Grette and Salo 1986).

4.4.4 Shoreline and Aquatic Area Bathymetry

As shown in Figure 4-11, the aquatic area of Lockheed West is situated on a relatively flat bathymetric bench with elevations varying between about +14 to -40 feet MLLW. Underwater slopes continue to the north at an angle ranging from about 5 horizontal to 1 vertical (5H: 1V) to 2H:1V.

The Site is located in a transition zone between estuarine and marine environments. As described above, shoreline areas of the Site include open, exposed slopes with sand and gravel, a new interlocking sheetpile bulkhead across the former shipway, and older retaining walls and riprap-reinforced areas. Exposed shoreline areas have relatively steep slopes. Debris piles of amalgamated sandblast grit and slag are also locally present in the intertidal area. Intertidal areas contain scattered debris and gravel near the shoreline. Sandy surficial sediments in the subtidal areas contain less gravel and debris.

Intertidal habitat is affected by relatively low-saline water from the Duwamish River that forms an approximate 3- to 6-foot layer over denser saline waters. There is an apparent upwelling effect of marine waters toward the northern edge of the property to the west, toward Duwamish Head.

As part of the summary of existing data, a high resolution multibeam sonar bathymetric survey was conducted for Lockheed by Tetra Tech on May 20, 2006. The multibeam sonar system provided a high resolution, full bottom coverage, bathymetry of the area in the vicinity of the Lockheed West project site, from which contour lines and hill-shade maps (hard copy and electronic) digital terrain models where created.

The survey data was collected to chart bottom features and provide detailed bathymetric data to: 1) support future site characterization activities; 2) determine bathymetric anomalies (e.g., debris); and 3) provide data for potential remedial designs. Additionally, the collected data may also be used to: 1) analyze bottom substrate composition; and 2) evaluate sediment transportation.

The survey was conducted using the latest technology and followed all appropriate QA protocols. The results from the multibeam bathymetry survey are shown in Figure 4-11. Bathymetry data extended from near shore to approximately 192 feet below MLLW off shore. The high resolution bathymetry data shows topographic details of the seafloor including areas that have been historically dredged and the location of debris deposits, which are primarily in the area around the former drydocks. Timber pilings, lying on the seafloor, are also apparent in the bathymetric data.

4.4.5 Regional Geology

Information on the geology of the Lockheed West Site is derived from investigations previously conducted and summarized in the EIS and Aquatic RI for the SWH project (Parametrix 1994a,b). Prior to the 20th century, the surface of the delta consisted of an estuary of shallow, meandering channels, marshland, and tidal mudflats. During the 20th century, the Duwamish River channel has been straightened, and the marshes and mud/sand intertidal substrates at the mouth of the river have been filled. The prevalence of human activity over the last 100 years, including the channelization of the river, construction of shoreline protection, extensive pavement, and development of the Longfellow Creek storm water outfall, have stabilized the geology of the Site. Geologic cross sections, derived from soil borings taken from offshore and upland portions of the Lockheed West Site, indicate the presence of layers of sand, silty sand, and occasionally silt. Four distinct geological units are present in the upland and offshore portions of the Site. These units are described as follows (in descending order from the soil/sediment interface downward):

- **Upland Fill.** The soil unit underlying the present upland configuration consists of an approximate 20-foot-thick layer of medium dense fill material containing varying amounts of sand, silt and clay. Review of historical dredging permits indicates the source of this fill to be material previously dredged from areas within the West Waterway of the Duwamish River (adjacent to and within the Site).
- **Recent Sediment Deposits.** The upper offshore geological unit is comprised of a veneer of soft, organic silt and sand deposited at the Site after completion of historical dredging activities were performed to construct the current configuration of the Site.
- **Post-Glacial Deposits.** Underlying the Recent Sediment Deposits is a post-glacial unit comprised of soft, organic silt ranging from approximately 3 to 7 feet in thickness. Below the surface silt layer are sands with interbedded thin silt layers. This post-glacial unit ranges from approximately 100 to greater than 155 feet in thickness. This deposit is likely the result of estuarine deposition from the Duwamish River.
- **Glacial Deposits.** A unit of hard sandy silt was observed in the two southernmost portions of the offshore area of the Site. This unit is a glacially overridden deposit

and was encountered at elevations of approximately -60 to -140 feet MLLW. This unit is assumed to slope downward into the Site toward Elliott Bay.

These layers are not continuous across the Site, but alternately grade laterally from sand to silty sand back to sands, with localized areas of silt. The variable deposition, resulting in indistinct contact between materials, is consistent with an offshore deltaic environment. The changing currents near the Duwamish delta have moved different materials intermittently through space over time to result in the variation in grain size. No continuous layers of any one material were noted across the entire Site. One boring on the Site indicated "over consolidated" materials that would possibly represent glacial deposits and therefore the hydraulic bottom of the system, with the contact between low-density and high-density sediments lying about 60 feet below MLLW. This sample may represent the edge of materials that have been glacially overridden. Other borings drilled to depths of almost 160 feet below MLLW indicated only low-density sediments. These silts and sands are at high risk of liquefaction, given the relatively high level of seismic activity in Washington associated with plate tectonic movement.

4.4.6 Currents, Tidal, and Wave Influences

4.4.6.1 Tides

The tides in the Duwamish River estuary have marked inequalities in the successive high- or low water stages. Based on a tide reference station approximately 1 mile from the mouth of the estuary, the mean tide stage is 6.5 feet above MLLW, and maximum and minimum estimated stages are 15.00 feet ± 0.5 foot above MLLW and 4.5 feet ± 0.5 foot below MLLW, respectively (King County Department of Natural Resources 2001).

4.4.6.2 Currents

Physical properties of the waters of the Site are similar to salinity and current patterns in inner Elliott Bay. Both are affected by the interaction of tidal flows and outflow from the Duwamish River. Circulation and salinity distribution in the inner bay were investigated by NOAA (Sillcox et al. 1981). The general circulation pattern in the inner bay is counterclockwise with Duwamish River flows discharging to the bay. This pattern can create eddies at the mouth of West Waterway during high river flows and during ebb tides. During flood tides with low river flow, long shore currents are reported to be in the range of 0.2 foot per second (ft/sec). West Waterway flows reach as high as 1.4 ft/sec just below the water surface. The combination of tidal and river flows results in a consistent flow across the Site from west to east. Wind-driven circulation will upset this circulation pattern at some time, but east winds are not frequent or strong enough to reverse the overall circulation pattern. Current meters placed over 100 meters deep showed that current velocities in the bay were too low to resuspend sediments (Sillcox et al. 1981). However, localized wind-driven currents may be sufficient to resuspend sediments in the shallow areas. Wind-induced resuspension was not investigated by NOAA. Circulation of water in the Duwamish estuary is a function of river flows and the movement of saltwater upstream during tidal cycles. The intrusion of saltwater into the river creates a saltwater wedge overlain by freshwater that extends as far as 10 miles upstream (NOAA 1987, Ebbesmeyer et al. 1998).

4.4.6.3 Waves

A coastal engineering analysis was conducted by Coast and Harbor Engineering, Inc. (CHE) in 2004 in support of sediment remediation efforts at the Lockheed Shipyard 1, which is representative of conditions at the Site. This analysis evaluated wind-wave, vessel wake, and prop wash data, which are all forces potentially influencing the stability of aquatic sediment. See CHE (2004) for additional details regarding methods, analysis assumptions, and input data. The following discussion summarizes their findings.

Wind speed and direction data were derived from the National Data Buoy Center C-MAN Station WPOW1 at West Point Washington, collected from 1984 through 2001. The Site is open to direct wind-wave impacts from primarily the north and northwest. Of these, wind from the northwest direction is estimated to be critical for the wind generated wave conditions.

Wind data, in combination with bathymetry data derived from NOAA (1930 to 1999) and the USACE (2004), were used to hindcast wave conditions in the vicinity of the Site. Extreme wave heights ranging from 3.6 to 3.9 feet are expected to occur every 5 to 10 years, respectively, with larger waves (4.4 feet to 4.7 feet) occurring at intervals of 25 years or greater. Wind-wave heights, periods, and directions are strongly affected by local site features, with the greatest extreme wave heights occurring in Elliott Bay and declining as the distance landward in the West Waterway increases.

The vessel wake analysis determined that a vessel traveling at 8 knots would produce a wake 2 feet high with a period of 3.5 seconds. Propeller wash effects on bottom velocities are dependent on the vessel propeller position, the vessel size (large/small), and the vessel orientation. Based on a large vessel with a distance and orientation (propwash directed toward shore) typical of operational conditions in the West Waterway, peak bottom velocity was estimated to be 6.5 feet per second.

4.4.7 Sedimentation

Previous site investigations provide a considerable amount of data describing the physical characteristics and distribution of surface and subsurface sediments. Investigations include 25 soil borings completed by Hart Crowser for engineering design support for proposed improvements of the SWH Project (Hart Crowser 1995), and other work presented in the Parametrix RI (1994b) and Enviros (1990).

Sediment sampling and drilling data from Hart Crowser's 1995 site explorations indicate the presence of soft organic silt commonly extending from the surface to depths of about 3 to 7 feet below the mudline. These sediments represent the majority of materials affected by historical contaminants at the former shipyard. Other investigations (e.g., Parametrix 1994b) describe the uppermost sediments as sand with varying amounts of gravel and silt. The uppermost sediments are underlain by interbedded sands and silts of alluvial origin from the deltaic environment of the Duwamish River, or fill derived from these materials. Alluvial sands and gravels extend to depths of 100 feet or more below mudline and have varying densities.

Individual layers of silt, sand, and gravel are laterally discontinuous and do not have obvious physical characteristics that produce preferential pathways for groundwater flow or contaminant migration. Contacts between units are not distinct and suggest variations in depositional environment or filling.

4.4.7.1 Sedimentation Loading

Sediment loading to Lockheed West is primarily from the Duwamish River and Elliott Bay. Most of the Duwamish River sediment originates from the Green River, with annual loading ranging from 160,000 to 190,000 cubic yards per year (Weston 1993). The total sediment load for the Duwamish River is estimated to range from approximately 210,000 to 270,000 cubic yards per year (USACE 1983). Approximately 80 percent of the Duwamish River sediment load settles out in the river because of differing densities in the saline water entering from Elliott Bay during tidal cycles (Weston 1993). The remaining sediment is transported to the East Waterway, West Waterway, and North Harbor Island area and is assumed to be redistributed through tidal fluctuations. It is assumed that sediment loading to the Site is also likely to result from localized long-shore currents within Elliott Bay.

4.4.8 Hydrogeology and Groundwater Flow

Site hydrogeology and groundwater flow are dominated by the influence of tides and the presence of denser, saline marine water. Groundwater movement beneath the Site is affected by tidal action, although the net tidal inflow and groundwater outflow appear to balance out. Tidal response is generally controlled by density-driven flow and local variations in sediment permeability. Groundwater flowing northward from the adjacent upland areas discharges to Elliott Bay at elevations of about -40 feet (MLLW) and above. More dense marine waters flow inland below this elevation. The difference in hydraulic response of the two zones is driven by density gradients and slight local variations in sediment permeability. At low tide, groundwater may discharge to surface waters of Elliott Bay through intertidal seeps. Depth to shallow groundwater in upland areas adjacent to Lockheed West varies considerably depending on tide.

The western portion of the Lockheed West aquatic area and adjacent shoreline may be influence by groundwater flow from the upland areas of the adjoining PSR site. Groundwater flow before implementation of the PSR slurry wall remedy had a component of groundwater flow to the Northwest toward the Lockheed West site. More recently, there was evidence of groundwater flow around the eastern end of the PSR slurry wall and toward the Lockheed West site (RETEC 2004). Additional information on the nature of these potential sources in upland portions of the PSR Site and the outcome of remediation previously completed have been obtained and will be incorporated into the Source Control Evaluation Report.

4.4.9 Biota

Flora and fauna of the aquatic area and shoreline include a typical mix of invertebrates and algal plants found in Elliot Bay and similar environments of Puget Sound with a history of industrial use. Fine sediments are dominated by bivalves, crustaceans, and several species of worms. Coarser sediments host a diverse array of crustaceans and amphipods. The environment also reportedly supports crabs, squids, octopi, and resident fish such as perch, sculpins, and rockfish, as well as anadromous fish. This assemblage of species provides a fairly diverse marine community representative of shallow areas of Elliott Bay and Puget Sound with modified or disturbed shoreline features. It is noted that the current use of aquatic biota for human consumption is unknown.

4.4.10 Debris and Structures

From observations of the Site, review of recent high resolution bathymetry, and from areal photos, there are several structures and debris located along the shoreline of the Site. There are historical piers and a shipway that were associated with the operations of the former shipyard site. During redevelopment of the upland container facilities for Terminal 5, the Port constructed a sheet pile bulkhead across the apron of the former shipway in the western portion of the Site. Many pilings remain in place at the shipway location. The shoreline to the east consists of areas of open slope, riprap-reinforcement, and wooden or steel retaining walls in generally poor condition. Since closure of the shipyard, the Port has demolished Piers 21 and 22. In addition, the decking has been removed from Piers 23 and 24.

Numerous apparent debris piles are observed in the area of the former drydocks. Additionally, multiple pilings are observed on the seafloor throughout the Site (Figure 4-11).

4.5 SUMMARY OF EXISTING SITE CHARACTERIZATION STUDIES

Previously collected data for the Site are summarized below (Table 4-3) and in Appendix A. These data are summarized to serve as a background for understanding the general CSM, nature and extent of contamination and identification of data gaps, however; the majority of the information is aged. Data collection for the RI will supplement the existing data and will provide a contemporaneous and more comprehensive data coverage than does the existing data. The data collected during the RI will provide a more comprehensive suite of information for the evaluation and selection of remedial alternatives for the Site. Given that extensive data collection will be completed as part of this RI, the summary of existing data is presented to inform development of the RI sampling activities and to provide general background for the planned RI/FS activities and is, therefore, not intended to be fully comprehensive.

4.5.1 Existing Groundwater Monitoring Data

Preliminary groundwater monitoring at the Lockheed West Site began in 1989 by McLaren Engineering and Enviros Corporation (McLaren 1989, Enviros 1989). During the summer of 1990, further groundwater characterization was conducted (McLaren-Hart 1990, Enviros 1990). Groundwater data are summarized Appendix A and in the Enviros Distillation Report (see Appendix A-3) and McLaren Hart and Enviros Remedial Investigation Work at the Former Lockheed Shipyard (Yard II) in West Seattle, Washington (Enviros 1993).

Currently there are seven groundwater monitoring well locations (Figure 4-12). Four are located near Lockheed West, including one just south of pier 24, one east of pier 23, and two near the southeast corner of the Site. The Port of Seattle has not performed groundwater quality monitoring at these wells as part of the long-term remediation monitoring. The Port is currently working with Ecology to finalize a long-term groundwater monitoring program for the site.

4.5.2 Existing Uplands Data

The Port's Terminal 5 expansion project, completed in 1998, involved the remediation of the uplands portion of the Site, with the objective of removing the Site as potential source of continuing contamination to the environment and to complete the Port's obligations from the acquisition of the shipyard property from Lockheed. Prior to this, upland remedial investigation work had been conducted between 1988 and 1992 by McLaren-Hart, on behalf of Lockheed, and Enviros, on behalf of the Port. Documents containing and summarizing the RI work and associated data upon which the Terminal 5 uplands remediation activities were based include McLaren-Hart (1992) and Enviros (1991, 1992a,b).

The work by McLaren-Hart, which incorporates data collected by Enviros collected in 1991, was directed towards determining the magnitude and extent of contamination in site upland soil, groundwater, and storm drain sediments. Soil samples were obtained from approximately 222 locations around 35 potential sources areas on site using grab sampling, drill rig, and hand auguring techniques.

4.5.3 Sediment Quality Data

Since 1984 an extensive series of studies have been independently conducted by LMC and the Port in an effort to determine the nature and extent of sediment contamination in the Lockheed West Site and vicinity (Table 4-3). Historical and recent sample locations are shown Figure 4-12.

Much of this information was compiled by Parametrix and by Enviros (1990) to support characterization of the Lockheed Shipyard No. 2 for the Southwest Harbor Cleanup and Redevelopment Project (SWHCRP). This work included 23 surface grab samples and 85 individual core samples from 22 locations at various depth intervals. Previous work also supported studies for the Harbor Island RI/FS (Weston 1993), evaluation of sediments in the West Waterway of the Duwamish River, and other sediment quality evaluations. 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 (TCLP);
- Forty benthic flux samples from two locations;
- Sixty interstitial porewater samples from six squeeze core locations;

- Five interfacial pore water surface samples; and
- Sequential Batch Leaching Test extractions from three locations and two composite samples.

Results of the technical studies by Parametrix, Enviros, and others were evaluated to identify SWHCRP remedial alternatives in the 1994 FS (Parametrix 1994c) and EIS (Parametrix 1994d). In addition to sediment characterization, collected data were used to develop contaminant migration models, assess potential toxicity to marine life, and evaluate potential human health risks.

In a separate study for the Port, Hart Crowser (1995) completed 24 additional subsurface geotechnical borings to assess sediment types and physical properties throughout the Lockheed West Site and the adjacent West Waterway (Figure 4-12). Data from these borings were used for engineering design and stability analysis of the Port's development of Terminal 5, which included the construction of the 400-foot pier extension south of Lockheed West.

4.5.4 Existing Geotechnical Data

Two geotechnical investigations have been completed in and around the Site and are described below.

- **Enviros (1990)**. A total of 5 deep borings were drilled along the outer harbor line to depths ranging from approximately 60 to 110 feet. Additionally, a total of 12 shallow borings were drilled within the Site boundary to depths ranging from approximately 4 to 25 feet. Standard penetration test data and split spoon samples were collected in the field and laboratory analyses were performed to determine sediment moisture content and gradation properties.
- **Hart Crowser (1995).** A total of 25 borings were completed offshore, from existing pier structures and within upland areas of the Site to depths ranging from approximately 40 to 170 feet. Standard penetration test data and split spoon samples were collected in the field and laboratory analyses were performed to confirm field sediment classifications and to determine sediment moisture content, Atterberg Limits, gradation, consolidation, and shear strength properties.

4.5.5 Summaries of Previous Risk Assessments

Both (HHRAs and ERAs) have been performed for either the Lockheed West property or for sites located in the vicinity of the Lockheed West Site. The aquatic habitats of the Lockheed West Site are marine along the Elliott Bay shoreline, and the lower water column and sediments are mostly marine along the West Waterway shoreline. The sites that are located in the vicinity of the Lockheed West Site for which RAs have been performed in the past are either fully marine habitat, such as the PSR Site located to the west of Lockheed West along Elliott Bay, or may have some minimal influence of freshwater from the Duwamish River outflow, such as the West Waterway Operable Unit (OU) of the Harbor Island Site or the LDW Site, located adjacent to and flowing partly into the West Waterway. For the Harbor Island sites such as Lockheed-Harbor Island and the West Waterway OU, the site-associated sediments have been evaluated as marine sediments. There is minimal influence from the freshwater component of the flow coming in the Duwamish River discharge on the sediment regime of the Harbor Island sites, due to the water depth and presence of the marine waters of Elliott Bay.

The baseline HHRA and ERA have recently been completed for the LDW site. The LDW consists of a gradient of salinities with the highest salinity in the downstream portion of the waterway, at the mouth of the waterway adjacent to Harbor Island. Both the ERA and HHRA for the LDW site assess exposures to contaminants in sediment areas located throughout the LDW site as a primarily marine or estuarine habitat. The assessments encompass human exposures and fish and wildlife exposures to primarily marine intertidal and subtidal sediments. Since the Lockheed West site is comprised of similar marine/estuarine habitat, the RAs for the LDW site are considered appropriate for comparison in the development of plans for the Lockheed West streamline ERA and HHRA. Although the LDW RAs and those performed previously for Lockheed West and nearby PSR and West Waterway sites provide useful information on approaches and data, some of which are used in planning the RAs for Lockheed West, the PSR and West Waterway RAs in particular are considered to be dated because they were completed prior to establishment of the Framework used on the LDW.

Summaries of the previous RAs conducted at nearby sites and for other media at Lockheed West are presented in Appendix A.

4.6 PRELIMINARY CONCEPTUAL SITE MODEL

This section of the Work Plan provides a general summary of how contamination of the Lockheed West Site is suspected to have occurred, taking into account the historical uses and operations in combination with current physical and chemical data described above. An understanding of the contamination process is critical to ensuring that remedial actions are targeted at both the problem, as well as the sources that caused the problem. Figure 4-13 provides a schematic of the historical and current discharges and the groundwater flow regime of the Lockheed West Site. This section discusses how different discharges and transport pathways at the Site may relate to the contaminated sediment distributions found at the Site. The preliminary CSM will be refined using data collected, and analyses completed as part of the RI. The development of baseline ERA and HHRA will include more specific CSMs (see Section 11).

The general mechanisms by which the sediments adjacent to the former shipyard could have been contaminated include the following:

- Historical shipyard operations/activities;
- Direct discharges from historical shipyard operations into the receiving water (e.g., loss of wastes from floating drydocks);
- Transport and discharge from groundwater flowing from the uplands area into Elliott Bay;
- Atmospheric deposition from the shipyard; and
- Transport via sediment, water, or atmospheric from other regional activities throughout Elliott Bay and the Duwamish Estuary.

4.6.1 Known and Suspected Sources of Contamination

4.6.1.1 Historical Site Uses

Potential sources of contamination related to historical site uses are presented in Section 4.3.1.

4.6.1.2 Potential Ongoing Sources to Sediment Contamination

Potential ongoing sources to sediment contamination are presented in Section 4.3.2.

4.6.1.3 Adjacent Site Uses

Currently, both the uplands portion and the offshore portion of the former PSR Site have had remedial actions performed. These actions presumably have controlled the potential historical sources from this Site. At present, the uplands portion of the PSR Site is part of the Port's Terminal 5 operation and is subject to the source control activities conducted by the Port. The shoreline and offshore portion of the PSR Site is not currently used for a specific purpose. It also has restrictive signs and fencing that limit public access to the shoreline for recreational purposes.

The West Waterway continues to be maintained and functions as an industrial waterway for navigation and commerce. Several cleanup actions have taken place along the waterway (e.g., LSSOU, Todd Shipyard) that have reduced the potential sources from these locations. The West Waterway continues to be subject to influences from the Lower Duwamish River.

4.6.2 Types of Contamination and Affected Media

Sediment contamination at Lockheed West includes a variety of metals and organic constituents related to historical activities at the shipyard and potentially from nearby areas. Sediments are the primary affected media at the site; other potentially affected media include marine organisms that may contact contaminated sediment, surface waters of West Waterway and Elliott Bay that overlie contaminated sediment, and possibly upland sources such as groundwater and upland soils that may contribute to sediment or sediment porewater contamination. The COIs at Lockheed West are those listed in the Washington State SMS (Chapter 173-204 WAC) and chemicals that have been previously detected at the site or are suspected of contaminating site sediments based on findings of contamination at nearby sites such as the upstream LDW site. Tributyltin TBT is not a compound regulated under the SMS but is, however, included as a COI due to its association with shipyard activities. For TBT, concentrations were compared to the confirmational number established for the nearby Harbor Island LSSOU. Other non-SMS COIs that may be present at Lockheed West based on their known presence in sediments in the upstream LDW site include carcinogenic PAHs and dioxins/furans.

Based on historical activities at the former shipyard and adjacent sites, elevated concentrations, and possible identification as chemicals of concern in the risk assessments, are likely to be the metals arsenic, copper, lead, mercury, and zinc, and PAHs and PCBs.

4.6.3 Known and Potential Routes of Migration

Historical site use and operation provided several potential pathways for shipyard-related sediment contamination. As discussed above, direct discharges from stormwater outfalls and from the operation of the dry docks, shipways, and pierside new ship construction likely contributed contamination directly to marine waters and to sediments. However, these were historical activities that no longer contribute new contaminants to the Site.

Current routes of potential contaminant migration into the Site include on the on-going deposition of particulates and contaminants from the surrounding and adjacent waterways (i.e., West Waterway, Lower Duwamish). In addition, stormwater runoff from upland areas may continue to be a source; however, the uplands portion of the former shipyard was remediated and the stormwater system was cleaned and re-routed, so this likely represents a very minor contribution, if at all. Marine biota, through direct contact and ingestion of water and sediments are exposed to the contamination that can ultimately bioaccumulate in marine tissues. Baseline ERAs and HHRAs will evaluate the potential for contaminant migration into these receptors.

4.6.4 Exposure Media, and Known or Suspected Human and Ecological Receptors

The primary receptors exposed through each transport pathway are marine waters, sediments, and marine biota. For the historical site operation-related discharges (dry docks, piers, and shipway), the first receptor is the marine water. Soluble contaminants would have dissolved into the receiving water. A secondary receptor is the marine sediments. Soil particles, paint fragments, and other shipbuilding-related debris would ultimately mix with the sediments where contaminants could be absorbed onto sediment particles. For direct discharges from surface runoff or from deposition from the West water/Duwamish River, a similar two-step receptor pathway would occur. For groundwater discharge, the receptor pathways are reversed. Sediments would be the initial receptor, followed by marine water. For all discharge mechanisms, marine biota are a secondary receptor in that they are exposed to water-borne and/or sediment-borne contaminants. Human receptors would include tribal and recreational consumption of marine biota and potential direct exposure to on-site workers and/or through recreational activities.

4.6.5 CSM Summary

Based on the current understanding of the nature and extent of contamination related to historical shipyard activities in the Lockheed West sediments and the current status of source control discussed above, the conceptual model for the Site can be summarized as follows:

- COIs for the Lockheed West Site are primarily related to shipyard activities, though contributions may also come from other areas (e.g., cPAHs, dioxin/furans), and include but are not limited to PAHs, PCBs, arsenic, copper, lead, mercury, TBT, and zinc.
- Primary potential pathways for COIs include historical site operations and activities associated with the dry docks, shipway, and pierside new ship construction along with direct discharge of materials from over-water structures.
- Secondary potential pathways for site-related COIs to sediments include discharges from storm drain outfalls, discharge of contaminated groundwater, and erosion of contaminated upland soils.

- There is no evidence of mass sediment redistribution at the site as shown by the presence of historically contoured bottom features, such as drydock areas and former pier areas, in the recent hydrographic survey.
- There is some evidence that regional influences have affected the Site in the past and continue to affect the Site, especially on the eastern side of the Site where the effect of West Waterway is most prevalent. Concentrations of mercury and PCBs were relatively greater on this part of the Site, and sediment studies of adjacent areas in the West Waterway indicate that these chemicals are prevalent throughout the area.
- Several ongoing potential contaminant sources exist. The West Waterway, currently under a No-Action ROD, contains elevated concentrations of COIs relative to the Site and is a potential source of sediment to the Site. Likewise, the upstream LDW Superfund Site, which also contains concentrations of COIs above those at the Site, is a sediment source.

The preliminary CSM will be refined using data collected as well as analyses completed as part of the RI. The development of baseline ERA and HHRA will include more specific CSMs (see Section 11).

4.7 IDENTIFICATION OF DATA GAPS

Based on the summary of existing data, the following data gaps have been identified. RI sampling, analysis, and data evaluation discussed in Section 8 will provide any additional data necessary to meet the requirements of the SOW. Section 8 describes the specific sampling, analysis, and technical evaluations that will be completed to fill the data gaps discussed below.

4.7.1 Nature and Extent of Contamination

4.7.1.1 Spatial Resolution of Contaminant Distributions

The data discussed in the above sections and in Appendix A are suitable for establishing a background understanding of the Site. They were used to identify COIs and the general spatial distributions and trends of these contaminants. However, with the exceptions of the areas addressed by Hart Crowser in 2003, the majority of the data was collected prior to 1998. Therefore, additional surface and subsurface sediment sampling is necessary to confirm and further delineate the nature and extent of sediment contamination (including hot spots and the potential presence of sand blast grit) and is identified as a data gap. The

RI sampling, analysis, and data evaluation necessary to address this data gap are summarized below in Section 8.

4.7.1.2 Depth of Sediment Contamination and Volume

Existing data are insufficient to determine the nature and extent of subsurface sediment contamination at the Site. The RI sampling, analysis, and data evaluation necessary to address this data gap are summarized below in Section 8. Additional subsurface borings will resolve uncertainties regarding depth of contamination and overall volume of contaminated sediment at the Site.

4.7.2 Physical Site Characterization

4.7.2.1 Physical Characterization of the Waterway

Evaluation of the existing data indicates that additional physical characterizations (e.g., grain size, TOC) are necessary to support the evaluation of remedial options. Multibeam bathymetry survey data were collected as part of the work performed for the summary of existing data; however, a topographic survey of the banks and shoreline to tie into the bathymetric data is needed. A need for a shoreline conditions survey was identified and conducted to document current physical conditions (e.g., substrate type, slope, debris, structures, seeps, outfalls) along the shoreline at the Site. This survey was conducted during a daylight low tide in August 2006 prior to the RI field sampling activities. Sufficient geotechnical explorations have been conducted to evaluate the impact of possible sediment removal or capping on waterway structures and slope stability, so no additional geotechnical data collection activities are identified.

4.7.3 Assessment of Habitat Distribution

A large amount of information on habitat distribution and resource use for the general Elliott Bay and Lower Duwamish River are available. This information will provide the basis for any habitat evaluations that may be needed. In addition, existing information on habitat distribution and resource use was supplemented with a shoreline video survey that documented existing intertidal habitat. A current habitat assessment was completed as part of the shoreline conditions survey in August 2006. Additional habitat data collection needs have not been identified at this time.

4.7.4 Human Health and Ecological Baseline Risk Assessment.

As discussed in Section 2.1, LMC is committed to active remediation of the entire Lockheed West Site. At the minimum, remediation plans consist of placing a cap over all contaminated sediments at the Site. The placement of a cap will eliminate all exposures of humans and ecological receptors to the sediment contaminants. Because of plans to mitigate such future exposures, streamlined baseline risk assessments, performed under EPA guidance for CERCLA Superfund sites, will be performed at the Lockheed West Site. Risks to human health and ecological receptors from exposures to chemicals in Site sediments will be evaluated through streamlined approaches. The streamlined RAs will evaluate potential risk by structuring the assessments to use technical information from the risk assessments performed at the nearby LDW site. Thus, site-specific tissue data are not necessary to complete the streamlined baseline HHRAs and ERAs. The specific approaches to the streamlined RAs are discussed as part of the Risk Assessment Work Plan (Section 11).

4.7.5 Preliminary Design Parameters for use in Selection of Remedial Alternatives

4.7.5.1 Sediment Contaminant Mobility

Site-specific contaminant mobility tests are necessary to support an evaluation of capping options, evaluation of the behavior of potential dredge material to support detailed evaluation of confinement options, and an assessment of potential water quality impacts during dredging. This testing will be limited to subtidal areas where, based on existing data, remedial options will likely require capping or removal.

4.7.5.2 Sediment Stability

Results of high resolution multibeam bathymetry data do not indicate significant erosional features at the Site. There is little evidence of sediment redistribution at the site as shown by the presence of historically contoured bottom features, such as drydock areas and former pier areas. However, confirmation of sediment stability to determine the ability to support a cap or dredge cuts is needed. Additional information on current site scour potential, and sediment stability is needed to fully evaluate capping and dredging remedial options for the Site.

4.7.5.3 Potential for Sediment Recontamination

A comprehensive understanding of potential sources of recontamination is essential to ensuring that the remedy is protective and to determining parameters on which to measure long-term performance.

Based on a review of the historical land use information and existing outfalls and surface sediment samples, potential sources that may require further evaluation have been identified. Additional data from previous cleanup actions by the Port in the uplands and by EPA at the PSR sites are needed. In addition, ongoing inputs from West Waterway need to be evaluated.

- Obtain and review available summary reports and groundwater monitoring data for Lockheed West and PSR sites through EPA, Ecology, and the Port.
- Determine whether Ecology has issued determination of completion or no further action for Lockheed uplands.
- Verify the current condition and status of previous cleanup actions to assess cleanup performance and potential for sediment recontamination.
- Evaluate potential benefits and impacts of the PSR remediation on Lockheed West.
- Evaluate potential impacts of sediment transport from the Duwamish River and West Waterway on the Lockheed West Site.
- Evaluate post-remediation groundwater elevation data and post-remediation groundwater chemistry data for the former shipyard remedy. The Port is currently negotiating the post-remediation groundwater monitoring work plan for T5. LMC will work with the Port to obtain both groundwater elevation and groundwater chemistry data. These data will be used to determine if the adjacent uplands groundwater is a potential ongoing contaminant source to project site sediments.
- Evaluate post-remediation monitoring data for PSR. The year one monitoring report will be reviewed when available to determine if capped sediments at the PSR Site are a potential source of contamination to Lockheed West.

4.7.5.4 Future Potential Site Development/Property Use Restrictions

LMC's understanding of current and planned property use are discussed above in Section 4.1. No data gaps exist and LMC will continue to communicate and plan strategies for discussions with the Port on the potential for performing remedial actions on Port property including evaluation of future site uses.

Table 4-1. Historical Site Development, Dredging, and Filling Summary from Lockheed West Seattle

Date	Ownership	Operations and Activities
Early 1900s	Undeveloped	Dredging and filling to create uplands near Site
1917	Undeveloped	Dredging for West Waterway
Early 1940s	Associated Shipbuilders (operated by Puget Sound Bridge and Dredging Co.) operates the Site	Construction, dredging and filling operations.
1942	Associated Shipbuilders dredging permits transferred to Puget Sound Bridge and Dredging Co.	Construction, dredging and filling operations. New ship construction and repair began during WWII.
1945-1947	Puget Sound Bridge and Dredging Co. obtain permits for dredging and dolphin placement for dry dock moorage.	Two dry docks present.
1952	Puget Sound Bridge and Dredging Co.	Permitted for dredging of approx. 260,000 cy (target elevation of -45 ft MLLW) from the east side of the Lockheed West property and the West Waterway for dry dock berthing and disposal of the dredged material west of the dredged area, at Lockheed West uplands site (see Figure 4-2). Vessel construction, maintenance, repair, and dredging/filling.
1954	Puget Sound Bridge and Dredging Co.	Permitted for dredging of approx. 60,000 cy (target elevation of -30 ft MLLW)from the east side of the Lockheed West property and disposal of the dredged material west and just north of the dredged area at the Lockheed West Site (see Figure 4-2). Vessel construction, maintenance, repair, and dredging/filling.
1954	Puget Sound Bridge and Dredging Co.	Permitted for dredging of approx. 140,000 cy (target elevation of -45 ft MLLW) from the east side of the Lockheed West property and West Waterway for dry dock berthing. Disposal of dredged material in Elliot Bay at -60 ft MLLW (see Figure 4-2). Vessel construction, maintenance, repair, and dredging/filling.
1959	Puget Sound Bridge and Dredging Co purchased by Lockheed. Then operated as Puget Sound Bridge and Drydock Co.	Vessel construction, maintenance, repair, and dredging/filling.
Early 1960s	Land west of Pier 25 purchased from Neddleton Company (wood products manufacturing)	Vessel construction, maintenance, repair, and dredging/filling.
1965	Name changed to Lockheed Shipbuilding and Construction Company.	Vessel construction, maintenance, repair, and dredging/filling. Embayment southwest of shipyard filled.
1988	Port of Seattle acquires upland area of Lockheed West for Terminal 5 expansion.	Lockheed ceased operations at Lockheed West.
Date Unknown	Port of Seattle acquires 7 acres of Lockheed West Aquatic Area from Lochkeed.	No shipyard activity.
Circa 1995-1999	Lockheed and Port of Seattle	Port of Seattle completes Terminal 5 400-ft pier extension in West Waterway, upland improvements, and upland remediation

Table 4-2. Ownership and Historical Use of Lockheed West Aquatic Area Cleanup Area Site Units

Site Unit	Ownership	Area (acres)	Previously Estimated Volume of Contaminated Sediments (cubic yards)	Reported Depth of Constituents Exceeding SQS (feet below mudline)	Historical Use
Lockheed West Waterway	State Owned	7	200,000 (proposed for dredging for second Terminal 5 berth); 80,000 PSDDA-suitable[1/]	5	Navigation and estuary
East Dry Dock	State-Owned	7.2	235,000[1/]	>13	Dry dock, ship repair, navigation, and moorage
West Dry Dock	Primarily Port-owned, some state owned	5.7	140,000	>5	Dry dock, ship repair, and moorage
Central Area	Primarily state-owned, some Port owned	14.8	645,000[2/]	>12	Navigation, moorage, new ship construction, ship repair
Ship Way	Primarily state-owned, some Port-owned	3.5	75,000	>24	Ship construction, repair, and moorage

[1/] Included sediment outside of lease area
[2/] Identified for natural recovery
Source: Lockheed Aquatic Area Draft CAP (Ecology 1996) and SWH Project Feasibility Study (Parametrix 1994b)

Table 4-3. Summary of Key Existing Data for Lockheed West

Study Description	Author	Study Date	Number of Sampling Locations in the General Vicinity of Lockheed West	Sample Location Identifier	Parameter Groups Analyzed
Dredged material characterization for the American President's Line maintenance dredging project	Unknown	1992	2	AMPRES92C001, AMPRES92C002	conventionals, metals, PCB, pesticides, SVOC, VOC
Duwamish Head sediment quality survey	Unknown	1984	1	U120	conventionals, grain size, metals, SVOC
Elliott Bay sediment quality survey	Unknown	1995	8	NH-04,NH05, NH-06, WW-10,WW-13, WW-15, WW-17, WW20	conventionals, grain size, metals, PCB, pesticides, SVOC, TPH, VOC
Sediment quality survey of Duwamish River	EPA	1982-1983		41, 42, 43, 5, 6, 6B, 6C	metals, TBT, PCB, pesticides, SVOC, VOC
Gamponia sediment quality survey of Elliott Bay	Unknown	unknown	5	8500342, 8500346, 8500354, 8500358, 8500364	metals, PCB, SVOC
Harbor Island Sediment Operable Unit Remedial Investigation	Weston	1994	244	E-01, E-02, E-03, E-06, E-06-D1, E-06-D2, E-07, E-08, E-09, E-11, E-12, E-13, E-14, E-15, E-15-D1, E-15, D2, E-16, E-17, E-19, E-20, E-21, E-22, E-23, ICE-03-01, ICE-03-01-D1, ICE-03-02, ICE-03-02-D1, ICE-03-03, ICE-03-03-D1, ICE-03-04, ICE-03-04-D1, ICN-04-01, ICN-04-01-D1, ICN-04-02, ICN-04-02-D1, ICN-04-03, ICN-04-03-D1, ICN-04-04, ICN-04-04-D1, ICN-17-01, ICN-17-01-D1, ICN-17-02, ICN-17-02-D1, ICN-17-03, ICN-17-03-D1, ICN-17-04, ICN-17-04-D1, ICN-24-01, ICN-24-01-D1, ICN-24-02, ICN-24-02-D1, ICN-24-03, ICN-24-03-D1, ICN-24-04, ICW-21-01, ICW-21-01-D1, ICW-21-02, ICW-21-02-D1, ICW-21-03, ICW-21-03-D1, ICW-21-04' ICW-21-04-D1, ICW-21-05, ICW-31-01, ICW-31-01-D1, ICW-31-03, ICW-31-03-D1, ICW-39-01, ICW-39-01-D1, ICW-39-02, ICW-39-02-D1, ICW-39-03, ICW-39-04, K-02, K-02-1, K-02-10, K-02-2, K-02-3, K-02-4, K-02-5, K-02-6, K-02-7, K-02-8, K-02-9, K-02-D1, K-02-D2, K-03, K-03-D1, K-03-D2, K-04, K-04-D1, K-04-D2, K-05-1, K-05-1-D1, K-05-1-D2, K-05-2, K-05-2-D1, K-05-2-D2, K-05-3, K-05-3-D1, K-05-3-D2, K-06, K-07,	conventionals, grain size, metals, TBT, PCB, pesticides, SVOC, TPH, VOC

Table 4-3. Summary of Key Existing Data for Lockheed West (continued)

Study Description	Author	Study Date	Number of Sampling Locations in the General Vicinity of Lockheed West	Sample Location Identifier	Parameter Groups Analyzed
Harbor Island Sediment Operable Unit Phase II Remedial Investigation	Weston	1995	22	N-09, N-10, N-11-10-15, N-11-10-9, N-12, N-19, N-20, N-21, N-28, W-29-10-3, W-29-10-4, W-30, W-33, W-36, W-37, W-40, W-42, W-44, W-48, W-49, W-52, W-53	conventionals, grain size, metals, TBT, PCB, pesticides, SVOC, TPH, VOC
Lockheed Shipyard No. 2 Sediment Characterization	Hart Crowser	2003	19	HC-03-01, HC-03-02, HC-03-03, HC-03-04, HC-03-05, HC-03-06, HC-03-07, HC-03-08, HC-03-09, HC-03-10, HC-03-11, HC-03-12, HC-03-13, HC-03-14, HC-03-15, HC-03-16, HC-03-17, HC-03-18, HC-03-19	conventionals, metals, TBT, PCB, SVOC, VOC
Lockheed Shipyard No. 2 Sediment Characterization and Geotechnical Study	Enviros	1990	68	D1-C, D1-D, D1-S, D2-C, D2-D, D2-S, D3-A, D3-B, D3-C, D3-D, D4-D, D4-S, D5-C, D5-D, G1, G10, G11, G12, G13, G14, G15, G2, G3, G4, G5, G6, G7, G8, G9, M1-C, M1-D, SA10-A, SA10-B, SA10-C, SA10-D, SA10-S, SA1-A, SA1-B, SA1-C, SA1-D, SA2-C, SA2-D, SA2-S, SA3-A, SA3-B, SA3-C, SA3-D, SA4-C, SA4-D, SA5-A, SA5-C, SA5-D, SA6-C, SA6-D, SA6-S, SA7-A, SA7-B/C, SA7-D, SA8-A, SA8-C, SA8-D, SA9-A, SA9-B, SA9-C, SA9-D, SB1-A, SB1-C, SB1-D	conventionals, grain size, metals, TBT, dioxin, PCB, Pesticides, SVOC, VOC
Sediment Quality Survey of Elliott Bay	NOAA	1980	1	10028	metals, SVOC, VOC
PSAMP Measures of Bioeffects Survey	NOAA	1999	10	197-1, 197-1-1, 197-2, 197-2-1, 197-2-2, 198-1, 198-1-1, 199-1, 199-1-1, 315-2	conventionals, grain size, metals, TBT, PCB, Pesticides, SVOC, VOC
Terminal 5 Sediment Quality Investigation	Port of Seattle	1997	1	C2/1/1	conventionals, metals, TBT, PCB, pesticides, SVOC, VOC
Elliott Bay Full Monitoring Investigation	PSDDA	2000	3	E023, E024, E025	conventionals, metals, VOC
Elliott Bay Tiered Partial Monitoring Investigation	PSDDA	2002	3	EBB01-A, EBB01-B, EBB01-C	conventionals, grain size, metals, VOC
Southwest Harbor PSDDA Related Sediment Quality Investigation	Port of Seattle	1992	6	PC-1A, PC-1B, PC-1C, PC-2A, PC-2B, PC-2C	conventionals, metals, PCB, pesticides, SVOC, VOC
Phase I Survey of PSDDA Disposal Sites	PSDDA	unknown	2	EBB01C, EBB01I	conventionals, grain size, metals, TBT, PCB, pesticides, SVOC, VOC

Table 4-3. Summary of Key Existing Data for Lockheed West (continued)

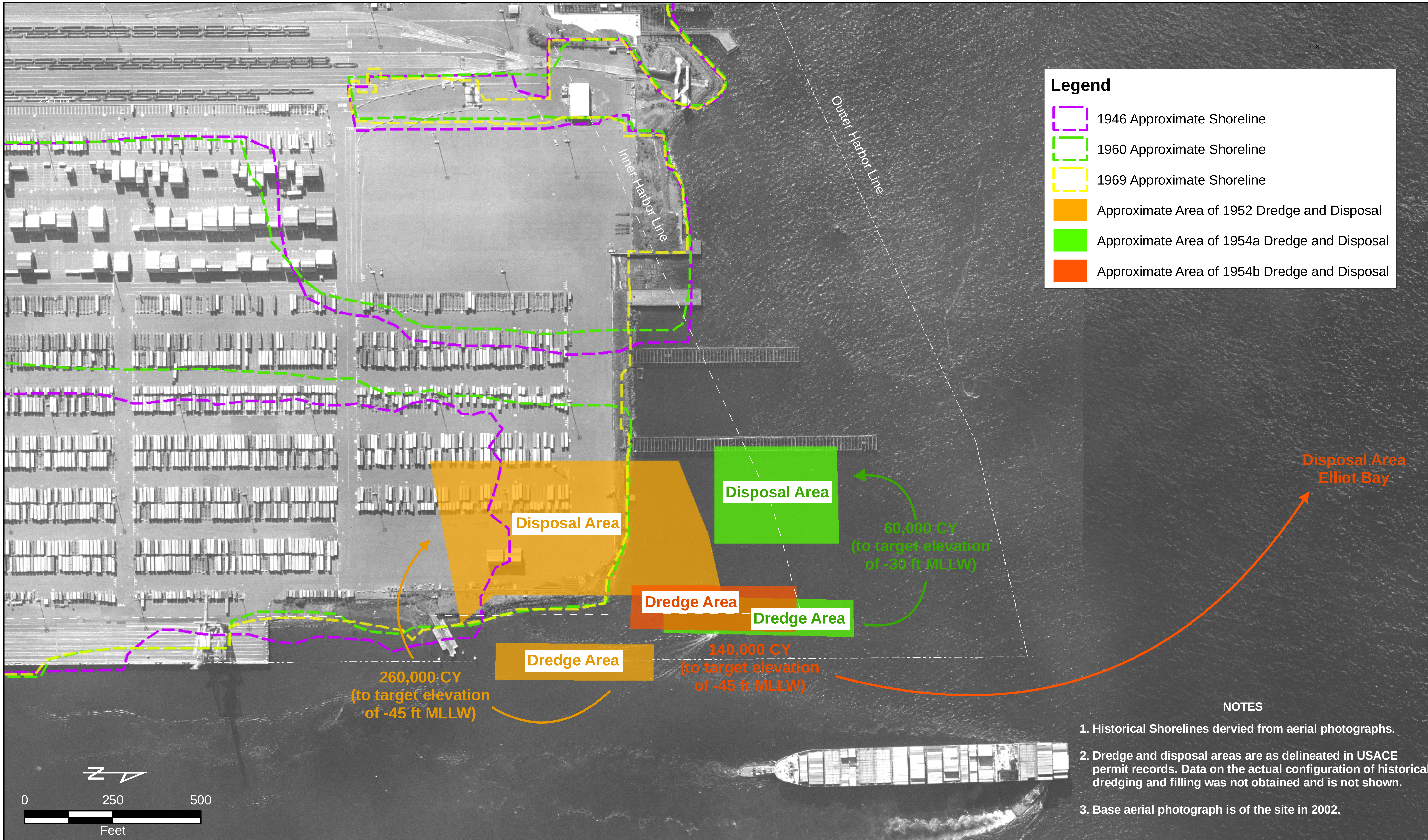
Study Description	Author	Study Date	Number of Sampling Locations in the General Vicinity of Lockheed West	Sample Location Identifier	Parameter Groups Analyzed
PSDDA Post-Disposal Site Monitoring Investigation	PSDDA	1990	1	EB90_B01	conventionals, grain size, VOC
Elliott Bay Full Monitoring Investigation	PSDDA	1992	3	PMONB01AS025, PMONB01AS026, PMONB01AS027	conventionals, metals VOC
Southwest Harbor Remedial Investigation Sediment Quality Investigation	Hartman et al.	1991	8	C1, C2, C3, C4, C5, C6, C7, C8	conventionals, metals, PCB, SVOC, VOC
Terminal 5 Pier Extension Sediment Quality Investigation	Port of Seattle	1994	2	C1, C2	conventionals, metals, PCB, pesticides, SVOC, VOC
Harbor Island Supplemental Remedial Investigation	EVS	1994	73	EW-01-HC, EW-02, EW-03, EW-04, EW-08, EW-09, EW-10, EW-11-HC, EW-12, EW-5, EW-6-HC, EW-7, HI-EW-01, HI-EW-06, HI-EW-11, HI-NS-04, HI-NS-08, HI-WW-05, HI-WW-10, HI-WW-27, HI-WW-30, NS-01, NS-02, NS-03, NS-04-HC, NS-05, NS-06, NS-07, NS-08-HC, NS-09, NS-10, NS-11, NS-12, NS-13, NS-14, NS-15, NS-16, RF-01, RF-02, RF-03, WW-01, WW-02, WW-03, WW-04, WW-05-HC, WW-06, WW-07, WW-08, WW-09, WW-10, WW-11, WW-12, WW-13, WW-14, WW-15, WW-16, WW-17, WW-18, WW-18B, WW-19, WW-20, WW-21, WW-22, WW-23, WW-24, WW-25, WW-26, WW-27-HC, WW-28, WW-29, WW-30-HC, WW-31, WW-32	conventionals, grain size, metals, TBT, PCB, pesticides, SVOC, VOC
TPPS Preliminary Sediment Quality Survey	TPPS	unknown	1	S0063	metals, PCB, Pesticide, SVOC

TBT – tributyltin
TPH – Total Petroleum Hydrocarbons
PCB – Polychlorinated Biphenyl
SVOC – Semi-Volatile Organic Compound
VOC – Volatile Organic Compound

TETRA TECH

Lockheed West Seattle
Superfund Site
Seattle, WA

Figure 4-1
1946 Aerial Photograph



TETRA TECH

Lockheed West Seattle
Superfund Site
Seattle, WA

Figure 4-2
Site Development, Dredging, and Filling History

DATE: 8/7/2006 10:44:37 AM
MXD NAME: F:\projects\TT-LMC\GIS\Data Summary\Work Plan RI NatureExtent Figures\Finalized TT Work Plan Figures\Figure 4-2 Site Development and Dredging History.mxd

TETRA TECH

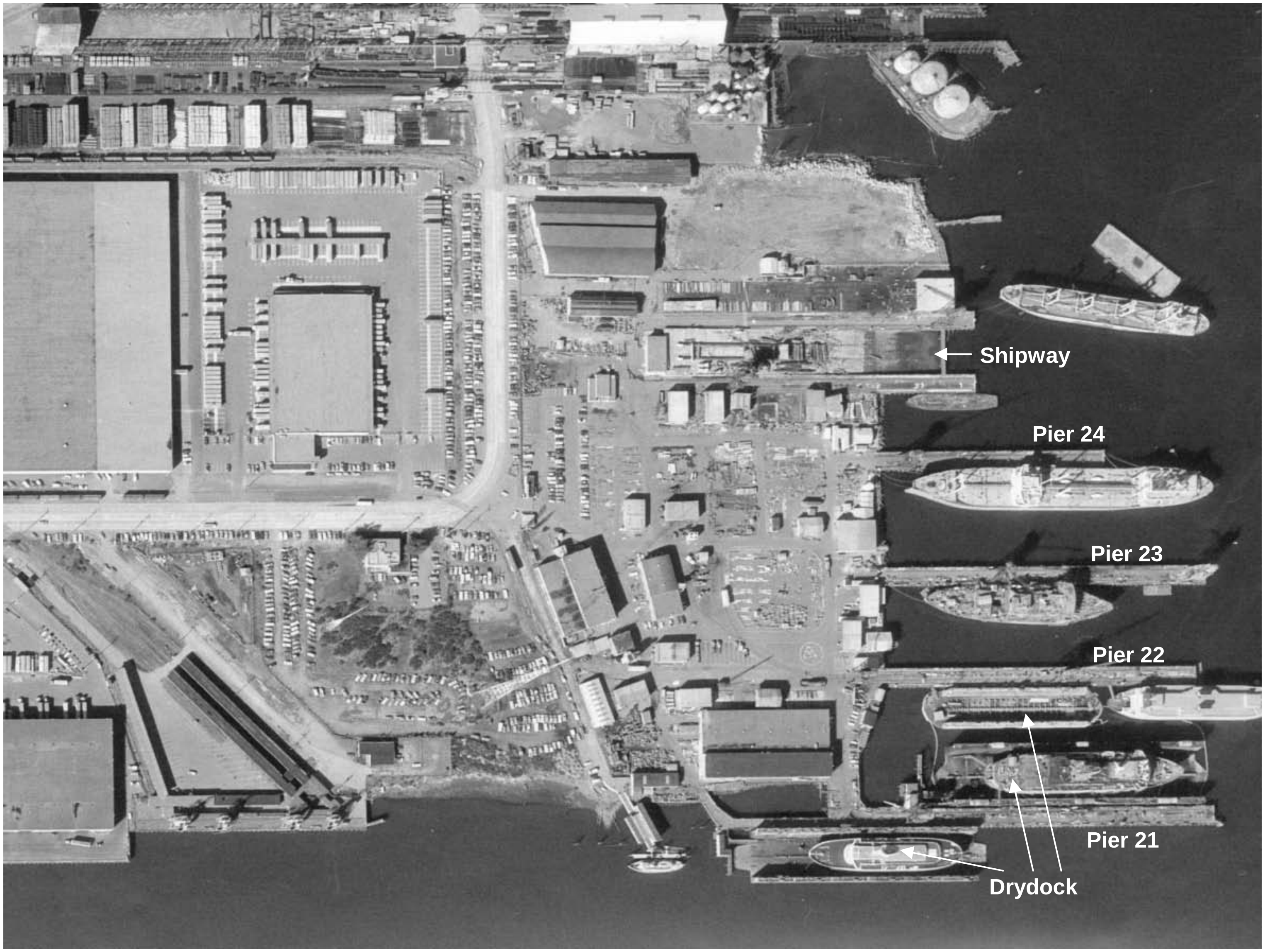
Lockheed West Seattle Superfund Site Seattle, WA

Figure 4-3
1960 Aerial Photograph

TETRA TECH

**Lockheed West Seattle
Superfund Site
Seattle, WA**

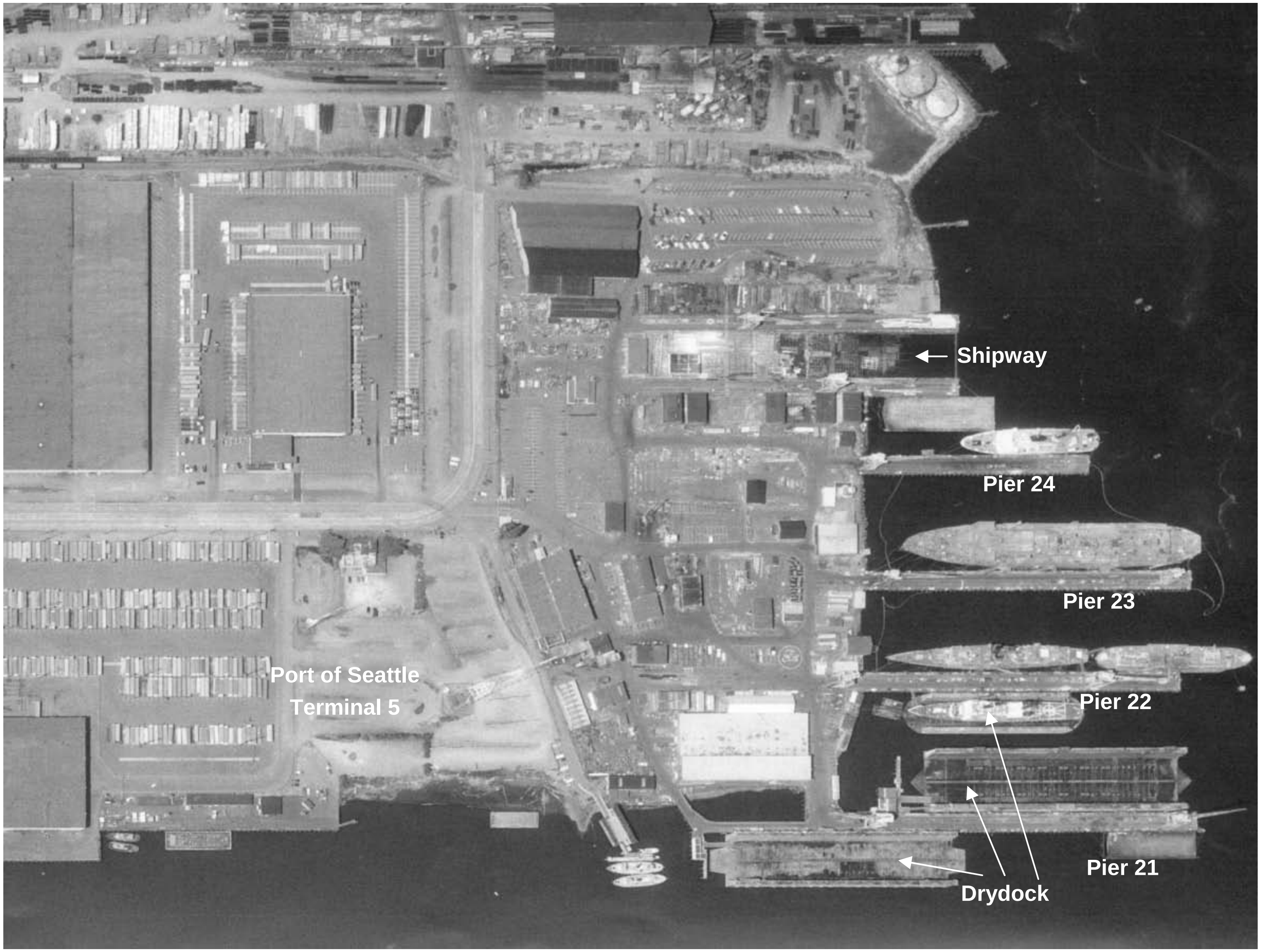
**Figure 4-4
1969 Aerial Photograph**



TETRA TECH

Lockheed West Seattle Superfund Site
Seattle, WA

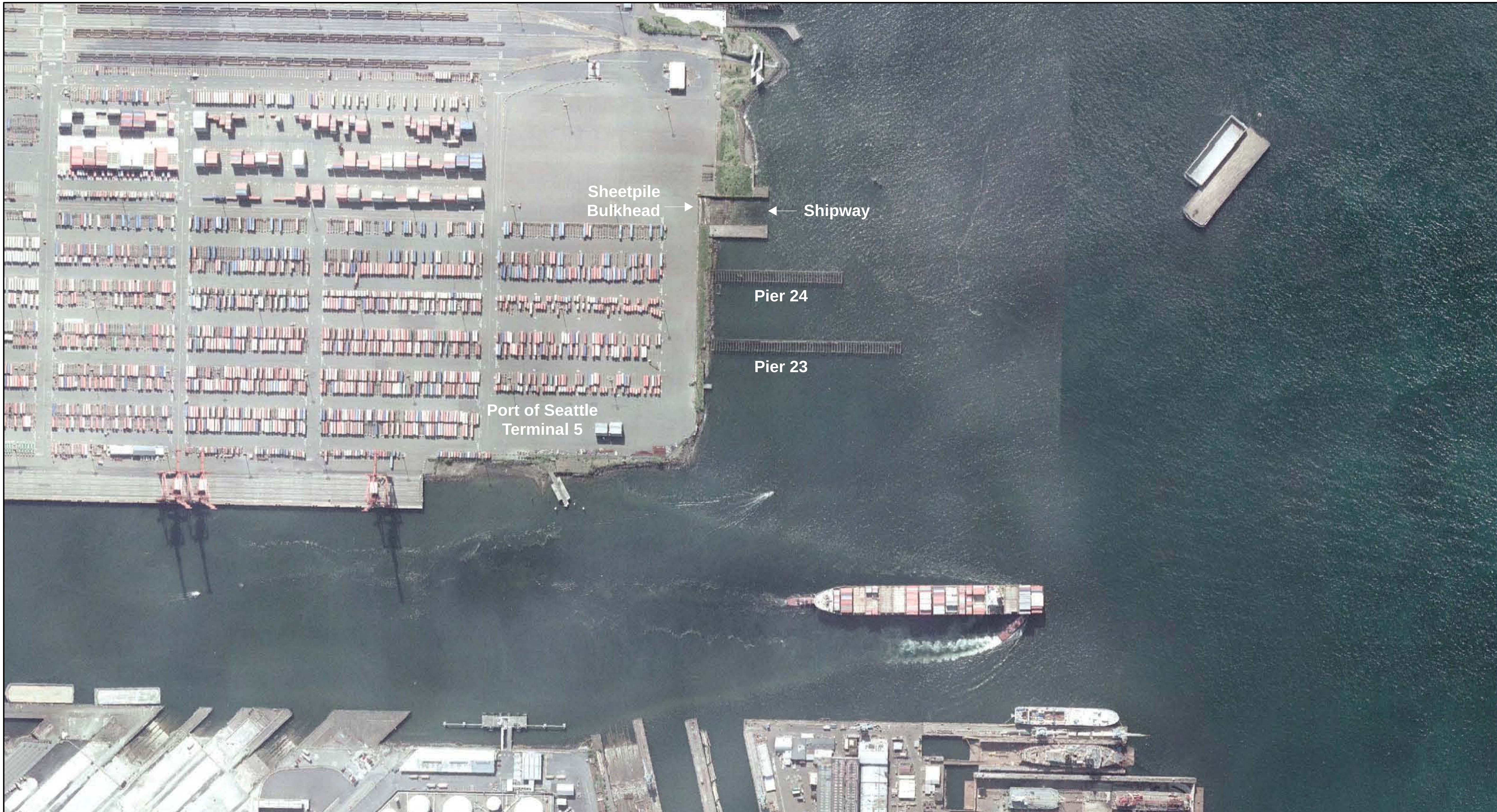
Figure 4-5
1974 Aerial Photograph



TETRA TECH

Lockheed West Seattle Superfund Site Seattle, WA

Figure 4-6
1980 Aerial Photograph



TETRA TECH EC, INC.

Lockheed West
Shipyard No. 2
Seattle, WA

Figure 4-7
2002 Aerial Photograph

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\work_plan_figures_04-01-08\Fig_4-7_aerial.mxd

TETRA TECH EC, INC.

Lockheed West
Shipyard No. 2
Seattle, WA

Figure 4-8
Aquatic Area Site Boundary
and Site Units

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\work_plan_figures_04-01-08\Fig_4-8_site.mxd

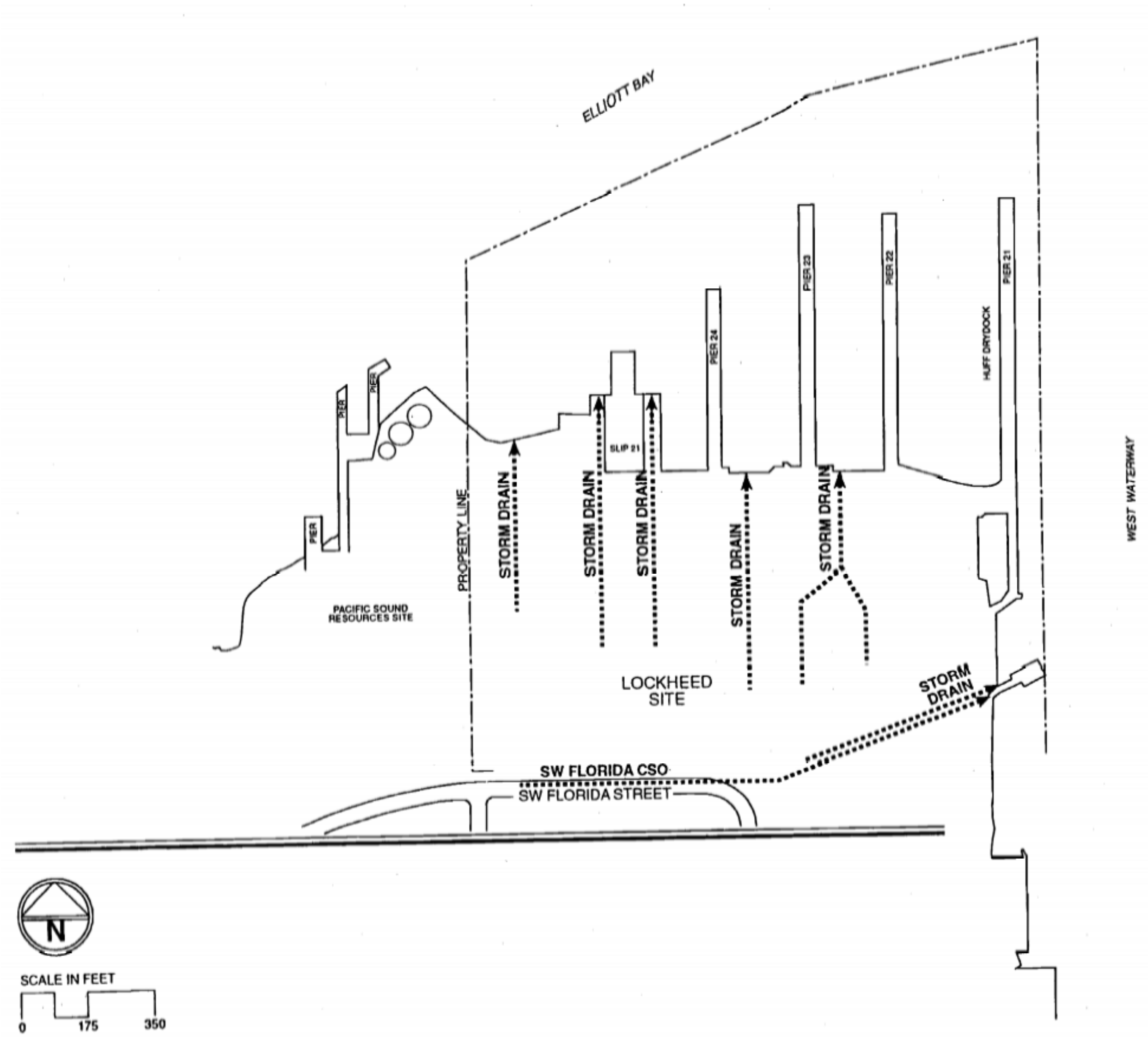
TETRA TECH

Lockheed West Seattle Superfund Site Seattle, WA

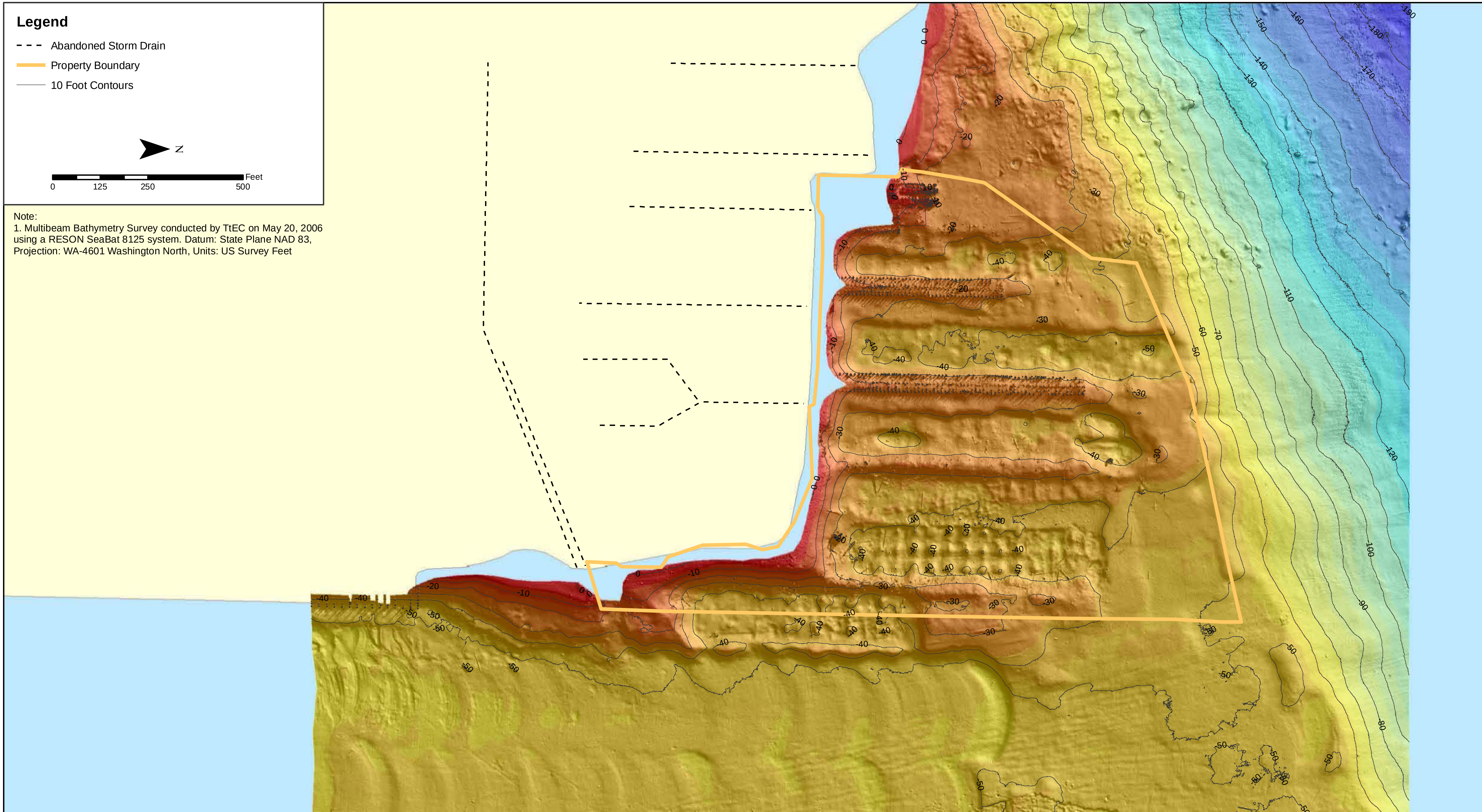
Figure 4-9 Property Boundary Map

DATE: 8/9/2006 7:27:21 AM
MXD NAME: F:\projects\TT-LMC\GIS\Data Summary\Work Plan RI NatureExtent Figures\Finalized TT Work Plan Figures\Figure 4-9 Site Boundary Map.mxd

Figure 4-10. Historic Site Stormwater Drainage



This page is intentionally left blank.

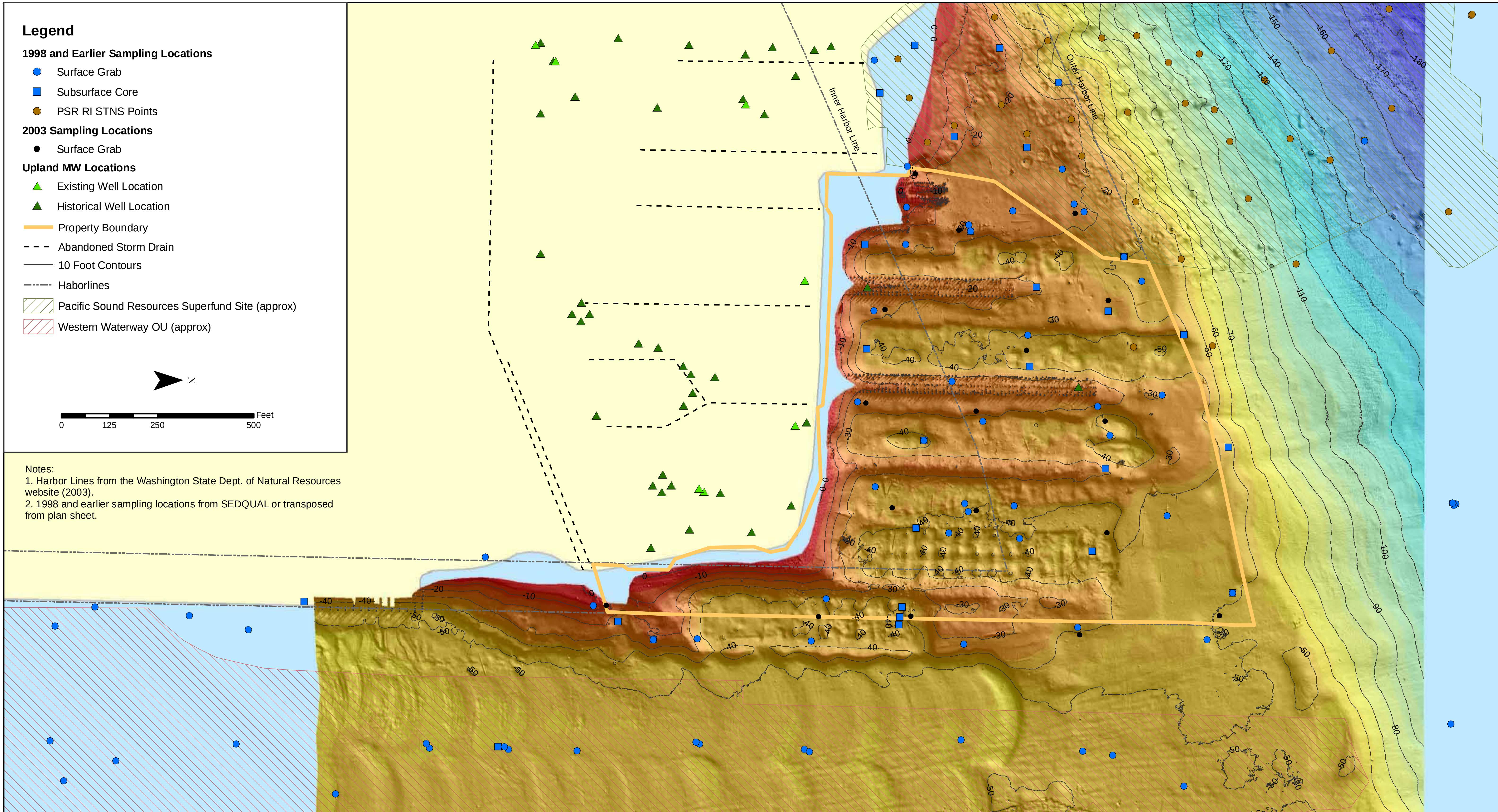


TETRA TECH EC, INC.

Lockheed West
Shipyard No. 2
Seattle, WA

Figure 4-11
Lockheed West Site Bathymetry

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\work_plan_figures_04-01-08\Fig_4-11_bathy.mxd



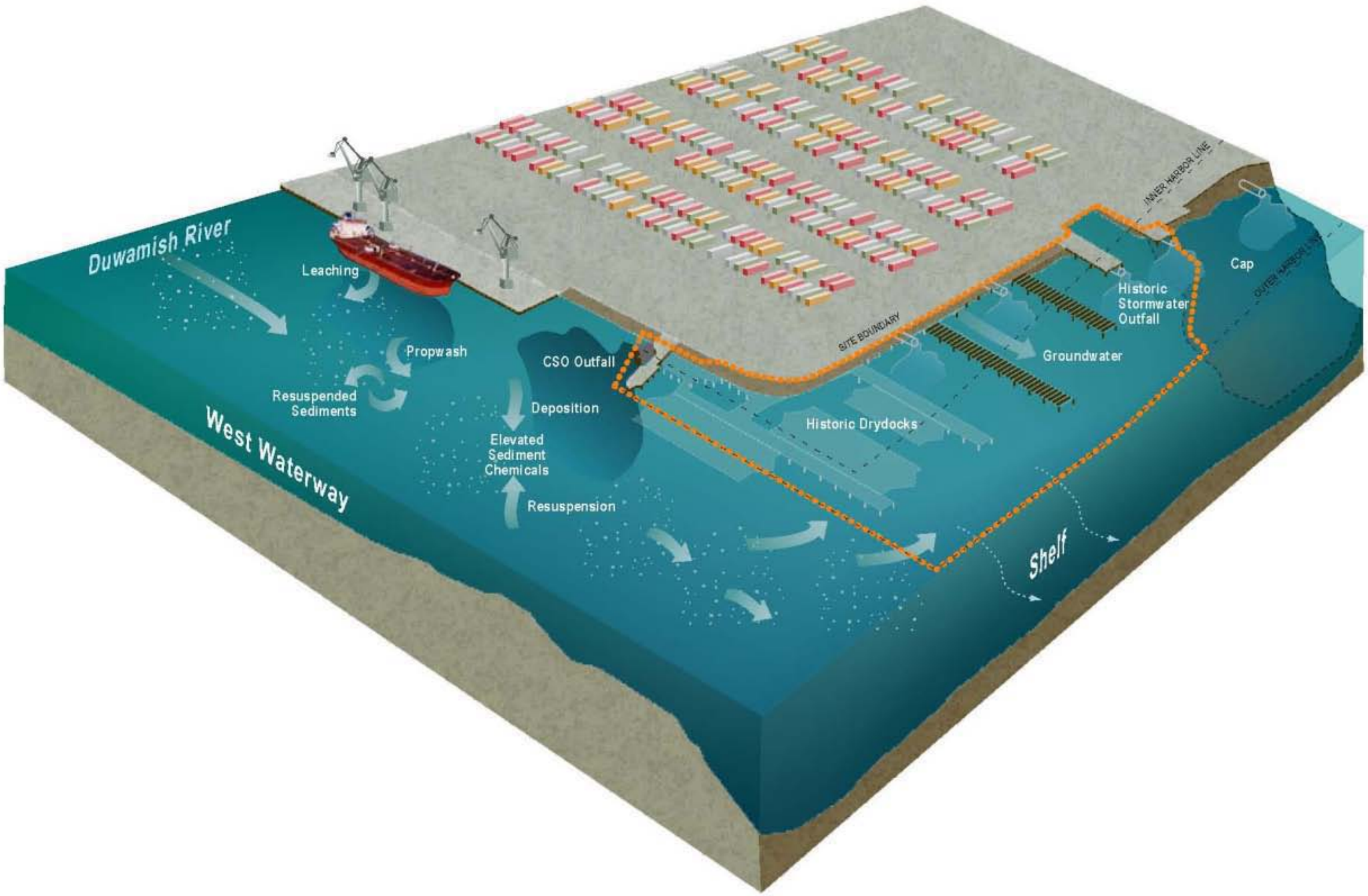
Notes:
1. Harbor Lines from the Washington State Dept. of Natural Resources website (2003).
2. 1998 and earlier sampling locations from SEDQUAL or transposed from plan sheet.

TETRA TECH EC, INC.

Lockheed West
Shipyard No. 2
Seattle, WA

Figure 4-12
Summary of Existing Sediment Sample and Upland Well Locations

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\work_plan_figures_04-01-08\Fig_4-12_wells.mxd



TETRA TECH	**Lockheed West Shipyard No. 2 Seattle, WA**	**Figure 4-13 Site Conceptual Model**

5. PRELIMINARY IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES AND POTENTIAL REMEDIAL ALTERNATIVES

Remedial action objectives (RAOs) provide the foundation upon which remediation alternatives are developed. RAOs are generally developed once it has been determined that significant risks to human health and/or the environments are present at a site. These risks, together with other federal, state, and local regulatory requirements, are considered as the preliminary RAOs are defined.

RAOs are required to support remedial action planning for the Site. The RAOs are needed to clearly articulate the intent of any remedial actions that may be undertaken to address risks to human health and/or ecological receptors at the Site. PRGs are then developed to address the RAOs. PRGs are the target concentrations in the affected media that correspond to the specific RAOs. For example, if the RAO is protection of humans from incidental ingestion of sediments during recreational activities, the PRG may be the concentrations of the COCs that correspond to an acceptable risk level.

Establishment of preliminary RAOs, and associated PRGs, will also enable evaluation of the various remedial alternatives that are identified for the Site relative to their ability to reduce risks to human health and ecological receptors to acceptable levels and their relative costs. The development of RAOs requires a long-term vision for the Site.

5.1 REGULATORY REQUIREMENTS

The identification of federal, state, and local regulatory requirements is a key component in the development of preliminary RAOs and the planning, evaluation, and selection of comprehensive remedial action alternatives. They are necessary to evaluate the appropriate extent of site cleanup, scope and formulate remedial alternatives, and control the implementation of the selected remedial action. A list of preliminary regulatory requirements and ARARs is presented in Section 3.

5.1.1 Preliminary Remedial Action Objective

Restoration of natural resources and their uses has been identified as an important long-term goal for the Site. However, this goal is too general to support the development of meaningful planning, research, and management initiatives for the Site. To be useful, this ecosystem goal must be further clarified and refined to establish specific objectives that are more closely linked with ecosystem science. In turn, more specific ecosystem objectives support the identification of indicators and metrics that provide the information needed to more directly assess the health and integrity of the ecosystem.

The following is a list of preliminary RAOs that have been identified for the Lockheed West Site:

- Reduce site COCs to acceptable levels in sediments that may be acting as an ongoing source of sediment contamination at the site.
- Restore the Site benthic habitats to a condition that will promote a healthy and diverse benthic community.
- Reduce the concentrations of site-related COCs in the tissues of fish and other prey species to levels that do not pose unacceptable risks to ecological and human health endpoints (e.g., tribal, recreational, and worker exposure scenarios).
- Reduce to acceptable levels the risk to tribal members (adults and children) from ingestion of fish and shellfish taken from the site.
- Reduce to acceptable levels the risk to tribal members (adults and children) from dermal contact with contaminated sediments while harvesting fish and shellfish from the site.
- Reduce to acceptable levels the toxicity to benthic organisms at the site.
- Reduce to acceptable levels the risks to fish that feed on benthic organisms at the site.

The focus of the preliminary RAO development is the impact of the contaminated sediments on human health and the benthic invertebrate communities. The preliminary RAOs will be refined and updated as site conditions, COCs, and RAOs become better defined based on additional site information collected as part of the remedial investigation (see Section 12). While such RAOs define the narrative intent that any remedial actions that may be undertaken to address these risks will need to meet, numerical PRGs are also required to support the evaluation of remedial alternatives for the Site. Such PRGs define the concentrations of COCs in the affected media that correspond to the RAOs (i.e., that will be protective of ecological and human health receptors). Development of PRGs is discussed in Section 6.

5.2 POTENTIAL REMEDIAL ALTERNATIVES

As discussed in Section 2.1, risk assessments performed at the LDW Superfund Site have concluded that the cleanup levels mandated under the Washington State SMS (WAC 173-

204) may not meet risk-based cleanup levels for certain contaminants when site-specific input assumptions are used. Given this finding, LMC concluded that No Action and Natural Recovery remediation alternatives are infeasible for meeting risk-based cleanup levels and that more active remediation alternatives would be required throughout the extent of contaminated sediments on the Lockheed West Site. At the minimum, remediation of the Site will consist of placing caps over contaminated sediments identified by the Remedial Investigation as being the result of historical shipyard activities. Other remediation approaches, such as dredging, may also be implemented if site conditions warrant their use.

6. PRELIMINARY REMEDIATION GOALS AND CLEANUP LEVELS

The primary focus of the RAO development is the impact of the contaminated media to the human health and ecological receptors (i.e., endpoints) identified in the baseline RAs. While such RAOs define the narrative intent that any remedial actions that may be undertaken to address these risks will need to meet, numerical PRGs are also required to support the evaluation of remediation alternatives for the Site. Numerical PRGs define the concentrations of COCs in the affected media that correspond to the RAOs (i.e., that will be protective of human health and ecological receptors on the Site). PRGs recommended to support the evaluation of remediation alternatives for the Lockheed West Site are discussed below.

Generally, PRGs that are protective of human health and the environment are developed early in the RI process based on readily available screening levels for both human health and ecological risks. As discussed in Section 3, the key ARARs for this project include the Washington State SMS, CWA, Model Toxics Control Act (MTCA; WAC 173-340), and Rivers and Harbors Act. As per EPA guidelines, PRGs are based on a combination of ARARs and the RAOs that are designed to minimize risks to human health and the environment.

For the Lockheed West Site, PRGs can be identified as SMS for benthic invertebrates, and risk-based concentrations presented in the human health and ecological risk assessment plans (Section 11) for human and ecological receptor exposures, respectively. The following sections discuss SMS as benthic invertebrates PRGs, and the development of risk-based PRGs for human health and ecological receptors.

6.1 BENTHIC PRGS – WA SEDIMENT MANAGEMENT STANDARDS

The Washington State SMS (Chapter 173-204 WAC) provide a basis for the management and reduction of pollutant discharges and guide contaminated sediment cleanup efforts. The SMS are regionally-developed numerical sediment guidelines for the protection of benthic invertebrates. There are two primary types of SMS: source control standards, which define the maximum degree of sediment contamination allowed in sediments impacted by ongoing discharges; and, screening standards, which indicate the maximum degree of sediment contamination allowed before an evaluation of contamination is required.

The SMS define two levels of chemical and biological standards. The more stringent level, the SQS, is the sediment cleanup objective and corresponds to a sediment quality which has no acute or chronic adverse effects on benthic marine organisms. The less stringent level, the cleanup screening level (CSL), is the level above which minor adverse effects may occur in benthic marine organisms. The biological standards are based on results of biological tests that demonstrate adverse effects in benthic organisms that dwell in sediments. If both biological and chemical data are obtained at a site, the biological data determine compliance with the SMS.

According to the SMS, sediment cleanup standards for benthic invertebrates are established on a site-specific basis (WAC 173-204570). The site-specific standard must be between the SQS, which is the cleanup objective, and the CSL, also known as the minimum cleanup level (MCUL). The SMS address standards for chemical concentrations, biological effects, human health, and other toxic, radioactive, biological, or deleterious substances criteria related to sediment quality. The SMS acknowledge the Water Pollution Control Act (Chapter 90.48 RCW) and the MTCA (Chapter 70.105D RCW) as the primary authorizing legislation for establishing sediment source control and cleanup standards, respectively.

6.2 RISK-BASED CONCENTRATIONS AND CLEANUP LEVELS

This section presents the plan for refining the preliminary RAOs and PRGs to determine sediment cleanup levels and performance criteria for the Lockheed West Site. As per EPA (1988) guidance on conducting RI/FS under CERCLA, RAOs are to be developed based upon the results of the human health and ecological risk assessments. RAOs are medium-specific goals designed to protect human health and the environment, and consist of both narrative statements and numerical values as remediation goals (RGs). Narrative RAOs for the Lockheed West Site are presented in Section 5. Numerical PRGs can consist of risk-based concentrations for COCs and other values, such as ARARs and background concentrations. EPA (1999c) guidance further states that RAOs based on the risk assessments should specify the following:

- COCs,
- Exposure routes and receptors, and
- Acceptable contaminant level or range of levels for each exposure route.

As presented in Sections 2.1 and 11, the streamlined approaches to the RI and the baseline RAs are based on the recognition that the “no action” or “natural recovery” alternatives for sediment remedy at the Lockheed West Site would likely not meet risk-based cleanup levels for PCBs because the most stringent cleanup levels would be based on human health risks related to the tribal seafood consumption exposure pathway, and would be very low. This conclusion is based on review of potential RGs and associated sediment concentrations at the LDW Site. The streamlined approach to the RI also recognizes that the most stringent risk-based cleanup levels, particularly for PCBs, could be below background concentrations.

For the Lockheed West Site, the risk-based cleanup levels will be determined for the list of COCs identified in the streamlined risk assessments, and will be acceptable levels for the primary exposure pathways of highest risks, in accordance with EPA guidance. The development of acceptable levels for each COC for each exposure route is a refinement of the PRGs and they serve as risk-based RGs. Additional cleanup levels will be determined for select COCs based on background concentrations, under the assumption that risk-based levels for these COCs will be below background.

In summary, sediment cleanup levels for the Lockheed West Site will be developed based on at least the following:

- Washington State Sediment Management Standards
- Risk-based levels
- Background concentrations for COCs with risk-based levels less than background.

Final cleanup levels will consist of either the risk-based levels or the background concentrations, whichever are greater. The following describes how each of these sets of cleanup levels will be determined for the Lockheed West Site.

6.2.1 Development of Risk-Based Cleanup Levels

6.2.1.1 Approach

Risk-based cleanup levels for Lockheed West Site sediments will be developed as risk-based concentrations (RBCs), which are determined as concentrations for each COC in sediment that correspond to acceptable risk levels for each human health and ecological exposure pathway. The focus of the RBCs will be the protection of the exposure pathways of highest risk for human activities and ecological receptors. RBCs for the exposures of highest risk in a given exposure medium will be protective of all other exposures. The RBCs will be considered to be one of the refined numerical PRGs for the Site, as per EPA (1988) guidance. The RBCs will form the basis for setting both risk-based cleanup levels for Site sediment and risk-based monitoring criteria for post-remedy sediments and capping material.

RBCs will be identified for each COC for each of the major exposure pathways, if data are available. The recent draft RI for the LDW site developed RBCs for a subset of COCs that were identified as the risk drivers, but not for all COCs due to a lack of data or lack of quantifiable relationships between sediment and tissue concentrations at the site. For those reasons, the LDW RI did not develop sediment RBTCs that consider bioaccumulation and consequent seafood consumption risks of cPAHs, arsenic, or dioxins/furans. The major exposure pathways are defined as those presenting the highest risk estimates in the streamlined human health and ecological risk assessments. The selected exposure scenarios are deemed to provide the most stringent (i.e. lowest cleanup level) when considering all populations of receptors that might undergo that exposure. For example, Asian and Pacific Islander seafood consumers are likely to have lower exposures to seafood contaminants than Tribal seafood consumers, and so are not included here. The exposure pathways that will be evaluated in the streamlined RAs and for which COCs will be identified are listed below.

Human Health Risk Assessment

The HHRA exposure pathways will consist of the following:

- Tribal consumption of seafood – indirect exposure to sediment COCs through ingestion of fish, clams, and crabs from the Site;
- Tribal clamming – direct exposure to intertidal sediment COCs through dermal contact and inadvertent sediment ingestion during clam harvesting;
- Tribal netfishing – direct exposure to intertidal and subtidal sediment COCs through dermal contact and ingestion; and
- Child beach play - direct exposure to sediment COCs through dermal contact and ingestion during beach play in intertidal areas.

Ecological Risk Assessment

The ERA exposures will consist of the following:

- Benthic invertebrate community exposures to intertidal and subtidal sediment COCs;
- Fish and crab exposures to intertidal and subtidal sediment COCs; and
- Sandpiper exposure to intertidal sediment COCs.

Estimates of potential health or ecological risk associated with each of these exposures will be determined in the streamlined RAs based on the level of risk for human health or exceedance of toxicity reference values (TRVs), or sediment criteria for ecological receptors. PRGs for benthic invertebrates were identified above as SMS. The RBCs will be identified for the exposure or exposure pathways showing the highest potential risk based on the streamlined risk assessments. RBCs will be concentrations in sediment associated with regulatory risk thresholds for human health and ecological receptors for these exposures.

Once the RBCs are identified for the exposure pathways, the most stringent levels for intertidal and subtidal sediments will be identified as the RGs (risk-based cleanup levels and risk-based monitoring criteria).

6.2.1.2 Sources of Risk-Based Concentration Values

Consistent with the streamlined approach to the RI, human health and ecological receptor exposure pathways in the Lockheed West Site RAs are a subset of those exposure pathways evaluated in the RAs for the nearby LDW Site. The RBCs for Lockheed West sediment will be identified for the Lockheed West exposure pathways as those RBCs and cleanup levels for the same exposure pathways evaluated at the LDW site. The draft LDW RI evaluates risk-based threshold concentrations (RBTCs) for COCs for all exposure pathways for both human and ecological receptors at the LDW (Windward 2007c), and develops RBTCs for some COCs for some of the exposure pathways and ecological receptors. Not all the COCs for the different seafood ingestion scenarios were assigned sediment RBTCs due to lack of quantifiable relationships between tissue and sediment concentrations. Because of the use of exposure pathways and inherent exposure assumptions from the LDW site for the Lockheed West Site (see Section 11, Risk Assessment Work Plan), the RBTCs developed for the LDW Site will be the primary source of RBCs and hence risk-based cleanup levels for the Lockheed West Site. For those COCs for which RBTCs are not available from the LDW site, the final approach to setting cleanup levels for those chemicals at the LDW site will be evaluated for application to the Lockheed West site cleanup.

RBTCs are defined as concentrations for COCs that are associated with various regulatory risk levels; i.e., 10^{-6} cancer risk for human health and HQ of 1.0 for human health noncancer risks and ecological receptor exposures. RBTCs are developed in the draft LDW RI for PCBs, arsenic, and PAHs in sediment for the direct sediment exposures of netfishing, beach play, and clamming, and in clam and fish tissue for exposures due to seafood consumption. The RBTCs for the direct sediment contact pathways are developed essentially by back-calculation from the regulatory risk level, using exposure parameters specific to each scenario, to arrive at a sediment concentration associated with the regulatory risk level.

Sediment RBTCs for seafood consumption are developed in the draft LDW RI from food the web model for PCBs, which was developed using LDW data. An attempt to use regression modeling or simple biota-sediment accumulation factors (BSAFs) developed from co-located sediment and clam data from the LDW to develop tissue-sediment relationships for arsenic and PAHs was found to result in poor relationships. Consequently, sediment RBTCs that consider bioaccumulation of arsenic and cPAHs and seafood consumption were not developed.

Consistent with the streamlined approach to the RI, RBTCs from the LDW RI document will be used as the basis for risk-based cleanup levels for the Lockheed West COCs. For those COCs for which RBTCs are not available from the LDW site, the final approach to setting cleanup levels for those chemicals at the LDW site will be evaluated for application to the Lockheed West site cleanup. An alternative approach to developing risk-based cleanup levels for the seafood consumption scenario for those chemicals lacking RBTCs from the LDW site consists of modeling tissue to sediment relationships with BSAFs. In this approach, BSAFs would be taken from literature sources referenced in EPA-approved LDW documents. If data become available on co-located tissue and sediment samples from Lockheed West Site, or from the LDW site in the future, they may serve as another source for BSAF development.

The draft RI for the LDW Site recognizes that the driving risk scenario for deriving risk-based cleanup levels for the LDW is tribal consumption of seafood, which as mentioned above is also assumed to be the risk driver pathway for the Lockheed West Site. For the tribal seafood consumption scenario at the LDW Site, the COCs driving the cancer risks are total PCBs and arsenic, with contribution from cPAHs. Because it is the driving risk scenario for setting cleanup levels at the LDW site, the procedure for developing RBTCs based on the tribal seafood consumption scenario is described in more detail below. Tissue dioxin/furan results were not available for the LDW project, but it was noted that if tissue dioxin/furan data had been available, that seafood consumption risks would likely have been unacceptable. For the LDW site, sediment dioxin/furan remediation will be based on background levels of these contaminants.

An RBTC for mercury was not developed in the LDW RI, but could be developed from site-specific data in the LDW risk assessments and the RI, or using data from the West Waterway on sediment and tissue mercury concentrations (EPA 2003a). Alternatively, if site-specific clam tissue and sediment data become available for the Lockheed West Site, they may be used to derive BSAF relationship for mercury that could be used to set an RBTC based on seafood consumption. Similarly, if site-specific clam tissue and sediment data become available for the Lockheed West Site, or similar data become available for the LDW RI, they may be used to derive BSAFs for cPAHs that could be used in RBTC development. Although the data have not been reviewed for their applicability for this purpose, the PSR site sediment concentrations of PAHs that were associated with acceptable risk for clam consumption could be used, with adjustments to the intake rates, if necessary, in accordance with the Framework document, to develop RBTCs. Use of data from other sites for the development of BSAFs and RBCs for application to the Lockheed West Site in derivation of cleanup levels would be decided by consultation with EPA.

6.2.1.3 RBCs for Indirect Sediment Exposures: Seafood Consumption

As mentioned above, the tribal seafood consumption pathway is the anticipated risk driving exposure scenario for the Site, based on results from the LDW Site HHRA and the similarity between the two sites. The sediment RBCs for seafood consumption are sediment concentrations of COCs associated with seafood tissue concentrations at acceptable levels of risk based on seafood consumption. The sediment RBCs are calculated from the acceptable tissue concentrations of COCs using acceptable risk thresholds and exposure parameters for tribal seafood consumption, including seafood ingestion rates. The calculation starts with the regulatory risk thresholds of 10^{-4}, 10^{-5}, and 10^{-6} cancer risk, and the non-cancer HQ of 1. For PCBs, arsenic, and cPAHs, the primary risk driver chemicals at the LDW site and assumed risk driver chemicals for the Lockheed West Site, the primary regulatory risk threshold is excess cancer risk. Working backward through standard risk assessment equations, the regulatory risk level is factored in with the exposure parameters for tribal consumption of fish, tribal body weight, and exposure frequency and duration, resulting in regulatory risk threshold-associated fish tissue concentrations of PCBs, arsenic, or cPAHs. From these tissue concentrations, quantifiable tissue-to-sediment relationships are used to determine associated sediment concentrations. Quantifiable tissue-to-sediment relationships can consist of BSAFs or regression relationships, which could be developed for use at the Lockheed West Site, or the food web model that was developed for use with PCBs at the LDW Site.

The above procedures were explored in the draft LDW RI to develop the RBTCs for carcinogenic risk drivers for the indirect exposure pathway of seafood consumption. As mentioned above, BSAFs or regression relationships may be used to develop RBTCs for any risk driver COCs at the Lockheed West Site for which RBTCs have not been developed in the LDW RI, if data are or become available. For dioxins and furans, RBTCs will not be developed in the LDW RI due to the lack of suitable data, and hence sediment dioxin/furan remediation will be based on background levels of these contaminants. In the development of RBTCs for seafood consumption, exposure parameters for tribal seafood consumption will be based on the LDW HHRA, which were developed using exposure parameters from the EPA Framework document. The quantifiable tissue-to-sediment relationships for COCs for the Lockheed West Site will be based on BSAF modeling using either the literature sources developed for the LDW site or site-specific clam tissue and sediment data that may be collected for the Lockheed West Site. Secondary sources may include data from other nearby sites such as the LDW, PSR, or West Waterway Sites. Further discussion on the derivation and use of tissue-to-sediment relationships for setting RBTCs for COCs in sediment is presented below. The quantitation of any sediment-to-tissue relationships for the Lockheed West Site will follow the derivation method used for the LDW Site.

6.2.1.4 Approach to Applying Sediment-to-Tissue Relationship Data to the Lockheed West Site

The above described approach to applying sediment-to-tissue relationship data to the Lockheed West Site is not designed to be highly site specific. As mentioned earlier, the intent of the method chosen for identifying risk-based cleanup levels and performing the risk assessments is to streamline the process. Since the site will be fully remediated, with no evaluation of natural recovery of sediments, identification of site-specific risks is not critical to the remediation, although an assessment of risks is needed to support the need for remediation. As described in Section 11, risks to humans and ecological receptors will be assessed by using exposure scenarios and pathway parameters from the risk assessments performed for the upstream LDW site, in conjunction with site-specific sediment data. The COCs, primary risk driver COCs, and exposure pathways for the Lockheed West Site will be identified through that process. The use of the LDW site parameters for risk assessment or cleanup levels does not entail assumptions about their applicability to the Lockheed West Site, but is intended to provide a means to streamline the process. Cleanup levels need to be sufficiently protective of the exposure pathways and ecological receptor exposures that drive risks at the site. The exposure pathways and ecological receptor exposures that drive risks at the Lockheed West Site are anticipated to be the same as identified for the upstream LDW site, and therefore cleanup levels based on risk-based concentrations from the LDW site will be sufficiently protective of exposures at the Lockheed West Site. As described more fully below, the risk-based cleanup levels that have been developed for risk drivers (i.e., PCBs and arsenic) at the upstream LDW site have been evaluated as being below background concentrations. As such, cleanup levels and criteria for monitoring the performance of the remediation at Lockheed West will likely be background concentrations for those risk drivers, or will be low enough to be sufficiently protective of future human and ecological exposures at the site.

At present, site data on chemical concentrations in clam tissue and collocated sediment samples are not available for the Lockheed West Site for use in deriving site-specific BSAFs. Should such data become available in the future, or if not, should similar data become available for the upstream LDW site, the field data may be used for deriving BSAFs for use in development of RBTCs for the Site. In the absence of any future field data, literature values will be used to derive BSAFs for application to developing RBTCs. Note that the risk assessments will use literature BSAFs for modeling tissue concentrations from sediment data (see Chapter 11). Existing data on clams and collocated sediment chemistry from the LDW site that might be useful for BSAF development are available only for filter feeder clams and are not preferred over literature values for deposit feeder clams. Evaluation of data on collocated clam and sediment chemistry from the LDW in the draft RI did not observe significant relationships between tissue and sediment for either arsenic or cPAHs. The stated reason was likely due to the use of filter feeder *Mya* species that likely had significant water column exposures in addition to sediment exposures (Windward 2007b). A deposit feeding organism would have a stronger relationship with the surrounding sediment. Thus the use of any existing LDW data to derive BSAFs would add a high level of uncertainty to risk estimates and cleanup levels. In addition, BSAFs for the LDW were deemed to be of limited reliability given the decrease in tissue PCB levels that occurred following 2004 tissue sampling.

Should future clam data collection efforts at the LDW site focus on deposit feeders, resultant data would be evaluated for potential application for BSAF development for the Lockheed West Site. However, according to the LDW RI report, deposit feeder clams are not abundant in the LDW, so their future collection from the LDW site is uncertain. Whether deposit feeder clams are present at the Lockheed West Site is also uncertain since a clam survey has not been performed at the Site. Because both the LDW site and West Waterway area of the Lockheed West site are estuarine in nature, both receiving some influences from the Duwamish River, they may have similar clam communities. The Elliott Bay area of the Lockheed West Site is more saline than the West Waterway area; however, it is not known whether the clam community compositions differ between these two areas of the Site.

6.2.1.5 Sediment-to-Tissue Relationships for COCs

Sediment-to-tissue relationships are quantified in the draft LDW RI by two primary approaches: BSAF or regression modeling, and a food web model (Windward 2007c). Consistent with the streamlined approach to the RI, the BSAF approach for evaluating sediment-to-tissue relationships will be preferred. As mentioned earlier, consistent with the streamlined approach to the Lockheed West RI, BSAFs derived from site data may be used as a secondary resource in developing RBTCs for cleanup. Derivation of BSAFs with site data will use collocated sediment and tissue data if they are available for either the Lockheed West Site or the LDW site. The use of the BSAF and food web modeling approaches to derive RBTCs is described in more detail below.

Biota-Sediment Accumulation Factors

As mentioned earlier, consistent with the streamlined approach to the Lockheed West RI, BSAFs derived from site data may be used as a resource in developing RBTCs for cleanup, should they become available in the future. Derivation of BSAFs would use collocated sediment and tissue data on clams. Deposit feeding clams are the preferred species due to their closer relationship with the sediment than filter feeder clams. Whether sufficient abundance of deposit feeding clams for BSAF derivation are available at either the Lockheed West Site or the LDW site is presently unknown. In lieu of field data for BSAF derivation, literature values will be used, as are planned for use in the HHRA and ERA (see Chapter 11).

For any data that might be used from the LDW RI to develop BSAFs for application to the Lockheed West Site, the locations and spatial extent of collocated samples will depend on the exposure area for seafood types, which depends on their relative home ranges within the LDW. For example, collocated data for clams would be based on specific sample station locations in intertidal sediments; collocated data for crabs or fish with small home ranges, such as sculpin, would be taken from intertidal and subtidal sediments on an area-wide scale, with a focus on the sampling areas with the most marine habitat (i.e., probably excluding upstream areas); and collocated data for English sole would be based on the full intertidal and subtidal data set from the LDW site on a site-wide sampling basis. The LDW ERA and RI present analyses of relationships between chemicals in sediment and those in tissue collected from the LDW that tend to support smaller home ranges for sculpin and shiner surf perch on an area basis, and larger home ranges for English sole and crab on a site-wide basis.

Food Web Modeling

As part of the RI for the LDW Site, the LDW Group has developed a food web model (FWM) that predicts total PCB concentrations in tissue of fish and crabs from sediment PCB concentrations. The FWM was used in the draft RI for the LDW Site to translate acceptable RBCs in fish and crab tissue into RBTCs for sediment. If modeled relationships were needed for chemicals at the Lockheed West Site, the food web model could be used to model RBTCs for other hydrophobic organic compounds in the LDW for subsequent application to the Lockheed West Site. Since the intent for the Lockheed West RI is to streamline the approach to identifying cleanup levels, including borrowing directly from the LDW site, the use of food web modeling is considered a tertiary resource to simple BSAF or regression modeling based on field data, or the use of BSAFs from the literature.

The food web model being developed for PCBs for the LDW site data could be adapted to relate sediment and tissue concentrations for other chemicals for the Lockheed West Site. The habitat parameterization of the LDW food web model was determined through several technical memoranda (Windward 2005b,c). If the food web model were to be used to develop sediment RBCs for additional COCs at the Lockheed West Site, the model could use the established parameterization for the LDW in primarily marine areas as the habitat most similar to the Lockheed West Site.

6.2.2 Identify Sediment Cleanup Levels

The RBCs for the Lockheed West Site, as identified or developed as per the above approaches, will be used as refined numerical RGs for the Lockheed West sediments, following EPA guidance on developing cleanup levels for contaminated sites under CERCLA. Since these refined numerical RGs are based on the RBCs, they are defined as risk-based RGs or risk-based cleanup levels for the site sediment. As described above, the risk-based RGs as developed from RBCs will be based on the RME risk driver scenarios for the Site. The primary risk driver scenario for sediment cleanup is expected to be the tribal consumption of seafood, as it has been identified for the LDW site. The RBCs for the tribal seafood scenario will be developed from the RME exposure parameters, including tribal seafood consumption rates, that are documented for RBTC development in the LDW draft RI, which follow from the EPA Region 10 Framework, which includes consultation with the affected tribes. The RME tribal exposure for the Lockheed West site will be parameterized using Tulalip survey data. Selection of whether Tulalip or Suquamish consumption rates constitute RME will be made in consultation with the tribes.

These risk-based cleanup levels will be compared with background concentrations of the COCs to determine whether a cleanup to the risk-based levels would be achievable. Based on the preliminary analyses from the nearby LDW Site, it is anticipated that risk-based cleanup levels for carcinogenic COCs at the Lockheed West Site that are determined from the tribal seafood consumption exposure pathway will be less than background concentrations. As per EPA (2002b, 2002c) and Ecology MTCA guidance (WAC 173-340) on cleanup of hazardous waste sites, cleanup below background is not feasible for long-term remedy and would not be required. Due to the urbanized region of the Lockheed West

Site location, regional background concentrations of COCs in sediment may be the lowest values achievable for site cleanup. In this case, background concentrations of COCs become the cleanup levels for the site sediments (EPA 1999c).

Based on the above, the suite of cleanup levels for the Lockheed West Site sediments will be identified in the RI as the following:

1. Risk-based cleanup levels developed from the RBTCs and RBCs for the LDW Site, including any RBCs developed from LDW site data or Lockheed West Site data, and SMS for benthic invertebrates. Use of established RBTCs as risk-based cleanup levels assumes that the primary risk COCs for Lockheed West sediment will be total PCBs, arsenic, and cPAHs. For other potential COCs such as mercury and other metals, risk-based cleanup levels for the Lockheed West Site may be developed using data from the LDW and possibly other sites, or from site-specific data if available.
2. Background concentrations of COCs, as determined through site-specific sampling or as previously determined at nearby sediment sites. Issues with determining background concentrations of COCs for the Lockheed West Site are discussed below.

From this suite of cleanup levels, the final cleanup level for each COC in sediment will consist of either the risk-based level or the background concentration, whichever is greater.

6.3 DETERMINATION OF BACKGROUND CONCENTRATIONS

The approach for determining background concentrations for evaluation as cleanup levels will be documented as the RI process ensues. For the purposes of this work plan, the discussion on background concentrations focuses on the present usage under State of Washington guidelines. Background determination for the Lockheed West Site for use in the RI/FS to set cleanup levels will follow the approach of the final RI for the LDW site, and will be appropriate for the Lockheed West Site. The final approach will be determined with EPA. At present, the draft RI for the LDW site presents background data for natural and urban areas, based on data collected from the Puget Sound area, intra site data, and upstream of the site. The application of these data to determining background for the cleanup of the LDW site is still to be determined with EPA and Ecology. The specific approach or application of the LDW approach to the Lockheed West Site RI will be developed in the future.

Both EPA and Ecology recognize two types of background, natural and urban (also referred to as anthropogenic or area), although their definitions and uses differ. The most important difference is in the potential application of urban or area background concentrations in making risk management decisions. Since the Lockheed West site is under EPA lead, the approach to background that Ecology uses is not considered applicable to the site. EPA generally does not require cleanup levels below urban background concentrations because of the potential for recontamination from sources unrelated to the site, cost effectiveness, and technical practicability (EPA 2002d). Under Ecology’s regulations, when area background concentrations would result in recontamination of the site to levels that exceed cleanup levels, that portion of the cleanup action that addresses cleanup below area background concentrations may be delayed until the offsite sources of hazardous substances are controlled. In these cases, the cleanup action will be considered an interim action until cleanup levels are attained.

Background concentrations of COCs at the Lockheed West Site will be determined after consultation with EPA and stakeholders. Preliminary discussion of background concentrations include identification of potential data sources, as summarized in the following sections. The approach to identification of background concentrations will be further refined through technical workshops with EPA and the project stakeholders. Details of the approach stemming from the technical workshops will be documented and submitted for review and approval.

6.3.1 Existing Background Data

Data on existing background concentrations of COCs for Puget Sound are presently available from two sources. (1) Metals in sediment are available as background concentrations from the PSAMP program and may be available from the Ecology SEDQUAL database. (2) Background concentrations for PAHs have been identified for Puget Sound sediment in the RI for the PSR Site (Weston 1998a). These background data may be used for development of area or natural background.

6.3.2 Site-Specific Background Data

Background concentration data for arsenic and organic chemicals (e.g., PCBs and PAHs) that are identified as COCs may be collected as part of the RI for the Lockheed West Site. The identification of appropriate background areas and approaches to determining background will be decided after consultation with EPA.

6.3.3 Background Concentration Data from the LDW Site

Background concentration data for COCs (e.g., arsenic, PCBs, and PAHs) have been compiled from the LDW in the draft RI for the LDW Site, as mentioned above. Background concentrations of PAHs in Puget Sound have also been compiled for the PSR site. Any data collected on background for nearby sediment sites, particularly the LDW, will be evaluated for potential application as background to the Lockheed West Site, in consultation with EPA.

7. SEDIMENT STABILITY

The stability of the sediments within the Lockheed West Site will be evaluated to ensure the long-term integrity of potential capping materials at the Site. The evaluation of sediment stability will be conducted using a three-tiered approach, (1) evaluation of existing data on bathymetry, subsurface sediment quality, sedimentation rate and flow characteristics for the West Waterway and Elliott Bay (completed as part of this work plan; see Section 4.4), (2) collection of subsurface chemical data (to be completed as part of the proposed site investigation activities; see Section 8), and (3) numerical modeling using wind, current, and propeller scour predictions.

Sediment stability at the Site will be indicated by evidence of the burial of historical shipyard contamination, the presence of newly deposited material transported from the Duwamish River and Elliott Bay, the absence of significant geomorphic features indicative of scour or failure, a net sedimentation rate, and evidence of increasing site elevations over-time.

In addition to the existing and supplemental data evaluations completed for Tiers 1 and 2, numerical modeling will be conducted to evaluate the potential effects of wind, waves, currents and propeller wash on site sediments.

7.1 EVALUATION OF EXISTING DATA (TIER 1)

Tier I analysis relies on existing data on bathymetry, subsurface sediment quality, sedimentation rate and flow characteristics for the West Waterway and Elliott Bay to determine the long-term stability of sediments at the Site. Stability will be indicated by evidence of sediment burial over-time. Characteristics of a stable environment at the Site are the burial of historical shipyard contaminants and infilling of site features over-time. Evaluation of the potential burial rate will consider indicator contaminants unique to the shipyard and the operational history.

The following data will be considered as part of the initial evaluation tier.

- Review existing sediment quality data to identify subsurface sediment chemical concentration trends indicative of an accretional environment.
- Existing geotechnical data will be reviewed to determine the physical characteristics of sediment at the Site (Hart Crowser 1995 and Enviros 1990). Sediment physical characteristics, such as grain size can be representative of the depositional energy within the site area. It can also be used to help identify potential cap material types and grain sizes.

- The most recent bathymetric survey (Tetra Tech 2006) will be reviewed to identify geomorphic features on the seafloor that may be indicative of sediment scour, land slides and other actions that may impact sediment stability.
- Previous bathymetric surveys will be qualitatively compared to the most recent bathymetric survey to identify areas of potential sediment erosion or accretion over-time.
- Subsurface sediment chemical concentration trends will be evaluated to determine if surface COC concentrations are increasing, remaining stable, or decreasing. Decreasing surface COC concentrations are indicative of sediment deposition and stability, and can potentially be correlated with a regional sedimentation rate for Elliott Bay.

7.2 EVALUATION OF SUBSURFACE SEDIMENT QUALITY (TIER 2)

Tier 2 evaluation of sediment stability will utilize the supplemental subsurface sediment quality data collected as part of the RI/FS field investigation. The supplemental subsurface sediment quality data will be used to confirm the sediment chemical trends identified in the Tier 1 analysis.

The following data will be considered as part of the Tier 2 evaluation:

- Subsurface sediment quality data, generally collected in one-foot intervals at select locations, will be evaluated for concentration trends indicative of sediment deposition and stability.

7.3 EMPIRICAL MODELING EVALUATION (TIER 3)

Tier 3 will include numerical modeling of wind, waves, currents and propeller scour. The sediment dynamics of the Site will be evaluated using an empirical model. This modeling will provide information on how hydrodynamic forces such as wind-induced waves, currents, and vessel wakes and propeller scour impact sediment transport, bottom and shoreline sediment scouring, and sediment accumulation in the project area. The results of the modeling evaluation will be used to determine the cap erosion potential. Erosion from wind-induced waves, currents, vessel wakes and propeller scour can reduce cap thickness and degrade slope stability. Input parameters for the modeling evaluation will be obtained from existing site information when possible, or adjacent representative site information. Additional numerical modeling, if not completed as part of the RI/FS, may be performed as part of the remedial design.

8. SAMPLING AND ANALYSIS

This section provides an overview of, and strategies for the remedial investigation field sampling and data gathering activities. Detailed descriptions of the activities are presented in the supporting project SAP, QAPP, and HASP (Appendices C - E to this Work Plan).

8.1 OVERVIEW OF SEDIMENT SAMPLING AND ANALYSIS

8.1.1 Data Quality Objectives

The rationale for the sampling approach is based on the assessment of existing data and identification of data gaps (see Section 4.9). EPA's seven step Data Quality Objectives (DQOs) process was followed to develop all the data collection efforts (e.g., Guidance on Systematic Planning using the DQOs Process (QA/G-4), EPA 240/B-06/001 Feb 2006), and provides the technical and decision-making basis for the collection of all data. Table 8-1 summarizes the results of the DQO development process for the identified data gaps.

8.1.2 RI Sampling Summary

The primary objectives of sediment sampling and analysis are the support of the spatial resolution of chemical contaminant distribution to identify areas and volumes of sediment that may require active remediation, to characterize exposure and consequent risk for human and ecological receptors. Several of the RI activities described below have been implemented. The bathymetric and shoreline surveys were conducted in the summer of 2006. The subtidal sediment and background range finding studies were conducted in January 2007 and intertidal sediment sampling was conducted in April 2007. Data collected as part of these activities will also support the assessment of sediment contaminant mobility, the potential for sediment recontamination, and physical characterization of the Site.

The consulting team is responsible for the tasks associated with the collection of sediment and site characterization data for Lockheed West. The scope of work includes the following:

- Collection and analysis of samples for chemical, conventional, and physical testing; and Site characterization for remedial design planning; and
- Data analysis, interpretation, and reporting (see Sections 10 and 13).

The organization of activities and field procedures required to meet the DQOs and overall objectives of this work are described in the Site Characterization SAP (Appendix C). This SAP and the other RI documents (QAPP, HASP) were prepared following the general guidance provided by the EPA for conducting investigations at Superfund sites and by Ecology.

Following approval of these RI Work Plans by the EPA, field crews were mobilized to collect the required environmental samples and physical data. All samples and field data were collected in accordance with the procedures outlined in the SAP and QAPP (Appendix C and D, respectively). Environmental samples were submitted for testing and analysis in accordance with the requirements of the QAPP.

A synopsis of the RI field program is provided below. Based on the summary of existing information, knowledge of historical site uses, future site plans, and recent high-resolution site bathymetry, the Site was divided into general use areas (Figure 8-1). These general areas were used to focus the selection of additional sampling needs, as explained below. Surface data will be used to define potential remediation areas. Subsurface data will be used to define the maximum potential dredging depth and will indicate whether any of the sediments may be suitable for disposal under the PSDDA program. A full PSDDA characterization is not being performed during the RI sampling activities.

Surface Sampling. Surface sampling was conducted as part of the field effort to ensure that the surface sediments are undisturbed and not impacted by the other RI field activities. Sample locations were selected to be representative of the surface sediment conditions and to provide adequate spatial coverage of the Site based on the historical site uses. Surface samples were used for bulk chemical analysis.

Subtidal surface samples were collected using standard van Veen grab methods deployed from a work vessel. Intertidal bank samples were collected with bowls and spoons at low tide to allow field personnel to assess the slope and substrate for optimal sampling locations.

Subsurface Sampling. Subsurface sampling was performed using a vibracore system. Data gathered from the subsurface cores will be used for characterization of the subsurface material, sediment chemical characterization, and dredgability and contaminant mobility testing. Sample locations were selected to provide adequate spatial coverage of the Site based on historical site uses and previous sediment core results. The coring system was operated from a work vessel.

Most subsurface cores were advanced beyond the deepest extent of PRG exceedances indicated by the existing data or to native material, expected to be an approximate elevation of -45 feet MLLW, which is the historical dredging depth. Several cores were advanced to -53 MLLW, the maximum depth potentially required for navigation. The primary objective was to determine the vertical extent of sediment potentially requiring remediation. Subsurface sediment intervals may also be used to support a preliminary PSDDA evaluation in the area south of the property boundary along the West Waterway. The Port of Seattle may expand Terminal 5 into this area. If this preliminary evaluation indicates that PSDDA requirements have a reasonable probability of being achieved, LMC will discuss the need for a full PSDDA characterization with EPA.

In areas where removal may be a feasible remedial option, a sediment composite representative of the potential dredge prism was created from representative subsurface core intervals to support contaminant mobility testing. The specific elements of the investigation are summarized in the following sections and discussed further in the SAP (Appendix C).

8.2 IDENTIFY EXTENT OF SEDIMENT CONTAMINATION EXCEEDING PRGS

Sediment sampling and analysis as performed in accordance with the SOW for the purpose of identifying the extent of chemical concentrations in sediment that exceed the PRGs protective of human health and the environment as described in Section 6. Sediment sampling was performed in the general vicinity of the Lockheed West property boundaries. Sediment samples included surface (0 to 10 cm) grab samples and subsurface core samples. All sampling, handling, and analyses was performed in general accordance with EPA-recommended methodology and PSEP protocols. The sampling program included evaluation of intertidal and subtidal surface and subsurface samples for the COCs. Sediment sampling was performed at 51 locations throughout the Site as shown on Figure 8-2. Subsurface and co-located surface sediment sampling was performed at 35 locations, surface sediment sampling only will be performed at 7 locations, and nine discrete intertidal bank samples are collected along the shoreline. The rationale for samples is included in Table 8-2. In addition, 7 locations in Elliot Bay were sampled to find a range of background-like locations. The rationale for the range-finding background sample locations are discussed below.

8.2.1 Surface Sediment Samples

Surface sediment samples were collected to determine the horizontal extent of COIs exceeding PRGs and the exceedances of human and environmental health risk-based concentrations. COIs consist of the SMS parameters with SQS and CSL chemical criteria as well as bulk sediment TBT and supporting conventional parameters.

The surface sediment samples are comprised of the top 0 to 10 cm at three types of locations:

- Forty-two surface samples collected from the subtidal areas of Lockheed West;
- Representative samples (up to nine) collected from the intertidal bank areas of Lockheed West and analyzed for COIs; and
- Seven Range-finding background samples collected from around Elliot Bay for comparison to the Lockheed West Property samples.

Subtidal Surface Sediment Samples. A total of 42 surface samples, representative of the upper 10 cm of sediment, were collected at 42 locations in the subtidal area for the purposes of determining surface sediment quality and establishing the locations of chemical "hot spots." Samples collected from the subtidal portion of the Site were collected using a van Veen grab sampler deployed from a work vessel. Additional sediment was collected at all the surface grab locations and archived for potential PCB Congener analysis. Additional sediment was archived for potential dioxin/furan analysis at two locations (i.e., 38 and 39). Additional material was collected at 7 surface sediment sample locations for the analysis of porewater for the COIs.

Intertidal Surface Sediment Bank Samples. Waterway bank areas are representative of nearshore surface sediments that may be impacted by eroding banks, historical and current outfalls, seeps, or surface runoff. These areas are also subject to deposition of suspended particulate material that may be re-suspended during storm events, from vessel wakes, or during dredging within the waterway. No data exist on the condition of the banks. Based on a visual survey of the Lockheed West bank areas, four bank segments have been identified. Designation of bank segments considered similar physical attributes, potential significant sources, and current property ownership.

Sediment samples were collected from the intertidal bank areas for the purpose of determining the sediment chemical concentrations and extent of sandblast grit, defining the location of chemical "hot spots," and determining the intertidal sediment physical characteristics. These data will also provide data that will define the upper (shoreward) boundary of the sediments in Lockheed West.

To characterize the upper portion of the slope (intertidal zone), samples were collected along the Site shoreline bank (locations IT-1 through IT-9). Each sample is comprised of a discrete sampling location and analyzed for COIs. The samples were collected from the top 10 cm of silt and/or sand, either at the sediment/riprap interface at the top of the slope or along the exposed bank slope if no riprap is present. The bank locations are shown on Figure 8-2. Locations were determined in the field, based on the results of the low tide habitat and structure survey. Areas that were avoided are rip rap and areas with little sediments. In the event that a suspected source material was identified, the location documented, a discrete sample was collected, and EPA will be notified. A sufficient volume of sediment will be collected from each location for analysis of the COIs listed in Table 8-3. The location of each discrete sample, tidal elevation, material description, and identification of suspected source material documented and presented in the RI Data Collection Report.

Rangefinding Samples. Proposed cleanup actions at the Lockheed West Site requires characterization of background sediment quality conditions. Background sediment quality concentrations for the Lockheed West COCs will be used as site cleanup objectives if risk-based cleanup numbers based on the human health and ecological risk assessments are determined to be below background. In this case, use of background sediment concentrations as cleanup objectives would represent the lowest, practically achievable sediment quality condition within the greater Elliott Bay system. Determination of the sediment background concentrations for the LW site will be conducted in conjunction with EPA. However, the process of establishing background is likely to require sampling and chemical analysis of sediment samples from Elliott Bay to determine the potential range in the concentration of COCs. To begin this process, LMC collected rangefinding sediment samples from greater Elliott Bay as part of the RI field sampling effort.

Elliott Bay is an urbanized water body subject to multiple natural and anthropogenic processes that affect background concentrations (Figure 8-3). The background range finding process was intended to identify a representative range of concentrations for Lockheed West contaminants of concern throughout Elliott Bay through sampling and chemical analysis of sediment samples collected from within the bay. Based on the sampling and analysis results, the range of concentrations for the Lockheed West contaminants of concern will be analyzed to determine if the samples collected are representative of the background sediment quality condition and are not directly affected by anthropogenic or natural processes. Sampling locations showing uncharacteristically high concentrations, relative to the other location samples, would be considered to be non-representative and therefore, not considered in the determination of cleanup objectives for the Site. Additional field sampling would be performed if necessary, if the initial characterization does not yield a data set sufficient to characterize a background characteristic of Elliott bay.

Objectives and rationale for the selection of proposed Elliott Bay background sediment concentration rangefinding sampling locations are described below. Sampling and analysis of the proposed locations was performed in conjunction with the surface sediment sampling effort.

Objectives for selection of urban background sediment quality sampling locations include the following:

- Sample areas that are representative of the overall ambient sediment quality condition,
- Sample in areas that do not have a potential to be biased by known or suspected contaminant sources,
- Sample at depth ranges comparable to those of Lockheed West Site (e.g., less than 45 feet MLLW), and
- Sample sediments that are comparable to those of Lockheed West Site (e.g., %TOC, grain size).

Locations and Rationale. Proposed Elliott Bay background sediment concentration range-finding sampling locations are presented on Figure 8-3. Rationale for selection of the proposed locations is presented below.

- Sampling Location 1 is representative of northern Elliott Bay and is the same as the LDW background site 2. This site is situated near the Magnolia marina and Terminals 90 and 91 and will be located at depths that are comparable to those of Lockheed West. This location is not in the immediate vicinity of known outfalls or industrial use areas that may provide point sources of contamination.
- Sampling Location 2 is representative of northern Elliott Bay and is the same as the PSR background location “BK02.” This location is situated along a municipal park and is at depths that are comparable to those at Lockheed West. This location is not in the immediate vicinity of known outfalls or industrial use areas that may provide point sources of contamination. The location is not situated within an area to have been subject to anthropogenic disturbances. The nearest industrial use is the Port of Seattle bulk grain loading facility.
- Sampling Location 3 is representative of the eastern portion of Elliott Bay. This location is situated along the central waterfront of Downtown Seattle. This location is not in the immediate vicinity of known outfalls or industrial use areas that may provide point sources of contamination. The location is not situated within an area to have been subject to anthropogenic disturbances. Uses of areas near the sampling location are primarily commercial and maritime transportation.

- Sampling Location 4 is representative of the southeastern portion of Elliott Bay. This location is situated along the large container dock south of the central waterfront of Downtown Seattle. This location is not in the immediate vicinity of known outfalls or industrial use areas that may provide point sources of contamination. The location is situated within an area that was last dredged in 1979. Uses of areas near the sampling location are primarily commercial and maritime transportation.
- Sampling Location 5 is representative of the southern portion of Elliott Bay. This location is situated along the north shore of Harbor Island. The location is not in the immediate vicinity of known outfalls. The nearshore and onshore areas located near the Site are used for maritime commerce purposes such as tug boat storage and shipbuilding. The location is not situated within an area to have been subject to anthropogenic disturbances. Sediment cleanup has been completed at the shipyard facility to the west of the proposed sampling location.
- Sampling Location 6 is representative of southwestern Elliott Bay. This location is situated along the west shore Harbor Avenue. This location is not in the immediate vicinity of known outfalls or industrial use areas that may provide point sources of contamination. Uses of areas near the sampling location are primarily public access, municipal parks, and commercial businesses. The location is not situated within an area to have been subject to anthropogenic disturbances. Sediment cleanup has been completed at the PSR facility to the east of the proposed sampling location.
- Sampling Location 7 is representative of western Elliott Bay. This location is situated along the west shore Harbor Avenue. This location is not in the immediate vicinity of known outfalls or industrial use areas that may provide point sources of contamination. Uses of areas near the sampling location are primarily public access, municipal parks, and commercial businesses. The location is not situated within an area to have been subject to anthropogenic disturbances.

Sampling Approach. Surface sediment samples (0 to 10 cm) were collected from the locations using a grab- type sampling device deployed from a work vessel. On collection, sediment samples were observed to ensure that the sampling objectives (described above) were met. Acceptable samples were submitted to the analytical laboratory for chemical analysis. In the event a given sample location did not yield a sample meeting the above objectives, a second attempt was made at an alternative location in the vicinity of the proposed location. In the event the second sample location did not yield a sample meeting the above objectives, a third attempt was made at an alternative location in the vicinity of the proposed location. In the event the third offset sample is found to be unacceptable then the proposed location was be sampled.

8.2.2 Subsurface Sediment Sampling and Analysis

Subsurface coring was performed primarily using a vibracore system. Sample locations were selected systematically to provide adequate spatial coverage of the Site. The coring system were operated from a work vessel.

Chemistry Sample Collection. Subsurface sediment cores were collected at 37 co-located surface sample locations to determine the vertical extent of chemical concentrations in subsurface sediment exceeding the SQS or CSL chemical criteria and to determine volumes of sediment that may require remediation. The primary objective will be to determine the vertical extent of sediment requiring remediation down to native material or a maximum elevation of -53 MLLW. This is the deepest elevation that would be required for navigation. Therefore, based on site bathymetry and proposed locations, cores ranged from approximately 3 to 20 feet in length. Each subsurface core was logged and subsampled in the field. Sample intervals were generally divided by considering sediment stratigraphy and then into 1-foot intervals or as required volumes for chemical analyses. A minimum of two sample intervals were analyzed from each core. Selection of samples to be submitted for chemical analyses was representative of the various subsurface sediment types observed based on the visual observations and core logs. A relatively uniform subsurface sediment stratigraphy is expected within the Lockheed West Site; therefore, an estimated two to three sediment sample intervals from each core was submitted for chemical analysis (Table 8-3). As co-located surface sediment samples (0 to 10 cm) will be collected at each core location, an estimate of four samples (three core intervals and one surface) may be submitted for analysis at each location. The remaining core intervals were collected and archived and held under chain of custody for determination as to which additional samples may need to be submitted for analysis.

Contaminant Mobility Sample Collection. Two sediment composite samples representative of the potential dredge prism were created from the cores to support sediment contaminant mobility testing. Each composite was volume weighted (equal volume from unit length) from all cores based on chemical analyses and sediment stratigraphy as necessary to create a representative composite. Multiple cores were necessary at any one location to collect adequate volumes for the planned analyses. Further discussion of contaminant mobility is included in Section 8.4.

8.2.3 Marine Biota Tissue Sampling

The relationship between surface sediment chemical concentrations at Lockheed West and the potential for adverse bioaccumulation of COPCs will be evaluated using a literature-based Biota Sediment Accumulation Factor (BSAF) approach consistent with the LDW, as described in Section 11. Field sampling and analysis of biota tissues collected from the Site may be performed to further refine the BSAF evaluation. Consistent with the tissue sampling approach used at the LDW, clams will be targeted for sampling and analysis, if found to be present in sufficient quantities to provide samples representative of the LW Site.

Due to the relatively steep shorelines, habitat for clams at the site is limited. At EPA's request, LMC has agreed to complete a field reconnaissance survey at the Site to identify the presence and abundance of clams. Detailed plans for the field reconnaissance will be developed in conjunction with EPA. The general approach will be to survey the surface sediments within clam habitats at the site for evidence of their existence and relative abundance.

The field reconnaissance data will be used to determine if tissue sampling is warranted and to develop tissue sampling and analysis plans, should testing be found appropriate. If clam data collection activities are found to be needed, more detail on the sampling approach will be developed in conjunction with EPA.

8.3 PHYSICAL CHARACTERIZATION

8.3.1 Multibeam Bathymetry

Bathymetry work has been completed for the Site to support sampling location control and remedial design planning and evaluations. This work is discussed in Section 4 and included in Appendix B. The bathymetric survey of the open water area, shipways, and underpier areas was performed to provide existing elevations throughout the Site. The new survey is used to develop a basemap for remedial design activities, including volume calculations, debris, area definitions, sampling positioning, etc. The key components of the survey are identified below:

Open Water Bathymetry. High resolution multibeam bathymetry data were collected on May 20, 2006 throughout the Site. Horizontal positioning is based on North American Datum (NAD) 1983 and vertical positioning was based on the Port of Seattle MLLW datum for Elliott Bay.

Location of Existing Piling. The approximate locations of underpier support pilings were determined based on locations of exterior pilings, typical piling spacing.

Shipway Details and Bathymetry. The approximate layout of the shipway and associated piling was identified to the extent possible using field measurements and drawings as available. Elevations of shipway ramp and mudlines below ramp were determined where accessible.

Location of Debris and Large Obstructions. The location of significant debris accumulation and other large obstructions which were encountered during the surveys were noted and identified on the basemaps. Significant debris and/or obstructions can impact the feasibility and cost for dredging and/or capping.

Outfall Locations. This survey identified the location of visible and accessible outfalls on the Site (e.g., Florida Street combined sewer outfall).

8.3.2 Topographic Survey

The purpose of the topographic survey is to document the current upland elevations to tie in the current bathymetry survey. This survey provides additional data that will be used during the FS and design. A survey firm licensed in Washington conducted a full-coverage topographic survey of the upland area adjacent to Lockheed West Site. The survey area extended from the top of the shoreline bank to the water's edge.

8.3.3 Shoreline Conditions Survey

The purpose of the shoreline conditions survey is to document the current physical conditions such as existing habitat and structures along the shoreline at the Lockheed West Site. This survey was conducted in advance of the other RI field efforts to take advantage of the available daytime low tides. The survey was performed August 9, 2006, during a daytime low tide (predicted as -2.6 feet MLLW at 11:26 am) to maximize the extent of the survey. A small vessel was used to access the Site. A field team consisted of three personnel (a senior benthic ecologist, a senior engineer, and an additional environmental scientist or engineer, all with sediment remediation experience). In addition to the small vessel used to access the Site and the required marine safety equipment, the field team were equipped with personal protective equipment, a video camera, a digital camera, a hand-held GPS unit, a surveyor's tape, and field log books. The existing habitat, presence or absence of biota, existing structures, and presence of any groundwater seeps was documented with field notes and digital camera and or video. A technical memorandum summarizing the survey will be included in the RI report.

8.3.4 Physical Testing

Characterization of the physical properties of the Lockheed West sediments was accomplished to provide the information necessary for an evaluation of remedial options. Physical properties analysis of the sediments was conducted on selected samples to identify and estimate the dredge and disposal characteristics of sediments likely requiring removal and confinement. Physical characterization testing included the following:

- PSEP grain size, percent solids, and TOC were determined at all surface and subsurface locations.
- In addition, samples from the subsurface cores (discussed in Section 8.2.2) were submitted for:
  - Atterberg limit determinations by American Society for Testing and Materials (ASTM) Method D4318-84; and
  - Sediment specific gravity determination by ASTM Method D854.

Test results will be used to characterize the sediments, evaluate sediment transport, and assess the feasibility of removing and/or capping impacted sediments. Specifically, these tests will be used to estimate the dredgability, water generation during dredging, and bulking of sediments subjected to different types of removal techniques.

Specific procedures for sediment sampling handling and analysis to support these sediment physical characteristics testing are presented in the SAP (Appendix C) and the QAPP (Appendix D).

8.3.5 Sediment Stability

As discussed in the Data Gap Analysis section, results of high resolution multibeam bathymetry data do not indicate significant erosional features at the Site. There is no evidence of mass sediment redistribution at the site as shown by the presence of historically contoured bottom features, such as drydock areas and former pier areas. Sediment stability is important to evaluate because it impacts the potential remedial actions that can be proposed for the Site. If the sediment is unstable, then contaminated subsurface sediments may become re-exposed or a sediment cap may be subject to erosion.

A radioisotope study was performed for the Harbor Island Sediment OU as part of the Harbor Island SRI to determine sedimentation rates within the West Waterway (EVS 1996). The results of that natural recovery evaluation demonstrated that the West Waterway is a depositional area with sedimentation rates on the order of 1 cm/yr. These results can be applied to Lockheed West, where conditions in the open water areas are similar to those measured and modeled in the West Waterway (e.g., similar water depths, location relative to the bay and river influences). Seafloor conditions at Lockheed West are expected to be more quiescent, thus more suitable for capping. Because routine dredging is not required or necessary at the Lockheed West Site, conditions are favorable for long-term contaminant isolation.

Of primary concern regarding the long-term stability of Lockheed West surface and subsurface sediments is its exposure to erosion forces from Elliott Bay and within the West

Waterway. Erosion from wind-induced waves (including storm events), currents, and vessel wakes (and particularly propeller wash) may disturb bottom sediments and degrade slope stability of the Site. The potential for erosion in the intertidal and subtidal zones will be determined based on current velocities, wave-induced scour, and propeller wash.

The evaluation for erosion will be divided into two main components: evaluate existing physical characteristics and modeling evaluation.

- **Physical Characteristics Evaluation.** Existing and proposed sediment grain size data in the open water areas will be examined to help determine potential cap material type and grain size. The existing grain size will indicate the minimum cap grain size required to prevent significant erosion at the Site.
- **Modeling Evaluation.** Both empirical and numerical models may be used to determine current and wave impacts, and cap erosion potential. These models may include, but are not limited to Coastal Engineering Research Center's Automated Coastal Engineering System, USACE STUDH, propeller wash modeling (PROPWASH), and ship-induced waves (SHIPWAVE). Input parameters for the models will be obtained from existing site information.

Existing information provides typical ranges of current velocities within the West Waterway and in the vicinity of the Lockheed West Site that will be used to evaluate erosion potential.

8.4 ASSESSMENT OF CONTAMINANT MOBILITY

Subtidal cores were archived pending review of sediment chemistry results. A sediment composite was created from archived subsurface cores. Based on a review of sediment stratigraphy, sediment chemistry results, and dredging plan specifics, a volume weighted sediment composite sample (e.g., equal volume of sediment for each depth interval that may require removal) was created that is representative of sediments that may require removal from the subtidal area. The sediment composite sample was submitted for analysis (Table 8-3). Selected contaminant mobility testing was performed on the sediment composite to provide an assessment of contaminant mobility testing during dredging and aquatic confinement and disposal (i.e., thick capping, capped aquatic disposal, or upland disposal).

The tests include a Column Settling Test (CST) and a Dredging Elutriate Test (DRET). These sediment contaminant mobility tests are described below.

8.4.1 Dredging Elutriate Test

The sediment composite will be submitted for the DRET. The DRET will be used to predict the potential short-term contaminant release at the point of dredging. The DRET was performed in accordance with WES-recommended procedures (DiGiano et al. 1995) using a solids concentration of 10 g/L and a settling time of one hour. The elutriate was analyzed for those constituents that have marine acute and chronic water quality criteria.

8.4.2 Column Settling Test

The sediment composite will be submitted for the CST. The CST is used to model the settling behavior of sediments that may be dredged. The objective is to predict the gravity settling rate and behavior of dredged contaminated material. The results of the testing may be used to select an appropriate dredging method, predict potential water quality effects and to design a dredged material disposal/containment area. The test is conducted by placing a known quantity of sediment slurry in a settling column and observing the amount of time necessary to settle different size fractions of the sample. The CST were conducted in general accordance with WES-recommended procedures (USACE 1993) using a solids concentration of 150 g/L.

8.5 ASSESSMENT FOR THE POTENTIAL FOR SEDIMENT RECONTAMINATION

Based on a review of the historical land use information and existing outfalls and surface sediment samples, potential sources that may require further evaluation have been identified. Additional data from previous cleanup actions by the Port in the uplands and by EPA at the PSR sites will be gathered and evaluated. In addition, ongoing inputs from West Waterway will be evaluated:

- Obtain and review available summary reports and groundwater monitoring data for Lockheed West and PSR sites through EPA, Ecology, and the Port. Use this data to evaluate the potential for ongoing upland sources (e.g., compare groundwater contaminant concentrations with water quality criteria and evaluate the potential to impact sediment)
- Determine whether Ecology has issued determination of completion or no further action for Lockheed uplands.
- Verify the current condition and status of previous cleanup actions to assess cleanup performance and potential for sediment recontamination.
- Evaluate potential benefits and impacts of the PSR remediation on Lockheed West.

- Evaluate potential impacts of sediment transport from the West Waterway on the Lockheed West Site by evaluating the contaminant distribution patterns. No specific samples beyond the surface samples discussed above will be collected.

As part of the shoreline survey, if outfalls are located and evidence of active discharge is found, discrete bank/sediment samples will be collected and analyzed for the COIs.

Potentially significant sources identified in Section 4 will be used in conjunction with the waterway bank and adjacent surface sediment evaluations to identify the potential for ongoing upland sources to cause recontamination after the remedy is implemented. Confirmation of ongoing sources may require additional actions by EPA and Ecology or additional data collection and evaluations.

Additional data collection and evaluation requirements may be proposed if potential upland sources are found and may include the following:

- Additional source characterization data, including surface sediments, bank samples, and seep/outfall samples;
- Dispersion and dilution of the input at or near the point of discharge;
- Adsorption, flocculation, settling, sediment deposition, and sediment mixing of discharged contaminants; and
- A request that further evaluation, design, and control of potentially significant sources identified on upland properties not controlled by LMC be addressed by EPA and Ecology.

8.6 ASSESSMENT OF HABITAT DISTRIBUTION AND RESOURCE USE

The objective of this task is to provide general baseline information on habitat type, distribution, and estimated use at the Lockheed West Site to support the implementation of the selected remedy. A shoreline inventory will supplement existing shoreline and benthic habitat assessments and will define the type, distribution, and estimated use by important species of intertidal habitats. The shoreline inventory was conducted as part of the shoreline survey in August 2006 and recorded on color video from the shoreline or from a vessel as it slowly motored along the shoreline during low tide conditions. This color video will be provided in the RI Data Collection Report.

8.7 WATER QUALITY

Surface water samples were collected from representative locations as supply water for the column settling and elutriate tests. The water was collected below the water surface (i.e.,

>3 ft) but above the bottom using a peristaltic pump with weighted Teflon-lined tubing. The water for the column settling test was stored in pre-cleaned polyethylene containers. Water for chemical and elutriate testing was collected and stored in 1-liter amber glass bottles. The bottles were shipped to the lab and analyzed for the chemical parameters (elutriate tests and baseline chemical testing of surface water). Representative surface water collected and used in the elutriate testing were analyzed in duplicate for both dissolved and total contaminants of concern.

8.8 HYDROGEOLOGY

No additional geophysical or hydrogeology data are proposed for collection. If additional data requested from the Port of Seattle are not obtained or are insufficient to evaluate source control, a reevaluation of these data need may be conducted in consultation with EPA.

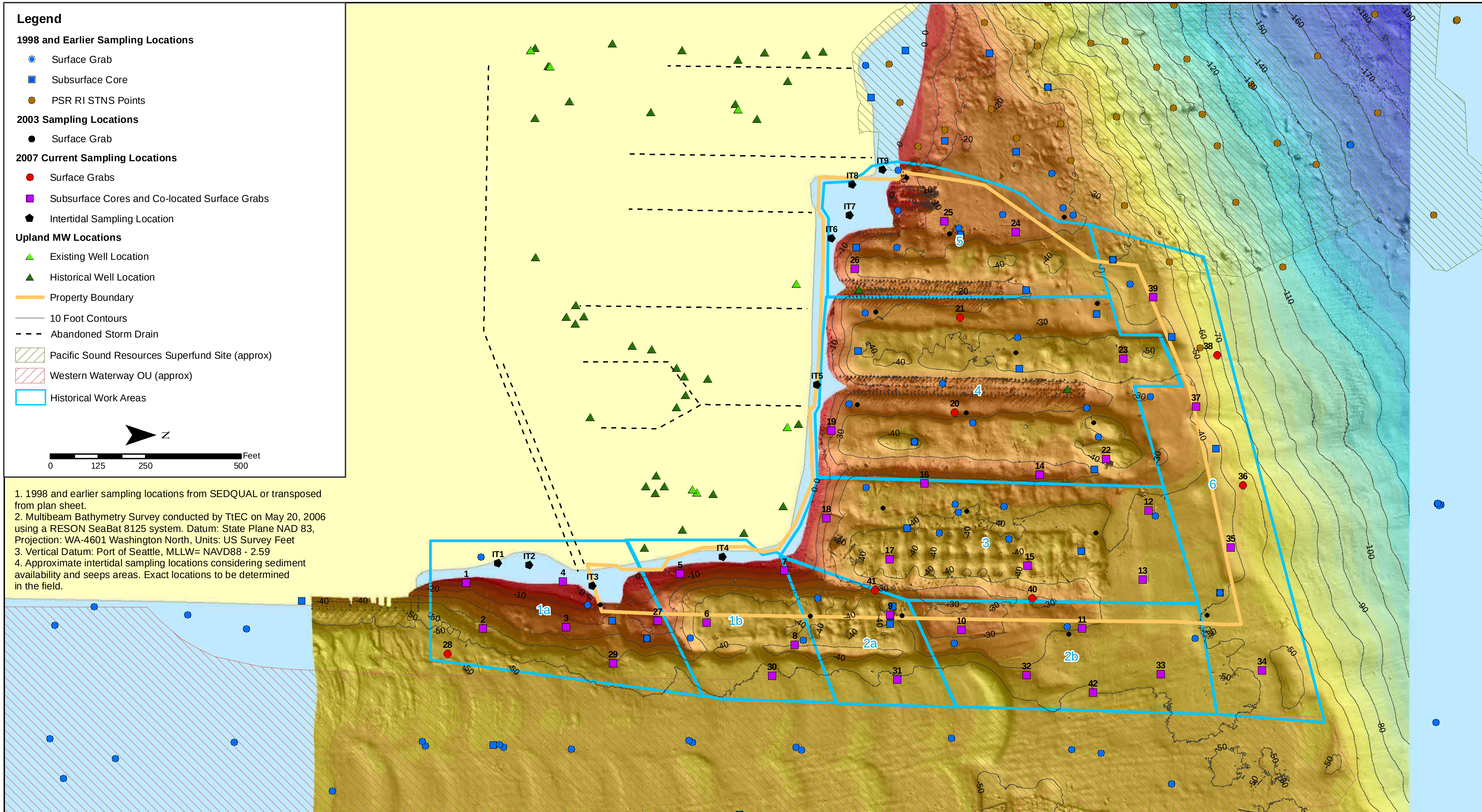
This page is intentionally left blank.

TETRA TECH EC, INC.

Lockheed West
Shipyard No. 2
Seattle, WA

Figure 8-1
Site Bathymetry
and Historic Use Areas

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\updated_report figs_021907\fig8-1_bathy_Wareas.mxd



TETRA TECH EC, INC.

Lockheed West Shipyard No. 2 Seattle, WA

Figure 8-2 Historical and Current Sediment Sampling Locations

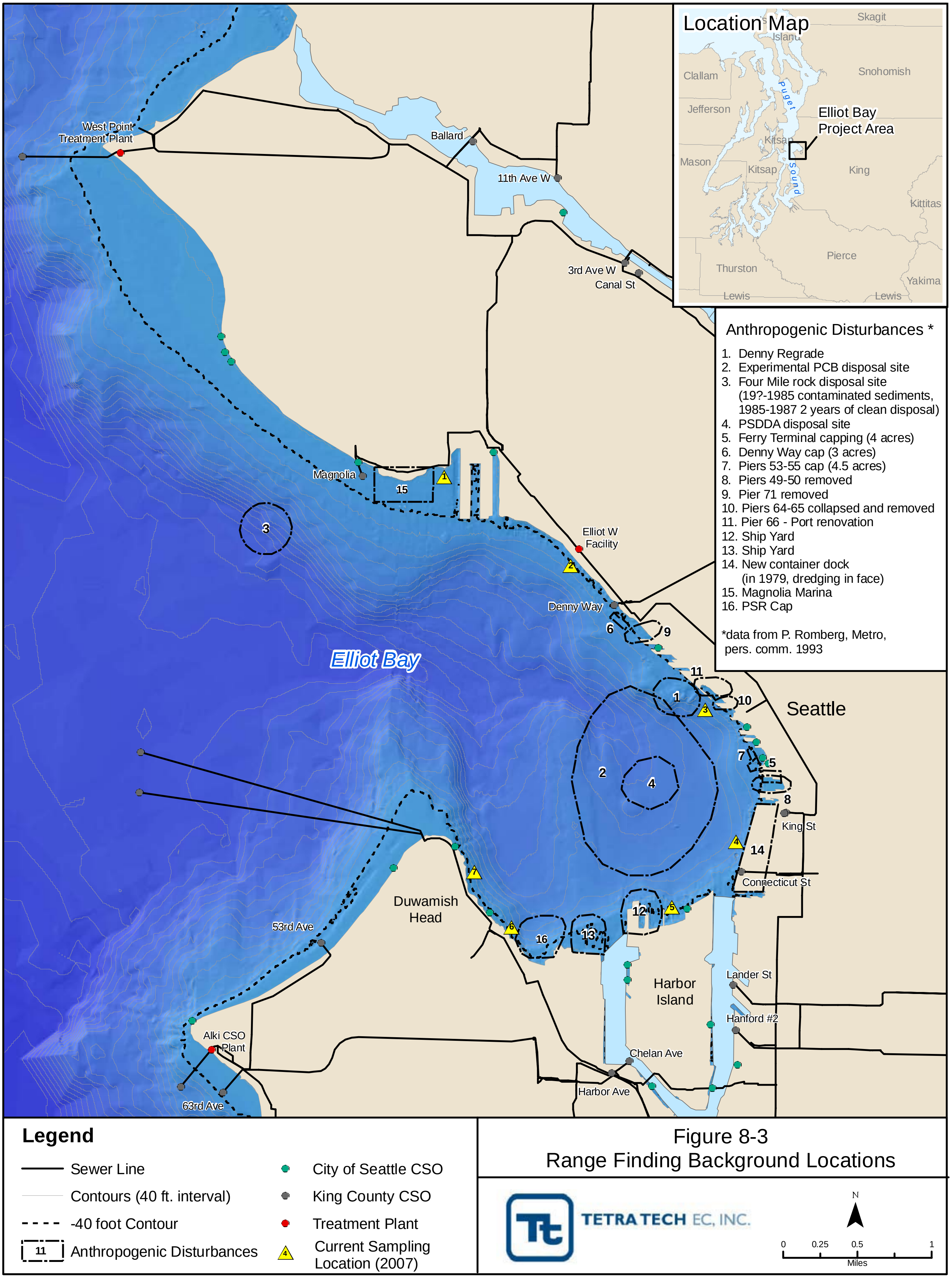


Figure 8-3
Range Finding Background Locations

Y:\GIS\Pdrive\Projects_2006\Lockheed\maps\work_plan_figures_04-01-08\Fig_8-3_background.mxd

Table 8-1. Lockheed West Remedial Investigation Data Quality Objectives

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Statement of Problem	**Decisions**	**Inputs to the Decisions**	**Boundaries of the Study**	**Decision Rules**	**Units on Decision Errors**	**Optimize the Sampling Design**
Confirm existing sediment quality condition and increase data density.	Additional data are required to determine the nature and extent of contamination and evaluate risks.	Collect additional sediment quality samples in the vicinity of existing sampling locations to confirm previous results and potential changes in sediment quality that may have occurred between sampling events. Supplement existing sediment quality data by collecting additional subsurface and surface samples.	Current property boundary reflects the historical ownership and lease areas; it is not intended to imply a nature and extent boundary, additional sampling is planned beyond the former property boundaries.	Collected sediment data will be compared to human health and ecological PRGs, and background concentrations as appropriate.	To ensure proper decisions are made, samples will be analyzed using approved EPA methods and definitive quality levels. Sediment data will be screened against HHRA and ERA PRGs and background data as appropriate. Percent completeness will be evaluated for data collected in support of the work effort.	The additional sampling has been optimized based on the knowledge of the site history and previous site characterization work.

Table 8-1. Lockheed West Remedial Investigation Data Quality Objectives (continued)

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Statement of Problem	**Decisions**	**Inputs to the Decisions**	**Boundaries of the Study**	**Decision Rules**	**Units on Decision Errors**	**Optimize the Sampling Design**
Based on evaluation of existing data, there is uncertainty about the Sediment Stability in the project area.	Additional information is needed to determine if site sediments, in particular subsurface sediments, are stable. Determine if sediments are contaminated will they be disturbed or re-exposed due to sediment instability.	A tiered approach to evaluating sediment stability is proposed: • Compile and review existing sediment transport data for the lower Duwamish River, West Waterway and Elliott Bay; • Evaluate high resolution bathymetry for geomorphic features indicative of sediment erosion and accretion; • Collect subsurface sediment quality data; and • Perform numerical modeling (if necessary) of wind, wave, current and propeller scour conditions.	Sediment stability concerns apply to the entire Site. Samples representative of the Site will be collected.	Evaluation of stability will utilize the multiple tiers to make a stability determination. If necessary, results of the additional modeling (e.g., prop scour, wave and wind generated disturbance) will be used in combination to further evaluate the stability determination.	The collection and analysis of subsurface cores will utilize EPA-approved methods and definitive quality levels. Only valid data will be used to assess sediment stability.	The additional sampling has been optimized based on the knowledge of the site history and previous site characterization work. A registered geologist will be assessing the stratigraphy of the subsurface cores with geotechnical analyses of pertinent sample increments..

Table 8-1. Lockheed West Remedial Investigation Data Quality Objectives (continued)

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Statement of Problem	**Decisions**	**Inputs to the Decisions**	**Boundaries of the Study**	**Decision Rules**	**Units on Decision Errors**	**Optimize the Sampling Design**
Conditions along the Site shoreline have not been characterized and there is uncertainty about the status of current physical conditions (e.g., substrate type, slope, debris, structures, seeps, outfalls) along the shoreline at the Site.	Additional information is required to determine the current status of shoreline conditions. This data will help refine the bank sampling approach and assist in the evaluation of potential remedial actions.	Conduct a preliminary shoreline structure survey to document the location, type, and condition of existing shoreline and over water structures (scheduled for August 2006 low tide period). Conduct a topographic survey of the banks to mesh with the site bathymetry.	The boundaries of this survey will be in the intertidal area from the lowest tide mark to the top of bank along the Site.	Information gathered during the survey will help define similar bank areas for composite sampling; document the conditions of shoreline structures (e.g., bulkheads) for remedial option evaluations, and provide documentation of existing intertidal habitat conditions.	This is a preliminary qualitative survey.	The survey has been designed to gather the maximum amount of information during the low tide survey event.
Current habitat conditions along the Site shoreline have not been characterized.	Documentation of existing intertidal habitat conditions is needed to assess the impacts and benefits of future remedial actions.	Conduct a low-tide video survey of the Site to document habitat conditions for the intertidal area of the Site (scheduled for August 2006 low tide period).	The boundaries of this survey will be in the intertidal area from the lowest tide mark to the top of bank along the Site.	The low tide video survey will be used to document existing site conditions and may be used to evaluate the impacts and benefits of remedial options.	This is a qualitative survey. If additional site-specific habitat quantity and quality are determined to be needed based on this reconnaissance survey, a formal quantitative survey will be performed.	A video survey that documents current intertidal habitat conditions is adequate for the intended purposes. It will be used in conjunction with the other qualitative data collected as part of the shoreline conditions survey.

Table 8-1. Lockheed West Remedial Investigation Data Quality Objectives (continued)

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Statement of Problem	**Decisions**	**Inputs to the Decisions**	**Boundaries of the Study**	**Decision Rules**	**Units on Decision Errors**	**Optimize the Sampling Design**
An assessment of the potential for sediment recontamination is necessary to support the remedial design and to refine the CSM.	Documentation of upland source control is needed to determine the potential for sediment recontamination from upland sources. Determination of ongoing contaminant sources from the West Waterway/ LDW.	Review and evaluation of available groundwater and cleanup action data provided by the Port of Seattle for the site uplands and from EPA on the PSR cleanup. Review information from the West Waterway and LDW sites.	Former shipyard and PSR uplands boundaries. Inputs from West Waterway/Lower Duwamish Waterway at the project's eastern boundary.	If review of existing data shows that the sources have been controlled, then no additional data collection will be required. If ongoing sources are suspected or found, then a request that further evaluation, design, and control of potentially significant sources be addressed by EPA and Ecology	If additional groundwater or discrete outfall or sediment samples are collected, they will be analyzed by EPA approved methods and protocols.	The existing data from EPA and the Port of Seattle will be used to compare groundwater contaminant concentrations with water quality criteria and evaluate the potential to impact sediment. If existing data show no impacts then no additional data will be collected and analyzed.

Table 8-1. Lockheed West Remedial Investigation Data Quality Objectives (continued)

Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7
Statement of Problem	**Decisions**	**Inputs to the Decisions**	**Boundaries of the Study**	**Decision Rules**	**Units on Decision Errors**	**Optimize the Sampling Design**
Existing baseline HHRAs and ERAs are inadequate.	Baseline HHRAs and ERAs will be used as part of the RI/FS to assist in the evaluation of potential remedial alternatives for the Site.	Complete Baseline Human Health and Ecological Risk Assessments Work Plan and determine what assumptions are to be used and to determine if site-specific data are needed. Evaluate conservativeness of literature BSAFs by conducting a clam reconnaissance survey.	Baseline risk assessments apply to the entire Site.	Sediment data from the Site will be used as inputs to the baseline RAs to calculate risks and to assist in establishing PRGs. Results of clam reconnaissance survey and sample collection in intertidal and subtidal areas will be used to develop site-specific BSAFs for comparison with literature BSAFs.	Any data collected as part of the RI that is used for the risk assessments will have been analyzed following EPA-approved methods and QC protocols, and the uncertainties associated with the data identified. All data will be validated prior to use.	The additional sampling has been optimized based on the knowledge of the site history and previous site characterization work.

Table 8-2. Sampling Locations Rationale

Work Area	Sample Number	Type	Rationale (Note: Historical sample information is described in Appendix A)
Area 1a (Future POS Terminal) Area 1b (Eastern Drydock)	1-8, 27, 29, 30 cores 28 grab	Cores to -53 MLLW	• Four cores near shore on slope to assess the combined sewer outfall and depositional area. Currently the slope at the north end of Area 1 is 2:1 (goal is 1:1.75 side cut on slopes). • All 7 cores in and adjacent to the West Waterway go to elevation -53 MLLW or 20 feet maximum for nature and extent plus port development. • Surface grab added to bound surface contamination.
Area 2a (Eastern Drydock)	9, 31 cores	Cores to -53 MLLW	• Core (9) near the 3 cores SB-1, D5, and M1 because of the inconsistencies of previous sample results. • Core (31) adjacent to West Waterway to bound spatial contamination.
Area 2b (North of Eastern Drydock)	10, 11, 32, 33, 42 cores	Cores to -53 MLLW	• Cores (10) to assess the mound north of the dry dock. • Core (11) to characterize in the middle in the deeper area just outside the property boundary to confirm the surface and depth boundary of contamination near some surface samples (no cores collected previously in this vicinity). • Three cores added to bound surface contamination along West Waterway.
Area 3 Western Former dry dock area	12, 13, 15-18 cores 40-41 grabs	Cores to -53 MLLW	• Contains SA8 and SA9 samples under former dry dock. PCBs, PAHs, and metals are issues. • Beyond the dredge cut on the north end has uncharacterized surface sediments. Cores (12 and 13) added at north end to assess surface sediment quality and vertical contamination. • Three in middle of area (15-17) to assess entire dry dock area which is likely to be dredged (and perhaps capped). • Core (18) located close to shore to assess high ground. • Two additional surface grabs are located along historical pier location; no other grabs proposed, as area is well characterized on the surface by the co-located grab/cores.

Table 8-2. Sampling Locations Rationale (continued)

Work Area	Sample Number	Type	Rationale (Note: Historical sample information is described in Appendix A)
Area 4 Former Mooring Area.	14, 19, 22, 23 cores 20, 21 grabs	Cores to -53 MLLW	• Core (14) located to assess historic pier location. • Core (19) added near shore. • Grab (20) added to confirm results from SA6 core, G8 core, and HC-03-06 surface sample area with metals and PCBs on surface. • Core (22) located in deeper hole near G9 surface sample, cores HC-03-17 and 30-1-197 to assess vertical and spatial contamination. • Core (23) added to assess spatial and vertical extent. • Grab (21) on west end to assess surface sediment. • No additional cores are proposed near SA5 since there were no exceedances.
Area 5 (Shipway)	24-26 cores	Cores to -53 MLLW	• Shipway area containing SA3 and SA2 (SA2 is not bound vertically). • Core (24) located to determine spatial and vertical boundary of PAH and SVOC. • Core (25) needed in between pier and mass of pilings in SW corner of Site. • Core (26) added to assess vertical contamination at SA3 in former mooring area.
Area 6 (North boundary)	34,35, 37, 39cores, 36, 38 grabs	Cores to -53 MLLW; surface grabs	• No exceedances found at depth. Cores to assess vertical contamination. • Two surface samples added to bound spatial contamination at surface.
Intertidal	9 surface grabs: IT-1 through IT-9	grabs	• Assess intertidal area between MLLW and Ordinary High Water Mark.

Table 8-3. Sampling Locations and Analyses Summary

Location	Type	Easting[1/]	Northing[1/]	Mudline Elevation (MLLW)	Sample Depth (feet)[2/]	Target Elevation (MLLW)	Conventionals[3/]	metals	SVOC	PCB	Pesticides	TBT bulk	Archive for PCB/Dioxin	Porewater[4/]	Geotechnical[5/]	Contaminant Mobility[6/]	PSDDA Cores
1	Core and Grab	1263235.3	216012.3	-8.3	16	-24.3	x	x	x	x	x	x	x		x		1
2	Core and Grab	1263355.3	216056.9	-40.4	12.6	-53.0	x	x	x	x	x	x	x				1
3	Core and Grab	1263351.9	216274.6	-24.8	28.2	-53.0	x	x	x	x	x	x	x	x	x		1
4	Core and Grab	1263249.0	216267.8	0.0	20	-20.0	x	x	x	x	x	x	x		x		1
27	Core and Grab	1263334.8	216515.7	-14.9	38.1	-53.0	x						x		x		1
28	Grab	1263421.0	215964.3	-51.9	10 cm grab	--	x	x	x	x	x	x	x				
29	Core and Grab	1263446.7	216397.7	-41.4	11.6	-53.0	x	x	x	x	x	x	x		x		
5	Core and Grab	1263211.3	216573.8	-3.3	6.1	-9.4	x	x	x	x	x	x	x		x		1
6	Core and Grab	1263339.9	216644.1	-41.5	11.5	-53.0	x	x	x	x	x	x	x		x	1	
7	Core and Grab	1263202.7	216848.1	-6.4	5	NA	x	x	x	x	x	x	x				
8	Core and Grab	1263398.2	216875.6	-40.1	12.9	-53.0	x	x	x	x	x	x	x		x	1	
30	Core and Grab	1263479.5	216815.7	-51.4	1.6	-53.0	x	x	x	x	x	x	x				
9	Core and Grab	1263319.7	217126.0	-41.1	11.9	-53.0	x	x	x	x	x	x	x	x	x	1	
31	Core and Grab	1263489.1	217144.2	-50.4	2.6	-53.0	x	x	x	x	x	x	x		x		
10	Core and Grab	1263358.7	217312.7	-28.7	24.3	-53.0	x	x	x	x	x	x	x		x	1	
11	Core and Grab	1263355.3	217629.9	-40.0	13.0	-53.0	x	x	x	x	x	x	x			1	
42	Core and Grab	1263524.1	217658.5	-49.9	3.1	-53.0	x	x	x	x	x	x	x	x			
32	Core and Grab	1263476.2	217485.2	-42.2	10.8	-53.0	x	x	x	x	x	x	x				
33	Core and Grab	1263473.0	217836.1	-46.7	6.3	-53.0	x	x	x	x	x	x	x				
12	Core and Grab	1263045.0	217804.8	-41.9	11.1	-53.0	x	x	x	x	x	x	x			1	
13	Core and Grab	1263226.7	217789.3	-45.2	7.8	-53.0	x	x	x	x	x	x	x	x		1	
15	Core and Grab	1263190.7	217485.9	-45.3	7.7	-53.0	x	x	x	x	x	x	x	x	x	1	
16	Core and Grab	1262974.0	217215.4	-35.7	17.3	-53.0	x	x	x	x	x	x	x			1	
17	Core and Grab	1263173.6	217124.1	-43.8	9.2	-53.0	x	x	x	x	x	x	x		x	1	
18	Core and Grab	1263065.6	216957.8	-17.7	10	NA	x	x	x	x	x	x	x				
40	Grab	1263275.8	217499.2	-29.2	10 cm grab	--	x	x	x	x	x	x	x				
41	Grab	1263254.0	217086.8	-31.8	10 cm grab	--	x	x	x	x	x	x	x				
14	Core and Grab	1262951.6	217517.9	-25.0	28.0	-53.0	x	x	x	x	x	x	x				
19	Core and Grab	1262835.8	216971.6	-17.1	10	NA	x	x	x	x	x	x	x				
20	Grab	1262787.8	217299.0	-27.3	10 cm grab	--	x	x	x	x	x	x	x	x			
21	Grab	1262535.8	217309.3	-33.6	10 cm grab	--	x	x	x	x	x	x	x				
22	Core and Grab	1262909.5	217693.3	-42.2	10.8	-53.0	x	x	x	x	x	x	x				
23	Core and Grab	1262647.2	217737.9	-45.4	7.6	-53.0	x	x	x	x	x	x	x				
24	Core and Grab	1262314.6	217455.0	-26.3	10	NA	x	x	x	x	x	x	x				
25	Core and Grab	1262285.5	217268.2	-25.9	10	NA	x	x	x	x	x	x	x	x			
26	Core and Grab	1262410.5	217033.0	-28.7	10	NA	x	x	x	x	x	x	x				

Table 8-3. Sampling Locations and Analyses Summary (continued)

Location	Type	Easting[1/]	Northing[1/]	Mudline Elevation (MLLW)	Sample Depth (feet)[2/]	Target Elevation (MLLW)	Conventionals[3/]	metals	SVOC	PCB	Pesticides	TBT bulk	Archive for PCB/Dioxin	Porewater[4/]	Geotechnical[5/]	Contaminant Mobility[6/]	PSDDA Cores
34	Core and Grab	1263466.5	218102.6	-51.1	1.9	-53.0	x	x	x	x	x	x	x				
35	Core and Grab	1263141.5	218021.3	-47.7	5.3	-53.0	x	x	x	x	x	x	x				
36	Grab	1262978.6	218051.8	-53.9	10 cm grab	--	x	x	x	x	x	x	x				
37	Core and Grab	1262771.1	217930.3	-39.4	13.6	-53.0	x	x	x	x	x	x	x				
38	Grab	1262637.1	217984.6	-66.9	10 cm grab	--	x	x	x	x	x	x	x				
39	Core and Grab	1262481.9	217819.9	-43.6	9.4	-53.0	x	x	x	x	x	x	x				
IT-1	Intertidal Grab[7/]	1263183.4	216096.7	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-2	Intertidal Grab[7/]	1263188.2	216179.1	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-3	Intertidal Grab[7/]	1263242.0	216345.1	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-4	Intertidal Grab[7/]	1263166.8	216686.4	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-5	Intertidal Grab[7/]	1262714.3	216934.3	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-6	Intertidal Grab[7/]	1262330.4	216973.0	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-7	Intertidal Grab[7/]	1262269.1	217020.6	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-8	Intertidal Grab[7/]	1262188.8	217026.5	NA	10 cm grab	--	x	x	x	x	x	x	x				
IT-9	Intertidal Grab[7/]	1262149.9	217106.8	NA	10 cm grab	--	x	x	x	x	x	x	x				

1/ Target locations actual location will be determined in the field.
2/ Most cores will be pushed to approximately -53 MLLW or to a maximum of 20 feet. Cores along POS Terminal slope will be pushed to slope cut. Cores located in probable cap area will be pushed to 10 ft.
3/ Conventional analysis includes total solids, grain size, and TOC.
4/ Analysis of porewater will be conducted on the surface grab sample.
5/ Atterberg Limits will be analyzed on samples within the potential dredge prism and should primarily consist of clays, therefore to be determined in the field. Specific gravity will be analyzed on each stratigraphy layer of cores located within the dredge prism.
6/ Contaminant mobility samples will be a composite sample of core increments located within the dredge prism as well as a surface water sample.
7/ Intertidal Bank Samples (IT-1 though IT-9) will be collected during a daylight low tide in the second phase of field work.

9. DATA MANAGEMENT

A project database will be established that incorporates both historical data and the data resulting from the remedial investigation sampling. The project database will allow efficient management of chemical, biological, and physical data received from the laboratories and will provide electronic data submittals in accordance with the EPA's instructions for formatting digital data (EPA 1993a) and in a format compatible with software currently available within EPA Region 10 (Microsoft® Access format). Electronic data submittals will also allow for entry into Ecology SEDQUAL (or next generation of Ecology database).

The data management system will be used for both past and future data and shall be integrated with knowledge of historical land uses. The data management system will be able to handle physical as well as chemical data so that it will be useful for Remedial Design and Remedial Action work as well as for the RI/FS. The database software for data management will be compatible with Geographic Information System (GIS) software. This GIS compatibility will allow the preparation of a Site base map that includes topographic information, physical features of and near the Site, and the location of all well, sediment, and water samples, both vertically and horizontally.

- Data file structures will be developed to provide the flexibility to meet known and predicted data analysis goals. Data structures will be designed using database normalization techniques to minimize the number and size of files, while considering effective methods of data manipulation for the requirements of data analysis and summarization. Typical files will include the following:
  - Location file identifying where samples were collected, including location identifier numbers;
  - Sample file describing when and what samples were collected, including sample depth and sample collection method;
  - Analytical chemistry results, including concentrations, units of measure, and qualifiers; and
  - Biological test results with identification of test organisms and test conditions.
- A library of routines will be used to translate typical electronic output from laboratory analytical systems and generate data analysis reports. The use of automated routines ensures that all data are consistently converted into the desired data structures and operator time is kept to a minimum. In addition, routines and

methods for quality checks will be used to ensure such translations are correctly applied. Final electronic files will be made available in an agreed upon format.

- Written documentation will be used to clarify how field and laboratory duplicates and QA/QC samples were recorded in the data tables, as well as provide explanations of other issues that may arise. The procedures for data reduction (e.g., handling of duplicate and replicate samples, selection of best results when multiple results exist, approaches to significant figures and rounding, calculating totals for PCBs, PAHs, pesticides) are detailed in the QAPP (Appendix D). The data management task will include keeping accurate records of field and laboratory QA/QC samples so that study team members who use the data will have appropriate documentation. In addition to placing all data and identifiers into an electronic database, hard copies of all original analytical data or study records will be placed into a filing system. Each analytical data set or document will be given a unique code and filed based on that code. A master list of all filed documents will be maintained for easy retrieval.

10. FIELD DATA COLLECTION AND DATA REPORTING

Once the Work Plan documents are approved by EPA, the field investigations identified above in Section 8 will be implemented in accordance with the schedule set forth in Section III of the SOW. After implementation of the EPA-approved field investigation, LMC will submit to EPA a draft and final Data Report for EPA review and approval that presents the results of sampling and analysis activities completed under the SAP. The data report will include:

- A summary of field activities and methods, including a discussion of any discrepancies with the sampling and analysis plan and the effect of such changes upon data usability.
- Data quality assurance/quality control review including how analytical results met specified reporting limits and rules for data reduction and use,
- Tabulated chemical, physical, and biological data,
- A sample identification matrix that relates sample identification numbers to sample locations,
- Maps showing actual sample locations,
- Field logs, and
- Laboratory data sheets.

If requested by EPA, LMC will also make available any additional records generated to support data collection, such as chain-of-custody forms. The Data Collection Report will also include a discussion of data validation conducted in accordance with the EPA-approved QAPP and, if any, QAPP addenda. Once the data have been through the data validation and quality reviews, the quality-assured chemical and biological data will be submitted in an electronic format consistent with the data management plan. In the event multiple data collection events are warranted, results of subsequent sampling and analysis will be presented as addenda to the Data Collection Report or other acceptable format.

11. BASELINE RISK ASSESSMENT PLAN FOR LOCKHEED WEST

Baseline risk assessments (RAs) for the Lockheed West Site will be performed as per Section II, Subtask 1.8 of the Statement of Work (SOW), Appendix A to the Administrative Settlement Agreement and Order on Consent (ASAOC) for the Lockheed West Site. The baseline risk assessments will be performed as streamlined risk assessments, as explained more fully below. This section of the work plan provides the purpose and scope of the streamlined human health risk assessment (HHRA) and streamlined ecological risk assessment (ERA), and presents the technical approach to performing the streamlined RAs that is consistent with the SOW and EPA guidance for performing RAs under CERCLA.

11.1 PURPOSE OF THE STREAMLINED RISK ASSESSMENT

Consistent with the EPA (1991) OSWER Directive 9355.0-30, the overall purposes of the streamlined baseline RAs for the Lockheed West Site are to identify potential human health and ecological risks at the Site, to identify chemicals of concern (COCs), to support remedy selection, and to provide information for selecting risk-based cleanup levels and remediation monitoring criteria. LMC is committed to active remediation of the entire Lockheed West site. At the minimum, remediation plans consist of placing a cap over all contaminated sediments at the Site. Because of the decision to actively remediate the entire Site, the RI/FS work plan does not include an evaluation of the no-action alternative, nor does it include evaluations of any natural recovery alternatives; instead, the plan calls for active remediation of the entire Site to mitigate all assumed human health and ecological risks. Although the placement of a cap will eliminate all exposures of humans and ecological receptors to the sediment contaminants, the presence of Site contamination requires performance of a baseline risk assessment to indicate the potential extent of risk under present site conditions, to support the remedy selection for the sediments that will mitigate the risk, and to assist in interpreting the significance of post remediation monitoring results.

The plan to actively remediate the entire site minimizes the need to calculate site-specific risks at a level of specificity to demonstrate acceptability of the no-action alternative or natural recovery of sediments. The RAs do need to support the decision to remediate the site. Based on preliminary screening-level risk estimates, highly site-specific RAs are expected to demonstrate unacceptable risks to human health and possibly ecological receptors at the Lockheed West Site. The overall approach that will satisfy the risk assessment goals for the Lockheed West Site will not be based on site-specific exposure parameters, although the RAs will use sediment data collected from the site. Instead, the approaches to estimating risks to human health and ecological receptors from exposures to chemicals in Site sediments will each follow a streamlined process. The streamlined RAs will evaluate potential risk by structuring the assessments to use technical information from the risk assessments performed at the nearby LDW site. In addition to performing baseline risk assessments, sediment cleanup levels need to be identified for the Site in order to select criteria for evaluating the performance of the remedy selection. Section 6 in this work plan identifies preliminary cleanup levels and remediation monitoring criteria consistent with the streamlined approach to the RI and the RAs.

The overall approach to the streamlined RAs is considered to be appropriate for the potential human populations, ecological receptors, potential future exposure conditions, and planned remediation at the Site. In particular, the human health risk assessment will be protective of tribal consumers of seafood, who have treaty rights for seafood collection from the Site, and of children who may play in the intertidal sediment. Similarly, the ecological risk assessment will be protective of ecological receptors, including aquatic organisms and shoreline birds that may use the Site.

11.2 SCOPE

The scope of the RAs will consist of full baseline risk assessments, following USEPA guidance for Superfund sites, described more fully below. Because the exposure scenarios, parameters, ecological receptors, and toxicity data will borrow extensively from the nearby LDW site, the RAs are considered to be streamlined, rather than site-specific. The basic premise for the streamlined approach to the RAs can be summarized as the following:

- The entire sediment Site will be actively remediated, with the result that there will be no surface sediments remaining at present levels of contamination. After remediation, in the absence of contamination of surficial sediments and any associated exposures or risks, there will be no monitoring of natural recovery or changes in baseline risks, although remediation performance will be monitored.
- Risks will be estimated using exposure assumptions developed for the LDW site. In other words, the risk estimates for the Lockheed West Site will not be based on site-specific exposure assumptions, but on exposures assumed for the nearby LDW site. The applicability of the LDW site exposure assumptions and associated exposure parameters to the Lockheed West Site is not evaluated. However, the activities that describe the exposure scenarios are assumed to reflect future potential uses of the Site. Thus, although the Lockheed West Site is substantially smaller than the LDW

site, the methodology for assessment of risks will be the same and subsequent risk-based cleanup levels will be consistent with the larger region of the LDW.

- Furthermore, EPA notes that "The Lockheed West site is one of many cleanup sites within the Duwamish and Elliott Bay and that these sites must be considered holistically in addressing contamination in the system as a whole. Dividing a larger contaminated area into small cleanup sites and then declaring that exposure assumptions suitable for the larger contaminated area are not applicable to small cleanup sites is not appropriate."
- Baseline risks will be estimated for human and ecological receptors at the Site using surface sediment data collected in 2007.
- The risk assessments will focus on the same human populations and ecological receptors that were identified as the risk driver scenarios for the LDW site. The risk assessments will use the same exposure parameter values as the LDW site, and will focus on reasonable maximum exposure (RME) scenarios.

An important consideration under this streamlined approach is that no assumptions are made that the exposure parameter values in the LDW risk assessments are directly applicable to the Lockheed West site, and no site-specific exposure parameters are developed. Only exposure concentration data for sediment will be site-specific. Use of the LDW exposure scenarios and all inherent assumptions and exposure parameters for the Lockheed West site is not considered to reflect all site-specific exposures, particularly with the smaller size of the exposure area, limited access to the Site, and limited available ecological habitat under present conditions. Instead, use of LDW exposure scenarios and assumptions is intended to help ensure consistency in site cleanup approaches between the Lockheed West and LDW sites. As described more fully below, although the LDW site has a stronger freshwater component than the Lockheed West site, though both are considered estuarine sites, the LDW site was evaluated using marine species typical of Puget Sound bays. Thus, although the Lockheed West site environment may be more marine due to the presence of Elliott Bay on the north side, the LDW risk assessments evaluated the same marine species that would be present at the Lockheed West site as food sources for humans and as ecological receptors of concern.

Brief summaries of previous RAs that have been performed on sites in the general area of Lockheed West are presented in Appendix A of this work plan. In particular, the RAs for the LDW site are summarized therein. Local information was considered useful for planning the RAs for the Lockheed West Site because of the similarity in environmental locations, physical characteristics, and biological habitats. However, in reviewing these other site RAs, note that a number of policy/regulatory initiatives have occurred since the first RA conducted in the area in 1991; these changes focus the RA approaches to the Lockheed West Site relative to those that have been employed in the past. The key initiatives that are of relevance to the Lockheed West Site are as follows:

- For Elliott Bay and the Lower Duwamish Waterway, the Washington Department of Ecology has replaced the default seafood consumption rate and source fraction terms (effective consumption rate 27 grams per day) used in the Model Toxics Control Act with a consumption rate that accounts for the fraction of site affected seafood. That consumption rate is 57 grams per day. http://www.ecy.wa.gov/programs/tcp/SAB/SAB_mtg_info/mtg_060915/02%20RecapAPIFishConsumptionRateDiscussions.pdf
- EPA Region 10 has developed a policy document, "The Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia, August, 2007" that delineates EPA's position on Tribal seafood consumption risk assessment in Puget Sound. The Framework specifies consultation with affected tribes. In consultation with the Suquamish and Muckelshoot Tribes, EPA will determine the best approach for applying the Framework at the Lockheed West site.
- The Lower Duwamish Waterway HHRA has been the most comprehensive and recent effort to assess seafood consumption risks in the Puget Sound area. Consequently, approaches taken in the LDW HHRA document form the starting point for risk assessment considerations at the Lockheed West site.

These recent initiatives establish a framework for the present HHRA in particular, that supersedes the previous approaches to risk assessments in the area.

11.3 BASELINE HUMAN HEALTH RISK ASSESSMENT PLAN

The following presents the plan for the baseline human health risk assessment for the Lockheed West site. The components of the plan include Hazard Identification, Exposure Assessment, Toxicity Assessment, and Risk Characterization (EPA 1989a). The plan for the ecological risk assessment follows this section.

11.3.1 Hazard Identification

For the Lockheed West site, the Hazard Identification step will identify chemicals of potential concern (COPCs) by screening sediment data collected for the RI against appropriate human health-based screening criteria. COPCs for the HHRA will be identified for each exposure scenario.

11.3.1.1 Chemical Data

The list of chemicals analyzed in sediment is presented earlier in this work plan and serves as the starting point for selecting COPCs. The chemical analyte list for the 2007 sampling event was compiled from existing data and chemicals that were suspected to be present in Lockheed West sediments. For example, hydrophobic organic chemicals, such as organochlorine pesticides, that have been detected in LDW sediments upstream of the Lockheed West site are included in the list of chemical analytes for sediments at the Lockheed West site. Their inclusion is based on the assumption that they could transport downstream as particle-bound constituents that may deposit on Lockheed West site. The methods for data collection and analysis of surficial sediments at the Lockheed West site were generally consistent with reporting limits that best met risk-based analytical concentration goals (RBACGs). This is shown by comparison of the method detection limits for the COIs with RBACGs, as described below and as listed in Table 11-1, presented at the end of this chapter.

Surface sediment chemistry data that will be used in the risk assessments were collected from the top 10 centimeters of the subtidal and intertidal sediment of the site. This depth in the sediment has been identified in the State of Washington as the biological productive zone in Puget Sound sediment, and as such, serves as the standard sampling depth for investigations in Puget Sound. The protectiveness of the 10-cm depth will be briefly discussed in the risk assessment.

For sediments, RBACGs are concentrations of chemicals in sediment that are associated with an acceptable risk level as derived from state standards, the toxicity literature, or human health guidance documents. Sediment RBACGs were taken from the LDW site, which are considered protective of humans and ecological receptors exposed to chemicals via direct contact or incidental ingestion of sediment, and for ingestion of fish and shellfish by humans and by ecological receptors as prey (Windward 2005a). In the development of RBACGs for the LDW site, sediment risk-based concentrations (RBCs) were first identified or derived for the protection of benthic invertebrates, spotted sandpipers, and humans. RBCs for the protection of human health were derived for both direct and indirect (i.e., seafood consumption) exposure pathways. For non-bioaccumulative chemicals, RBCs were calculated for direct exposure pathways. For bioaccumulative chemicals (EPA 2000), RBCs were calculated for the seafood consumption pathway. Sediment RBCs for the seafood consumption pathway were based on modeling acceptable levels from clam tissue to sediment based on biota-sediment accumulation factor (BSAF) relationships. In other words, acceptable levels in clams were first determined, as based on the tribal consumption rate for clams and other tribal exposure parameters, then those concentrations were used with BSAFs to model acceptable levels in sediment. (The derivation and use of the RBACGs are further discussed below in the identification of screening criteria and exposure estimates for both human health and ecological receptors below and in the following section on the ERA work plan.) The RBACGs for sediment in the LDW were then set equal to the lowest RBC for each chemical. The RBACGs developed for the LDW site but adjusted as described below were used for setting analytical detection goals for the Lockheed West site sediment.

11.3.1.2 Screening Steps

The following steps will constitute the COPC screening process for human health exposures for the Lockheed West site, using the 2007 sediment data:

1. For chemicals that are always undetected, if detection limits are below RBACGs, they will be screened out from further evaluation. Undetected chemicals with detection limits exceeding RBACGs will be noted through the evaluation.

2. Frequency of Detection – Chemicals that are detected in less than 5 percent of sediment samples will be screened out from further evaluation. An infrequently detected contaminant will be rejected if is not found in other environmental media, if there is no reason to believe that the contaminant should be found, and if there is not a unique site feature that may explain the presence of the contaminant. Note that the full sediment data set collected in 2007 contains 51 stations, so only those chemicals detected in only one or two stations would be rejected as below the frequency of detection criterion. No chemicals will be rejected on the basis of frequency of detection for the intertidal data set, since nine sediment station samples comprise the data set.

3. Comparing detected chemicals against background – Chemical concentrations will be compared with available background concentrations for metals. For the purpose of comparison, background will be defined as the concentrations identified in the LDW risk assessments. EPA (2002c) also describes evaluation of background in soils, and the procedure is to compare the site data distribution with the background data distribution. If appropriate background concentrations of chemicals detected at Lockheed West sediments are unavailable, as determined in consultation with EPA, this comparison step will not be performed. No COIs will be eliminated from further evaluation based on a comparison with background.

4. Screening against risk-based screening criteria – Sediment chemicals that pass the above steps will be screened against risk-based screening criteria that are based on acceptable risk levels from direct and indirect contact with sediment. The criteria will be concentrations associated with acceptable risks for human exposures. Maximum concentrations in the surface sediment samples will be screened against the screening criteria, and concentrations above the criteria will be identified as COPCs. Identification of the screening criteria for human exposures is presented below.

Chemicals with the maximum sediment concentrations exceeding risk-based screening criteria will be identified as COPCs. Results of the comparison of sediment chemistry data with the risk-based screening criteria and the identification of COPCs will be presented in tabular format, with sediment concentrations identified as above or below the screening criteria. The presentation will include the rationale for each COPC selection. The primary risk drivers will also be identified, based on the level of exceedance of criteria and possibly other considerations, such as level of certainty in the analytical data or screening criteria, consistent with the approach used in the HHRA for the LDW site. A contaminant may still be a risk driver even if it contributes a small fraction of overall risk yet is associated with high absolute risk.

11.3.1.3 Risk-Based Screening Criteria

Risk-based screening criteria for application to sediment have not been developed by EPA, so each of the sediment exposures will be evaluated with alternative criteria: for the direct sediment contact, surrogate criteria that are considered by EPA to be sufficiently conservative for application to sediment exposures will be used, and consist of soil criteria and sediment thresholds, as developed for the LDW site; for seafood consumption exposures, screening values from the HHRA for the LDW site that have been developed specifically for application to sediment for the protection of consumers of seafood (Windward 2007a) will be used. The sources and development of each of the screening criteria for each exposure pathway are described below.

EPA Screening Criteria for Direct Sediment Exposures

Screening criteria specific to sediment exposures of people have not been developed by EPA; surrogate values will be used instead. EPA has developed risk-based concentrations for the incidental ingestion and dermal contact of soils, and these values were used as COPC screening criteria in the HHRA for the LDW site (Windward 2007a). Soil RBCs are available for both residential and industrial exposure pathways. The source of the RBCs for soil that were used in the HHRA for the LDW site was the Region 9 PRGs for residential and industrial soil. The Region 9 values were considered at the time to be appropriately conservative for the screening process; e.g., Washington State Model Toxics Control Act (MTCA) residential soil RBCs are higher (i.e., less protective) than the Region 9 values because of different exposure parameter assumptions.

Subsequent to the release of that HHRA, EPA has requested that Region 6 screening levels be used in the screening for COPCs instead of Region 9 PRGs. Region 6 screening levels are intended to be protective of humans exposed to residential soils ("Residential Soils") and to soils during outside work ("Industrial Worker Outdoor"). The equations that are used by Region 6 to calculate the screening levels incorporate the cumulative exposures to soil via ingestion, dermal contact, and inhalation of soil particles.

Residential soil screening levels from EPA Region 6 will be used to screen the beach play and clamming exposures, and the industrial outdoor screening levels from Region 6 will be used to screen the netfishing exposures. Region 6 screening levels for noncarcinogenic toxicity endpoints will be decreased by a factor of 10 to account for the target hazard quotients (HQs) of 0.1 used in screening by EPA Region 10. This approach is consistent with the draft LDW HHRA, with the switch from Region 9 to Region 6 values as recommended in EPA comments on the LDW HHRA. Updated Region 6 screening values for direct exposures to residential soil are included as direct exposure criteria in Table 11-2, with criteria for non-carcinogenic effects modified by a factor of 0.1.

Sediment Criteria for Protection of Seafood Consumption

Screening criteria that are applicable to sediments for the protection of seafood consumption have not been developed by EPA. This pathway of exposure to sediment chemicals is also termed the indirect sediment exposure pathway, since the exposure is not directly to sediments but through the consumption of seafood that has taken up chemicals from sediment. Screening criteria for the indirect sediment exposure pathway were developed as risk-based analytical concentrations goals (RBACGs) for the LDW site in the QAPP for the sediment data collection (Windward 2005a). These criteria will be applied to sediment at the Lockheed West site for the protection of seafood consumption.

The development of the screening criteria for indirect exposure at the LDW site was based on the relationship between chemical concentrations in sediment and those in seafood tissue. The RBACGs were developed from acceptable risk thresholds for seafood consumption, corresponding concentrations of chemicals in the seafood tissue, and the application of BSAF to the tissue concentrations to identify the associated risk-based sediment concentrations. BSAFs describe the relationship between sediment and tissue as the following:

$$BSAF = \frac{C_{WB} \div F_L}{C_{sed} \div F_{oc}} \qquad \textbf{Equation 1}$$

where:

C_{WB} = chemical concentration in whole-body tissue (mg/kg ww)
C_{sed} = chemical concentration in sediment (mg/kg dw)
F_L = fraction lipid in tissue (kg lipid/kg ww)
F_{oc} = fraction organic carbon in sediment (kg OC/kg dw)

Equation 1 can be rearranged to solve for C_{sed} as follows:

$$C_{sed} = \frac{(C_{WB} \div F_L) \times F_{oc}}{BSAF} \qquad \textbf{Equation 2}$$

The BSAF equation is based on the assumption that the concentration of chemical in sediment (C_{sed}) represents the average chemical concentration in sediment to which the organism is exposed. For animals with very small home ranges, such as clams, this assumption may be reasonable if sediment data are collected concurrently with tissue data at the tissue collection locations. For animals with larger home ranges, such as fish, there is greater uncertainty in this assumption because many fish are highly mobile and are not likely to inhabit all areas of their home range with equal frequency. Consequently, fish BSAFs for a given chemical easily range over at least an order of magnitude (USACE 2003). Given this large uncertainty, BSAFs for clams rather fish were used in the LDW QAPP to derive the sediment screening criteria for seafood consumption. The values for the tissue concentrations in clams (C_{WB}) that were used to derive the sediment criteria (i.e., C_{sed}) were the acceptable risk-based concentrations (i.e., RBACGs) calculated for clam tissue in the benthic invertebrate sampling QAPP for the LDW site (Windward 2004a).

In order to be health protective for this screen, the sediment RBACGs for seafood consumption were calculated in Windward (2005a) with the assumption that all of the seafood consumed is made up of clams, but rather than use a clam consumption rate, the consumption rate for total seafood consumed from Puget Sound was used at 98 g/day. This value includes consumption rates for all tribal seafood categories except salmon, as described below. In other words, the RBACGs calculated for clam tissue were based on the assumption that clams were consumed at the tribal seafood consumption rate of 98 g/day. These clam tissue RBACGs were then used as the values for C_{WB} in Equation 2 to derive C_{sed} as the sediment RBACG for seafood consumption. Assigning the full seafood consumption rate to clams to derive C_{WB} and then using the clam BSAFs in deriving the

RBCAGs was designed to be sufficiently protective of exposures through consumption of combined fish, crabs, and clams as total seafood exposures.

The tribal consumption rate of 98 g/day was developed in the Framework (EPA 2006a) using the following process:

1. The consumption rates of Puget Sound harvested seafood (pelagic fish, benthic/demersal fish, and shellfish) by surveyed Tulalip Tribal members were determined (Toy et al. 1996).
2. These rates were rank ordered and used to determine a 95th percentile consumption rate of 194 g/day.
3. The total rate was allocated to individual market basket fractions by the following calculation:

   Market basket rate = total rate x avg. rate for a market basket fraction ÷ sum of all avg. market basket rates.

Using this process, salmon comprised 96.5 g/day of the total consumption rate. EPA (2006a) decided that salmon did not accumulate a significant site-related contaminant body burden from the LDW. Consequently, the "effective" consumption rate was 194 g/day – 96.5 g/day = 97.5 g/day consumption of species with a site related contaminant body burden. The 95th percentile values are provided in Table 2 of EPA (2005), as taken from Appendix B of the revised Framework document (EPA 2006a).

Because this approach to developing screening criteria was approved by USEPA Region 10 for the LDW human health risk assessment, the screening values from the LDW reports will be used as screening criteria for the Lockheed West site risk assessment. Given that the purpose of the risk assessment is to establish that risks are sufficient to require cleanup and that the entire Site is to be remediated, USEPA Region 10 has recommended that this is a quick and protective approach to assess bioaccumulation. The RBACGs used in the screening are those calculated from BSAFs at the 90th percentiles. Though bivalve BSAFs might be lower than organisms higher on the food chain with greater lipid content, bivalves comprise the majority of seafood consumption in tribal studies. Note that the RBACGs and BSAFs that they are derived from are used only for this screening step to select COPCs. The modeling of tissue concentrations of COPCs for estimating exposures and risks will use updated BSAF values that are more specific to the type of tissue being evaluated. In other words, fish BSAFs will be used for estimating fish tissue concentrations, crab BSAFs will be used for crab tissue concentration, and clam BSAFs will be used for clam tissue concentrations (see Section 11.3.2.4).

The BSAFs used to calculate the seafood-based screening criteria for sediment (i.e., C_{sed} in Equation 2) for the LDW site were taken from four sources:

- US Army Corps of Engineers Environmental Residue-Effects Database (ERED) - http://www.wes.army.mil/el/ered/
- Tracey GA, Hansen DJ. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. Arch Environ Contam Toxicol 30:467-475.
- EPA. 1997d. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National Sediment Quality Survey. EPA 823-R-97-006. US Environmental Protection Agency, Office of Science and Technology, Washington, DC.
- Washington State Department of Health. 1995. Tier I report, development of sediment quality criteria for the protection of human health. Washington State Department of Health, Olympia, Washington.

Although BSAFs for bivalve mollusks are most appropriate for this screening criteria calculation, some fish BSAFs were used in Windward (2005a) when bivalve BSAFs were not available. The calculated sediment screening values for protection of seafood consumption from Windward (2005a) are included as indirect sediment criteria in Table 11-2.

Note that this procedure differs from the screening procedure used for the risk assessments at the LDW site. At that site, screening was performed using tissue data and appropriate tissue-based screening criteria. The use of sediment RBACGs for screening based on exposure to tissue (i.e., consumption of seafood) is a more conservative approach because of the use of conservative BSAF values in the screening criteria development. The screening process using the more conservative RBACG approach is expected to result in substantially more COPCs for tissue exposures than were identified for the LDW risk assessments.

11.3.1.4 Tissue Screening Criteria for Seafood Consumption

A reconnaissance survey for the presence of clams is presently planned for the Lockheed West site. If clams are determined to be present in sufficient abundance, a SAP for clam tissue collection and analysis will be developed and implemented. However, data will not be available for use in screening chemicals in clams for seafood consumption. Clam tissue data will be collected in parallel with performance of the risk assessment, for use in determining that the BSAFs used in the development of the screening criteria for seafood consumption are sufficiently conservative. The tissue data will be used with co-located sediment chemistry data to calculate site-specific BSAFs, which will be compared with the values used to develop sediment RBCs for seafood consumption.

If necessary for screening purposes, the available clam tissue data will be screened against the RBACG values developed in the LDW QAPP for analyzing tissue samples (Windward 2004b). The RBACGs for tissue are based on EPA Region 3 risk-based concentrations (RBCs) (EPA 2007a), as adjusted for application to the LDW site to account for tribal exposures (Windward 2007a). Adjustments were made to the RBCs for the LDW site to incorporate Region 10 recommendation of a target HQ of 0.1 to account for cumulative effects from multiple chemicals and pathways, and to account for site-specific tribal exposure assumption differences, as per the EPA Region 10 Framework (EPA 2006).

The adjustments to the exposure parameters used to calculate the Region 3-based RBCs in Windward (2007a) accounted for the tribal seafood consumption rate, exposure frequency, body weight, and exposure duration identified in the EPA Framework (EPA 2005, 2006). The following modifications were made to the Region 3 RBCs; additional details for the modifications can be found in the HHRA for the LDW site (Windward 2007a):

- Consumption rate – 98 g/day, modified from 54 g/day, as described above.
- Exposure frequency – 365 days/yr, modified from 350 days/yr
- Body weight – 81.8 kg modified from 70 kg, as per EPA (2005)
- Exposure duration – 70 years, modified from 30 years, as per EPA (2005).

The results of these modifications were to adjust the Region 3 RBCs for carcinogenic effects by a factor of 0.26, and the RBCs for non-carcinogenic effects by 0.64. These modifications result in more conservative RBCs for the tissue screening criteria than the unmodified Region 3 RBCs.

11.3.2 Exposure Assessment

The Exposure Assessment consists of a description of the exposure scenarios, human receptor populations, pathways of exposure, and exposure parameters to characterize and quantify exposures.

11.3.2.1 Exposure Scenarios and Populations

Identification of potentially exposed populations, pathways of exposure, and exposure media make up the conceptual site model CSM for the baseline HHRA. Because of the similarities in aquatic habitat and potential future human uses between the Lockheed West and LDW sites, the exposure pathways and exposed populations for Lockheed West will be consistent with the scenarios developed for the LDW HHRA. The exposure scenarios described below are taken from the LDW site based on the assumption that the types of activities could occur under future use of the Site. Presently the Lockheed West site is difficult to access from the upland, but the subtidal and intertidal areas are accessible from the water by boat.

Tribal Uses

The Lockheed West site is located within the boundaries of the federally adjudicated Usual and Accustomed Fishing Area for both the Muckleshoot Indian Tribe and the Suquamish Tribe, which includes rights to harvest seafood, including clams, from the intertidal and subtidal sediments. Access to the intertidal sediment areas can be attained by water vessel. Seafood harvesting is performed by netfishing and clamming. Scenarios related to tribal consumption of seafood, including fish and clams, are identified separately below.

Netfishing – Tribes harvest migrating salmon and other fish by netfishing the waterway. Parameters for this exposure scenario will be taken from the LDW HHRA. Netfishing is assumed to occur throughout the Site, along the West Waterway and Elliott Bay shorelines, with exposures to sediments occurring to the total sediment dataset. For the netfishing scenario, intake from direct contact (dermal absorption) and sediment ingestion will be evaluated.

Clamming – Clamming would occur in the intertidal sediment of the site. During collection of clams, exposures would occur by direct contact with sediment followed by dermal absorption of contaminants, and inadvertent ingestion of sediment. Exposure parameters will include those for the 120 days/yr and 183 days/yr scenarios that were evaluated in the LDW HHRA.

Recreational Uses

Recreational uses of the West Waterway may include boating, fishing, shoreline/riverbank activities, such as clam harvesting, and swimming. However, there are presently no public access points at the Lockheed West site, and access is restricted to the intertidal sediments where clams would be harvested and children would play. However, potential future uses of the Site could include increased recreational uses. Based on results of a qualitative survey of the Site shoreline, access and the presence of intertidal sediment areas for clamming and recreational activities by children will be evaluated. Those areas considered possible for human exposure to intertidal sediment will be evaluated.

A child beach play scenario will be evaluated using the exposure parameters in the LDW HHRA for the beach play areas of highest exposure potential, consisted with the streamlined approach to the risk assessment. Intake routes to be evaluated include dermal contact and sediment ingestion. There are no residential neighborhoods adjacent to the Lockheed West site, and no access to the intertidal sediments by residents would be anticipated. Therefore, no residential-specific scenario for sediment contact will be evaluated. Note that the seafood consumption scenario described below will be more stringent than a recreational scenario in terms of exposure to site-related sediment chemicals.

Direct contact with surface water while swimming is a potential exposure scenario to site-related chemicals. Risks due to direct contact with surface water through swimming have previously been evaluated for the West Waterway and the LDW sites. Those assessments demonstrated the small exposures and risks through this pathway. Consistent with the LDW HHRA, the swimming exposure scenario will not be quantitatively evaluated in the Lockheed West HHRA. Results of the King County risk assessment for swimming in the Duwamish Waterway will be discussed.

Seafood Consumption

Seafood may be consumed by tribal members at higher rates than recreational fishers at the Site. Risks due to public consumption of fish caught at or near the Site have previously been evaluated for the West Waterway and for the LDW. Tribal consumption of fish, crabs, and clams will be evaluated. Consistent with the streamlined approach to the risk assessment, tribal seafood consumption exposure parameters will be taken directly from the LDW HHRA, and will be consistent with the Framework for application to the LDW sites (EPA 2005, 2006). Exposure estimates will be based on the Tulalip and Suquamish tribal parameters as described in the application guidance document, and consistent with the LDW HHRA. Child tribal members will be evaluated at the 40 percent of adult seafood ingestion rates, as per the LDW HHRA.

Industrial Use of the West Waterway

The Duwamish Waterway serves as a major shipping route for containerized and bulk cargo, and the shoreline along the Lockheed West site has been developed for industrial and commercial operations. However, industrial workers in shipping will have minimal contact with sediments at the Lockheed West site, and are not considered a potential human population of concern. Industrial uses by tribes during netfishing activities are described above.

11.3.2.2 Summary of Human Exposure Assessment Scenarios

The uses of the aquatic environment of Lockheed West and populations of concern to be evaluated as exposure scenarios are identified as the following; exposure parameters are taken directly from the LDW assessments without consideration for applicability to the Lockheed West Site, as per the streamlined approach:

Direct exposures

- Netfishing
- Child Beach Play
- Clamming at 183 days/year
- Clamming at 120 days/year

Indirect exposures

Tribal seafood consumption rates will be used (USEPA 2006); other parameters from the LDW HHRA (Windward 2007a).

- Adult tribal seafood consumption parameterized using Tulalip survey parameters
- Child tribal seafood consumption parameterized using 40% of Tulalip consumption rate
- Adult tribal seafood consumption parameterized using Suquamish survey parameters (as per EPA and Tribe request).

Seafood species (same species as evaluated at the LDW site):

- Benthic fish – English sole
- Pelagic fish – perch (shiner, striped, pile)
- Crabs – Dungeness, red rock
- Clams – species uncertain, presence of *Mya* species at the Lockheed West site that were evaluated in the LDW HHRA is uncertain.

In general, the risk assessment will use LDW exposure parameter values (other than exposure point concentrations) to characterize risks across a range of exposures for human populations. Exposures through clam ingestion may be modified to reflect Site conditions that differ from the LDW site. The planned collection of clams at the Lockheed West site will provide supporting data on the presence of suitable habitat and species of clams.

EPA has pointed out that division of a large contaminated area into operable units may result in conclusions that a risk does not exist when if all the operable units were considered together, a substantial risk might exist. Further, small groups of anglers may obtain a large fraction of their seafood from a small area. For these reasons, EPA has concluded in the Framework that site size should not affect the fraction of seafood affected by source specific contamination. As part of the streamlined approach to this risk assessment, exposure parameters and chronic daily intake calculations, including seafood ingestion rates, will be taken from the LDW HHRA and be consistent with the Framework.

11.3.2.3 Conceptual Site Model for Human Exposures

Information on the sources of contamination, exposure pathways, and human receptor populations described above will be depicted in a CSM for the HHRA. A CSM for the Lockheed West HHRA is presented in Figure 11-1. As per the approach to the baseline risk assessments for the Lockheed West site, the CSM is consistent with the HHRA CSM developed for the nearby LDW site.

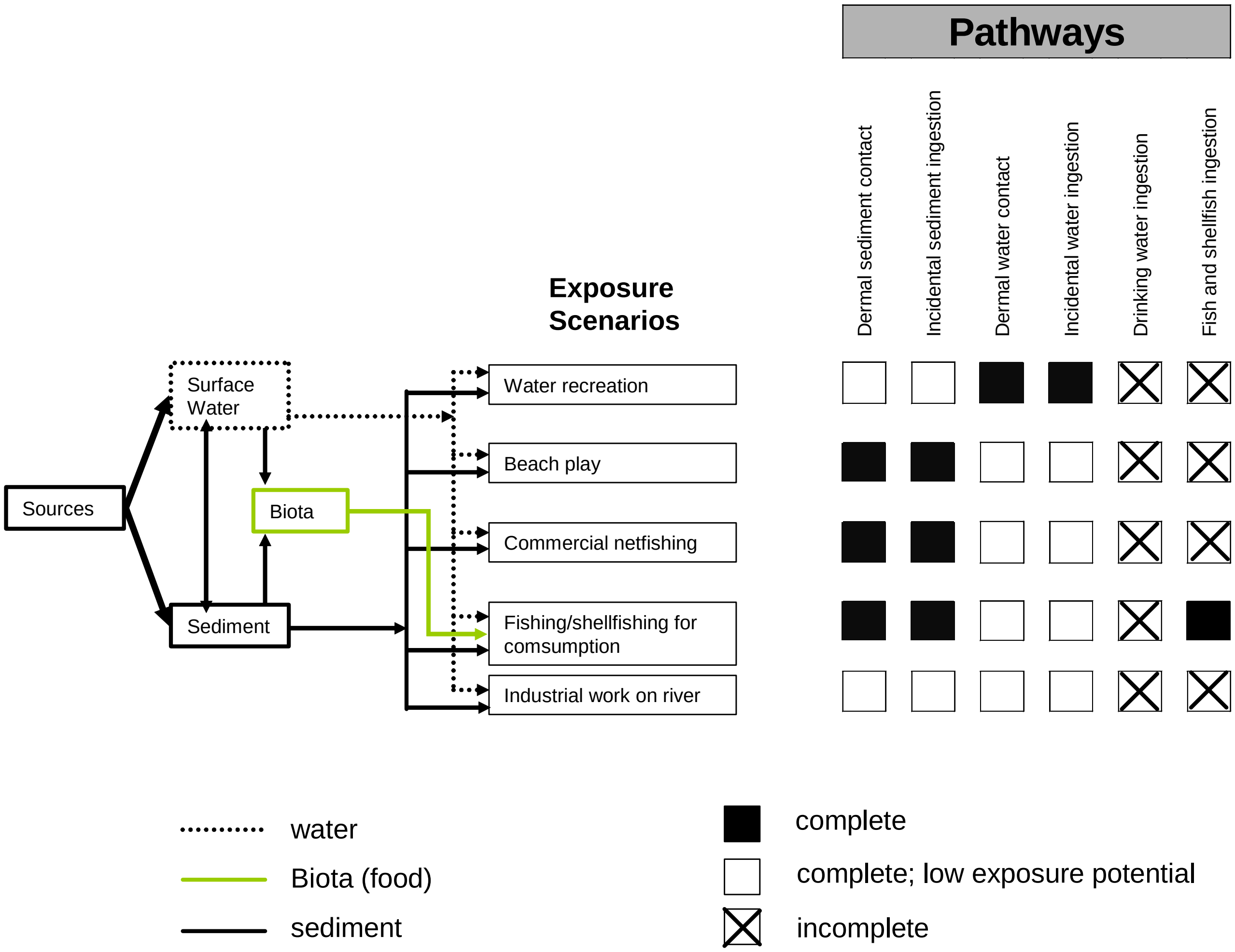


Figure 11-1. Conceptual Site Model for Lockheed West Human Health Risk Assessment

11.3.2.4 Exposure Point Concentrations

Existing chemical contaminant datasets are evaluated in the RI work plan. Only the sediment dataset collected in early 2007 is planned for use in the HHRA; no tissue data have been collected from areas consistent with the sampling boundaries presently identified for the Site. Tissue data that may be collected for clams at the Site will be used to corroborate the conservativeness of the BSAFs that are used to model tissue concentrations, as mentioned above and explained more fully below.

The following describes the sediment chemistry data to be used to evaluate exposures in the Lockheed West HHRA.

- *Netfishing* – The netfishing scenario will be based on COPC data collected from the intertidal and subtidal sediments throughout the Site, i.e., on east side of the Site in the West Waterway and Elliott Bay.
- *Beach Play* - The beach play scenario will be based on COPC data collected from the intertidal sediments along all shoreline areas of the Site.
- *Clamming* - The clamming scenario will be based on COPC data collected from the intertidal sediments along all shoreline areas of the Site.
- *Clam Consumption* - For the consumption of clams, sediment data will be COPC data collected from the intertidal sediments along all shoreline areas of the Site, similar to the clamming scenario.
- *Fish and Crab Consumption* – For the fish and crab consumption scenarios, COPC sediment data will be from combined intertidal and subtidal sediments throughout the Site, i.e., the same data as the netfishing scenario.

Exposure point concentrations (EPCs) will be determined following EPA guidance on calculating the UCL of the mean concentration for a given COPC, using the ProUCL program (EPA 2004b). Rules for the calculation of EPCs for sediment will be consistent with the rules outlined in the LDW HHRA (Windward 2007a). Sediment EPCs will be calculated for the area of exposure identified for the netfishing, clamming, and beach play scenarios. EPCs for tissues will be modeled from BSAFs and sediment areas, as described above in Section 11.3.1.3. BSAFs will be used to relate sediment and tissue concentrations of all COPCs for clams, and will be evaluated for use for fish species. As described earlier in Sections 6 and 8, BSAFs for developing EPCs in tissue will be taken from the literature, and site-specific data that are presently planned for collection on sediment and clam tissue chemical concentrations may also be used to develop BSAFs. Should co-located tissue and sediment data from the LDW site be available for the Lockheed West COPCs, they may be used to develop BSAFs for the Lockheed West site, in consultation with EPA Region 10.

A summary of the types of EPCs that are planned for use in the HHRA is shown in Table 11-3. As mentioned earlier, EPCs are the only data that will be specific to the Lockheed West site; with other exposure data and exposure parameters taken from the LDW HHRA, in the streamlined approach to the HHRA.

11.3.3 Toxicity Assessment

The toxicity assessment will present reference doses and cancer slope factors for the COPCs. Sources of toxicity criteria will be identified following the USEPA hierarchy (EPA 2003b):

- Tier 1 – Integrated Risk Information System (IRIS) database (EPA 2007b)
- Tier 2 – Provisional Peer-Reviewed Toxicity Values (PPRTVs), EPA Office of Research and Development/National Center for Environmental Assessment (NCEA)
- Tier 3 – Other toxicity values. Tier 3 includes additional EPA and non-EPA sources of toxicity information. Priority is given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed. Sources include EPA regional offices, EPA Health Effects Assessment Summary Tables (HEAST) values, California EPA, and Agency for Toxic Substance and Disease Registry (ATSDR) minimal risk levels.

The sources for the PPRTV, NCEA, HEAST, and ATSDR toxicity values are the EPA Region 3 RBC table (EPA 2007a), and the Region 6 screening tables (EPA 2007c). For PAHs, the CalEPA slope factors will be used (CalEPA 1994). These sources will be queried for updated information on toxicity values during the HHRA. Descriptive information on the toxicity of the COPCs responsible for the majority of the risk will be described, based on information provided in the IRIS database and ATSDR toxicological profiles. The toxicity profiles provided in attachment 3 of the LDW HHRA (Windward 2007a) will be included in the Lockheed West HHRA as appropriate.

The toxicity assessment will present the quantitative relationship between estimated exposure (dose) to COPCs and the likelihood of adverse effects. The quantitative relationships are toxicity values used to quantify risk, and are expressed as cancer slope factors (CSFs) for carcinogenic effects and reference doses (RfDs) for non-carcinogenic effects. CSFs are used to estimate the probability that a person would develop cancer given exposure to site-specific contaminants. This site-specific risk is in addition to the risk of developing cancer due to other causes over a lifetime. Consequently, site-specific risk estimates are frequently referred to as "incremental" or "excess lifetime" cancer risks. The CSF is expressed in units of the inverse of chemical intake or dose $(mg/kg\text{-}day)^{-1}$. RfDs represent a daily contaminant intake below which no adverse human health effects are expected to occur.

11.3.4 Risk Characterization

The risk characterization will consist of risk estimations for each exposure scenario and pathway, and discussions of uncertainties in the exposures, toxicity, and risk estimates. Risk estimations will be tabulated, and will be consistent with EPA (1998a) recommendations for results presentation. Risks are estimated by integrating information and data from the exposure and toxicity assessments. Risks will be estimated for cancer and non-cancer endpoints, and will follow EPA (1989) guidance on risk characterization. Conclusions about cancer and noncarcinogenic risks and exceedances of EPA risk ranges under CERCLA will be presented. Risks will be summed across relevant pathways of exposure, as per the LDW HHRA. A discussion of potential background concentrations of select chemicals will be included; for example, regional or area background on arsenic, PCBs, and PAHs may be available from the LDW RI, or may be developed as part of the Lockheed West RI/FS (see Section 6 for more discussion). The incremental site-related risk above background will be discussed as appropriate.

11.3.4.1 Cancer Risks

For carcinogens, risks will be expressed as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the carcinogen. Risks are probabilities that usually are expressed in scientific notation (e.g., 1×10^{-6} or 1E-6). An excess lifetime cancer risk of 1E-6 indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. The EPA generally acceptable cancer risk range under the NCP and CERCLA guidance is 1E-4 to 1E-6.

11.3.4.2 Non-Cancer Risks

The potential for noncarcinogenic effects will be evaluated by the HQ, which compares an exposure level over a specified time period (e.g., lifetime) with an RfD derived for a similar exposure period. An HQ less than 1 indicates that an individual's dose of a single contaminant is less than the RfD and toxic effects from the chemical are unlikely. An HI will be generated by adding the HQs for all COPCs that affect the same target organ (e.g., liver) or act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An HI less than 1 indicates that, based on the sum of all HQ's from different contaminants and exposure routes, toxic noncarcinogenic effects from all contaminants are unlikely. An HI greater than 1 indicates that site-related exposures may present a risk to human health, and target organ or effects-specific HQs will be developed.

11.3.5 Uncertainty Assessment

The uncertainty assessment will describe uncertainties in the exposure and toxicity assessments, and the risk characterization for the Site. Uncertainties will be described qualitatively, with an estimate of the impact of the uncertainty on the risk estimates. Risks to human health typically may be over- or underestimated based on the appropriateness of the assumptions regarding exposure, the availability and assumptions associated with the derivation of toxicity factors, and the use of modeling to represent exposure point concentrations. For the Lockheed West Site, exposure parameters will not be site-specific but will be taken from the LDW HHRA. Their appropriateness to the Lockheed West Site will be discussed. Because of the uncertainties that affect the estimations of risk, EPA (1989) suggests that estimates are only accurate to within an order of magnitude.

11.4 BASELINE ECOLOGICAL RISK ASSESSMENT PLAN

The ERA for the Lockheed West site will be based on EPA guidance for performing ERAs at Superfund sites (EPA 1992, 1997b,c, 1998a,b). The basic format of the ERA will start with the Problem Formulation step, where the ecological receptors to be evaluated, their habitats at the Site, and the sources and pathways of chemical exposures are developed. The Analysis step consists of an evaluation of the potential adverse effects from chemical contamination, and an estimation of the exposures of wildlife receptors to Site chemicals. The Risk Characterization step will present the risk results for the Site, discuss the level of certainty in their estimates, and identify uncertainties in source information.

11.4.1 Problem Formulation

The Problem Formulation will establish the scope of the assessment, including ROCs, selection of COPCs, assessment endpoints, and exposure pathways. The habitat present at the Site will be identified, based on existing information and survey information collected during RI activities.

The aquatic environment at the Lockheed West site consists of marine waters and sediments. Benthic habitats include intertidal habitat (exposed by low tides) and subtidal habitat (never exposed by low tides). Much of the subtidal habitat has been dredged at various times in the past, in both the north and east portions of the Site. The east subtidal habitat includes part of the deeper navigation channel of the West Waterway.

Although the sediments on the east portion of the Site lie in the West Waterway segment of the Duwamish River discharge, and the region of Puget Sound is considered to be an estuary, the sediments and bottom water column layer of all the aquatic habitat of Lockheed West are generally marine in nature. The Duwamish Waterway is characterized by a salt-water wedge that originates in Elliott Bay and moves up and down the Waterway. At moderate freshwater inflows of the river (greater than 1,000 cubic feet per second), the saltwater wedge extends upstream to the East Marginal Way Bridge, approximately 8 miles upstream of Harbor Island, regardless of the tide height (Stoner et al. 1975). Under high-flow conditions, the saltwater wedge is estimated to be pushed as far downstream as 3 miles above Harbor Island during flood tides and 2 miles above Harbor Island during ebb tides. The Lockheed West site is located across the West Waterway from the downstream end of Harbor Island.

Although freshwater overlies the saltwater wedge in the lower Duwamish, including the waterways around Harbor Island, there is little to no downward movement of water from the upper layer into the saltwater wedge (Santos and Stoner 1972). Also, at any given time and location along the waterways, the salinity at a given depth is nearly the same from one side of the channel to the other (Santos and Stoner 1972). Primary habitat for the aquatic lands can be identified as the intertidal marine sediments along the Site shoreline and the subtidal marine environment adjacent to the Site.

11.4.1.1 Selection of Receptors of Concern

Selection of ROCs for the ERA is based on the habitat present at the Site. For a primarily marine intertidal and subtidal habitat at Lockheed West, the selected ROCs are consistent with the ROCs identified for the nearby LDW site. The recent ERA for the LDW site selected ROCs with a thorough evaluation of potential ecological receptors that may use the Site and a set of criteria for identifying ROCs. The following criteria were used to select ROCs:

- Potential for direct or indirect (e.g., ingestion of fish or invertebrates) exposure to sediment-associated chemicals
- Human and ecological significance
- Available habitat and site usage
- Sensitivity to COPCs at the site
- Susceptibility to biomagnification of COPCs (i.e., higher-trophic-level species)
- Data availability.

The key direct and indirect exposure routes from sediment were identified (e.g., direct exposure to sediment or ingestion of prey associated with sediment either directly or through prey). Groups of organisms that may be exposed via these pathways were then identified, and representative species that were thought to be most exposed were selected from these groups representing the greatest potential for exposure.

Benthic Invertebrates

***Benthic invertebrate communities* –** Benthic invertebrate communities serve as a major food resource for commercially and recreationally important fish and wildlife, and they are active in detrital processing and nutrient cycling. The benthic community as a whole will be evaluated as an ROC. A wide variety of benthic invertebrates would be expected to inhabit the sediments at Lockheed West, similar to population assemblages of Elliott Bay and nearby sediment sites such as the West Waterway and Lower Duwamish Waterway. Most of the marine benthic species are in direct contact with sediment year-round and have a limited home range. Benthic invertebrates are exposed to sediment through several different pathways, such as filter feeding and detritus feeding. Benthic invertebrates include sediment dwellers (benthic infauna, which includes clams) and organisms closely associated with the sediment surface (epibenthos). Species and assemblages have been identified for the lower Duwamish Waterway and Elliott Bay (Windward 2007b).

The benthic invertebrate community is selected as a ROC for the Lockheed West ERA. The community consists of infauna and epibenthic organisms in both intertidal and subtidal habitats.

***Crabs* –** Crabs are selected as an ROC to represent higher-trophic-level benthic invertebrate species present at the Site. Evaluation of benthic invertebrates using SMS and toxicity-based criteria for sediments does not account for exposures or risks to higher trophic benthic organisms. Crabs were selected as ROCs for the LDW ERA to fill the role of higher trophic benthic receptor.

Fish

A diversity of fish species is found in the Duwamish River and Elliott Bay, and available studies documenting fish communities have been summarized in the West Waterway OU risk assessments (ESG 1999, Weston 1994) and the LDW ERA (Windward 2007b). As summarized in Windward 2007b), shiner surfperch, snake prickleback, Pacific sandlance, Pacific staghorn sculpin, longfin smelt, English sole, and starry flounder were particularly abundant in these studies, as were juvenile chinook, chum, and coho salmon.

English sole, Pacific staghorn sculpin, and juvenile chinook salmon were selected as the ROCs for the LDW ERA. English sole was selected to represent benthivorous fish species; Pacific staghorn scuplin was selected to represent upper trophic level fish; and juvenile Chinook salmon were selected to reprensent anadromous fish. English sole and scuplin were selected largely because of their potential for exposure to sediment chemicals, based on their prey preferences and feeding behavior, and because of a high abundance in the

LDW. Juvenile Chinook salmon were selected as a ROC for the LDW because the Puget Sound evolutionary significant unit of chinook salmon is a federally threatened species under ESA, and to serve as a surrogate for other juvenile anadromous salmon species. Their exposure to sediment chemicals at the LDW site was considered to be less than that of sole or scuplin based on feeding behavior. Due to the substantially smaller size than the LDW site, juvenile chinook salmon would not be expected to be present at the Lockheed West Site for as long a duration as at the LDW site, particularly compared with the longer residence times of a non-migratory species such as the sculpin. Their exposures to sediment chemicals would be expected to be significantly less than those of sole or sculpin.

The low exposure of juvenile salmon to sediment chemicals in the Duwamish system was demonstrated in the LDW ERA, where dietary exposure estimates for juvenile salmon exposures to sediment chemicals were below risk thresholds. The screening risk evaluation for juvenile salmon in the LDW particularly focused on exposure to PAHs through dietary sources (Section A.2.5.2, Windward 2007b). The dietary exposure was evaluated through comparison of both maximum PAH concentrations in diet of fish and of PAH concentrations in stomach contents of juvenile salmon with TRVs developed by NOAA based on exposure of juvenile Chinook salmon to a mixture of PAHs. The concentrations of total PAHs in dietary exposure and in the juvenile salmon stomach contents were an order of magnitude less than the juvenile salmon TRV for total PAHs. Also, the maximum total PAH concentration in sediment in the LDW at 133 mg/kg dw is substantially higher than the maximum total PAH concentration in the Lockheed West sediment, at 73 mg/kg dw, which, coupled with the smaller size of the Lockheed West site, suggests lesser exposure of juvenile salmon to PAHs in sediment at Lockheed West. This comparison of maximum total PAH concentrations in sediment of the two waterways and the analysis of PAH risks in the LDW ERA supports a low risk for juvenile Chinook salmon exposed to sediments at the Lockheed West Site.

An addition, at the Lockheed West Site, the exposures of fish to chemicals evaluated by the tissue residue approach will be quantified by modeling from sediment concentrations to whole body using BSAFs for upper trophic level fish, since BSAFs are not available for individual species such as juvenile Chinook salmon. Thus, for each COPC a single BSAF would be used for all fish species, and risks will be presented for fish as an ROC group, including English sole, sculpin, and salmon. For chemicals evaluated by the dietary approach, such as PAHs, English sole are modeled for exposure to sediment and benthic invertebrate ingestion, and sculpin are modeled for ingestion of sediment plus fish plus benthic invertebrates plus crab (see below). The amount of time that juvenile Chinook salmon would be expected to spend foraging at the Lockheed West Site is not known but is assumed to be low in comparison with the amount of time spent in the much larger upstream LDW, and diet would consist partially of pelagic prey items with much less exposure to sediment chemicals than benthic invertebrate prey of English sole or sculpin. For the above reasons, the exposures of juvenile chinook salmon to Lockheed West sediment will be much lower than those of sole and sculpin, and the risk estimates of English sole and Pacific staghorn sculpin will be protective of lesser exposed species, such as the juvenile salmon.

Based on the above analyses, and in keeping with the streamlined approach to the ERA to focus on risk driver receptors and exposures, English sole and Pacific staghorn sculpin are the two fish species selected as ROCs for the Lockheed West risk assessment.

Fish ROCs are grouped into broad categories based on potential sediment exposure at the Site:

- Benthivorous fish— represented by English sole, and including rock sole and starry flounder. This category was also considered to be protective of fish that prey on pelagic and encrusting organisms, such as Pacific herring and pile perch.
- Upper-trophic-level fish —represented by Pacific staghorn sculpin, and including bull trout and sand sole. Pacific staghorn sculpin is used to represent piscivorous and omnivorous species that prey on other fish.

Wildlife

Potential wildlife uses of the Duwamish River estuary and Elliott Bay include a variety of bird species and waterfowl, and marine mammals. Large carnivorous birds such as osprey and great blue heron forage over a much larger area than the size of the Lockheed West site. Herons also need larger expanses of shallow water than available at the Lockheed West site. Avian exposures that may be more specific to the Site are best represented by waterfowl and shoreline birds that forage primarily in intertidal sediments. Waterfowl may feed on benthic invertebrates and may incidentally ingest sediment while foraging, but this exposure is assumed to be less than that of benthivorous birds such as shorebirds, which may ingest significant amounts of sediment while probing intertidal sediment for benthic invertebrates. Spotted sandpipers are a common bird in Puget Sound, and nests have been observed along the lower Duwamish River. They feed primarily on insects, small crustaceans and mollusks, worms, and other invertebrates. Marine mammals, such as seal and otter, forage over much larger areas than the small habitat available at the Lockheed West site.

Wildlife species that may be exposed to the Site on an intermittent basis include herons, osprey, river otter, and harbor seals, and to a lesser extent, sea lions and orcas. Exposures of these wildlife species to the Site would be limited due to the small size of the Site and limited availability of wildlife habitat. In addition, the risks to these wildlife species at the LDW site were much smaller than for the species selected as ROCs for the Lockheed West site.

In addition to the bird and mammal species identified above, other species that were evaluated but not selected in the ERA for the LDW site, and hence not considered for the Lockheed West ERA, include rockfish, due to lack of sufficient presence; bull trout because sculpin were evaluated as representative of the feeding guild; aquatic plants, which were evaluated in the Phase 1 ERA for the LDW site and found to be well below any risk concern (Windward 2003a); and reptiles and amphibians, which are not likely to be exposed to sediment contamination because habitat for these species is limited, and their presence has not been reported in any wildlife surveys conducted in the area (Windward 2007b).

11.4.1.2 Summary of ROCs

Consistent with the rationale in the LDW ERA (Windward 2007b), species selected as ROCs for the Lockheed West ERA are identified as the following:

- Benthic invertebrate community
- Crabs – Dungeness or red rock crab
- Fish – English sole, Pacific staghorn sculpin
- Birds – Spotted sandpiper.

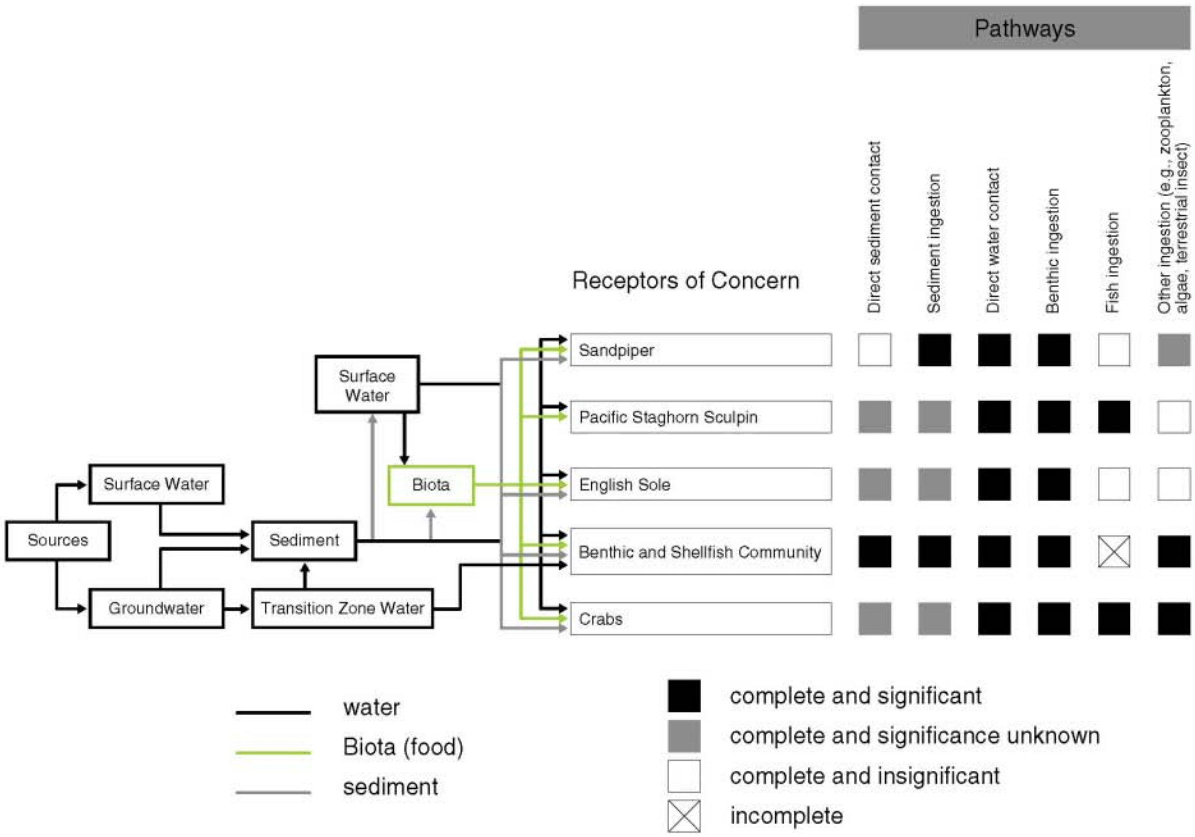
Spotted sandpiper will be included if shoreline habitat is present; 65 percent of the LDW shoreline was found to contain sandpiper habitat, suggesting a high likelihood that habitat will be present at the Lockheed West site. Because of the limited habitat and exposure areas and relatively low risks at the LDW site when compared with the ROCs identified above, ROCs will not include other birds such as bald eagle, osprey, or great blue heron; or mammals such as river otter and harbor seal.

Assessment endpoints are selected in the Problem Formulation step, and are the characteristics of communities and populations that can be affected by chemical exposures and impact the survival or ecological health of that community or population. EPA guidance identifies mortality, growth, and reproduction as appropriate endpoints for evaluating chronic risks to ecological receptors.

11.4.2 Conceptual Site Model for Ecological Exposures

The habitats, ROCs, sources of chemical contamination, and pathways of exposure are graphically depicted in a CSM. A CSM for the ERA for Lockheed West is shown in Figure 11-2. Pathways for the exposure of ROCs to sediment-associated chemicals at Lockheed West can be designated in one of four ways: complete and significant, complete and significance unknown, complete and insignificant, or incomplete. Each of the four designations is defined below, including whether it will be further evaluated in the ERA.

- Complete and significant – There is a direct link between the receptor and chemical via this pathway, and the specific pathway is considered to be potentially important.
- Complete and significance unknown – There is a direct link between the receptor and the chemical via this pathway; however, there is insufficient data available to quantify the significance of the pathway in the overall assessment of exposure.
- Complete and insignificant – There is a direct link between the receptor and the chemical via this pathway; however, the significance of this pathway in terms of overall exposure is considered to be negligible. Pathways classified as complete and insignificant will not be evaluated in the ERA.
- Incomplete – There is no direct pathway between the receptor and the chemical. Pathways classified as incomplete will not be evaluated in the ERA.



Note: Groundwater at the adjacent PSR site may impact sediment benthos through transition zone water.

Figure 11-2. Conceptual Site Model for the Benthic Invertebrate Community, Fish, and Wildlife at Lockheed West

As indicated above, due to lack of habitat and the small size of the Lockheed West site, avian and mammalian wildlife species are not identified as potential ROCs and will not be evaluated in the Lockheed West ERA. Sandpiper is included as a potential ROC, although there is limited availability of habitat. Groundwater and its resulting transition zone water may be a concern for direct toxicity of transition zone water to benthic organisms. Groundwater monitoring will be performed as part of RI activities, particularly the groundwater that may come from the adjacent PSR site. Because the entire contaminated sediment area of the Site will be covered as a remedial measure, groundwater will be evaluated in the FS for its potential to impact the Lockheed West remedial design cap. The CSM will be finalized for the ERA in a format that is consistent with EPA guidance.

11.4.3 Selection of Chemicals of Potential Ecological Concern

Chemicals of potential concern (COPCs) for ecological risk assessment are those contaminants related to the Site that may pose a risk to ecological receptors. COPCs will be determined through a screen conducted using site-specific exposure data where available. The list of chemicals that were analyzed in sediment is presented elsewhere in the RI work plan and will serve as the starting point for selecting COPCs; the chemical list and risk-based analytical concentration goals for sediment chemicals are shown in Table 11-2. The screen will consist of comparisons of chemical concentrations in environmental media with screening criteria appropriate to the ROCs. Conservative exposure assumptions (e.g., maximum chemical concentrations) will be used in this screen to determine which COPC will be relevant for which ROC.

11.4.3.1 COPC Screening Steps

The process used to screen and select COPCs is taken from the screening criteria developed and approved by EPA for the LDW ERA (Windward 2007b). The screening process will consist of the following steps:

1. For chemicals that are always undetected, if detection limits are below RBACGs, they will be screened out from further evaluation. Undetected chemicals with detection limits exceeding RBACGs will be noted through the evaluation.
2. Frequency of Detection – Chemicals that are detected in less than 5 percent of sediment samples will be screened out from further evaluation. An infrequently detected contaminant will be rejected if is not found in other environmental media, if there is no reason to believe that the contaminant should be found, and if there is not a unique site feature that may explain the presence of the contaminant.
3. Comparing detected chemicals against background – Chemical concentration will be compared with available background concentrations for metals. For the purpose of comparison, background will be defined as the concentrations identified in the LDW risk assessments. EPA (2002c) also describes evaluation of background in soils, and the procedure is to compare the site data distribution with the background data distribution. If appropriate background concentrations of chemicals detected at Lockheed West sediments are unavailable, as determined in consultation with EPA, this comparison step will not be performed. No COIs will be eliminated from further evaluation based on this comparison..
4. Comparison with risk-based screening criteria – Sediment chemicals that pass the above steps will be screened against risk-based screening criteria that are based on acceptable risk levels associated with exposure to sediment chemicals. Maximum concentrations in the top 10 cm of sediment will be screened against the screening

criteria. Identification of the screening criteria for ecological ROCs is presented below.

11.4.3.2 Benthic Invertebrates Screening Criteria

For benthic invertebrates, including clams, maximum concentrations in surface sediments of chemicals that pass the first three screening steps will be compared to SQS (Ecology 2001b). For chemicals with no SQS, maximum concentrations will be compared to DMMP guidelines (USACE et al. 2000) that were determined to be toxicologically based for benthic invertebrates (Windward 2007b). In cases where no DMMP value are available or the available DMMP value is not toxicologically based (i.e., total DDTs), the values identified as toxicologically based in the LDW ERA (Windward 2007b) will be used. Chemicals exceeding the SQS, DMMP guidelines, or toxicologically based values will be identified as COPCs for benthic invertebrates. For TBT, the screening value will be taken from the one calculated in Windward (2005a) for the sediment sampling QAPP.

11.4.3.3 Fish and Crab Sediment Screening Criteria

For fish and crabs, chemicals in Lockheed West sediments that have passed the first three screening steps will be screened by comparison of their maximum sediment concentrations with the following criteria:

1. Bioaccumulative chemical identified in USEPA (2000)
2. Sediment bioaccumulation criteria (PSDDA 1988, USACE et al. 2000, ODEQ 2007).
3. Toxicity-based screening criteria:
   a. Screening values for fish and crab that are calculated from toxicity reference values (TRVs) in the LDW ERA (Windward 2007b)

   OR

   b. Chemical concentrations developed from LDW data on sediment associated with acceptable risk levels for fish or crab.

      The LDW RI developed RBCs for sediment that are protective of risks to ecological receptors, based on results from the baseline ERA. These RBCs are also referred to as risk-based threshold concentrations (RBTCs). The ERA RBTCs provide sediment concentrations specific to the LDW that are associated with regulatory risk levels for ecological receptors. These ERA RBTCs can be used as a source of screening levels for chemical concentrations in Lockheed West site sediments to select COPCs for the ERA.

11.4.3.4 Fish and Crabs Tissue Screening Criteria

Fish or crab tissue data are not planned for collection at the Site. Should any fish or crab tissue data become available for the Site, COPCs will be identified using a critical tissue-residue approach and a two-step process described for the LDW ERA. The first step is an initial screen to select chemicals that meet these criteria:

- Detection in at least 5 percent of surface sediment samples
- Identification as a bioaccumulative chemical in USEPA (2000).

In the second step, the maximum exposure concentration of each chemical passing the above screen will be compared to a NOAEL for that chemical, using the NOAELs developed for fish and crabs in the LDW ERA (Windward 2007b). If the maximum exposure concentration is greater than the NOAEL for fish or crab, the chemical will be identified as a COPC for fish or crab.

11.4.3.5 Sandpiper Screening Criteria

Selection of COPCs for sandpiper will consist of screening of maximum concentrations against NOAEL-based screening values from the LDW ERA. These criteria are listed in Table 11-2.

11.4.4 Analysis

The analysis phase of the ERA consists of an exposure assessment and an effects assessment.

11.4.4.1 Exposure Assessment

Measures of exposure refer to how the exposure of each ROC will be estimated. Measures of exposure must provide data that can be compared directly to toxicity data in the risk characterization. Because toxicity data may be based on chemicals present in the ROC tissue or on chemicals that the ROC is exposed to through dietary intake, the matrix for exposure (e.g., tissue or exposure media such as sediment or prey tissue) is a critical determinant. The measures of tissue chemical concentrations provide an estimate of integrated exposure through all significant pathways.

Measures of exposure will be described for each of the ROCs, and will be the concentrations of COPCs in the medium to which the ROC is exposed, or in tissue for those ROCs that are assessed based on tissue levels of COPCs. Exposure media for this ERA consist of sediment and tissue.

- *Sediment exposures* – will be determined from data collected in 2007 under the RI work plan for the Site.
- *Tissue as exposure media* – may consist of the whole body chemical residue of the particular ROC, or tissue of dietary prey items.

As described below, tissue concentrations of COPCs will be estimated by modeling from sediment concentrations. A summary of the types of exposure data and how they will be used in the ERA for each of the ecological ROCs is provided in Table 11-4.

A summary of the exposure point concentrations to be used in the ERA consist of:

- Benthic Invertebrates – Single point concentrations of the full surface sediment data set for comparison with SMS values.
- Fish and crab exposure – The 95 percent UCL of the full 2007 Lockheed West site surface sediment data set; tissue concentrations of ROCs and prey will be estimated by one of the tissue modeling methods described below.
- Sandpiper exposure – The 95 UCL of the 2007 Lockheed West site intertidal surface sediment data; benthic invertebrate tissue concentrations (as prey) will be estimated by one of the modeling methods described below.

Tissue modeling approaches

Options for modeling tissue concentrations at the Lockheed West site consist of the following, listed in priority of selection.

Option 1 – Literature BSAFs

Tissue data will be modeled using BSAFs and the approach used in the QAPP for collecting sediment samples at the LDW (Windward 2005a). This method has been described above in the derivation of screening criteria. For the exposure assessment for all ROCs, BSAFs will be identified for the various ROC categories, including benthic invertebrates, clams, crabs, and fish. Clam BSAFs will be based only on deposit feeders, unless unavailable. Windward (2005a) found that reliable BSAFs are available only from clam data; BSAFs for fish varied by orders of magnitude (USACE 2003). Nonetheless, fish BSAFs will be taken from available sources as 90^{th} percentile values of the data, or as reported percentiles if data are not presented. In addition to the literature BSAFs, the regression equations developed in the LDW ERA for PCBs, arsenic, and TBT exposures of benthic invertebrates will be used for benthic invertebrate and clam modeling.

Sources of the BSAFs that were used in the LDW QAPP and will be used in the Lockheed West ERA are the following:

> US Army Corps of Engineers Environmental Residue-Effects Database (ERED) - http://www.wes.army.mil/el/ered/
>
> Tracey GA, Hansen DJ. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. Arch Environ Contam Toxicol 30:467-475.
>
> EPA. 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National Sediment Quality Survey. EPA 823-R-97-006. US Environmental Protection Agency, Office of Science and Technology, Washington, DC.
>
> Washington State Department of Health. 1995. Tier I report, development of sediment quality criteria for the protection of human health. Washington State Department of Health, Olympia, Washington.

In addition to the above sources, BSAFs will be taken from the following:

> PTI. 1995. Bioaccumulation Factor Approach Analysis for Metals and Polar Compounds. Washington Department of Ecology. BSAFs are available for metals as 90th percentile values for deposit feeder clams, or filter feeders if deposit feeder data are unavailable.
>
> Oak Ridge National Laboratory. 1998. Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation. Bechtel Jacobs Co. BSAFs are available for metals in freshwater clams, as 90th percentile values.
>
> Windward. 2007. Ecological Risk Assessment, Lower Duwamish Waterway, Attachment 11. Regression equations on collocated benthic invertebrates and sediment data were developed for arsenic, PCBs, and TBT using LDW site data.

Option 2 - LDW site data

LDW site data may be reviewed and used to develop BSAFs, following consultation with EPA. BSAFs were not calculated in the LDW risk assessments or the draft RI (Windward 2007b,c). For some risk driver chemicals, derivation of BSAFs from the LDW site may not be possible. For PCBs, a food web model (based on the Gobas model) was used in the LDW RI to model relationships between sediment and tissue of total seafood (fish, crabs, clams) for the derivation of risk-based threshold concentrations (RBTCs). Whether specific and significant relationships may exist between sediment PCBs and PCBs in fish, crab, or clam was not explored. For other chemicals, tissue-to-sediment relationships were evaluated only in clams because their consumption represented the vast majority of risk. However, for arsenic and PAHs, no relationships between tissue and sediment data from the

LDW were found and no BSAFs were derived. Site-specific issues related to modeling tissue concentrations of the ROCs or their prey in the Lockheed West ERA are discussed below.

Option 3 – Other site data

As mentioned in the work plan text for the HHRA, data may be available in the future for collocated clams and sediment. These data could be used for the development of site-specific BSAFs for clams; however the data are planned to be collected in parallel with the risk assessment and may not be available for use in the risk assessment. In addition, data from the adjacent PSR and West Waterway sites may be evaluated for potential use in deriving BSAFs if needed.

Benthic Invertebrate Exposures

Benthic invertebrates will be assessed for risks as a community of organisms. Quantitation of exposures will be based on concentrations of COPCs measured in sediment, which will be compared with sediment quality guidelines as presented in the next section on effects analysis. Intertidal and subtidal sediment data described in this RI work plan will be used to develop exposure concentrations for benthic invertebrates.

Consistent with other ERAs at local sites (e.g., LDW), crabs are used as surrogates for higher-trophic-level benthic invertebrates. Crab exposure to sediment-associated chemicals will be estimated by modeling from sediment concentrations. The modeling method will use sediment concentrations of COPCs and BSAF values for COPCs in crab. BSAF values will be identified as described above, or based on data collected from co-located crab and sediment samples collected in the LDW if such data are available for the suite of COPCs. The LDW ERA collected data on tissue residues in both edible meat and hepatopancreas of Dungeness crab, which were used to estimate whole body concentrations. Chemical concentrations in both edible meat and whole body of crab would be modeled from Lockheed West sediment concentrations, using the appropriate BSAF values derived from the LDW studies.

EPCs for crabs will be used as the exposure term for those COPCs that are evaluated for risk by comparison of the tissue concentration with a tissue-based toxicity value. Modeled tissue data for crab will also be used in the dietary approach for sculpin.

Fish

The approach to determining exposures of fish to site-related chemicals depends on the specific method for evaluating risks. For those COPCs for which risks are evaluated using tissue concentrations, exposures will be estimated using whole-body tissue residues. Examples of these chemicals include PCBs, mercury, DDT, and TBT. For those COPCs for which risks are assessed through dietary exposures, exposures to fish will be determined through concentrations of COPCs in dietary items. A dietary approach will be used for exposures to PAHs and metals because these chemicals are either metabolized or actively regulated by fish. The selection of tissue residue or dietary method for evaluating fish risks will follow the approach described in the ERA for the LDW site (Windward 2007b).

Tissue Residue Approach

For those COPCs for which risks to fish are evaluated through the tissue residue method, concentrations in fish tissue will be estimated through modeling. Consistent with the streamlined approach to this risk assessment, modeling will be performed following the BSAF method; the food web model developed for PCBs at the LDW site will not be used unless the BSAF method is viewed in consultation with EPA Region 10 as unsatisfactory. The food web model developed for the LDW site predicts concentrations of total PCBs in tissues of a variety of marine species, including the fish and crab ROCs identified for this ERA, from sediment total PCB concentrations. The LDW food web model was developed for predicting reductions in sediment concentrations of total PCBs in fish tissue based on decreases in sediment PCBs following remediation. The parameterization of the LDW food web model was determined through several technical memoranda (Windward 2005b,c). Parameterization was finalized by calibrating the model to known tissue and sediment concentrations, and included parameterization for four areas of the LDW site.

The downstream area closest to Harbor Island is marine at the sediment layer and is parameterized for the marine environment. In addition, the other areas of the LDW that have minimal freshwater influences on sediments may be considered for modeling if sufficient data from the downstream area are not available. For the Lockheed West site, if the food web model is applied to predicting PCB concentrations in tissues, application of the model may consider the established parameterization for the LDW area adjacent to Harbor Island, in addition to the full LDW modeled area. Average concentrations of COPCs from the intertidal and subtidal surficial sediment samples collected from the Site in 2007 will be used as sediment data in any modeling.

The primary method for estimating fish tissue concentrations of COPCs will be the BSAF relationships. BSAFs for COPCs for fish ROCs will be taken from the sources identified above, or they may be derived from co-located sediment and fish tissue data from the LDW, including the area nearest Harbor Island. The BSAFs will be used to predict fish tissue concentrations of COPCs related to the sediment concentrations at Lockheed West. This approach may be explored for all COPCs at the Lockheed West site.

Dietary Approach

For COPCs that are evaluated by dietary exposures, exposures are typically estimated for all pathways, including prey, sediment ingestion, and water. Prey tissue concentrations of COPCs will be modeled following the BSAF approach discussed above. For benthic invertebrates as dietary components of fish, modeling will be performed using BSAFs. Arithmetic mean concentrations of COPCs in intertidal and subtidal sediments will be used to estimate benthic invertebrate concentrations as prey for English sole and Pacific staghorn sculpin. For sandpiper, average concentrations using the intertidal sediment samples identified in the RI work plan will be used to model benthic invertebrate tissue concentrations.

For clams as potential dietary components of ROCs, tissue concentrations will be determined by modeling from sediment concentrations; in addition, tissue chemistry data may be available in the future from the clam sampling from the Site. For modeling concentrations in clams, tissue concentrations will be estimated using average sediment concentrations and appropriately derived BSAFs, as described above.

For a dietary approach for fish exposures, the procedure for compiling benthic data will follow the procedure used in the LDW ERA. In that procedure, all benthic invertebrates collected from a location were combined and analyzed as a composite sample. Following this approach for English sole, benthic invertebrate tissue data modeled from the full sediment data set would be used to estimate dietary exposure to prey. English sole would also be assumed to incidentally ingest sediment throughout the Lockheed West sediments, at the rate of one percent of total diet, as identified in the LDW ERA. Because the home range or foraging range of English sole exceeds the area of Lockheed West sediment, a site use factor would typically be considered for a site-specific assessment of risk. However, in keeping with the intent of the streamlined approach to the ERA, all site use factors will be set at 1.0.

Sculpin exposures to PAHs and metals will be assessed using similar methods to those described for English sole, but modeled fish tissue and crab tissue data will be included along with benthic invertebrates for the prey ingestion component, using parameters and dietary percentages identified in the LDW ERA. Perch tissue concentrations of COPCs will be estimated by modeling from sediment concentrations using the BSAF approach developed for the LDW site and adapted to the Lockheed West site, as described above.

Wildlife

Sandpiper exposures will be evaluated by exploring relationships between sediment concentrations of COPCs at Lockheed West and sandpiper intake at similar concentrations, using information from the LDW draft ERA. The LDW ERA estimated exposures and risks to sandpiper through a dietary approach, where exposure estimates were based on tissue concentrations in prey, food and water ingestion rates, and body weight.

Based on the assumption that dietary intake of prey and water by sandpiper at Lockheed West are similar to those in the LDW, exposures to sandpiper for the Lockheed West site will be based on exposures parameters used for the LDW ERA. Use of the exposure data from the LDW site will be a linear extrapolation to the Lockheed West site, based on ratios of sediment concentrations related to potential risk to sandpiper.

Intake parameters, assumptions about exposures, and equations for developing intake will be consistent with the LDW ERA. For sandpipers, exposures to site-related chemicals will be based on dietary intake of benthic invertebrates and sediment during forging. The source of sediment data is listed below in Table 11-4; concentrations of COPCs in prey items will be derived by modeling using BSAFs, as described above for fish prey.

For PCBs, data on total PCBs as Aroclors in sediment will form the basis for estimating PCB exposures and risks to ROCs at the Lockheed West site. The LDW draft ERA demonstrated that risks from exposures to PCBs measured as Aroclors and those estimated as congeners, using the TEQ approach, were not substantially different, and hence risks will focus on PCBs as Aroclors.

Bioaccumulation of Sediment COPCs

Several of the ROCs described above address exposures to sediment COPCs by bioaccumulation through the food chain. For example, crabs have been selected to represent benthic organisms that may bioaccumulate sediment COPCs. Similarly, sculpin were selected to represent upper trophic level piscivores that may bioaccumulate chemicals from sediment through ingestion of benthic invertebrates and small fish as prey items.

Bioaccumulation of key COPCs in the LDW has been evaluated based on data on co-located sediment and benthic invertebrate tissue samples (Windward 2007b). Regression equations may be useable for the bioaccumulative COPCs PCBs, TBT, and arsenic. Bioaccumulation tests are not planned in support of the Lockheed West ERA. The evaluation of risks to higher trophic ROCs such as crabs, sandpiper, and sculpin will address the potential bioaccumulation of COPCs and resultant risks to ecological receptors.

Key bioaccumulation issues such as for TBT will be addressed by using the regression relationship established for the LDW (Windward 2007b).

Summary of Biological Resources Evaluated in the Risk Assessments

The following is a brief summary of the biological resources that will be evaluated for both the ecological and the human health risk assessments for the Lockheed West site:

- Benthic invertebrate community, including clams
- English sole as: 1) an ROC in the ERA representing benthic fish that primarily consume invertebrates, and 2) seafood consumed by people
- Pacific staghorn sculpin as: an ROC in the ERA representing fish that consume both invertebrates and small fish
- Shiner surfperch as: 1) prey for wildlife ROCs, and 2) seafood consumed by people
- Crabs as: 1) an ROC in the ERA representing larger and more mobile invertebrates, 2) prey for sculpin, and 3) seafood consumed by people
- Clams as: 1) prey for wildlife ROCs, and 2) seafood consumed by people.

As part of the streamlined approach to this risk assessment, all exposure parameters and dietary intake calculations for the Lockheed West ROCs will be taken from the LDW ERA.

11.4.4.2 Effects Assessment

The effects assessment presents toxicity data on potential adverse effects to ROCs from exposures to site-related COPCs. The effects data are used to estimate risks associated with exposure estimates in the risk characterization. The types of effects data depend on the ROC. For example, fish effects data consist of either tissue concentrations related to toxicity (critical tissue residue approach) or dose related to dietary intake toxicity, whereas benthic invertebrate community effects data consist of sediment data related to effects. Fish tissue data or site-specific toxicity tests can also be used to evaluate effects data, but those data are not planned for collection in the Lockheed West ERA. Clam tissue data, if collected to verify the BSAFs used in tissue modeling, may be useful in a future evaluation of clam tissue residue-based effects.

Benthic Invertebrate Community

For the benthic invertebrate community, sediment quality guidelines will form the basis of effects-based sediment concentrations. Sediment quality guidelines will consist primarily of Washington State SMS, and for any COPCs for which SMS are unavailable, dredge disposal guidelines (USACE et al. 2000) or other federal agency guidelines for marine sediments will be used (e.g., NOAA). For COPCs lacking sediment quality guidelines, toxicity values compiled recently for application to the LDW site will be used (Windward 2007b).

For evaluating TBT in the benthic community, because of the lack of SMS, tissue concentrations have been used for comparison with tissue-based toxicity criteria, as recommended by EPA (2000) and used in the Phase 1 ERA for the LDW (Windward 2003a). For the tissue-based TBT assessment, all relevant tissue-based TRVs involving survival, growth, and reproduction are available in the LDW draft Phase 2 baseline ERA report (Windward 2006b).

The most common sublethal endpoints from TBT exposures to benthic invertebrates are growth inhibition, shell chambering in oysters, histological and behavioral abnormalities, and imposex in prosobranch gastropods. Molluscs appear to be the most sensitive taxon to TBT, primarily due to their weak ability to metabolize this compound and their high rate of uptake. Studies have noted that many of the sublethal responses reported for TBT exposure would eventually lead to death of the organism in the environment (Meador et al. 2002). NOAA's National Marine Fisheries Service (NMFS) has determined that a threshold concentration of 6 mg/kg OC-norm will result in adverse effects to prey species of salmonids (Meador et al. 2002). The NMFS sediment concentration of TBT will be used as a protective value to compare with concentrations measured in sediment at the Site.

In addition to sediment criteria, toxicity thresholds for imposex in gastropods related to TBT in sediment in the LDW will be applied to Lockheed West sediment. In the LDW ERA, the basis of the assessment of risk to gastropods was the level of imposex observed in field-collected gastropods (Windward 2007b). The range of concentrations of TBT in LDW sediments in areas where gastropods were found was insufficient to result in a level of imposex to present a risk of sterilization, and hence of causing population-level effects. The associated sediment levels of TBT can be assumed to represent a range of field-based imposex endpoint concentrations applicable to the Lockheed West sediments. The results of the gastropod field observations in the LDW will be used as the effects endpoint in the comparison of TBT concentrations in Lockheed West sediments with those in LDW sediments.

Because of the plans to actively remediate the entire sediment Site, sediment toxicity testing will not be conducted as part of the streamlined approach to the ERA. Existing toxicity test results are considered to be out-dated and will not be used in the ERA.

Crabs

For crabs, a critical tissue residue approach will be used to assess effects from exposure to sediment-associated COPCs. Tissue-based TRVs associated with survival, growth, and reproduction will be the TRVs compiled in the LDW Phase 2 ERA (Windward 2007b).

Fish

For fish, toxicity criteria will be selected as concentrations in tissue or as doses associated with adverse effects and with no effects on the population-level endpoints of survival, growth, and reproduction. Toxicity criteria for fish will be the TRVs compiled in the LDW ERA (Windward 2007b).

Wildlife

For sandpiper, dietary intake-based TRVs from the LDW ERA (Windward 2007b) will be used, as developed from recently compiled toxicity data.

11.4.5 Ecological Risk Characterization

The risk characterization section of the Lockheed West baseline ERA will estimate risks to the ROCs that may contact COPCs in sediment, and will present an assessment of uncertainties in the various parts of the RA for each ROC. The typical approach to estimating risks is to compare the effects-based toxicity criteria (i.e., TRVs) with exposure data for the COPC. As per EPA guidance, TRVs based on no effects and on effects will be compared to the EPC to calculate hazard quotients (HQs). For this ERA, where ROCs and COPCs are the same or similar as in the ERA for the LDW site, comparisons of chemical concentration data for Lockheed West sediment will be made with TRVs and toxicity-based criteria identified or developed in the LDW ERA.

The comparison of exposure concentrations to TRVs, and quantitation as HQs, will be performed for each of the benthic invertebrate, fish, and wildlife ROCs. For fish, HQs may be derived from comparison of whole body tissue concentrations of COPCs with appropriate TRVs, or from concentrations of COPCs in dietary items with appropriate dietary TRVs.

For TBT, risks to gastropods will be based on a comparison of sediment levels of TBT at Lockheed West with those in sediments of the LDW in the area nearest Harbor Island that were found to be below risk levels for gastropod reproductive effects. The LDW ERA based the assessment of risk to gastropods on the level of imposex observed in field-collected gastropods (Windward 2007b). Exceedance by Lockheed West sediment TBT concentrations of the range of endpoint-related concentrations in LDW sediments may constitute a risk to gastropods, but the lower threshold for effects, i.e., a low-observed-effect-concentration for sterility in gastropods collected from the LDW is unknown. In addition, risks to benthic invertebrates will be evaluated by comparing sediment concentrations with the toxicity-based value identified in Meador et al. (2002), as described above as a screening criterion for TBT.

Should TBT concentrations in Lockheed West sediments exceed the gastropod endpoint-related concentrations in LDW sediments, risks to gastropods may be further evaluated, or may be deemed unacceptable under the streamlined approach to the ERA with no further evaluation. Further evaluation could consist of comparison of bulk sediment concentrations of TBT with evidence for a bulk sediment threshold for gastropod effects. Data from the bioaccumulation tests for the West Waterway OU ERA (ESG 1999), and other data from that site, will be examined for possible bulk sediment threshold relationships (EVS 1999a,b). Should further assessment of TBT be necessary, porewater and/or gastropod tissue concentrations of TBT may be determined for comparison with the porewater and tissue residue threshold values recommended by EPA (1999b).

Risks to the benthic invertebrate community from exposures to TBT in sediment will also be evaluated following the approach in the ERA for the LDW site. A regression relationship was established in the draft ERA between sediment TBT and benthic invertebrate TBT concentrations, which can be used to model TBT concentrations in benthic invertebrates related to sediment at Lockheed West. The modeled tissue concentrations could then be compared with the TRV identified for the benthic invertebrates in the LDW ERA and with a tissue-based TRV for gastropods.

11.4.6 Uncertainty Assessment

Uncertainties inherent in the problem formulation, exposure and effects assessment, and risk characterization will be discussed in the uncertainty assessment. The discussion of uncertainties in the problem formulation will focus on selection of ROCs, assessment endpoints, exposure pathways, and quantitation of exposures. The discussion of uncertainties in the exposure assessment will focus on the availability or relevance of site-specific data to estimate or measure exposure, as well as parameters used in modeling exposure. The discussion of uncertainties in the effects assessment will focus on the availability and relevance of toxicological data for COPCs and ROCs evaluated in the ERA. The possible magnitude and direction of the uncertainties will be discussed.

Table 11-1. Laboratory Method Detection Limits and Reporting Limits

Method and Analyte	RL[1/] (mg/kg dw)	MDL[1/] (mg/kg dw)	Sediment ACG[2/] (mg/kg dw)
EPA Method 8270C -low level			
PAHs			
Acenaphthylene	0.02	0.00909	0.33
Benzo(a)anthracene	**0.02**	**0.00834**	0.0052
Benzo(a)pyrene	**0.02**	**0.00731**	0.00076
Benzo(b)fluoranthene	**0.02**	**0.00734**	0.0047
Benzo(k)fluoranthene	0.02	0.0104	0.047
Total benzofluoranthenes[3/]	0.02	0.0104	1.2
Benzo(g,h,i)perylene	0.02	0.00804	0.16
Chrysene	0.02	0.00809	0.48
Dibenzo(a,h)anthracene	0.02	0.00835	0.06
Fluoranthene	0.02	0.00849	0.80
Indeno(1,2,3-cd)pyrene	**0.02**	**0.00854**	0.0029
Phenanthrene	0.02	0.00863	0.50
Pyrene	0.02	0.00872	5.0
Acenaphthene	0.02	0.00936	0.08
Anthracene	0.02	0.00869	1.1
Fluorene	0.02	0.00917	0.12
Naphthalene	0.02	0.00753	0.50
2-Methylnaphthalene	0.02	0.00721	0.19
Dibenzofuran	0.02	0.00795	0.075
Total LPAHs [4/]	0.02	0.00936	1.9
Total HPAHs [5/]	0.02	0.0104	4.8
Total PAHs [6/]	0.02	0.0104	1,410
Other SVOCs			
1-Methylnaphthalene[12/]	0.02	0.00691	na
1,2,4-Trichlorobenzene	**0.02**	**0.00588**	0.0041
1,2-Dichlorobenzene	**0.02**	0.00876	0.012
1,3-Dichlorobenzene	0.02	0.00755	0.17
1,4-Dichlorobenzene	**0.02**	0.00816	0.016
2-Methylnaphthalene[12/]	0.02	0.0183	na
2-Methyl-4,6-dinitrophenol (4,6-dinitro-o-cresol)[12/]	0.2	0.11	na
2-Nitroaniline[1]	0.1	0.0542	na
2-Nitrophenol[1]	0.1	0.00878	na
2,4,5-Trichlorophenol	0.10	0.00834	610
2,4,6-Trichlorophenol	0.10	0.010	0.61
2,4-Dichlorophenol	0.10	0.00773	18
2,4-Dimethylphenol	0.02	0.01052	0.029
2,4-Dinitrophenol	0.20	0.1042	12
2,4-Dinitrotoluene	0.10	0.00897	12
2,6-Dinitrotoluene	0.10	0.01073	6.1
2-Chloronaphthalene	0.02	0.00832	490
2-Chlorophenol	0.20	0.00948	6.3
2-Methylphenol	0.02	0.0138	0.063
3,3'-Dichlorobenzidine	0.10	0.0617	1.1

Table 11-1. Laboratory Method Detection Limits and Reporting Limits (continued)

Method and Analyte	RL[1/] (mg/kg dw)	MDL[1/] (mg/kg dw)	Sediment ACG[2/] (mg/kg dw)
3-Nitroaniline[12/]	0.1	0.0532	na
4-Bromophenyl phenyl ether[12/]	0.02	0.0129	na
4-Chloro-3-methylphenol[12/]	0.1	0.0101	na
4-Chlorophenyl phenyl ether[12/]	0.02	0.012	na
4-Nitroaniline[12/]	0.1	0.0255	na
4-Nitrophenol[12/]	0.1	0.037	na
4-Chloroaniline	0.10	0.0257	24
4-Methylphenol	0.10	0.0135	0.67
Aniline	0.02	0.00912	85
Benzoic acid	0.20	0.105	0.65
Benzyl alcohol	0.40	0.041	0.057
Bis(2-chloroethoxy)methane[12/]	0.02	0.0123	na
Bis(2-chloroethyl)ether	0.02	0.00993	0.21
Bis(2-ethylhexyl)phthalate	0.02	0.0108	0.24
Bis-chloroisopropyl ether	0.02	0.00996	2.9
Butyl benzyl phthalate	0.02	0.0103	0.025
Di-ethyl phthalate	0.02	0.135	0.31
Dimethyl phthalate	0.02	0.0120	0.27
Di-n-butyl phthalate	0.02	0.0135	1.1
Di-n-octyl phthalate	0.02	0.0113	0.29
Hexachlorobenzene[9/]	**0.02**	**0.00928**	0.0019
Hexachlorobutadiene[9/]	0.02	0.00828	0.02
Hexachlorocyclopentadiene[12/]	0.10	0.0445	na
Hexachloroethane	0.02	0.00798	0.12
Isophorone	0.02	0.00738	510
Nitrobenzene	0.02	0.0159	2.0
N-Nitrosodimethylamine	**0.10**	**0.00912**	0.0095
N-Nitrosodi-n-propylamine	**0.10**	0.0102	0.069
N-Nitrosodiphenylamine	0.02	0.0107	0.055
Pentachlorophenol	0.10	0.0371	0.36
Phenol	0.02	0.00947	0.42
EPA Method 8082			
Aroclor 1016	**0.02**	0.00098	0.0061
Aroclor 1221	**0.02**	**0.00098**	0.00021
Aroclor 1232	**0.02**	**0.00098**	0.00021
Aroclor 1242	**0.02**	**0.00098**	0.00021
Aroclor 1248	**0.02**	**0.00098**	0.00021
Aroclor 1254	**0.02**	**0.00098**	0.00021
Aroclor 1260	**0.02**	**0.00098**	0.00021
Total PCBs [7/]	**0.02**	**0.00098**	0.00021
EPA Method 6020 (except as noted)			
Antimony	0.20	0.005	3.1
Arsenic	**0.20**	**0.02**	0.006
Cadmium	**0.20**	**0.02**	0.003
Chromium (EPA 6010B)	0.50	0.09	100
Cobalt	0.30	0.03	900
Copper (EPA 6010B)	0.20	0.04	1.3
Lead	2.00	0.12	40

Table 11-1. Laboratory Method Detection Limits and Reporting Limits (continued)

Method and Analyte	RL[1/] (mg/kg dw)	MDL[1/] (mg/kg dw)	Sediment ACG[2/] (mg/kg dw)
Molybdenum	0.50	0.06	39
Nickel	1.00	0.38	140
Selenium	5.00	0.3	14.9
Silver	0.30	0.03	6.1
Thallium	0.20	0.003	0.52
Vanadium (EPA 6010B)	0.30	0.03	55
Zinc (EPA 6010B)	0.60	0.29	16
EPA Method 7471A			
Mercury	**0.05**	0.003	0.016
TBT Method - Krone 1989			
Di-n-butyltin[12/]	0.006	0. 00479	na
n-Butyltin[12/]	0.006	0.00451	na
Tri-n-butyltin	**0.006**	0.00284	0.00028
EPA Method 8081A			
4,4'-DDD	0.002	0.000320	0.0083
4,4'-DDE	0.002	0.000166	0.0026
4,4'-DDT	**0.001**	0.000284	0.00092
2,4'-DDD	0.002	0.0011	0.0083
2,4'-DDE	0.002	0.000894	0.0026
2,4'-DDT	0.002	0.000870	0.00092
Total DDT [10/]	**0.002**	**0.0011**	0.00092
Aldrin	**0.001**	0.000054	0.000063
alpha-BHC	**0.001**	0.000214	0.09
beta-BHC	0.001	0.000045	0.00063
delta-BHC[12/]	0.001	0.00002	na
alpha-Chlordane	0.001	0.000144	0.01
gamma-Chlordane[12/]	0.001	0.00012	na
Total chlordane[11/]	0.001	0.000964	0.0017
Dieldrin	**0.001**	**0.000049**	0.000033
Endosulfan	0.001	0.000129	0.50
Endrin	0.002	0.00024	0.027
gamma-BHC (Lindane)	**0.001**	0.000141	0.00083
Heptachlor	**0.001**	0.000027	0.00025
Heptachlor epoxide	0.001	0.000122	0.053
Hexachlorobenzene	0.001	0.000034	0.0019
Oxy-chlordane[12/]	0.002	0.00012	na
trans-Nonachlor[12/]	0.002	0.000024	na
cis-Nonachlor[12/]	0.002	0.000055	na
Methoxychlor	0.010	0.000402	0.44
Mirex	0.002	0.00122	0.27
Toxaphene	0.100	0.0297	0.44
EPA Method 1668			
PCB-77 [8/]	2.0E-6	3.9E-7	3.5E-3
PCB-81 [8/]	2.0E-6	3.9E-7	3.5E-3
PCB-105 [8/]	2.0E-6	4.4E-7	3.5E-3
PCB-114 [8/]	2.0E-6	4.6E-7	7.0E-4
PCB-118 [8/]	2.0E-6	3.7E-7	3.5E-3
PCB-123 [8/]	2.0E-6	9.5E-7	3.5E-3
PCB-126 [8/]	2.0E-6	2.1E-7	3.5E-6
PCB-156 [8/]	2.0E-6	6.6E-7	7.0E-4

Table 11-1. Laboratory Method Detection Limits and Reporting Limits (continued)

Method and Analyte	RL[1/] (mg/kg dw)	MDL[1/] (mg/kg dw)	Sediment ACG[2/] (mg/kg dw)
PCB-157 [8/]	2.0E-6	6.6E-7	7.0E-4
PCB-167 [8/]	2.0E-6	3.5E-7	3.5E-2
PCB-169 [8/]	2.0E-6	4.4E-7	3.5E-2
PCB-189 [8/]	2.0E-6	3.4E-7	3.5E-3
EPA Method 1613B			
2,3,7,8-TCDD	1.0E-6	5.9E-8	3.5E-07
1,2,3,7,8-PeCDD[8/]	5.0E-6	1.53E-7	3.5E-07
1,2,3,4,7,8-HxCDD[8/]	5.0E-6	1.72E-7	7.0E-07
1,2,3,6,7,8-HxCDD[8/]	5.0E-6	1.18E-7	3.5E-06
1,2,3,7,8,9-HxCDD[8/]	5.0E-6	1.72E-7	3.5E-06
1,2,3,4,6,7,8-HpCDD[8/]	5.0E-6	1.69E-7	3.5E-06
OCDD[8/]	1.0E-5	5.18E-7	3.5E-06
2,3,7,8-TCDF[8/]	1.0E-6	7.7E-8	3.5E-06
1,2,3,7,8-PeCDF[8/]	5.0E-6	1.32E-7	3.5E-06
2,3,4,7,8-PeCDF[8/]	5.0E-6	1.43E-7	3.5E-06
1,2,3,4,7,8-HxCDF[8/]	5.0E-6	1.48E-7	3.5E-06
1,2,3,6,7,8-HxCDF[8/]	5.0E-6	1.54E-7	7.0E-06
1,2,3,7,8,9-HxCDF[8/]	5.0E-6	1.48E-7	3.5E-05
2,3,4,6,7,8-HxCDF[8/]	5.0E-6	9E-8	3.5E-05
1,2,3,4,6,7,8-HpCDF[8/]	5.0E-6	1.83E-7	3.5E-05
1,2,3,4,7,8,9-HpCDF[8/]	5.0E-6	8.1E-8	0.0035
OCDF[8/]	1.0E-5	3.81E-7	0.0035

Note: RLs or MDLs in BOLD are greater than at least one of their respective ACGs. All of the ACGs that are lower than RLs or MDLs are based on human health RBCs, with the exception of the following four chemicals, which are based on benthic invertebrate RBCs: 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, and hexachlorobenzene.
RL – reporting limit
MDL – method detection limit
ACG – analytical concentration goal
mg/kg dw – milligrams per kilogram dry weight
na – not available
[1/] RLs, MDLs, and ACGs from LDWG Surface QAPP (LDWG 2005)
[2/] ACG for sediment is the lowest of the RBCs for benthic invertebrates, spotted sandpipers, and humans.
[3/] Total benzofluoranthenes is the sum of benzo(b)fluoranthene and benzo(k)fluoranthene. RL and MDL are the highest of the RLs and MDLs for benzo(b)fluoranthene or benzo(k)fluoranthene.
[4/] Total LPAHs is the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. RL and MDL are the highest RL and MDL for the LPAHs. 2-methyl naphthalene is not included in the LPAH definition under the SMS and under the DMMP.
[5/] Total HPAHs is the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene. RL and MDL are the highest RL and MDL for the HPAHs.
[6/] Total PAHs is the sum of the LPAHs and the HPAHs. RL and MDL are the highest RL and MDL for either the LPAHs or HPAHs.
[7/] Total PCBs is the sum of the Aroclors. RL and MDL are the highest RL and MDL for the individual Aroclors.
[8/] Dioxin-like PCB and dioxin/furan congeners will be evaluated as toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. However, because TEQs are calculated, rather than measured by the laboratory, RBCs for individual congeners are presented to facilitate comparison with RLs for those congeners. In reality, risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), and thus comparison to RLs on a congener-specific basis is somewhat uncertain.
[9/] Hexochlorobenzene and Hexachlorobutadiene are also analyzed with 8081A to obtain lower DLs
[10/] Total DDT is the sum of 4,4'-DDD, 4,4-DDE, 4,4'-DDT, 2,4'-DDD, 2,4-DDE, and 2,4'-DDT. RL and MDL are the highest RL and MDL for the DDT isomers.
[11/] Total chlordane is the sum of oxychlordane, alpha- and gamma-chlordane, and cis- and trans-nonachlor. RL and MDL are the highest RL and MDL for the chlordane-related compounds.
[12/] RLs and MDLs from LDWG Subsurface QAPP (LDWG 2006)

Table 11-2. Receptor-Specific Risk-Based Criteria for Screening Sediment

	Receptor-Specific Sediment RBC (MG/KG DW)				
	Human Health[1/]			Spotted Sandpiper	
Analyte	**Indirect Exposure**	**Direct Exposure[2/]**	**Benthic Invertebrates[3/]**	**LOAEL-based**	**NOAEL-based**
PAHs					
Acenaphthene	[4/]	370	0.08	na	na
Acenaphthylene	na	na	0.33	na	na
Anthracene	900	2,200	1.1	na	na
Benzo(a)anthracene	0.0052	0.15	0.55	na	na
Benzo(a)pyrene	0.00076	0.015	0.50	na	na
Benzo(b)fluoranthene	0.0047	0.15	na	na	na
Benzo(g,h,i)perylene	na	na	0.16	na	na
Benzo(k)fluoranthene	0.047	1.5	na	na	na
Benzofluoranthenes (total)	na	Na	1.2	na	na
Chrysene	0.48	62	0.50	na	na
Dibenzo(a,h)anthracene	[4/]	0.015	0.06	na	na
Fluoranthene	2.1	230	0.80	na	na
Fluorene	[4/]	260	0.12	na	na
Indeno(1,2,3-cd)pyrene	0.0029	0.15	0.17	na	na
2-Methylnaphthalene	na	na	0.19	na	na
Naphthalene	na	5.6	0.50	na	na
Phenanthrene	na	na	0.50	na	na
Pyrene	8.9	230	5.0	na	na
Dibenzofuran	na	15	0.075	nd	nd
Total LPAHs	na	na	1.9	na	na
Total HPAHs	na	na	4.8	na	na
Total PAHs	na	na	na	1,410	na
Other SVOCs					
1,2,4-Trichlorobenzene	[4/]	6.8	0.0041	nd	nd
1,2-Dichlorobenzene	370	12	0.012	na	na
1,3-Dichlorobenzene	d	3.5	0.17	nd	nd
1,4-Dichlorobenzene	0.073	3.2	0.016	nd	nd
2,4,5-Trichlorophenol	na	610	na	nd	nd
2,4,6-Trichlorophenol	0.61	44	na	nd	nd
2,4-Dichlorophenol	na	18	na	nd	nd
2,4-Dimethylphenol	na	120	0.029	nd	nd
2,4-Dinitrophenol	na	12	na	nd	nd
2,4-Dinitrotoluene	na	12	na	nd	nd
2,6-Dinitrotoluene	na	6.1	na	nd	nd
2-Chloronaphthalene	na	390	na	nd	nd
2-Chlorophenol	na	6.4	na	nd	nd
2-Methylphenol	na	310	0.063	na	na
3,3'-Dichlorobenzidine	na	1.1	na	nd	nd
4-Chloroaniline	na	24	na	nd	nd
4-Methylphenol	na	31	0.67	nd	nd
Aniline	na	85	na	nd	nd
Benzoic acid	na	24,000	0.65	na	na
Benzyl alcohol	na	1,800	0.057	na	na
Bis(2-chloroethyl)ether	na	0.21	na	nd	nd
Bis(2-chloroisopropyl)ether	na	2.9	na	na	na
Bis(2-ethylhexyl)phthalate	na	35	0.24	12,400	53

Table 11-2. Receptor-Specific Risk-Based Criteria for Screening Sediment (continued)

	Receptor-Specific Sediment RBC (MG/KG DW)				
	Human Health[1/]			Spotted Sandpiper	
Analyte	**Indirect Exposure**	**Direct Exposure[2/]**	**Benthic Invertebrates[3/]**	**LOAEL-based**	**NOAEL-based**
Butyl benzyl phthalate	na	1,200	0.025	na	na
Di-ethyl phthalate	na	4,900	0.31	nd	nd
Dimethyl phthalate	na	61,000	0.27	nd	nd
Di-n-butyl phthalate	na	610	1.1	na	na
Di-n-octyl phthalate	na	na	0.29	nd	nd
Hexachlorobenzene	na	0.3	0.0019	110	na
Hexachlorobutadiene	0.023	6.2	0.02	na	166
Hexachloroethane	0.12	35	1.4	nd	nd
Isophorone	na	510	na	nd	nd
Nitrobenzene	na	2	na	nd	nd
N-Nitrosodimethylamine	na	0.0095	na	nd	nd
N-Nitrosodi-n-propylamine	na	0.069	na	nd	nd
N-Nitrosodiphenylamine	na	99	0.055	nd	nd
Pentachlorophenol	na	3	0.36	2,220	775
Phenol	na	1,800	0.42	na	na
PCBs					
Aroclor 1016	0.0061	0.39	na	na	na
Aroclor 1221	0.00021	0.22	na	na	na
Aroclor 1232	0.00021	0.22	na	na	na
Aroclor 1242	0.00021	0.22	na	na	na
Aroclor 1248	0.00021	0.22	na	na	14.5
Aroclor 1254	0.00021	0.11	na	33.2	na
Aroclor 1260	0.00021	0.22	na	na	na
Total PCBs	0.00021	0.22	0.06	na	na
Metals					
Antimony	na	3.1	150	na	na
Arsenic	0.006	0.39	57	1,374	705
Cadmium	0.003	3.9	5.1	1,656	705
Chromium	100	210	260	3,700	271
Cobalt	na	140	na	na	na
Copper	1.3	290	390	2,185	1,656
Lead	na	40	450	707	70.5
Mercury	0.016	2.3	0.41	3.2	na
Molybdenum	na	39	na	1248	na
Nickel	[4/]	160	140	3,771	2,714
Selenium	[4/]	39	na	29	14.9
Silver	[4/]	39	6.1	na	na
Thallium	na	0.55	na	nd	nd
Tri-n-butyltin	0.00028	1.8	0.0085	598	241
Vanadium	na	39	na	na	na
Zinc	16	2,300	410	4,335	2,890
Pesticides					
4,4'-DDD	0.0083	2.4	na	31.8	na
4,4'-DDE	0.0026	1.7	na	9.9	4.6
4,4'-DDT	0.00092	1.7	na	35.4	31.8
Total DDT	0.00092	1.7	0.0069	na	na
Aldrin	0.000063	0.029	0.01	1.41	na

Table 11-2. Receptor-Specific Risk-Based Criteria for Screening Sediment (continued)

	Receptor-Specific Sediment RBC (MG/KG DW)				
	Human Health[1/]			Spotted Sandpiper	
Analyte	**Indirect Exposure**	**Direct Exposure[2/]**	**Benthic Invertebrates[3/]**	**LOAEL-based**	**NOAEL-based**
alpha-BHC	[4/]	0.09	na	na	na
beta-BHC	0.00063	0.32	na	na	na
alpha-Chlordane	na	na	0.01	na	na
Chlordane[5/]	0.0017	1.6	na	1,938	49.3
Dieldrin	0.000033	0.03	0.01	16.6	8.46
Endosulfan	0.50	37	na	na	743
Endrin	0.027	1.8	na	9.9	5.66
gamma-BHC (Lindane)	0.00083	0.44	0.01	127	56.6
Heptachlor	0.00025	0.11	0.01	nd	nd
Heptachlor epoxide	[4/]	0.053	na	nd	nd
Methoxychlor	0.44	31	na	na	na
Mirex	[4/]	0.27	na	1,202	636
Toxaphene	[4/]	0.44	na	nd	nd

Note: RBCs for protection of fish and crab are not presented. Sediment risk-based threshold concentrations (RBTCs) associated with acceptable fish or crab tissue concentrations based on critical residue levels will be taken from the RI report for the LDW site, as available.

na – toxicity data not available or not applicable if not a bioaccumulative chemical for indirect sediment exposures, or SQS/SL values were not available

nd – not determined because it was not considered a chemical of interest for spotted sandpipers

1/ The RBC for a given chemical may be derived from either carcinogenic or non-carcinogenic endpoints. For chemicals with both endpoints, the lower RBC is shown. RBCs for indirect exposures to sediment are based on the clam RBACG from the LDW sediment sampling QAPP, using an ingestion rate of 98 g/day and clam BSAFs to relate acceptable tissue concentrations to sediment.

2/ RBCs for direct sediment contact are residential-based criteria for child beach play and clamming exposures; industrial-based criteria for application to netfishing are higher than these values and are not shown. Direct exposure screening criteria are updated with Region 6 values for residential exposures to soil (http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm); the lower of criteria for carcinogenic or noncarcinogenic effects are shown, with criteria for noncarcinogenic effects modified by a factor of 0.1; lead criterion for direct exposure is based on Region 9 2004 residential value.

3/ RBCs for benthic invertebrates are equivalent to the SQS/SL for chemicals with standards expressed on a dry weight basis. For chemicals with standards expressed on an organic-carbon normalized basis, an average LDW organic carbon content of 0.5% was assumed to convert the standards to dry weight.

4/ This chemical was identified as an important bioaccumulative chemical by EPA (2000), but no BSAF is available, so no RBC for indirect exposure was calculated.

5/ RBCs for chlordane for human health and spotted sandpiper are based on toxicity of mixtures of chlordane-related compounds (e.g., alpha- and gamma-chlordane, cis- and trans-nonachlor).

Source: Adapted from RBACGs in the Quality Assurance Project Plan for sampling sediments at the LDW site (Windward 2005a), as updated with Region 6 RBCs. BSAFs were developed in the LDW document from a mix of sources identified herein in Section 11.3.1.3.

Table 11-3. Exposure Point Concentration Data Types for HHRA

Exposure Scenario	Media of Exposure	Pathway of Exposure	Data Type	Modeling Approach
Tribal Netfishing	Sediment (intertidal + subtidal, site-wide)	Ingestion/Direct Contact	Sampling Data Tetra Tech 2007	na
Beach Play, Clamming	Sediment (intertidal, site-wide)	Ingestion/Direct Contact	Sampling Data Tetra Tech 2007	na
Tribal Seafood Consumption	Fish (benthic, pelagic)	Ingestion	Modeled from site-wide sediment data	BSAF
	Crabs (meat, whole body)	Ingestion	Modeled from site-wide sediment data	BSAF
	Clams	Ingestion	Modeled from intertidal sediments	BSAF

na – not applicable
BSAF – biota-sediment accumulation function

Table 11-4. Measures of Exposure and Data Types for the Lockheed West ERA

Ecological Receptor	Measure of Exposure[1/]	Use in Risk Characterization	Data Type	Modeling Approach[3]
Benthic				
Benthic invertebrates, including clams	Sediment (intertidal + subtidal)	Comparison with sediment criteria	Sampling Data[2/]	na
Crabs	Crab tissue	Comparison with toxicity data for crab tissue	Modeled Tissue	BSAF
Fish				
English sole	Prey (benthic invertebrates)	Dietary exposure, intake calculation	Modeled Tissue	BSAF
	Sediment (intertidal + subtidal)	Dietary exposure, intake calculation	Sampling Data[2/]	na
	Chemicals in English sole tissue	Comparison with toxicity data for fish tissue	Modeled Tissue	BSAF
Pacific staghorn sculpin	Prey (benthic invertebrates, fish)	Dietary exposure, intake calculation	Modeled Tissue	BSAF
	Sediment (intertidal + subtidal)	Dietary exposure, intake calculation	Sampling Data[2/]	na
	Chemicals in sculpin tissue	Comparison with toxicity data for fish tissue	Modeled Tissue	BSAF
Wildlife				
Sandpiper	Prey (benthic invertebrates)	Dietary exposure, intake calculation	Modeled Tissue	BSAF
	Sediment (intertidal)	Dietary exposure, intake calculation	Sampling Data[2/]	na

[1/] Measures of exposure include direct contact or through dietary intake, such as sediment and prey items by fish, or as tissue concentrations in the ROC. Dietary intake measures will be evaluated for those COPCs for which toxicity reference values (TRVs) are based on dietary intake (PAHs and metals except butyltins and mercury), whereas chemicals with whole body tissue TRVs will be evaluated by comparison with tissue levels.
[2/] Sources of sediment sampling data consist of Site data collected in 2007.
[3/] Tissue modeling will use BSAF relationships identified in the LDW ERA or developed from data collected at the LDW site (Windward 2007b,c). For the streamlined approach to this ERA, the FWM that was used in the LDW ERA is not planned for use at the Lockheed West site.

12. SOURCE CONTROL EVALUATION

The Source Control evaluation will identify and assess potential sources of contamination to the Lockheed West Site (Site). The purpose of the source control evaluation is to document the current status of source control and to determine whether there are sources with the potential to recontaminate the Site following its planned remediation.

The objectives of this Source Control Evaluation are to:

1. Identify potential sources and assess the potential pathways and the potential for recontamination of Lockheed West following its remediation.
2. Evaluate whether the resuspension, transport, and deposition of bottom sediments in the adjacent Elliott Bay and West Waterway are a potential ongoing source of chemical contamination that could result in recontamination of Lockheed West after remediation.
3. Qualitatively compare available source information to existing sediment quality data.
4. Identify data gaps that should be resolved so that the status of source control at Lockheed West can be confirmed.
5. Make recommendations to the EPA regarding the need for further investigation or control of identified potential sources.

The Source Control Evaluation approach will be further refined through technical workshops with EPA and the project stakeholders. Details of the Source Control Evaluation approach stemming from the technical workshops will be documented and submitted for review and approval.

12.1 OFFSITE SEDIMENT TRANSPORT AND DEPOSITION AT LOCKHEED WEST

Sediments at Lockheed West can potentially be impacted by a number of potential mechanisms giving rise to elevated chemical concentrations in the sediment including:

- Surface water runoff;
- Outfall discharges of water and sediment to the waterway;
- Direct discharge from vessel leaching and shipyard activities;

- Groundwater flow and discharge within the waterway;
- Transport and deposition of sediment from adjacent Elliott Bay, West Waterway and Lower Duwamish Waterway containing higher concentrations than the Lockheed West cleanup objectives due to resuspension from both natural and vessel induced waves and currents, and
- Atmospheric deposition.

A conceptual model of these mechanisms has been developed as part of the RI/FS Work Plan. Discussion of each of these potential mechanisms for sediment recontamination will be presented. Recontamination potential for each of these potential mechanisms will be evaluated using the available existing data from Lockheed West and the adjacent areas on sediment transport and contaminants of potential concern.

12.2 LOCKHEED WEST UPLANDS SOURCE CONTROL APPROACH

The objective of the source control assessment is to identify if there are uncontrolled sources that will recontaminate the sediments after remediation. For the uplands, the source control assessment will include evaluation of soil, groundwater, storm water, and storm drain sediments. The following approach is proposed for evaluation of these pathways:

- Historical contaminant data for soil and groundwater will be reviewed and summarized to determine a list of potential chemicals of concern and historical ranges of chemical concentrations. These data will be compared against appropriate human health and ecological screening criteria to assist in identifying potential uncontrolled sources.
- A background review of the adjoining PSR superfund site and other nearby sites will be performed to assess potential affects on the Lockheed West remedy.
- A review of storm water drainage information will be performed to determine the locations and conditions of outfalls proximal to the Lockheed West site.
- For selected chemicals, soil partitioning techniques will be used to evaluate potential impacts to marine sediments using maximum groundwater concentrations and accounting for partitioning coefficients.

Based on the findings of the initial source control assessment activities, data collection needs will be summarized and additional data will be collected as appropriate. The findings of the source control assessment will be presented in a report that will be submitted to EPA for approval prior to implementation of the Lockheed West remedy.

13. REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

The Remedial Investigation and Feasibility Study tasks described below will be completed and the results will be presented in a single report, per EPA's direction at the December 18, 2006 planning meeting. Both a draft and final streamlined RI/FS report will be prepared and submitted to EPA for review and approval. The following sections describe the scope of the RI/FS document.

13.1 REMEDIAL INVESTIGATION

An RI section will be prepared that synthesizes the results of all investigations conducted during the RI. All data will be reported in tabular form, and various map overlays and other plots will be used to present the information. The pertinent features of the RI report will be description of the investigations conducted, assessment of data adequacy to meet DQOs (including the rationale and basis for any additional data collection needs, if necessary), summary of the nature and extent of contamination identified, characterization of potential migration pathways, evaluation of contaminant fate and transport and incorporation of the baseline human health and ecological risk assessments. Sources of uncertainty, including internal and external sources, will be documented in the RI report and associated risk assessments. The RI portion of the report outline will follow the EPA guidance.

The RI report will include a summary of all data collected during the remedial investigation and a complete evaluation of the nature and extent of contamination based on RI field data. The final baseline risk assessments for human and ecological health (HHRA and ERA) will also be incorporated into the RI sections and included as appendices. The RI will evaluate the risk implications of potential exposure to subsurface sediments. This discussion will be based on the results of the baseline ERA and HHRA (and data used in these assessments) and subsurface sediment chemistry data. The RI report will specify sediment risk-based goals (RBGs) for cleanup.

The organization of the RI will be very similar to summary of existing data although the content will be updated with additional information and data collected during the RI, results of the risk assessments, and any additional modeling conducted. After the introduction, the main RI section headings will be:

- Environmental setting and previous investigations;
- Summary of nature and extent of contamination;
- Potential contamination sources, pathways, and source control;

- Fate and transport of sediment and sediment-associated chemicals;
- Summaries of baseline ERA and HHRA; and
- Calculation of sediment RBGs for chemical risk drivers.

13.2 REMEDIAL ACTION OBJECTIVES AND REMEDIATION GOALS

A Remedial Action Objective/Remediation Goal (RAO/RG) technical memorandum will be prepared and submitted to EPA for review. It will then be incorporated into the RI/FS report. Its purpose is to revise the preliminary RAOs proposed in the Work Plan and establish site-specific cleanup levels. RAOs will be based on the RGs; ARARs; and the results of the final baseline HHRA and ERA following the approach outlined in Section 6.2. The memorandum will clearly document the rationale and technical basis for the determined clean-up level goals. The memorandum will also identify cleanup area boundaries based on the determined cleanup levels. Areas and volumes of contaminated sediments will be delineated, taking into account requirements for protectiveness as identified in the RAOs. The chemical and physical characterization of the Site will also be taken into account.

13.3 SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS AND ALTERNATIVES ASSEMBLY

Following completion of the baseline HHRA, ERA, the RI and the RAO/RGs sections, remedial alternatives for site sediment cleanup areas will be developed. Identification and screening of remedial technologies and process options and the assembly of representative remedial alternatives for the Lockheed West Site and the methods/results will be documented in the RI/FS Report and limited to capping, dredging, or a combination of dredging and capping as the result of negotiations with EPA. The “no action” alternative and monitored natural recovery will not be considered. The range of alternatives identified will be modified in response to EPA’s comments (if required) to assure identification of a complete and appropriate range of viable alternatives to be considered in the detailed analysis. This deliverable will document the methods, rationale, and results of the technology screening and alternative assembly process.

Remedial alternatives for site sediments will be developed by assembling combinations of sediment-specific technologies into alternatives that address contamination on a site-wide basis. The purpose of this task is to identify and screen remedial technologies for sediments appropriate for conditions at the Site and to assemble representative remedial alternatives to be considered for detailed analysis in the FS section. This process consists of the following four general steps as described below.

- Identify and describe General Response Actions (GRAs) for sediment (the medium of concern), defining removal or containment, singly or in combination, which may be taken to satisfy the RAOs developed for the Site.
- Identify preliminary volumes or areas of sediment to which GRAs might be applied, taking into account the requirements for protectiveness as identified in the RAOs and the specific chemical and physical characteristics of the Site.
- Identify and screen the technologies and process options (e.g., specific processes within each technology type) applicable to each GRA to ensure that only those technologies and process options applicable to the contaminants present, their physical matrix, and other site characteristics will be considered and carried forward into the assembly of alternatives step. This screening will be based primarily on a technologies ability to effectively address the contaminants at the Site, but will also take into account a technology's implementability and cost.
- Combine retained technologies and process options into media-specific or site-wide representative alternatives. The developed alternatives should be defined with respect to size and configuration of the representative process options; time for remediation; rates of flow or treatment; spatial requirements; distances for disposal; and other factors necessary to evaluate the alternatives.

13.3.1 Identification and Description of General Response Actions

GRAs are medium-specific response categories that can be used to satisfy RAOs. GRAs will be developed for sediment, the medium of interest at Lockheed West. The remediation of contaminated sediments can be accomplished using a number of different technologies. As agreed with EPA, GRAs identified for sediment requiring remediation at Lockheed West include:

- Containment (Capping),
- Removal (Dredging),
- Disposal, and
- Beneficial Reuse.

These GRAs will be considered individually during the identification and screening of technology types and process options, and in combination to produce a range of remedial alternatives. Identified GRAs will be briefly introduced in this section.

13.3.2 Determination of Volumes and Areas

Site-specific analytical data will be compared to the PRGs developed for Lockheed West sediment. Areas where sediment contains elevated concentrations of above the PRGs present an unacceptable risk to human and/or ecological receptors at the Site and requires remediation. The estimated areal extent, depth, and volume of sediment requiring remediation will be calculated. These site-specific areas and volumes will be considered during the identification and screening of remedial technologies for this Site.

13.3.3 Identification and Screening of Remedial Technologies and Process Options

Based on site-specific characteristics (including areas and volumes) and GRAs identified above, remedial technologies and process options corresponding to GRAs for contaminated sediment at Lockheed West will be identified, briefly discussed, and screened. Process options are the specific processes within a technology type by which the technology may be implemented. Each process option will be evaluated in a qualitative manner against the evaluation criteria of effectiveness, implementability, and cost following the method suggested by the EPA guidance (EPA 1988a).

Those process options that were ranked "low" in either effectiveness or implementability will be eliminated from further consideration, with the exception of the No Action GRA, which is carried forward into the detailed evaluation in accordance with the NCP.

13.3.4 Assembly of Remedial Alternatives

An array of representative alternatives that ensure protection of human health and the environment will be assembled from retained GRAs, process options, and remedial technologies. The range of alternatives will include but will not be limited too the following:

1. In-place confinement (capping),
2. Dredging with disposal in existing landfills and/or elsewhere, and
3. Options combining aspects of these and/or other alternatives.

The assembled alternatives will be presented in a table listing the corresponding GRA, technology type or process option and the area of volume affected. A detailed description of each alternative will be presented.

13.4 FEASIBILITY STUDY

The FS sections of the RI/FS Report will incorporate applicable results of the RI, the RAO/PRG, and the Screening of Remedial Technologies and Process Options and Alternatives Assembly. The FS section will provide the basis for remedy selection by EPA and will document the development and detailed analysis of remedial alternatives.

Each of the remedial alternatives assembled and presented in the Screening of Remedial Technologies and Process Options and Alternatives Assembly section will be evaluated using the CERCLA evaluation criteria (EPA 1988a).

For each alternative assembled and presented in the described in Screening of Remedial Technologies and Process Options and Alternatives Assembly section, the FS section will include:

- A detailed description of each alternative that outlines the sediment management strategy involved and identifies the degree of protectiveness and key ARARs associated with that alternative; and
- An assessment of each alternative against each of the CERCLA criteria except Criteria 8 (state acceptance) and 9 (community acceptance) which will be addressed by EPA after the RI/FS report has been released to the public.

13.4.1 Alternatives Descriptions

A brief description of each of the remedial alternatives developed to address the sediment RAOs will be presented.

13.4.2 Detailed Analysis of Alternatives

A detailed analysis of each remedial alternative will be performed in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a) with respect to the first seven of the nine CERCLA evaluation criteria. The evaluation criteria include the following:

1. Overall protection of human health and the environment;
2. Compliance with ARARs;
3. Long-term effectiveness and permanence;
4. Reduction in toxicity, mobility, or volume;
5. Short-term effectiveness;

6. Implementability; and
7. Costs.

The capital costs, operation and management (O&M) costs, periodic costs, net present value in 2007 dollars, and the expected range of total present worth in 2007 dollars at the FS level (-30 percent to + 50 percent) of each alternative evaluated for Lockheed West will be calculated. Cost estimate summaries will be provided for each alternative. A discussion of the key assumptions used in the development of the cost estimates is also provided.

13.4.3 Comparative Evaluation of Alternatives

This section will include a comparative analysis of the remedial alternatives. The analysis will evaluate the relative performance of each alternative with respect to the first seven of the nine CERCLA evaluation criteria. The alternative that could perform best overall in each category will presented first, followed by other alternatives discussed in the relative order of potential performance.

13.4.4 Recommended Remedial Alternative for Lockheed West Sediments

Based on the detailed comparative evaluation of the remedial alternatives, one alternative will be recommended to EPA for implementation at Lockheed West. The alternative recommended must score very high with respect to the CERCLA evaluation criteria and must meet the site-specific RAOs and ARARs in addition to being cost-effective.

14. COMMUNITY INVOLVEMENT ACTIVITIES

Participation by Lockheed Martin and their contractors in community involvement activities will be initiated at the request of EPA. EPA is the lead for all these activities. Specific support activities have not been identified, but we anticipate supporting EPA's community involvement activities related to the Lockheed West SOW by 1) providing information and data in formats easily understandable by the public, 2) attending and participating in public meetings which may be held or sponsored by EPA to explain activities at or concerning Work performed pursuant to the ASAOC/SOW, and 3) any other activities requested by EPA.

15. REFERENCES

Arnot, J.A., FAPC Gobas. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. Environ Toxicol Chem 23:2343-2355.

Aspect (Aspect Consulting, Inc.). 2005. Southwest Harbor Project, Phase I, Groundwater Confirmation Monitoring Program, Hydrologic Characterization Report. Prepared for the Port of Seattle. March 3, 2005.

CalEPA. 1994. Health effects of benzo(a)pyrene. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, CA.

CHE (Coast and Harbor Engineering, Inc.). 2004. Coastal Engineering Analysis, Lockheed Shipyard 1.

ChemRisk. 1991. An evaluation of potential human health and aquatic impacts associated with current conditions and proposed future construction activities at the Lockheed Shipyard II site. Volume I, Risk Assessment. ChemRisk, Portland, ME.

Converse Consultants and Pacific Groundwater Group. 1993. Southwest Harbor Cleanup and Redevelopment Project, Sediment Dredge Disposal Containment Model Study. Prepared for the Port of Seattle.

Cubbage, James C. 1989. Concentrations of Polycyclic Aromatic Hydrocarbons in Sediments and Groundwater Near the Wyckoff Wood Treatment Facility, Seattle, Washington. Prepared for the Washington State Department of Ecology, Environmental Investigations and Laboratory Services, Toxic Investigations/Ground Water Monitoring Section, Olympia, Washington. Segment No. 04-09-05, August 1989.

Ebbesmeyer, C.C., C.A. Coomes, J.M. Cox, T.J. Crone, K.A. Kurrus. 1998. Current Structure in Elliott Bay, Washington: 1977–1996. Proceedings: Puget Sound Research 1998. Puget Sound Action Team.

Ecology (Washington Department of Ecology). 1990. Standards for Confined Disposal of Contaminated Sediments. Prepared by Parametrix for Washington Department of Ecology. January 1990.

Ecology. 1994. Natural background soil metals concentrations in Washington State. Publication 94-115. Toxics Cleanup Department, Washington Department of Ecology, Olympia, WA. October.

Ecology. 1996. Draft Cleanup Action Plan for Contaminated Sediments in the Lockheed Aquatic Area, Elliott Bay and Duwamish Estuary, Seattle, Washington, April 1996.

Ecology. 2000. Sediment quality in Puget Sound. Year 2 - central Puget Sound. No. 00-03-055. Washington Department of Ecology, Olympia, WA.

Ecology. 2001a. Guidelines and specifications for preparing quality assurance project plans for environmental studies. (Ecology publication no. 04-03-030, Revised July 2004).

Ecology. 2001b. Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC. Publication No. 94-06. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

Ecology. 2003. Sediment Sampling and Analysis Plan Appendix. Ecology Publication No. 03-09-043. Revised April 2003. 88pp.

Environmental Solutions Group. 1999. Waterway Sediment Operable Unit, Harbor Island Superfund Site. Assessing human health risks from the consumption of seafood: human health risk assessment report. Prepared for Port of Seattle, Lockheed Martin, Todd Pacific Shipyards. Environmental Solutions Group, Seattle, WA.

Enviros. 1989. Terminal 4 sediment characterization and geotechnical study. Draft report prepared for the Port of Seattle by Enviros, Kirkland, Washington.

Enviros. 1990. Lockheed Shipyard #2: Sediment Characterization and Geotechnical Study. Report prepared for the Port of Seattle, by Enviros, Inc., Kirkland, Washington.

Enviros. 1991. Final Report for the Combined Remedial Investigation of Lockheed Shipbuilding Company Seattle Yard II. Prepared for the Port of Seattle by Enviros, Inc., Kirkland, Washington.

Enviros. 1992a. Final Report, Former East Inlet Area Drilling and Sampling Project, Lockheed Shipbuilding Company Seattle Yard II, Seattle, Washington. March 4, 1992.

Enviros. 1992b. Final Report, Tidal Monitoring Investigation Report of the Lockheed Property, 2330 SW Florida Street, Seattle, Washington. September 17, 1992.

Enviros. 1993. Feasibility study of the former Lockheed Shipyard (Yard II) in west Seattle, Washington. Prepared for Port of Seattle, Seattle, Washington.

EPA (Environmental Protection Agency). 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. EPA/540/G-89/004. US Environmental Protection Agency, Washington, DC.

EPA. 1989a. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Part A. EPA/540/1-89/002. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 1989b. Wetlands Action Plan.

EPA. 1991. Role of the baseline risk assessment in Superfund remedy selection decisions. OSWER Directive 9355.0-30. Office of Solid Waste and Emergency Response, US Environmental Protection Agency, Washington, DC.

EPA. 1992a. Supplemental guidance to RAGS: Calculating the concentration term. Publication 9285.7-.81. Office of Solid Waste and Emergency Response, US Environmental Protection Agency, Washington, DC. May.

EPA. 1992b. Framework for ecological risk assessment. EPA/630/R-92/001. Risk Assessment Forum, US Environmental Protection Agency, Washington, DC.

EPA. 1993a. Instructions for Formatting Digital Data: Sediment (Chemical, Benthic, Bioassay), Water Column, and Shellfish Monitoring Data, Commencement Bay Nearshore/Tideflats Superfund Site. Prepared by USEPA, Region 10, Seattle, Washington.

EPA. 1993b. Wildlife exposure factors handbook. EPA/600/R-93/187a. Office of Research and Development, US Environmental Protection Agency, Washington, DC.

EPA. 1996a. EPA Region 10 supplemental risk assessment guidance for Superfund. Draft. Office of Environmental Assessment, Risk Evaluation Unit, US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 1997a. Exposure factors handbook. EPA/600/P-95/002Fa. Office of Research and Development, National Center for Environmental Assessment, US Environmental Protection Agency, Washington, DC.

EPA. 1997b. Ecological risk assessment guidance for Superfund: Process for designing and conducting ecological risk assessments. EPA/540/R-97/006. Interim final. Environmental Response Team, US Environmental Protection Agency, Edison, NJ.

EPA. 1997c. EPA Region 10 supplemental ecological risk assessment guidance for Superfund. EPA/910/R-97/005. Region 10 Office of Environmental Assessment Risk Evaluation Unit, US Environmental Protection Agency, Seattle, WA.

EPA. 1997d. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National Sediment Quality Survey. EPA 823-R-97-006. US Environmental Protection Agency, Office of Science and Technology, Washington, DC.

EPA. 1998a. Risk assessment guidance for Superfund. Volume 1. Human health evaluation manual. Part D, Standardized planning, reporting, and review of Superfund risk assessments. Interim Publication No. 9825.7-01D. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 1998b. Guidelines for ecological risk assessment. EPA/630/R-95/002 F. Risk Assessment Forum, US Environmental Protection Agency, Washington, DC.

EPA. 1999a. Proposed Plan for the West Waterway Operable Unit, Harbor Island Superfund Site, Seattle Washington. Prepared by USEPA, Region 10, Seattle, WA. November 1999.

EPA. 1999b. Development of a tissue trigger level for bioaccumulated tributyltin in marine benthic organisms: West Waterway Harbor Island Superfund Site, Seattle, WA. US Environmental Protection Agency Region 10, Seattle, WA.

EPA. 1999c. A Guide for Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents. EPA 540R-98-031. US Environmental Protection Agency, Washington, DC. July.

EPA. 2000. Bioaccumulation testing and interpretation for the purpose of sediment quality assessment: status and needs. EPA-823-R-00-001. Bioaccumulation Analysis Workgroup, US Environmental Protection Agency, Washington, DC.

EPA. 2001. Methods for Collection, Storage, and Manipulation of Sediment for Chemical and Toxicological Analysis: Technical Manual. EPA Office of Water, EPA-823-B-01-002.

EPA. 2002a. Updated Risk Assessment Information for the West Waterway Operable Unit of the Harbor Island Superfund Site, Seattle, Washington. (as cited in the ROD, USEPA 2003a).

EPA. 2002b. Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites. EPA 540-R-01-003. US Environmental Protection Agency, Washington, DC. September.

EPA. 2002c. Role of Background in the CERCLA Cleanup Program. OSWER 9285.6-07P. Office of Solid Waste and Emergency Response, US Environmental Protection Agency, Washington, DC. April 26.

EPA. 2003a. Record of Decision. Harbor Island Superfund Site, West Waterway Operable Unit, Seattle, Washington. US Environmental Protection Agency, Region 10, Seattle, WA. September 11.

EPA. 2003b. Human health toxicity values in Superfund risk assessments. OSWER Directive 9285.7-53. Office of Solid Waste and Emergency Response, US Environmental Protection Agency, Washington, DC.

EPA. 2004a. USEPA Region 9 preliminary remediation goals: 2004 PRG table [online]. US Environmental Protection Agency Region IX, San Francisco, CA. Updated December 2004. Available from: http://www.epa.gov/region09/waste/sfund/prg/index.html.

EPA. 2004b. ProUCL Version 3.0 user guide. Technical Support Center for Monitoring and Site Characterization, US Environmental Protection Agency.

EPA. 2006a. Draft Framework for Selecting and Using Tribal Fish and Shellfish Consumptions Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.

EPA. 2006b. Guidance on Systematic Planning Using the Data Quality Objectives Process. EPA QA/G-4. United States Environmental Protection Agency. Office of Environmental Information. EPA/240/B-06/001. Washington D.C. 100pp.

EPA. 2006c. USEPA Region 3 risk-based concentration table [online]. U.S. Environmental Protection Agency Region 3, Philadelphia, PA. Updated April 2006. Available from: http://www.epa.gov/reg3hwmd/risk/human/index.htm.

EPA. 2007a. USEPA Region 3 risk-based concentration table [online]. U.S. Environmental Protection Agency Region 3, Philadelphia, PA. Updated October 2007. Available from: http://www.epa.gov/reg3hwmd/risk/human/index.htm.

EPA. 2007b. Integrated Risk Information System (IRIS). http://www.epa.gov/iris/. U.S. Environmental Protection Agency.

EPA. 2007c. USEPA Region 6 Human Health Medium-Specific Screening Levels 2008. U.S. Environmental Protection Agency Region 6. Updated December 4, 2007. http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screenvalues.pdf

EPA. 2007d. Framework for selecting and using tribal fish and shellfish consumption rates for risk-based decision making at CERCLA and RCRA cleanup sites in Puget Sound and the Strait of Georgia – Working Document, August 2007. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

Environmental Solutions Group. 1999. Waterway Sediment Operable Unit, Harbor Island Superfund Site. Assessing Human Health Risks from the Consumption of Seafood: Human Health Risk Assessment Report. Prepared for Port of Seattle, Lockheed Martin, Todd Pacific Shipyards. Environmental Solutions Group, Seattle, WA. September.

Evans-Hamilton. 1987. Puget Sound Environmental Atlas. Prepared by Evans-Hamilton, Inc. D.R. Systems, Inc. for the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers.

EVS. 1985. Amphipod Bioassay Analyses of Sediments to be Dredged from the Duwamish West Waterway. Prepared for Dames & Moore.

EVS. 1996. Supplemental remedial investigation for Harbor Island Sediment Operable Unit. May 1996. Prepared for U.S. Environmental Protection Agency, Region 10, Superfund Program, Seattle, WA. EVS Environmental Consultants, Seattle, WA.

EVS. 1999a. Review of Tissue Residue Effects Data for Tributyltin, Mercury, and Polychlorinated Biphenyls. Prepared for Port of Seattle, Lockheed Martin, Todd Pacific Shipyards. EVS Solutions, Seattle, WA. May.

EVS. 1999b. Waterway Sediment Operable Unit, Harbor Island Superfund Site. Tributyltin in Marine Sediments and the Bioaccumulation of Tributyltin: Combined Data Report. Prepared for Port of Seattle, Lockheed Martin, Todd Pacific Shipyards. EVS Solutions, Seattle, WA. May.

Grette, B.B., E.O. Salo. 1986. The status of anadromous fishes of the Green/Duwamish River system. Final report for Seattle District U.S. Army Corps of Engineers. Submitted by Evans-Hamilton, Inc. Seattle, Washington.

Hart Crowser. 1995. Geotechnical Engineering Design Study, Southwest Harbor Project, Terminal 5 Expansion, 400 Foot Wharf Expansion, Port of Seattle, Washington.

Report prepared for KPFF Consulting Engineers, by Hart Crowser, Seattle, Washington.

Hart Crowser. 2003. Environmental Status Report Lockheed Yard 2 Aquatic Area, Seattle, Washington. Prepared for Lockheed Martin Corporation. April.

Hartman Associates, Hong West and Associates, AmTest, Inc., Invert*aid, and Laucks Testing Lab. 1991. Terminal 5, West Waterway, Duwamish PSDDA Sampling and Analysis Results. Prepared for the Port of Seattle.

King County Department of Natural Resources. 2001. Reconnaissance assessment of the state of the nearshore ecosystem: eastern shore of central Puget Sound, including Vashon and Maury Islands (WRIAs 8 and 9). Battelle Marine Sciences Laboratory, Pentec Environmental, Striplin Environmental Associates, Shapiro Associates, King County Department of Natural Resources. Seattle, Washington.

King County. 1999. King County combined sewer overflow water quality assessment for the Duwamish River and Elliott Bay. Vol 1, Appendix B2, B3, & B4: human health, wildlife, and aquatic life risk assessments. King County Department of Natural Resources, Seattle, WA.

Landolt, M.L., F.R. Hafer, A. Nevissi, B. Van Belle, K. Van Ness, and C. Rockwell. 1985. Potential toxicant exposure among consumers of recreationally caught fish from urban embayments of Puget Sound. NOAA technical memorandum NOS OMA 23. National Oceanic and Atmospheric Administration, Rockville, MD.

McLaren. 1989. Soil and groundwater investigation report. Lockheed Shipbuilding Company, Seattle Yard II Facility, 2330 SW Florida Street, West Seattle, Washington. Report by McLaren to Lockheed Corporation, Calabasas, California.

McLaren-Hart. 1990. Supplementary soil and ground water investigation at the former talk locations. Prepared for Lockheed Shipbuilding Company, Seattle, Washington.

McLaren-Hart. 1992. Remedial Investigation Report Lockheed Shipbuilding Company Seattle, Yard II Facility. Volumes 1-12. Casabases, California.

Meador, J.P., C.A. Krone, D.W. Dyer, and V. Varanasi. 1997. Toxicity of sediment-associated tributyltin to infaunal invertebrates. Species comparison and the role of organic carbon. Marine Environmental Research. 43(3):219-241.

Meador JP, Collier TK, Stein JE. 2002. Determination of a tissue and sediment threshold for tributyltin to protect prey species of juvenile salmonids listed under the US Endangered Species Act. Aquat Conserv: Mar Freshw Ecosys 12:539-551.

Nagy KA, Girard IA, Brown TK. 1999. Energetics of free-ranging mammals, reptiles, and birds. Annu Rev Nutr 247-277.

Nagy KA. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol Monogr 57(2):111-128.

ODEQ. 2007. Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment. Final. Oregon Department of Environmental Quality, Environmental Cleanup Program, Portland, OR. Updated April 3.

Parametrix, Inc. 1993. Southwest Harbor Cleanup and Redevelopment Project Aquatic Sediment Remedial Investigation (Draft Document). Parametrix, Inc., Kirkland, Washington.

Parametrix, Inc. 1994a. Southwest Harbor Cleanup and Redevelopment Project Final Environmental Impact Statement. Technical Appendix A-4 Risk Assessment. November 1994.

Parametrix, Inc. 1994b. Technical Appendix A-1 Remedial Investigation, Southwest Harbor Cleanup and Redevelopment Project Environmental Impact Statement, Prepared for Port of Seattle, Washington State Department of Ecology, and the U.S. Army Corps of Engineers. November 1994.

Parametrix, Inc. 1994c. Technical Appendix B-1 Aquatic Cleanup Feasibility Study (Companion Document), Southwest Harbor Cleanup and Redevelopment Project Environmental Impact Statement, Prepared for Port of Seattle, Washington State Department of Ecology, and the U.S. Army Corps of Engineers. November 1994.

Parametrix, Inc. 1994d. Southwest Harbor Cleanup and Redevelopment Project, Joint Federal/State Final Environmental Impact Statement. Prepared for U.S. Army Corps of Engineers (Seattle District), the Washington State Department of Ecology, and the Port of Seattle.

PSDDA. 1988. PSDDA Reports: Evaluation Procedures Technical Appendix - Phase I (central Puget Sound). Prepared for Puget Sound Dredged Disposal Authority. US Army Corps of Engineers, Seattle District; US Environmental Protection Agency, Region 10, Seattle, WA; Washington Department of Ecology; and Washington Department of Natural Resources.

PSEP (Puget Sound Estuary Program). 1997a. Recommended protocols for measuring metals in Puget Sound marine water, sediment, and tissue samples. Final Report. Prepared for U. S. Environmental Protection Agency, Seattle, Washington.

PSEP. 1986. Recommended Guidelines for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound, In: Puget Sound Protocols and Guidelines, Puget Sound Estuary Program.

PSEP. 1997b. Recommended guideline for measuring organic compounds in Puget Sound water, sediment and tissue samples. Final Report. Prepared for U. S. Environmental Protection Agency, Seattle, Washington.

PSEP. 1997c. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final Report. Prepared for U.S. Environmental Protection Agency, Seattle, Washington.

PTI. 1995a. Bioaccumulation Factor Approach Analysis for Metals and Polar Organic Compounds. Prepared for WA Dept Ecology, Environmental Review and Sediment Section. PTI, Bellevue, WA. October.

PTI. 1995b. Analysis of BSAF Values for Nonpolar Organic Compounds in Finfish and Shellfish. Prepared for WA Dept Ecology, Environmental Review and Sediment Section. PTI, Bellevue, WA. November.

RETEC. 2004. Five-Year Review Report, First Five-Year Review Report, Pacific Sound Resources Superfund Site, Seattle, Washington. Prepared by the RETEC Group, Inc. for the Port of Seattle, September 28.

Santos, J.F. and J.D. Stoner. 1972. Physical, Chemical, and Biological Aspects of the Duwamish River Estuary, King County, Washington, 1963 – 1967. Geological Survey Water Supply Paper 1873-C. Stock No. 2401-1207. U.S. Government Printing Office, Washington, D.C.

Silcox, R.L., W.R. Geyer, and G.A. Cannon. 1981. Physical transport processes in circulation in Elliott Bay. NOAA Technical Memorandum, OMPA-8.

Stober, Q.J., and K.K. Chew 1984. Renton Sewage Treatment Plant Project. Duwamish Head. Final Report for the Period 1 July to 31 December 1984. University of Washington Fisheries Research Institute, Seattle, Washington

Stoner, J.D., W.L Haushild, and J.B. McConnel. 1975. Numerical model of material transport in salt-wedge estuaries. U.S. Geological Survey Professional Paper 917.

Tetra Tech. 1988. Elliott Bay Action Program: Evaluation of Potential Contaminant Sources. Prepared for the U.S. Environmental Protection Agency.

Tetra Tech. 2006. High-Resolution Multibeam Sonar Bathymetric Survey conducted for Lockheed Martin Corporation. Prepared by Tetra Tech, Inc., Bothell, WA. Appendix B, this document.

Toy, K.A., N.L. Polissar, S. Liao, and G.D. Mittelstaedt. 1996. A fish consumption survey of the Tulalip and Squaxin Island tribes of Puget Sound region. Department of Environment, Tulalip Tribes, Marysville, WA.

Tracey GA, Hansen DJ. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. Arch Environ Contam Toxicol 30:467-475.

USACE (U.S. Army Corps of Engineers). 2004. Wind and Bathymetry Data.

USACE. 2003. Environmental Residue-Effects Database. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. On-line database - http://el.erdc.usace.army.mil/ered/. Database accessed November 2003.

USACE. 1983. Final Feasibility Report and Final Environmental Impact Statement, East, West, and Duwamish Navigation Improvement Study. Seattle, Washington.

USACE, EPA, WDNR (Washington Department of Natural Resources), Ecology. 2000. Dredged material evaluation and disposal procedures. A user's manual for the Puget Sound Dredged Disposal Analysis (PSDDA) Program. U.S. Army Corps of Engineers, Seattle District, Seattle, WA; U.S. Environmental Protection Agency, Region 10, Seattle, WA; Washington Department of Natural Resources; and Washington Department of Ecology, Olympia, WA.

WDOH. 1995. Development of Sediment Quality Criteria for the Protection of Human Health. Tier I Report. Washington State Department of Health, Office of Toxic Substances. June 1995.

Weston, R. F., Inc. 1993. Remedial Investigation, Harbor Island, Part 2 – Sediment. Prepared for the U.S. Environmental Protection Agency.

Weston. 1994. Remedial Investigation Report, Harbor Island (Part 2 – Sediment). Volume I. Prepared for USEPA Region 10, Seattle, WA. Roy F. Weston, Inc., Seattle, WA.

Weston. 1998a. Remedial investigation report, Pacific Sound Resources, Marine Sediments Unit, Seattle, Washington. Volume I. Prepared for the U.S.

Environmental Protection Agency, Region 10, Seattle, WA. Roy F. Weston, Seattle, WA.

Weston. 1998b. Appendix K. Technical Memorandum. Ecological and human health risk assessments. Pacific Sound Resources. Marine Sediments Unit. Vol. II. Prepared for USEPA Region 10, Seattle, WA. Roy F. Weston, Inc., Seattle, WA. April.

Weston. 1999. Site inspection report, Lower Duwamish River (RK 2.5-11.5), Seattle, Washington. Vol 1-Report and appendices. Prepared for US Environmental Protection Agency, Region 10. Roy F. Weston, Inc., Seattle, WA.

Williams, R.W., R.M. Laramie, and J.J. Ames. 1975. A catalog of Washington streams and salmon utilization. Vol. I: Puget Sound region. Washington Department of Fisheries. Olympia, Washington.

Windward. 2003a. Lower Duwamish Waterway Remedial Investigation. Phase 1 Remedial Investigation Report. Appendix A: Ecological Risk Assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2003a. Lower Duwamish Waterway Remedial Investigation, Appendix A. Phase 1 Ecological Risk Assessment. Prepared for the Lower Duwamish Waterway Group. Windward, Seattle, WA.

Windward. 2003b. Lower Duwamish Waterway Remedial Investigation, Appendix B. Phase 1 Human Health Risk Assessment. Prepared for the Lower Duwamish Waterway Group. Windward, Seattle, WA

Windward. 2004a. Lower Duwamish Waterway Remedial Investigation. Task 8: Phase 2 RI work plan. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2004b. Quality Assurance Project Plan: Fish and crab tissue collection and chemical analyses: Appendix D. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. August 27.

Windward. 2005a. Quality Assurance Project Plan: Surface sediment chemical analyses and toxicity testing of the Lower Duwamish Waterway. Appendix C. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. January 14.

Windward. 2005b. Lower Duwamish Waterway Remedial Investigation. Food web model memorandum 1: Objectives, conceptual model, and selection of food web model. Draft. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2005c. Lower Duwamish Waterway Remedial Investigation. Food web model memorandum 2: Modeling approach. Draft. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2006a. Lower Duwamish Waterway Remedial Investigation. Baseline human health risk assessment. Draft. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. August 4.

Windward. 2006b. Lower Duwamish Waterway Remedial Investigation. Baseline ecological risk assessment. Draft. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. September 1.

Windward. 2006c. Lower Duwamish Waterway Remedial Investigation. Food web model memorandum 3: Preliminary model results. Draft. Prepared For Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. April 7.

Windward. 2007a. Lower Duwamish Waterway Remedial Investigation. Baseline Human Health Risk Assessment. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. November.

Windward. 2007b. Lower Duwamish Waterway Remedial Investigation. Baseline Ecological Risk Assessment. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. July 31.

Windward. 2007c. Lower Duwamish Waterway Remedial Investigation. Draft. Remedial Investigation Report. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA. November.

APPENDICES