Terminal 4 Early Action Engineering Evaluation/Cost Analysis

PORT OF PORTLAND

Port of Portland
Portland, Oregon

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Respectfully submitted,

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Acronyms and Abbreviations

ADCM	Acoustic Doppler Current Meter
ADCP	Acoustic Doppler Current Profiler
ADDAMS	Automated Dredging and Disposal Alternatives Management System
AOC	Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirement
AST	aboveground storage tank
ASTM	American Society for Testing and Materials
BA	biological assessment
BEP	bis(2-ethylhexyl)phthalate
BMP	best management practice
BSAF	biota-sediment accumulation factor
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
City CPD	City of Portland Commission of Public Docks
CLP	Contract Laboratory Program
COPC	constituent of potential concern
CRD	Columbia River Datum
CST	column settling test
DDT	dichlorodiphenyltrichloroethane
DEQ	Oregon Department of Environmental Quality
DGPS	differential global positioning system
DQO	data quality objective
DRET	dredging elutriate test
ECSI	Environmental Cleanup Site Information
EE/CA	engineering evaluation/cost analysis
ERL	Effects Range Low
ERM	Effects Range Medium
FSP	field sampling plan
ft	foot, feet
HASP	health and safety plan
HHRA	human health risk assessment
IRM	International Raw Materials
KMBT	Kinder Morgan Bulk Terminals
LNAPL	light nonaqueous-phase liquid
MET	modified elutriate test
MOU	memorandum of understanding
MSL	mean sea level
NAVD	North American Vertical Datum
NELAP	National Environmental Laboratory Accreditation Program
NGVD	National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTCRA	Non-Time-Critical Removal Action
ODFW	Oregon Department of Fish and Wildlife
OHW	Ordinary High Water

OTC	Oregon Terminal Company
OWR&N Co.	Oregon-Washington Railroad and Navigation Company
PAH	polycyclic aromatic hydrocarbon
PBT	persistent bioaccumulative toxin
PCB	polychlorinated biphenyl
PEC	Probable Effects Concentration
PEL	Probable Effects Level
Port	Port of Portland
PRPs	potentially responsible parties
PSDDF	Primary-Secondary Consolidation, and Desiccation of Dredged Fill
QAPP	quality assurance project plan
RAO	Removal Action Objective
RD&D	research, development, and demonstration
RI/FS	remedial investigation/feasibility study
SAP	sampling and analysis plan
SCPT	seismic cone penetrometer test
SOW	Statement of Work
SQG	sediment quality guideline
SPT	Standard Penetration Testing
SVOC	semivolatile organic compound
SWMP	stormwater management program
SWPCP	stormwater pollution control plan
TBC	To Be Considered
TBT	tributyltin
TCLP	toxicity characteristics leaching procedure
TCLT	thin-column leaching test
tDDT	total DDT
TEC	Threshold Effects Concentration
TEL	Threshold Effects Level
tPCB	total PCBs
TPH	total petroleum hydrocarbons
TOC	total organic carbon
TRV	Toxicity Reference Value
TSCA	Toxic Substances Control Act
UPRR	Union Pacific Railroad
USACE	U.S. Army Corps of Engineers
USATS	U.S. Army Transport Service
USC&GS	U.S. Coast and Geodetic Survey
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
VCP	Voluntary Cleanup Program
VOC	volatile organic compound

1. Introduction and Purpose

In 2000, the U.S. Environmental Protection Agency (USEPA) added the Portland Harbor Superfund Site (Superfund Site or Site) to the National Priorities List (NPL) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, 42 U.S.C. § 9601, *et seq*. (CERCLA or Superfund) (USEPA, 2001a). As is shown in Figure 1-1 and described in Section 2.1, the Superfund Site Assessment Area encompasses about 6 miles of the Willamette River in Portland, Oregon and includes the Terminal 4 facility. The Port of Portland (Port) owns Terminal 4 and leases land there to several marine shipping operations. Figure 1-2 shows the current aerial view of Terminal 4.

In fall 2001, the USEPA and ten of the Superfund Site's potentially responsible parties (PRPs) entered into an Administrative Order on Consent for Remedial Investigation/Feasibility Study (RI/FS), CERCLA-10-2001-0240 (USEPA, 2001a). The RI/FS will characterize the nature and extent of contamination and assess the biological and human health risks at the Superfund Site. The Administrative Order on Consent allows Early Actions to be conducted to address known risks at specific locations within the Superfund Site. Contaminants found in Terminal 4 sediment samples led to a determination that a removal action at Terminal 4 is necessary to protect the public health, welfare, or the environment. Accordingly, the Port is conducting this removal action under an Administrative Order on Consent for Removal Action (hereinafter AOC), CERCLA 10-2004-0009, executed by the Port and USEPA in October 2003. The Terminal 4 Removal Action Area, which is defined in the AOC and in Section 2.1, is shown on Figure 1-3.

The Terminal 4 Removal Action will address only contaminated sediment. However, before the Port cleans up the sediment, the Port intends to address contaminated surface water and groundwater that is migrating to the river from the Terminal 4 uplands. This work will involve identifying sources in the Slip 1 and Slip 3 uplands and, where appropriate, performing necessary source control activities. The uplands work, already under way, is being conducted pursuant to a Voluntary Agreement between the Port and the Oregon Department of Environmental Quality (DEQ) (Oregon DEQ, 2003a) and pursuant to a DEQ Record of Decision (Oregon DEQ, 2003b). USEPA, DEQ and other government agencies agreed in a Memorandum of Understanding (MOU) that DEQ would be the lead agency for work relating to the upland portion of the Superfund Site.

The AOC requires the Port to conduct an engineering evaluation and cost analysis (EE/CA) on various alternatives for the Terminal 4 Removal Action. Data collection under the EE/CA will focus on acquiring only the information necessary and sufficient to compare Removal Action alternatives, select a preferred alternative, prepare a design, and implement the selected alternative. Broad-based characterization studies and general assessments are not necessary.

Under the AOC, the USEPA may, pursuant to CERCLA or other applicable law, require the Port to perform activities in addition to the Terminal 4 Removal Action work. (AOC § XX ¶¶ 63, 64). Thus, although the USEPA and the Port will strive, and have as a goal, to make the Removal Action work the final remedy and response action for the Removal Action Area, information learned from the Superfund Site risk assessments and RI/FS may require that additional response action be taken.

Terminal 4 is an active marine terminal. For this reason, the EE/CA and the selected Removal Action alternative will be designed and implemented to prevent interference with ongoing Terminal 4 operations and to allow flexibility in current and future Terminal 4 land use.

This work plan is written to present the EE/CA work to be performed at Terminal 4 and to fulfill the requirements set forth in the AOC and in the Statement of Work (SOW) attached to the AOC as Appendix B. In particular, Section II-1 of the SOW sets forth the following work plan requirements:

Respondent shall submit an EE/CA Work Plan that will include a summary of existing information, a project work plan, a Sampling and Analysis Plan (SAP) and a Health and Safety Plan (HASP).

The EE/CA Work Plan shall include, at a minimum, the following information:

- *Introduction/Purpose;*
- *Brief description of Port of Portland Terminal 4 Removal Action Area characteristics, including ecological and physical characteristics;*
- *Identification of historic and potential ongoing sources of contamination to the Port of Portland Terminal 4 Removal Action Area, including past and present operations, drainage, discharges, or other releases;*
- *Summary of existing information on upstream and upland contamination sources that have the potential to contaminate the Removal Action Area, including a description of environmental investigations, environmental cleanups and planned upland source control measures that will be conducted under agreements with DEQ as the lead agency;*
- *Terminal 4 historical information including dredging history and identification of past and present property owners, operators, and major tenants in the Port of Portland Terminal 4 Removal Action Area as well as owners and operators of all immediately adjacent upland properties;*
- *Summary of current Port and tenant marine and associated facility operations and potential access or operational constraints on Work Plan implementation;*
- *Description of the nature and extent of contamination in the Port of Portland Terminal 4 Removal Action Area, to the extent known, including a summary of existing sediment quality data with a comparison to existing sediment quality guidelines that represent a range of levels including low or no effects (e.g., Threshold Effects Concentrations [TECs], Threshold Effects Levels [TELs], Effects Range Low [ERLs]), as well as levels at which some effects are expected (e.g., Probable Effects Concentrations [PECs], Effects Range Medium [ERMs]). Existing chemistry data will be reviewed to establish Category 1 and Category 2 data categories in accordance with the Portland Harbor RI/FS protocols;*
- *Summary of results from sediment toxicity testing conducted to date;*
- *If accepted by the Tribes, a reference to the cultural resource survey performed in consultation with the Tribes, or a process for reaching agreement with the Tribes on a survey, and a process for developing procedures to protect and address such cultural resources;*
- *A description of the analysis to be conducted to determine the likelihood of post Removal Action recontamination of the Port of Portland Terminal 4 Removal Action Area by upland or upstream sources of contamination;*
- *Identification of Removal Action Objectives (RAOs), potential Applicable or Relevant and Appropriate Requirements (ARARs), and To Be Considered (TBCs) for the Port of Portland Terminal 4 Removal Action Area, in consultation with State of Oregon and other partners on the Removal Action;*
- *A description of the analysis to be conducted to determine disposal facility options for contaminated sediment, including a description of the public participation process for selecting a disposal facility; and*
- *Other information (including maps and figures) necessary to gain a general understanding of the Port of Portland Terminal 4 Removal Action Area.*

Respondent shall also identify data gaps that will be filled by the collection and analysis of field data. Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate the following:

- *Nature, extent, and volume of sediment contamination;*
- *Potential human health and ecological risks resulting from sediment contamination;*
- *Engineering characteristics of the Removal Action Area including sediment consistency, dredgeability, potential slope stability issues related to dredging, and potential sediment consolidation issues associated with capping;*
- *Potential water quality effects associated with dredging, piling removal, sheet pile installation, capping, or disposal technologies;*
- *Alternative technologies for sediment remediation including capping, dredging, treatment (not including treatability testing, which is reserved and may be performed later, if needed) and disposal (on-Site and off-Site); and*
- *Potential impacts to threatened or endangered species, other biological receptors, and the potential habitat benefits and impacts of the removal action and related disposal.*

The procedures Respondent plans to implement when conducting all field activities will be detailed in the SAP that will be included in the EE/CA Work Plan. The SAP will ensure that sample collection and analytical activities are conducted in accordance with technically acceptable protocols and that data meet data quality objectives. The SAP provides a mechanism for planning field activities and consists of a Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP). Details are provided in Section III of this SOW.

Respondent shall also prepare HASP that is designed to protect personnel from physical, chemical and other hazards posed by field sampling efforts. Details are set forth in Section III of this SOW.

Table 1-1 provides a detailed cross reference of the SOW requirements outlined above and the work plan sections that address them. Sections 2 through 4 deal primarily with historical and existing conditions at Terminal 4 and the Removal Action Area. Section 5 presents a conceptual model for the Removal Action Area based on potential sources of contamination, pathways of exposure, and receptors. Sections 6, 7, and 8 describe the work to be performed under the EE/CA. As part of the continuing collaborative process to implement the Port's Early Action, a Response to Comment document, attached as Appendix F, was developed to identify and respond to each comment provided on the Terminal 4 EE/CA draft work plan. The responses to comments were reviewed during a February 13, 2004, meeting and additional responses incorporated into the document. The following list summarizes the information contained in each section and appendix of this work plan:

- Section 2, Removal Action Area Characteristics, provides information on the location, history, land use, and physical, ecological, engineering, hydrogeologic, and hydraulic characteristics of the Removal Action Area.

- Section 3, Potential Sources of Contamination, provides information on potential sources of contamination to the Removal Action Area.

- Section 4, Summary of Existing Data on Sediment Quality and Toxicity, evaluates existing information on sediment quality, existing toxicity testing data, and the proposed constituents of potential concern in the Removal Action Area.

- Section 5, Preliminary Conceptual Model of the Removal Action Area, presents both ecological and geochemical models for the Removal Action Area based on potential sources of contamination and pathways of exposure to, and receptors within, the Removal Action Area.

- Section 6, Data Gaps and Data Quality Objectives, identifies data gaps and discusses proposed data-gathering activities to fill the data gaps, as appropriate.

- Section 7, Removal Action Area Characterization Activities, discusses how data-gathering activities will be executed.

- Section 8, Removal Action Evaluation Approach, explains the proposed approach to the EE/CA.

- Section 9, References, lists documents and other references cited in the text.

- Appendices provide additional detail on field work, sampling, analysis, and quality assurance (Appendix A), health and safety (Appendix B), deep geotechnical exploration logs (Appendix C), NOAA figures (Appendix D), historical aerial photographs (Appendix E), and tabulated responses to USEPA comments on the 12/30/03 Draft EE/CA Work Plan (Appendix F).

Table 1-1
SOW EE/CA Work Plan Requirements and Work Plan Section References

SOW Requirement	Work Plan Section Reference
Respondent shall submit an EE/CA Work Plan that will include a summary of existing information, a project work plan, a Sampling and Analysis Plan (SAP) and a Health and Safety Plan (HASP)	Existing information is presented in Sections 2.0 through 4.0. The project plans are presented in Sections 6.0 through 8.0. The SAP is in Appendix A and the HASP is in Appendix B.
Introduction/Purpose	Section 1
Brief description of Port of Portland Terminal 4 Removal Action Area characteristics, including ecological and physical characteristics	Section 2.4 presents physical characteristics. Section 2.5 presents ecological characteristics.
Identification of historic and potential ongoing sources of contamination to the Port of Portland Terminal 4 Removal Action Area, including past and present operations, drainage, discharges, or other releases	Section 2.2 presents a history of Terminal 4. Section 3.0 presents an assessment of the potential sources.
Summary of existing information on upstream and upland contamination sources that have the potential to contaminate the Removal Action Area, including a description of environmental investigations, environmental cleanups and planned upland source control measures that will be conducted under agreements with DEQ as the lead agency	Presented in Section 3.0.
Terminal 4 historical information including dredging history and identification of past and present property owners, operators, and major tenants in the Port of Portland Terminal 4 Removal Action	Presented in Section 2.2.

SOW Requirement	Work Plan Section Reference
Area as well as owners and operators of all immediately adjacent upland properties	
Summary of current Port and tenant marine and associated facility operations and potential access or operational constraints on Work Plan implementation	Port and tenant marine operations are presented in Section 2.2.3.3. Operational constraints on work plan implementation are presented in Section 8.5.2.
Description of the nature and extent of contamination in the Port of Portland Terminal 4 Removal Action Area, to the extent known, including a summary of existing sediment quality data with a comparison to existing sediment quality guidelines that represent a range of levels including low or no effects (e.g., Threshold Effects Concentrations [TECs], Threshold Effects Levels [TELs], Effects Range Low [ERLs]), as well as levels at which some effects are expected (e.g., Probable Effects Concentrations [PECs], Effects Range Medium [ERMs]). Existing chemistry data will be reviewed to establish Category 1 and Category 2 data categories in accordance with the Portland Harbor RI/FS protocols	Presented in Section 4.0.
Summary of results from sediment toxicity testing conducted to date	Presented in Section 4.5
If accepted by the Tribes, a reference to the cultural resource survey performed in consultation with the Tribes, or a process for reaching agreement with the Tribes on a survey, and a process for developing procedures to protect and address such cultural resources	A cultural resource survey, prepared in 2003, is presented in summary form in Section 2.2.1; the complete report has not yet been approved for public release. Section 2.2.1 describes the Port's past and planned efforts to reach agreement with the Tribes on the survey and the procedures set forth in the FSP for protecting and addressing such cultural resources.
A description of the analysis to be conducted to determine the likelihood of post Removal Action recontamination of the Port of Portland Terminal 4 Removal Action Area by upland or upstream sources of contamination	Presented in general terms in Section 7.7. Based on an agreement with USEPA reached on November 21, 2003, a technical memorandum will be issued after additional stakeholder input on this issue is gathered.
Identification of Removal Action Objectives (RAOs), potential Applicable or Relevant and Appropriate Requirements (ARARs), and To Be Considered (TBCs) for the Port of Portland Terminal 4 Removal Action Area, in consultation with State of Oregon and other partners on the Removal Action	Presented in Section 8.0.
A description of the analysis to be conducted to determine disposal facility options for contaminated sediment, including a description of the public participation process for selecting a disposal facility	Presented in Section 8.3.3.
Other information (including maps and figures) necessary to gain a general understanding of the Port of Portland Terminal 4 Removal Action Area	Presented throughout the work plan.

SOW Requirement	Work Plan Section Reference
Respondent shall also identify data gaps that will be filled by the collection and analysis of field data.	Presented in Section 6.0.
Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate nature, extent, and volume of sediment contamination	Presented in Sections 6.9 and 7.8.
Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate potential human health and ecological risks resulting from sediment contamination	Presented in Sections 5.0, 6.5, and 7.4.
Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate engineering characteristics of the Removal Action Area including sediment consistency, dredgeability, potential slope stability issues related to dredging, and potential sediment consolidation issues associated with capping	Presented in Sections 6.6 and 7.5.
Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate potential water quality effects associated with dredging, piling removal, sheet pile installation, capping, or disposal technologies	Presented in Sections 6.10 and 7.9.
Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate alternative technologies for sediment remediation including capping, dredging, treatment (not including treatability testing, which is reserved and may be performed later, if needed) and disposal (on-Site and off-Site)	Presented in Section 8.3.
Investigation activities will focus on problem definition and will result in data of adequate quality and technical content to evaluate potential impacts to threatened or endangered species, other biological receptors, and the potential habitat benefits and impacts of the removal action and related disposal	Presented in Sections 6.5, 7.4, and 8.6.
The procedures Respondent plans to implement when conducting all field activities will be detailed in the SAP that will be included in the EE/CA Work Plan. The SAP will ensure that sample collection and analytical activities are conducted in accordance with technically acceptable protocols	The SAP is in Appendix A.

SOW Requirement	Work Plan Section Reference
and that data meet data quality objectives. The SAP provides a mechanism for planning field activities and consists of a Field Sampling Plan (FSP) and a Quality Assurance Project Plan (QAPP). Details are provided in Section III of this SOW.	
Respondent shall also prepare HASP that is designed to protect personnel from physical, chemical and other hazards posed by field sampling efforts. Details are set forth in Section III of this SOW.	The HASP is in Appendix B.

2. Removal Action Area Characteristics

This section summarizes the history, current use and characteristics of Terminal 4 and the Removal Action Area. This information is provided to establish the general context for the Terminal 4 Removal Action Area and to support evaluation of potential sources (Section 3), development of a preliminary conceptual model (Section 5), and planning for the work to be performed under the EE/CA (Sections 6, 7, and 8).

Throughout this work plan, reference is made to "the head of the slip" and "the mouth of the slip." The head of the slip is the east, or land-bounded, end of the slip. The mouth of the slip is the west, or river-bounded, end.

The Port has granted access to the Terminal 4 facility for the purpose of conducting work specified in this work plan. All individuals needing access to the facility for this purpose must still inform the Port to coordinate the timing of any particular visit.

2.1 Area Setting and Boundaries

The **Removal Action Area** is within the Port of Portland's **Terminal 4 Facility** located at 11040 North Lombard Street in Portland, Oregon. The Terminal 4 facility itself is within or adjacent to the **Portland Harbor Superfund Site**. The Removal Action Area and the Portland Harbor Superfund Site are defined in the AOC as follows:

> **Portland Harbor Superfund Site** or "Superfund Site" or "Site" shall mean the Portland Harbor Superfund Site, in Portland, Multnomah County, Oregon, listed on the National Priorities List (NPL) on December 1, 2000, 65 Fed. Reg. 75179-01. The Site consists of the areal extent of contamination, including all suitable areas in proximity to the contamination necessary for implementation of response action, at, from and to the Portland Harbor Superfund Site Assessment Area from approximately River Mile 3.5 to River Mile 9.2 (Assessment Area), including uplands portions of the Site that contain sources of contamination to the sediments at, on or within the Willamette River. The boundaries of the Site will be initially determined upon issuance of a Record of Decision for the Portland Harbor Superfund Site.
>
> **Removal Action Area** or "Terminal 4 Removal Action Area"...shall mean that portion of the Site adjacent to and within the Port of Portland's Terminal 4 at 11040 North Lombard, Portland, Multnomah County, Oregon: extending west from the ordinary high water line on the northeast bank of the lower Willamette River to the edge of the navigation channel, and extending south from the downstream end of Berth 414 to the downstream end of Berth 401, including Slip 1, Slip 3, and Wheeler Bay.

The Terminal 4 facility is divided into three areas for the purpose of environmental characterization and possible remedial action. These areas are described below and depicted on Figure 2-1.

> **Terminal 4 Slip 1 Upland Area** is located at the north end of Terminal 4 and consists of uplands bounded to the north by the property boundary with the Schnitzer Steel facility, to the east by the Terminal 4 property boundary, to the south by Wheeler Bay

and the Terminal 4 Slip 3 Upland Facility (see Figure 2-1), and to the west by the ordinary line of the low water of the Willamette River (Oregon DEQ, 2003a).

Terminal 4 Slip 3 Upland Area is located east and south of Slip 3 and consists of uplands bounded to the north by the Terminal 4 Slip 1 Upland Facility (see Figure 2-1), to the east by the Terminal 4 property boundary, to the south by the Terminal 4 Auto Storage Area (see Figure 2-1), and to the west by the ordinary line of low water of the Willamette River (Oregon DEQ, 2003b).

Terminal 4 Auto Storage Area is located at the south end of Terminal 4 and consists of uplands bounded to the north by the Terminal 4 Slip 3 Upland Facility (see Figure 2-1), to the east and south by the Terminal 4 property boundary, and to the west by the ordinary line of low water of the Willamette River.

These three upland areas are in various stages of environmental investigation or remedial action pursuant to a Voluntary Agreement and a Record of Decision (Oregon DEQ, 2003a; Oregon DEQ, 2003b). As discussed in Section 1, these areas will not be actively investigated under this work plan.

2.2 Area History and Current Use

This section summarizes the history and current use of Terminal 4 and the Removal Action Area. General historical and cultural resource information provides an underlying context for the modern development of the marine facilities. Detailed information on facility development and operations is provided as a foundation for understanding the nature of potential contamination sources (Section 3) on or near Terminal 4.

This section presents the best information available at the time this work plan was prepared. However, research is ongoing and new findings may augment or supersede the information presented here. In particular, as described in Section 1, the Port is working with DEQ to identify contaminant sources in the Terminal 4 Slip 1 and Slip 3 uplands and to perform appropriate source control activities. As part of that work, the Port is compiling information regarding the use of, hazardous substance releases on, and remedial investigations of those areas. The Port will incorporate into the EE/CA any new information discovered during that process and will provide access to the documents containing contain such information.

2.2.1 Cultural Resources

Information presented in this section is summarized from A Cultural Resources Reconnaissance Survey of the Port of Portland’s Terminal 4, Portland, Oregon (Final Draft) (AINW, 2003), which was prepared by Archaeological Investigations Northwest. The complete report has not yet been approved for public release.

Copies of the draft cultural resources report for Terminal 4 were provided to all six Tribes on August 11, 2003, and a meeting was held with Tribal representatives to discuss the Terminal 4 cultural resources report on October 7, 2003. No comments or concerns regarding the report or cultural resources at Terminal 4 were expressed at the October 7 meeting nor have any comments been received subsequently. Letters requesting Tribal concurrence with the report and its findings were sent to the Tribes on February 10, 2004, and follow-up telephone contacts will be made with each of the Tribes. In addition, no comments have been received from the Tribes regarding the proposed Archaeological Monitoring Protocol outlined in the Terminal 4 field sampling plan. The Port will be further coordinating with the Tribes regarding the proposed protocol to ensure that it addresses Tribal concerns. As needed and appropriate, the Port will revise the cultural resources report or modify the Archaeological Monitoring Protocol after additional Tribal consultation as defined above.

2.2.1.1 Native American Cultural Resources

Terminal 4 lies within the traditional homeland of the Chinookan peoples who occupied most of the lower Columbia River valley at the time of Euroamerican contact. The present Portland area was historically occupied by groups speaking two Upper Chinookan dialects, Multnomah and Clackamas. The confluence of the Willamette and Columbia rivers and the Lower Willamette River were major resource locations and regularly drew native peoples from throughout the Columbia River drainage for seasonal fishing and trading expeditions (French and French, 1998; Silverstein, 1990).

William Clark of the Lewis and Clark Expedition made a brief exploration up the Lower Willamette River in April 1806. He and his men camped near a small Chinookan village on the east bank of the Willamette. Clark's description and maps of the location indicate this village was in the vicinity of Terminal 4. The village, designated "Ne-mal-quin-ner's," had an estimated population of 200. The residents of the village were absent at the time of Clark's visit and he was told by his Indian guide that the Ne-mal-quin-ner's people usually lived at Willamette Falls, moving to the lower river settlement "when they Come down to the Valley to gather Wappato" (Moulton, 1990, 1991).

There are no written references to the Ne-mal-quin-ner village or any settlement at that location after the time of the Lewis and Clark Expedition. A well-known archaeological site at the mouth of Gatton's Slough (the lower course of the slough was buried by construction of Terminal 4) is likely to have been the remains of Ne-mal-quin-ner's village. Prior to construction of Slip 1, Gatton's Slough was formerly a natural surface drainage feature discharging to the Willamette River. This feature is shown on Figure 2-20, and is discussed further in Section 2.2.2. John Wacheno, a Clackamas Indian, told an anthropologist in 1934 of a village in the St. Johns area known as wÜxsûn, the residents of which fished for sturgeon at the mouth of the Willamette River (Drucker, 1934). Treaties in 1855 led to the relocation of many Chinookans, and other native peoples who had traditionally used the Lower Willamette River, onto reservations. Accounts of early settlers in the St. Johns area indicate, however, that some Indians remained along the river through the 1850s and into the 1860s (Dickson, 1976; Singleterry, 1976). Other Indians are known to have left the reservations seasonally to visit traditional resource locations.

Other than the archaeological site at the mouth of Gatton's Slough, the only reported archaeological resources at Terminal 4 are a few artifacts apparently collected in the 1960s and 1970s by a former worker at the terminal. One of these artifacts was a net weight collected from under Pier 5 in Slip 3 (Schenkenberger, 1981). An archaeological reconnaissance survey of Terminal 4 conducted in January 2003 included an examination of the accessible banks and beaches. The bank exposures indicated that they are composed of dredged sands and silts. No evidence of any archaeological resources associated with American Indian use or occupation was observed (AINW, 2003).

On the basis of a review of historical-period records and other materials, the alignment of the historical-period Willamette River bank and the banks of the former Gatton's Slough have been identified as high-probability areas for archaeological resources associated with American Indian use and occupation of the Terminal 4 area (AINW, 2003).

2.2.1.2 Euroamerican Cultural Resources

The Terminal 4 area was initially of little interest to Euroamerican settlers because it was low, marshy, and subject to frequent flooding. A Donation Land Claim encompassing the future Terminal 4 location was settled in 1846 by James Loomis and his family, who built a cabin along the bank of the Willamette River. This occupation was probably short-lived. By the 1890s, the only use of the Terminal 4 location appears to have been for grazing cattle and possibly for growing hay. The Ogden family purchased the future Terminal 4 location in 1897 but built their house on the higher ground to the northeast. More intensive development occurred in the years before World War I, with construction of the railroad along the eastern edge of the floodplain in 1907 to 1908. A dock for ships to transfer oil to the Union Pacific Railroad and an associated pipeline were built in 1906 to 1907 along the south side and to the east of the future location of Slip 3. These are the only known uses of the Terminal 4 location prior to construction of Terminal 4, which began in 1917.

2.2.2 Physical History

The landscape and physical features of Terminal 4 have changed significantly in the past century with the preparation of the land for use as a marine terminal. What was once Willamette River floodplain occupied by grasslands, wet prairies, and small ponds (AINW, 2003) was modified by grading, dredging, and filling beginning as early as 1906 to 1907.

Prior to development, the banks of the terminal location were lined with trees, and Gatton's Slough (which discharged to the Willamette River) traversed the northern portion of the property (U.S. Coast and Geodetic Survey, 1895). A small stand of trees was located on the floodplain immediately south of the slough, beyond which were several small swales and ponds. The remainder of the area was occupied by grasslands, which were probably wet prairies. A U.S. Coast and Geodetic Survey (USC&GS) map from 1895 depicts a building (possibly a farmhouse) located at the eastern edge of the floodplain (southeast of the location of the now-removed Warehouse 6) along with a series of trees suggestive of a small orchard.

In 1897, the Ogden family purchased the land around lower Gatton's Slough. They built a house on the higher ground overlooking the floodplain, probably close to the modern entrance to Terminal 4 on North Lombard Street. In addition to farming, the Ogden family reportedly drilled for oil near the mouth of the slough, without success (Minkler, 1976).

The rural landscape portrayed in the 1895 map began changing in the first decade of the 1900s. The first development at Terminal 4 occurred in 1907 to 1908 when the Oregon-Washington Railroad and Navigation Company (OWR&N Co., a Union Pacific Railroad affiliate and part of the Union Pacific Railroad system, hereafter referred to as Union Pacific) constructed a railroad along the eastern edge of the floodplain (the railroad alignment now serves as the eastern boundary of Terminal 4). By 1912, Union Pacific had constructed its oil-supply dock for locomotives and, on the east slope above the rail tracks, the St. Johns Tank Farm which was used as a locomotive fueling station. Photographs from 1917 indicate that an oil pipeline extended east from the river across the floodplain to the tank farm. The oil pipeline later became an underground structure, and was presumably buried when the area of Slip 3 was filled and graded for development. However, the date of burial has not been verified. The pipeline alignment was along the south side of where Slip 3 would later be constructed. The oil was pumped uphill from the oil-supply dock to the tank farm.

In 1917, the site preparation for the development of Terminal 4 began. Trees and other vegetation were removed over most of the floodplain in the northern Terminal 4 area, and dredged fill material was deposited across the low-lying ground and then leveled with horse teams. Most of lower Gatton's Slough was filled at this time as well. Beginning about the same time, fill was also placed into the offshore shallows to extend the riverbank out into the channel. The 1895 U.S. Coast and Geodetic Survey map labeled the offshore area as "Linton Shoal," with water less than a meter deep in places. Filling this area was relatively easy and provided the new Terminal 4 with a larger land base. As described in more detail below, the northern Terminal 4 facilities were Piers 1 and 2 at Slip 1 and Pier 5 at Slip 3. A Slip 2 was planned and partially excavated but never completed. The remnant Slip 2 is known today as "Wheeler Bay." Photographs taken in 1917 trace the rapid transformation of this landscape (Port of Portland, 1917).

Pre- and post-construction maps of and plans for Terminal 4 indicate substantial changes occurred in the landscape with the development of Terminal 4 from 1917 to approximately 1921 (AINW, 2003). First, construction of the terminal involved placement of fill that extended 650 to 975 feet (ft) from the original riverbank. Second, the construction of Slips 1, 2, and 3 also required excavations into the original shoreline. Slip 1 was located at the entrance to Gatton's Slough, and the head of the slip extended up to 650 ft inland from the original riverbank. These excavations probably removed much of the upriver portion of the mouth of the slough; the downriver portion of the slough entrance was covered by Houses 1 and 2 at Pier 1 and portions of the grain complex. The inland excavations for Slips 2 and 3 (although Slip 2 was never finished) extended from 440 to 565 ft back from the original shoreline. The northern portion of Terminal 4 was thus developed through a combination of fill outward from the original riverbank and excavations into the original floodplain. All traces of lower Gatton's Slough were lost either through burial under fill or removal for the creation of Slip 1 (see also Section 2.2.4).

2.2.3 Chronology of Ownership and Operations

2.2.3.1 Property Acquisition and Development

Originally called the St. Johns Municipal Terminal, Terminal 4 was developed by the City of Portland Commission of Public Docks (City CPD) as a result of the push by the City to become a world-class shipping port and to capitalize on growth in the shipping industry following the opening of the Panama Canal in 1914 (Donovan and Associates, 1997). Following the physical preparation of the land (see Section 2.2.2), the City CPD initiated construction for development of the property as a marine terminal.

The main building construction and other physical developments at Terminal 4 are summarized in Table 2-1. Note that warehouses at Pier 1 were called "houses," while those at Pier 2 were called "warehouses."

Table 2-1
Chronology of Facility Development at Terminal 4

Year	Entity and Event
1906-07	St. Johns Tank Farm (with storage tanks and a pipeline to a terminal dock) constructed by Union Pacific at the future location of Slip 3; the facility handled Bunker C fuel oil for fueling steam locomotives south of modern Slip 3.
1917	$3,000,000 bond levy approved on June 17, 1917, for land purchase and development. City CPD purchases 117.55 acres of upland and purportedly 36 acres of submerged land centered on Gatton's Slough.
1917-20	Slips 1 and 3 dredged and Pier 1 (Berths 403-405), grain elevator, operating house, storage bins, track shed, and Warehouses 1-5 constructed. Spur tracks from

Year	Entity and Event
	existing Union Pacific lines constructed.
1919	Liquid bulk storage facility constructed at the head of Slip 1; House 4 constructed.
1919-20	Pier 2 and Berths 406-408 constructed. Vegetable oil weighing house constructed east of Slip 1.
1920	4.94-acre parcel acquired from Union Pacific adjacent to Slip 3; however, parcel developments (pipeline, oil supply tanks, and fuel oil dock) remained under ownership of Union Pacific. Flour mill, adjoining concrete warehouse for grain and flour, and Berth 409 constructed. Houses 1 and 2 constructed on the upstream side of Slip 1. Boiler house and service buildings (including an administration building, cafeteria/restaurant, and welfare building) constructed east of Slip 1.
1920-21	Substructure for Piers 3, 4, and 5 constructed (although Pier 3 was never completed). Quay dock, bulk handling facility, and Berths 412 and 413 completed on the upstream side of Slip 3. Union Pacific pipeline extended to service Berth 412 at Pier 5, Slip 3.
1920-24	Filling platform for liquid bulk storage facility constructed east of Slip 1.
1921	Storage bunkers constructed east of Slip 3.
1921-22	Warehouses 6 and 7 constructed on Pier 2, Slip 1 serviced by Berths 406 and 407.
1922	House 5 constructed perpendicular to House 4 along the river.
1923	Houses 6, 7, and 8 were constructed perpendicular to House 5 as a cold storage plant and ventilated warehouse. 150,000-gallon elevated water tank constructed. H.R. Leckenby fumigation plant constructed.
1930	Grain storage annex constructed north of the grain elevator.
1931	Tanks added to liquid bulk storage facility.
1932	Gearlocker building constructed north of the liquid bulk storage facility.
1940-41	Berth 401 and Airveyor system for unloading bulk grain from barges constructed on the harbor side of Houses 4 and 5 at Pier 1 for grain unloading.
1942	At the onset of WWII, the U.S. Army Transport Service (USATS) leased Terminal 4 from City CPD for Portland's Sub-Port of Embarkation. USATS added a second story to the gearlocker building. The USATS rehabilitated the loading apron at Pier 1, replaced decking and rehabilitated railroad track at Pier 2, and rehabilitated the slip side of Pier 5.
1944	Auxiliary pipeline constructed by the USATS at Slip 3 Pier 5.
1946-47	The USATS relinquished Terminal 4 to City CPD. Bulk loading facility constructed at Berth 412 on the slip side of Pier 5.
1948	20-acre parcel south of Pier 5 acquired from Union Pacific.
1951	A railcar dumper and a hydraulic truck unloading hoist and dust collection system added to the grain facility at Pier 1.
1953	Oil packaging plant constructed and eight aboveground storage tanks (ASTs) and an underground transfer pipeline installed at the head of Slip 3 by Quaker State for oil storage.

Year	Entity and Event
1954	Eight steel ASTs for grain storage constructed east of the grain storage buildings at Slip 1. Electric elevator system at grain elevator modernized.
1955	Pier 2 rehabilitated and two gantry cranes added. Berths 410 and 411 constructed on the downstream side of Slip 3. Fumigation plant removed.
1957	Berth 401 renovated.
1957-58	19.64-acre parcel upstream of Pier 5 acquired from Multnomah County.
1958	Second gallery for grain loading added at Pier 1.
1962	Pier 5 harbor-side wharf and Berth 409 at the head of Slip 1 removed. Dravo bulk unloader installed at Pier 4.
1963	Head of Slip 1 developed as small boat landing.
1966	Five tanks constructed by Pacific Molasses added to liquid bulk storage facility.
1968	Warehouse 4 constructed at Pier 2. Matson Navigation Co. installed 33-ton-capacity container crane on Pier 2. Three 36-ton revolver cranes purchased and installed at Pier 4.
1968-69	Berths 404 and 405 reconstructed (Berth 405 to handle offloading of barges for grain). Coal bunkers removed at Pier 5.
1971	Grain elevator remodeled; Union Pacific abandoned existing pipeline to St. Johns Tank Farm and installed a replacement pipeline; Port and City CPD consolidated; except for City's fire boat station, CPD properties and functions transferred to Port.
1973	Land purchased from Broadway Holding Company. House 8 demolished at Pier 1. Berth 417 constructed southwest and upstream of Slip 3.
1975	Berth 401 reconstructed to handle ships, adding grain loading equipment and conveyor system.
1978	Cold storage plant and ventilated warehouse (Houses 6 and 7) at Pier 1 removed.
1983	Union Pacific's operation of the St. Johns Tank Farm tanks and replacement pipeline ceased.
1984	Boat landing at the head of Slip 1 removed and ro-ro dock, called Berth 409, constructed in its place. Service buildings removed, including an administration building, cafeteria/restaurant, and welfare building. Whirley cranes removed from Berths 410 and 411.
1985	Quaker State ASTs and underground pipeline removed.
1986	City of Portland began construction of Outfall 52C and the associated storm sewer system serving Lombard Street properties.
1987	Bulk outloading facility constructed at Pier 4 by Hall-Buck Marine. Construction of City drainage system and Outfall 52C at the head of Slip 1. Tanks removed from Union Pacific's St. Johns Tank Farm.
1988	Diesel and gasoline underground storage tanks (USTs) and fueling station installed by Oregon Terminal Company.

Year	Entity and Event
1989	Second railcar dumper added to grain facility. Two pipes added at Pier 1 for liquid bulk storage facility.
1990	House 4 condemned.
1991	Guard station constructed.
1992	Four of the steel ASTs for grain storage (east of the storage bins to the north of Slip 1) modified.
1992-93	Downstream row of tanks at original liquid bulk storage facility removed.
1994-95	All but five of the tanks remaining at liquid bulk storage facility removed.
1995	Soda ash storage building constructed at Pier 4.
1996	House 6, House 7, Berth 406, and Berth 407 at Pier 2 dismantled.
1996	Oregon Terminal Company's diesel and gasoline USTs removed.
1997	Pipeline for liquid bulk storage facility rebuilt under Berth 408.
1997-98	Portions of Union Pacific's decommissioned/abandoned St. Johns Tank Farm pipeline removed from under Berth 412 and elsewhere.
1999	Houses 3, 4, and 5 and Berths 403 and 404 demolished. Mechanical/electrical building and bridge to Berth 401 constructed.

2.2.3.2 Historical Terminal Operations

Tenant operations at Terminal 4 are discussed here by operating areas, further subdivided by the piers and berths the tenants used.

Union Pacific Railroad

Union Pacific and its predecessor, OWR&N Co., built, maintained and operated a fuel oil dock, 10-inch steel pipeline, and the St. Johns Tank Farm and tank car loading facility near Pier 5 on the south (upstream) side of Slip 3 beginning in at least 1906 to 1907. The tank farm and loading facility included two 55,000-barrel aboveground storage tanks (ASTs) for oil and associated pumping and heating facilities. The tanks and the pumping and heating facilities were adjacent to the terminal on the bluff beyond the rail trackage east of Pier 5. The pipeline was used to transfer diesel fuel and, prior to 1955, Bunker C oil from marine vessels to the storage tanks, which delivered fuel oil via a loading rack on the main rail line above the terminal to locomotive steam engines and to rail tank cars for distribution to other facilities elsewhere in Union Pacific's system. Track scales were built to avoid having to transport cars to the railroad yard, which was some distance away. The track scales were operated under the supervision of the Weighing and Inspection Department of the Transcontinental Freight Bureau.

The City CPD purchased two parcels of land from Union Pacific that contained the pipeline and dock at Terminal 4, Pier 5 but not the tank farm: approximately 5 acres in 1920 and approximately 20 acres in 1948. The 1920 and 1948 deeds retained an easement for the existing pipeline that served the St. Johns Tank Farm on Union Pacific's property east of the terminal. The easement granted the railroad and its successors the right to operate and maintain the pipeline and associated dock.

From 1922 to 1939, General Petroleum Corporation leased the St. Johns Tank Farm from Union Pacific and operated a facility near Slip 3 for delivery of bunker fuel and unloading of fuel oil from vessels. Included in their operation was an approximately 30-ft AST used for fuel oil and two associated buildings, one of which was a designated pump house. All three structures were located along the area of the pipeline to the south of Slip 3 (Sanborn Fire Insurance Map, 1924). Neither the date of construction nor the date of demolition of these structures could be verified.

In 1952, Union Pacific requested an area for cleaning railcars and was offered the use of Track 10½ by the City CPD.

In 1969, Union Pacific leased the St. Johns Tank Farm and associated pipeline to Standard Oil Company of California (now known as Chevron). The arrangement provided that Standard Oil would supply Union Pacific with oil for its tank cars.

In 1971, Union Pacific abandoned the pipeline because of leaks. A new pipeline was then constructed parallel to the old one, but farther to the south across the adjoining 19.5-acre parcel. Standard Oil continued to operate the tank farm and replacement pipeline until 1983, when fuel transfer operations ceased altogether. The tanks were removed in 1987. In 1997, during removal of the dock at Berth 412, the under-dock portions of the pipeline were drained, cleaned, and removed. In 1998, other portions of the pipeline were drained and removed.

Cargill Grain Facility

The grain elevator and its operating house were completed in 1920 and were operated by the City CPD. The facility contained a conveyor belt system that carried sacked grain to the elevator for cleaning and storage. Northwest sacked wheat was susceptible to a wheat fungus known as smut. An initial lime scouring method for cleaning was later replaced when Wolf-Dawson wheat washers were installed. Dust collecting and sweeping systems controlled airborne particulates. A two-belt shipping gallery could load two vessels with bulk grain simultaneously. Track facilities were provided in the front and rear of the pier; the rear tracks had placement for 105 cars. The pier had cargo masts along its entire face, electric elevators, and electrically operated ramps for handling freight to and from river steamers and barges. The grain elevator had capacity to handle 1,053,800 bushels in eight hours. After the construction of the grain elevator annex in 1930, its grain-storing capacity of 2,000,000 bushels exceeded that of any other grain elevator on the Lower Columbia (Merchants Exchange Journals, 1932).

Barge delivery of bulk wheat to the grain elevator began to supplant sack delivery in 1939. The following year, the City CPD installed a Fuller Airveyor vacuum system for unloading grain barges in Slip 1. Another, higher-capacity vacuum system was added in 1957. Eight grain storage silos are located east of the grain terminal. When these were built and put into operation in 1954, the grain storage capacity at Terminal 4 increased to 7,400,000 bushels. To more readily accommodate grain delivery at the enhanced storage facility, a new box car unloader was added.

In 1942, Terminal 4 and operation of the grain facility were turned over to the U.S. Army Transport Service (USATS). In 1947, the facility was returned to the City CPD, which entered into a lease agreement with Kerr-Gifford. Kerr-Gifford operated the grain elevator at Pier 1 from 1947 until 1954. In 1953, Cargill agreed to purchase all of the stock of Kerr-Gifford, and in November 1954, Kerr-Gifford was merged into Cargill as the

Kerr Gifford Division. It was at that time that Kerr-Gifford's lease of the grain terminal was assigned to Cargill.

Table 2-2 summarizes the facilities Cargill used in connection with their operation of the grain facility.

Table 2-2
Cargill Operating Areas at the Grain Facility at Terminal 4

Cargill Facility	Location(s)	Constructed	Use/Former Use	Status
Operating House (grain elevator)	South of Storage Annex	1920	Transfer of grain	Present
Track Shed	South of Operating House	Prior to 1953	Cover for rail trackage	Present
Office Building (Building 168)	West of Flour Mill	1975	Administrative offices	Present
Conveyor Building (Building C-10)	West of Office Building	1970s	Conveyor equipment	Present
Longshoremen's Lunchroom	Adjacent to Berth 401	1980s	Longshoremen's facility	Present
Truck Shed (Building 178)	North of Building C-10	1976	Covered way for trucks	Present
Truck Dumper	East of Track Shed	Prior to 1953	Unloading trucks	Present
Gearlocker	South of Railcar Tipper north of Berth 405	Not confirmed	Storage of equipment	Present
Grain Storage Silos (8)	East of Operating House	Circa 1954	Grain storage	
Blacksmith Shop	South of Grain Storage Silos	Not confirmed	Not yet confirmed	Removed
Millwright Shop	West of Operating House	1958	Not yet confirmed	Removed
Pellet Mill	East of Storage Annex	1994	Processing beet pellets	Present
Maintenance Shop	East of Operating House	1970s	Equipment maintenance	Present
Oil Shack	North of Maintenance Shop	Not confirmed	Not yet confirmed	Not available
Bull Pen	Not yet confirmed	Not confirmed	Not yet confirmed	Unknown
Transformer House	Southeast of Pellet Mill between the Operating House and Storage Silos	1917	Transformer storage	Razed in 1977
Electrical Distribution Center	Adjacent to Berth 405	Not confirmed	Transformer storage	Removed
Electrical Transformers	Various locations	Varies	Energy conversion	PCB-containing transformers replaced in 1988
Railcar Tipper (installed circa 1954)	South of Track Shed	Prior to 1953	Unloading grain from railcars	Present
Work Pit	Beneath Railcar Tipper	Not confirmed	Not yet confirmed	Present
Deep Water Well	Southeast of Storage		Turbine pump	Abandoned

Cargill Facility	Location(s)	Constructed	Use/Former Use	Status
	Annex (northeast of Operating House)			and filled in 1992
Fueling Facility	Between Buildings 152 and 160	Not confirmed	Fueling equipment	Removed
Diesel UST (1,000-gallon) (T4-20)	West of Operating House	Not confirmed	Diesel storage	Removed 1989
Fuel oil UST (1,000-gallon) (T4-21)	West of Operating House	Not confirmed	Fuel oil storage	Removed 1989
Fuel oil UST (500-gallon) (T4-22)	Beneath the Operating House	Not confirmed	Fuel oil storage	Removed 1993
Used oil UST (T4-85)	North of Compressor House	Not confirmed	Used oil storage	Removed 1993
Diesel AST (500-gallon) (T4-45)	West of Car Shed	Not confirmed	Diesel storage	Removed September 2003
Diesel AST (675-gallon) (T4-47)	Southwest of Operating House	Not confirmed	Fueling locomotives and equipment	Removed September 2003
Used oil AST (250-gallon) (T4-48)	North of Maintenance Shop	Not confirmed	Used oil storage	Removed September 2003
Conveyor to Berth 405	Extends south of the Operating House to Berth 405	Prior to 1940	Grain transport	Present
Conveyor to Berth 401	Extends west from the Operating House to Berth 401	1975	Grain transport	Present
UIC Dry Well	Near Berth 401	1999	Stormwater Discharge	Present
Rail trackage	Throughout the leasehold	Varies	Transport of railcars and materials	Present
Sumps	Railcar Tipper, Building 141, Truck Dump, Building Basements	Not confirmed	Discharge	Present
Hydraulic equipment	Building C-10, near Track Shed, and west of Railcar Tipper	Not confirmed	Various uses	Present

Cargill maintained preferential berthing rights throughout their occupancy at Berths 401 and 405. Cargill transported materials to and from Berth 401 via railcars that moved along trackage located between Berth 401 and the track shed. Materials were transported to and from Berth 405 utilizing the conveyor system.

Cargill is in the process of terminating its lease of the grain facility.

Cold Storage Plant

The cold storage plant and ventilated storage warehouse, constructed at Pier 1 in 1923, provided refrigeration space for transit shipments of apples received for export. The facility, immediately north of the Pier 1 warehouses, was a concrete and brick structure divided into three compartments (Houses 6, 7, and 8).

The 1923 addition of the cold storage plant in the eastern third of the apple storage warehouse led to a five-year storage contract with the Apple Growers Association of Hood River (City CPD, 1923). The cold storage plant was 100 ft by 200 ft and had a capacity of 105,000 boxes. The ventilated apple storage warehouse adjoined the cold storage plant and had a capacity of 350,000 boxes. The Port of Portland led the ports of the Pacific in the shipment of apples; during an average year in the mid-1920s, approximately 1 million boxes were shipped.

H.N. Leckenby

In 1923, H.N. Leckenby constructed a fumigation plant near the head of Slip 1 (just in front of the modern International Raw Materials [IRM] tank location, see Figure 2-2). In 1924, Mr. Leckenby began fumigating Oriental cotton received at the Port and other commodities (e.g., peanuts, rice, beans, and other foodstuffs). The plant reportedly had a capacity of 250 tons per day. City CPD minutes from the 1930s indicate that the plant operated under the name of NW Pesticide Company. During World War II, the Army may have used the fumigation plant in connection with its operations (further discussed below). According to City CPD minutes (City CPD, 1949), after the military had vacated the terminal, arrangements were made in 1946 for Mr. Leckenby to enter into a lease with the City CPD and continue operating the plant. The plant continued in operation until sometime in the mid-1950s.

Liquid Bulk Storage

In 1919, a liquid bulk storage facility was constructed at the head of Slip 1. By 1931, additional bulk storage tanks were added and the facility included a City CPD-operated warehouse, tank car cleaning facility, and an edible-oil cleaning pit. In 1947, the facility was leased to Pacific Molasses (which later became PM-Ag). Products handled included liquid fertilizer, molasses, molasses products, tallow, urea, caustic soda, and fats. By 1966, the liquid bulk storage facility had been upgraded to include 14 steel tanks on a concrete foundation. Liquid bulk materials were pumped directly from vessels to the tanks via one of two 8-inch pipelines at Pier 1 and Pier 2. The liquid bulks could then be weighed on a 60-ton-capacity scale and pumped into railcars at the filling platform. Up to 10 tank cars could be filled at one time. Pacific Molasses also made use of a car cleaning pit and a steam cleaning area northwest of its tanks to clean food products out of the railcars prior to their filling.

PM-Ag formerly utilized an approximately 8,000-gallon underground storage tank (UST) for storing diesel. The UST was decommissioned by removal in 1991.

Between 1992 and 1995, all of the original public tanks were removed; five private tanks remain in use at present. In 1995, the lease for the liquid bulk storage facility was assigned to IRM, which continues to operate the facility.

The Port removed an approximately 3,000-gallon diesel UST from the IRM leasehold in 1995. Based on confirmatory sampling, the DEQ subsequently issued a No Further Action determination for the UST.

IRM also utilizes an approximately 15,000-gallon heating oil UST located next to the boiler house.

Flour Mill

A 1919 agreement between the City CPD and the Eagle Flour Mills Company for the construction of a flour mill north of Slip 1 was transferred to Terminal Flour Mills Company in 1923. A flour production and storage facility was completed and in operation at Terminal Flour by 1925. Terminal Flour operated the facility until 1992, at which time Terminal Flour's lease was assigned to Cereal Food Processors, which continues to operate the facility.

The mill originally consisted of a concrete building and an adjoining concrete grain and flour warehouse (Donovan and Associates, 1997). An annex was added at a later date (circa 1924 to 1950). A system of conveyors, which originally provided the mill with grain from the neighboring grain storage facility, was abandoned in 1966, and a track pit was added to the facility to accommodate hopper bottom railcars. In addition, two rail spurs running between the eight grain storage tanks served to accommodate delivery of bulk flour from the mill. Sacked flour was loaded directly onto vessels docked at Pier 1 using a conveyor belt system. In 1925, the flour mill had a capacity of 1,500 barrels a day. The output was nearly all for export. The export of flour ceased following World War II when Terminal Flour modified its operation and began milling flour for U.S. consumption. Grain was brought into the silos by rail, milled, and sold either in bulk or in sacks. At present, Cereal Food Processors mills flour for Portland-area customers and sells its product in bulk, exporting the flour from the facility via truck or rail.

Terminal Flour Mills formerly utilized an approximately 10,000-gallon fuel oil UST located north of the flour mill, an approximately 1,000-gallon diesel UST located south of the flour mill, and an approximately 1,000-gallon fuel oil UST located south of the flour mill. All three USTs were reportedly decommissioned by removal by Terminal Flour Mills. However, based on currently available information, neither the date of installation nor the date of removal of the USTs has been confirmed.

Oregon Sulphur Company

Oregon Sulphur Company operated on the east side of Slip 3 at Pier 5, importing bulk sulfur beginning in at least 1920. In photographs from 1920, there appears to be an open storage area, and sulfur was unloaded via clamshell bucket using a locomotive crane. The material was placed on the pier adjacent to the bunkers, where it likely remained until being loaded into railcars.

Matson Lines

Warehouses 6 and 7 at Pier 2, called the "Old Matson Warehouse," were constructed in 1922 and were used in Matson Navigation Company's Hawaiian trade (City CPD, 1947). Matson operated a freight dock at Slip 1 from 1955 to 1985. Matson initiated containerized cargo operations in 1964 at Berth 408, which was formerly used for the loading of scrap iron. This location fits within space designated as Berths 406 to 408. Pacific Northwest products, such as refrigerated meat, fresh fruit, potatoes, other vegetables, and canned goods, were shipped in containers to Matson's Hawaiian terminals on a biweekly basis. Return containers delivered commodities such as sugar, pineapple (fresh and canned), and tuna. Molasses shipped in vessel holds was used for ballast. Matson Navigation's agreement with the City CPD gave it preferential berthing at Pier 2 and provided for exclusive use of a paved portion of the yard south of the pier for Matson's container operations. Matson used space at Terminal 4 until expiration of the agreement in March 1982, at which time it transferred its container operations to Terminal 6 and discontinued the shipment of liquid molasses.

Quaker State

In 1953, Quaker State constructed an oil packaging (motor oil bottling) facility at the head (to the east) of Slip 3. The facility included an underground transfer pipeline, three 220,000-gallon tanks, one 42,000-gallon tank, four 10,000-gallon tanks, a main blending and bottling building, and a storage building. Bulk oil was brought in via railcars on the north side of the facility or via ships berthed at Pier 5, Berth 412. The oil was pumped directly to the tanks from the railcars or directly from vessels into the transfer pipeline that traversed from Pier 5 to the eight ASTs. The tanks, which were located west of the packaging plant building, were connected to the packaging plant via pipeline. Quaker State bottled motor oil in 1-quart containers; some of the oil was blended at the facility with detergent and with motor oils of different weights. Once the oil was packaged, it was loaded onto trucks or railcars via a spur track on the north side of the packaging plant (Figure 2-3).

Port drawings indicate that Quaker State also utilized a waste oil UST and a used oil AST located southeast of their main blending and bottling building. The UST was decommissioned in 1991. The date of removal of the AST has not been confirmed.

Quaker State continued its operations through 1985, when the ASTs and the abandoned underground pipeline were removed. The building was converted in 1985 to a new gearlocker building and electrical shop for Oregon Terminal Company. Port drawings indicate that a rail-covered shop work pit was constructed west of the gearlocker building and two USTs were installed east of the gearlocker building at that time.

Rail Development at Terminal 4

Terminal 4 had approximately 10 miles (of a projected 17 miles) of railroad line when operations began there in 1920. After the addition of the cold storage facility in 1922, approximately 15 miles of rail trackage served the terminal. City CPD annual reports (City CPD, 1927, 1931) subsequent to 1926 described the rail network as having a working capacity of 425 cars (130 at ship side) with the ability to accommodate up to 800 cars.

The USATS made additions to the terminal's rail network during its tenure between 1943 and 1947, constructing or repairing approximately 22 miles of rail trackage. The high-capacity movement of defense materiel through the Portland Sub-Port of Embarkation created railcar holding backlogs on the main lines. The War Department responded to this by leasing land adjacent to Terminal 4 and building a railcar storage yard to accommodate cargoes awaiting transshipment.

Following the facility's return to the City CPD, improvements were made in 1947 when additional trackage was installed for the new bulk outloader built by the City CPD at Pier 5, Berth 412 for handling expected coal and phosphate cargo. Rail improvements continued at Terminal 4 in the 1950s, including a spur track constructed in 1953 to serve the Quaker State oil packaging plant at the head of Slip 3, rail modifications to accommodate the addition of the Cargill grain storage tanks in 1954, the 1959 addition of rail lines for Pier 4 when it was developed, and improvements in 1964 at the time of Matson's container terminal operation. More recently, in 1996 Hall-Buck Marine required modification of the rail network to accommodate its soda ash export facility.

In 1964, when Matson Navigation began container terminal operations at Pier 2, the rail infrastructure was assessed for container operations. In 1985, the north throat and grain leads into Terminal 4 were reconstructed. In 1987 and 1996, Hall-Buck Marine's lease operations required modification of the rail network near Slip 3. Maps depicting rail lead designations are illustrated on Figure 2-4.

Exported freight is the railroad company's responsibility until facility operators take delivery with their locomotive, as is the case with Kinder Morgan Bulk Terminals (KMBT). Responsibility remains with KMBT and the longshoremen while product is transferred to a ship's hold. When the ship's hatches are closed, responsibility for the cargo is transferred to the vessel owners and operators. The same process applies to imported cargo. While the product is in the ship's hold, it is the vessel owner/operator's responsibility. During transfer, the responsibility shifts to the terminal operator (tenant) and its agents (longshoremen). This status is in effect while the railcar is shifted to another siding and an empty car takes its place. Union Pacific, or another railroad company, assumes responsibility when the completed load is hooked up and pulled out of the terminal.

Army Transport Service Sub-Port of Embarkation

In January 1942, the USATS leased all of Terminal 4 for use as the Portland Sub-Port of Embarkation, and municipal shipping activities were shifted to City CPD Terminal 1 and old Terminal 2. The facility was used to embark troops for overseas, as well as to store equipment and materials, house Army personnel, refuel ships, and load ships for transport overseas. The War Department in turn leased property and buildings to subtenants (e.g., Northwestern Ice and Cold Storage Company), providing services at the Portland Sub-Port of Embarkation. During its tenure at Terminal 4, the USATS operated the facilities described below.

Disinfestation/Fumigation Plant. Between May and September 1943, the USATS constructed a disinfestation (fumigation) plant to the east of Warehouse 1 for delousing soldiers and prisoners of war prior to their embarkation or debarkation. (Maps and drawings from the war years refer to a House 1 on both Piers 1 and 2. A report from February 1944 notes that the disinfestation plant was located in the former Water Division repair shop, but that location has yet to be verified.) The disinfestation plant was designed to delouse 150 men and their clothing and belongings per hour. The prisoners of war were reportedly held at Warehouse 1 (including a “delousing area”) prior to being transferred elsewhere. The materials used in the disinfestation process have not been confirmed. An Army directive of August 19, 1944 instructed military installations to use methyl bromide for disinfestation and fumigation.

Salvage Yard. The USATS established a small salvage yard at Terminal 4 for scrap metal (including scrap iron and ferrous metal) and rubber. A report from March 1943 noted the sale of more than 38,000 pounds of scrap iron and steel from salvage operations. The total tonnage of materials scrapped at the terminal during the USATS’s tenure was close to 350 tons, with most of that sold in 1944. Some of the materials were sold to the Zidell Manufacturing & Supply Company, Alaska Junk Company, and California Bag & Metal Company. Aerial photographs indicate that the USATS filled the salvage yard area sometime around 1945.

Auxiliary Oil Pipeline. In February 1944, the USATS completed construction of an auxiliary pipeline at Pier 5, Slip 3. The pipeline extended 340 ft to the slip side of the pier. The Army also constructed two standpipes adjacent to the slip to accommodate the auxiliary pipeline. The new line was built to permit tankers to transfer oil to upland facilities while other ships took on coal from the adjacent bunkers.

Other USATS Facilities. Two other facilities are of potential interest: a gasoline station and a sulfur plant. The gas station was located along the south side of Carroll Road (the entrance road to the terminal) slightly northeast of the vegetable oil storage tanks east of Slip 1. The gas station utilized an approximately 2,000-gallon gasoline storage tank and pump in connection with the processing of military vehicles. It is not known whether the storage tank was above or below ground. The sulfur plant was located east of the bulk storage bunkers on Pier 5 (corresponding with the former location of the Oregon Sulphur Company).

Terminal 4 was returned to the City CPD in February 1946. In 1947, the War Assets Administration purchased the northern portion of the City CPD terminal occupied by Oregon Shipbuilding Corporation in exchange for property on the west bank of the river that the City CPD later developed as Terminal 2.

Ore and Concentrate Handling

Pre-1950. From its inception, Terminal 4 was designed to handle imports and exports of bulk cargo. Rail transport by OWR&N Co. and its successor, Union Pacific, was the chief means of conveyance for import and export cargo. Ores and concentrates were an important element of this traffic beginning in 1921 with the completion of Pier 5 on the southern edge of Slip 3. A large area for open storage, to the east and south of Pier 5, lay adjacent to eight covered concrete bunkers with sloping interiors, which were serviced by a series of belt conveyors. This was the mineral bulk-handling facility at Terminal 4, details of which are provided in Table 2-3 based on information known to date.

Table 2-3
Chronology of Pre-1950 Mineral Bulk Handling at Terminal 4

Ore	Status	Transfer Method	Storage	Period
Phosphate rock	Export	Railcar from siding unloaded to either track hopper or cradle unloader to bunkers or cars; contents were discharged to open area storage. Material traveled by conveyor belt from bunkers to loading towers on the harbor face (Berth 414) of Pier 5, where it was loaded directly into ships' holds.	Open storage or covered bunker	1921-1950
Sulfur	Import	Ships unloaded by Terminal 4 locomotive crane onto Slip 3 side of Pier 5 (Berths 412 and 413).	Open storage	1921-1945
Manganese ore	Export	Same method as used for phosphate rock.	Open storage or covered bunker	1924-1925
Zinc concentrate	Export	Same method as used for phosphate rock.	Open storage or covered bunker	1925-1928
Coal	Ship fuel	Same method as used for phosphate rock.	Open storage or covered bunker	1923-1931, 1935-1936, 1940-1950
Chrome ore	Import	Same method as used for phosphate rock. Unloaded at Pier 5 in 1925 and at Pier 2 (Berths 406-408) in 1937-1941.	Open storage or covered bunker	1925, 1937, 1940-1941

Post-1950. At the end of World War II, the City CPD regained use of Pier 5 and constructed a new bulk outloader on the Slip 3 side of the pier (Berth 412) for handling expected cargoes of coal and phosphate. Starting in 1955, lead and zinc concentrates were directly transferred from ships in Slip 1 to open Union Pacific gondola railcars by two gantry cranes at Pier 2 equipped with clamshell buckets. The transfer of lead and zinc concentrates at Terminal 4 was relocated to Slip 3 (Berths 410 and 411) in 1961 with the completion of Pier 4 and the Dravo bulk unloading tower. The Dravo unloading tower remained in service until 1998, when it was decommissioned. Soda ash, initially exported from Pier 5, Berth 412, became a major export in 1988, when loading was transferred to Pier 4, Berths 410 and 411, where a new bulk outloader was constructed by Hall-Buck. Based on currently available information, details of these operations are summarized in Table 2-4.

Table 2-4
Chronology of Post-1950 Mineral Bulk Handling at Terminal 4

Ore	Status	Transfer Method	Storage	Period
Lead concentrate	Import	Gantry crane clamshell removed ore concentrate from ship hold to open railcar on Pier 2 (Berths 406-408) until 1961; Dravo unloading tower removed ore concentrates from ship hold to open railcar on Pier 4 (Berths 410 and 411) from 1961-1971. Railcars were spotted on Tracks 4-10, 4-11, 4-12, and 4-15. Cars were then pulled west to Tracks 4-2 and 4-3 for pushing under the Dravo loader. Loaded cars exited to the ladder tracks at the east of the pier for switching.	No storage	1955-1971
Coal	Export	Berth 412 bulk unloader; gantry cranes at Pier 2 also unloaded coal from barges.	Pier 5 storage bunkers	1952-1958
Zinc concentrate	Import	Same method as used for lead, same time frame.	No storage	1955-1971
Soda ash	Export	Bulk outloader; Pier 5-loaded railcars dumped soda ash into Berth 412 outloader, direct transfer to vessel. Pier 4-loaded railcars traveled along face of dock, in strings of six cars, through one of two dumper buildings. Soda ash was either transported directly to ship via conveyor or taken to storage building for later shipment. Ships could be simultaneously loaded from storage and rail.	30,000-ton A-frame storage building at Pier 4 since 1993; no storage at Pier 5 (direct transfer from rail to ship only)	1988-Present
Sulfur	Export	Transfer from railcars to barges by bulk unloader at Berth 412. After 1961, transferred by Pier 4 Dravo tower.	No storage	1955-1967
Alumina/Bauxite	Import	Gantry cranes at Pier 2 (Berths 406-408) removed ore from ship hold to Union Pacific railcars. After 1961, ships were unloaded at Pier 4 (Berths 410 and 411) by the Dravo unloading tower.	No storage	1955-1956, 1963
Ammonium sulfate	Import	Transferred from ship hold by Dravo tower into dump trucks.	Storage building south of Pier 5	1970
Bentonite clay	Export	Direct transfer from railcar to ship via Pier 5, Berth 412 bulk outloader via conveyor belt from railcars until new outloader constructed at Pier 4.	No storage	1967
Sodium sulfate	Export	Direct transfer from railcar to ship via	No storage	Not available

Ore	Status	Transfer Method	Storage	Period
		bulk outloader at Pier 5 until new outloader built at Pier 4.		
Soybean meal	Export	Direct transfer from railcar to ship via bulk outloader at Pier 5 until new outloader built at Pier 4.	No storage	Not available
Chromite	Import	Gantry cranes at Pier 2 removed ore from ship holds to Union Pacific railcars.	No storage	1956-1957
Ferro-phosphorous iron ore	Export	Transferred by Pier 2 gantry cranes from railcars (originating in Idaho) to SS *Jotunfjell* for shipment to Rotterdam, Holland.	No storage	1955-1957
Limestone	Import	Transfer from barge hold to railcar.	No storage	1966-1967
Manganese	Import	Gantry cranes at Pier 2 removed ore from ships to railcars.	No storage	1958
Potash	Export	Transferred from railcars to ships at Berth 412.	Storage bunkers	1959
Rutile ore sand (titanium oxide)	Import	Transferred from ship holds by Berth 412 bulk loader.	Storage bunkers	1970
Talc	Export	Transferred from Burlington Northern railcars to ship holds by Berth 412 bulk outloader (Berth 401).	Storage bunkers	1966
Tricaphos (tri-calcium phosphate)	Import	Discharged by a marine leg and conveyor belts at Pier 1.	Storage bunkers at Pier 1	1961

The Bunker Hill Company and Hecla Mining Company's Sullivan Electrolytic Zinc Plant were the major consignees for lead and zinc ore concentrates during the 1955 to 1971 period. Anaconda Mining Co. (a former ARCO subsidiary) and American Smelting & Refining Co. (known as ASARCO) also imported ores through Terminal 4. The American National Soda Ash Consortium (known as ANSAC) has supplied Wyoming soda ash to the KMBT (formerly Hall-Buck Marine) facility at Terminal 4 from 1988 to the present day.

Pencil Pitch Handling

Pencil pitch is a coal tar distillate used as anode material at aluminum refineries throughout the Pacific Northwest. It is manufactured by extruding finger-width coal tar pitch "pencils." Available Port records indicate that pencil pitch was handled at Terminal 4 from 1978 to 1998. The pencil pitch was manufactured in Germany and China and purchased from Koppers Industries, Inc. Ships carrying the pencil pitch were moored at Berth 411 in Slip 3. Longshoremen removed the pencil pitch from the ships' holds by means of the clamshell-equipped Dravo unloading tower on Pier 4 and loaded it directly onto truck trailers or railcars adjacent to the pier.

In 1978, 13,161 short tons of pencil pitch arrived at the Port in several ships and were transferred to rail and truck carriers at Pier 4. In 1979, Jones Oregon Stevedoring Co. signed an agreement to handle bulk pencil pitch cargo at Terminal 4. That agreement was renewed in September 1982. In 1987, the Port leased the bulk cargo handling operations to Hall-Buck Marine, Inc. At that time, the Port was using the Dravo unloading tower to transfer an estimated 25,000 to 35,000 tons of pencil pitch annually. Hall-Buck Marine modified the Dravo mechanism in 1988 and the rear section of the loading hopper enclosure in 1992 to improve operations. Statistics indicate that 182,748 short tons of pencil pitch were unloaded from at least 28 ships between 1978 and 1989. Port records register 11 ships calling between January 1997 and June 1998. Ten of those vessels were affiliated with General Steamship Corporation, Ltd. In 1998, Hall-Buck Marine ended bulk import of pencil pitch at Terminal 4. The Dravo unloading tower was decommissioned that same year.

General Cargoes

Terminal 4 was chiefly designed to handle bulk (as opposed to break-bulk) cargo. The grain elevator, vegetable oil and molasses tanks, and the bulk mineral facility at Pier 5 have been prominent elements of the bulk cargo handling at Terminal 4. Other bulk cargoes imported or exported through Slip 1 and its adjacent piers and warehouses were wool, cotton, and natural rubber. The entities handling these cargoes and the time frames involved are not presently known. Some break-bulk cargoes were processed through Terminal 4, including automobiles exported to the Far East beginning in 1925.

Prior to and during the terminal's use as a container station by Matson Navigation Company, the terminal was used to process whole log bundles for export to Japan.

In addition to the bulk storage plant for handling coal, phosphate rock, and other bulk products, the rear of the quay dock at Pier 5 had a 3.5-acre storage space available for lumber, logs, sulfur, and steel. The equipment used for loading and unloading these materials included two traveling towers, hoppers, tripper, chutes, bins, and automatic scales. The quay dock was removed from Pier 5 in 1962, and the bulk handling facility was demolished between 1968 and 1969. The bulk outloader on the slip side of Pier 5 was decommissioned and removed between 1990 and 1992.

City of Portland

The City of Portland owns a parcel of land adjacent to Wheeler Bay commonly known as the fire boat station parcel. When the Port and the City CPD were consolidated in 1971, the CPD's properties and functions were transferred to the Port. However, the fire boat station parcel was specifically exempted from the transfer of property. The exemption was recorded correctly, but the parcel was erroneously located on Multnomah County tax maps at Slip 1 instead of in Wheeler Bay. That error was corrected in 2002.

The City of Portland operated a fire boat station at Terminal 4 from a pier into Wheeler Bay from approximately 1960 through approximately 1986. At one point, the fire boat station was located on the upstream end of Wheeler Bay, attached to Berth 410. In approximately 1980, the Multnomah County Sheriff's Department moved a boat house and houseboat just inside the area closer to the head of the slip from the fire boat station. The City of Portland formerly utilized an approximately 1,000-gallon UST for the storage of gasoline. The former UST was decommissioned in 1995 and, following sampling of soil and groundwater, DEQ issued a No Further Action determination. The City of Portland relocated its fire boat moorage to the Port's Terminal 1 facility in 1995, at which time Carr Marine leased the ramp and floating dock to tie up barges. That lease ended in 1999. The fire boat parcel has been vacant since that time.

In 1986, the City of Portland constructed a municipal stormwater sewer conveyance system that drains properties located along North Lombard Street and North Roberts Avenue. The stormwater piping traverses the northern portion of the Slip 1 Upland Facility and ultimately discharges to Slip 1. The City of Portland refers to the outfall discharging to Slip 1 as Outfall 52C. According to City of Portland records, Outfall 52C is a 36-inch municipal storm drain with a catchment area of approximately 24 acres located above the railroad tracks east of the terminal.

Other Facilities

A gearlocker building, constructed as a one-story building in 1932, housed shops for carpentry, painting, blacksmithing, and repairs. In 1942, during the USATS's tenure, an internal, second-story loft was added to the building.

Oregon Terminal Company

In 1988, the Port ceded control of overall operations at Pier 2 under a management agreement with Oregon Terminal Company (OTC) for operation of all break-bulk berths. OTC handled Berth 408, the ro-ro dock, and associated warehouses. In addition, OTC operated the old Quaker State building as a gearlocker. A rail-covered work pit was constructed west of the gearlocker building at that time. In addition, one 4,000-gallon UST for diesel and one 4,000-gallon UST for gasoline were installed with a fueling station on the south side of the gearlocker building. An equipment wash station was installed on the slip side of the building; the wash station drained to the sanitary sewer. Both the USTs and the wash station were removed when the management agreement ended in 1996.

2.2.3.3 Current Terminal Operations

Throughout the 1980s and 1990s, some of the buildings, equipment, and docks at Terminal 4 became obsolete and were removed. Slip 1 is not presently deep enough to accommodate deeper-draft modern vessels and current Port plans do not call for such deepening in the foreseeable future. In the late 1980s and early 1990s, Warehouse 4 was condemned and removed, and the original tanks at the bulk liquid storage facility near the head of Slip 1 were removed. In 1996, Berths 406 and 407 and their associated docks and warehouses were dismantled. The demolition of Berths 403 and 404 and associated Houses 3 and 4 followed in 1999. Bulk operations at Berth 412 (Pier 5) were terminated in 1989, and the wharf at Berth 412 was removed in 1997.

Cargill

Cargill Grain, Inc. terminated its lease for approximately 15.1 acres at the grain terminal facility in 2003 (the Port received a Notice of Early Termination on May 6, 2003). Also included in the lease are the deck and fender system for Berths 401 and 405, rail tracks from the frog, and Cargill's share of the cost for Port maintenance of common-area rail and road. Cargill is currently in "hold over" status pending final investigation and cleanup of its leasehold and is in the process of implementing an exit audit of the facility. CLD Pacific Grain was a sublessee of Cargill.

Cereal Food Processors

Cereal Food Processors, Inc. (formerly known as Terminal Flour Mills) is currently in the last four years of a lease for approximately 1.6 acres at the flour mill facility at Terminal 4.

International Raw Materials

IRM is currently in year three of a 10-year lease (with two five-year option periods) for approximately 6.3 acres at the liquid bulk storage facility, excluding a Port building. The previous lease for the facility was assigned from PM-Ag to IRM in 1995.

Rogers Terminal

Rogers Terminal & Shipping (a division of Cargill Marine) is currently in "hold over" status with a lease of improved space east of Slip 1. The lease is for less than 1 acre and encompasses an 11,712-square-ft warehouse with 406 square ft of office space and a 15,451-square-ft yard. Rogers, a terminal service company, originally leased the space for stevedoring services supplied to Cargill's operation. Since Cargill is in the process of exiting its lease and is no longer operating at Terminal 4, Rogers is currently utilizing the leasehold for storage purposes. Rogers' initial lease agreement with the Port dates from 1983.

Rogers formerly utilized an aboveground used oil tank in connection with its operations. In addition, the Port removed an approximately 10,000-gallon gasoline UST from the Rogers leasehold in 1990. Sampling during decommissioning of the UST confirmed that there were no releases associated with the UST.

Kinder Morgan Bulk Terminals

In 1998, Hall-Buck was acquired by Kinder Morgan and renamed KMBT. KMBT continues to export soda ash through Slip 3. KMBT currently leases 6.56 acres adjacent to Berths 410 and 411 for ship loading of soda ash and/or unloading of bulk cargo from rail. The lease area includes rails, associated buildings, a storage dome, and utilities.

Additional agreements affecting Kinder Morgan's lease area include:

- a Portland General Electric easement for underground line;
- a Pipeline Crossing Agreement, Union Pacific (licensor) to Hall-Buck (licensee), allowing Hall-Buck to construct, maintain, and operate a pipeline; and
- a Revenue Sharing Agreement with Union Pacific.

KMBT currently utilizes an approximately 5,000-gallon diesel UST located north of the Rail Dump building, an approximately 675-gallon AST located in the eastern portion of the facility, and an approximately 2,000-gallon sulfuric acid AST located within Building 432. In addition, KMBT utilizes an approximately 43,000-gallon open settling tank for soda ash wash-down water.

Schnitzer

The Port has a moorage agreement with Schnitzer Investment Corporation for a portion of the mooring dolphin that extends onto submerged lands adjacent to property owned by Schnitzer at the Berth 401 grain elevator.

Rail Usage

The rail trackage within the confines of Terminal 4 is owned by the Port. The Port leases portions of the rail trackage to individual tenants as part of their facility leases. The Terminal 4 rail system is designated as capacity that the Port will afford a tenant under terms of the lease. Older, renewable leases, such as the one currently in effect with KMBT, subsume the particulars of car movement and loading under the general term of "operations." Newer facility leases deal with all aspects of terminal transfer operations in detail.

Although not specifically addressed in lease language, there are recognized responsibilities regarding rail activities at Terminal 4. KMBT's soda ash operations furnish an example. Union Pacific, or any other railroad company involved in car transit and delivery, is responsible for the line haul of consigned product from origin to destination. This includes delivery of the cars to the terminal. At the point when Union Pacific pulls away from the train, the Port's lessee, KMBT, takes charge of the cargo with its own locomotive. Under KMBT's original 1987 lease agreement that governs use of the facility, longshoremen provide the labor for product movement and transfer.

2.2.4 Dredging and Filling History

Dredging activity at Terminal 4 began with the work that provided fill for the general terminal space and created Slips 1 and 3 between 1917 and 1921. In the process, the former Gatton's Slough and adjacent Willamette River shoreline were reconfigured (see Section 2.2.2). Port of Portland dredges provided the dredged material for the City CPD's facility. Maintenance dredging of the slips and improvements to the terminal's harbor face occurred periodically in ensuing years. Based on currently available information, Table 2-5 summarizes the chronology of dredging events at Terminal 4.

Table 2-5
Chronology of Dredging Events at Terminal 4

Year	Location	Description
1917	St. Johns Elevator and Terminal	Slip excavation performed by Dredge Portland and "special channel" work performed by Dredge Willamette.
1918	St. Johns Terminal	Slip excavation performed by Dredge Portland and channel work performed by Dredges Columbia, Willamette, and Tualatin.
1919	Harbor Channel	Dredge Willamette dredged material from the harbor channel and applied fill to Terminal 4 during three separate time periods.
1919	Slips	Dredge Portland worked on slips during several time periods.
1920	Terminal and Harbor Channel	Dredge Willamette dredged material from the harbor channel and slips and applied fill to Terminal 4 during three separate time periods.
1920	Slips and Filling	Dredge Portland dredged material from slips and applied fill to terminal during three separate time periods.
1921	Slips and Filling	Dredge Portland dredged material from slips and applied fill to Pier 3 and Pier 4 areas during three separate time periods.
1922	Harbor Channel	Dredge Portland worked the shipping channel at Terminal 4 and deposited dredged material on an unspecified "east side" location in August.
1923	Harbor Channel	Job No. 1087: Dredged material discharged on Terminal 4 beach.
1924	Pier 5	Job No. 1100: Dredged material discharged on bank upstream from Terminal 4.

Year	Location	Description
1942	Slip 1	USATS maintenance dredging of Slip 1.
1948	Terminal 4	Dredging of Slip 3.
1957	Slip 3	Widening of Slip 3, dredge and fill.
1962	Slip 1	Dredging.
1968	Slip 1	Dredging.
1975	Slip 1	Dredging of Berths 403-405.
1977	Slips 1 and 3	Dredging of Berths 407-408 (Slip 1) and Berth 410 (Slip 3)
1984	Slip 3	Maintenance dredging.
1988	Slip 1	Maintenance dredging, Berths 403-408.
1994	Slip 3	Dredging associated with consent decree remediation.
1997	Slip 3	Maintenance dredging.
2002	Slip 3	Maintenance dredging.
2003	Slip 3	Maintenance dredging.

2.2.5 Adjacent Property Ownership and Operations

Terminal 4 is bordered to the north by Schnitzer Steel Industries and Northwest Pipe and Casing; to the north/northeast by the Burgard Industrial Park; to the south by the Terminal 4 auto storage area, which is occupied by Toyota; to the east by Union Pacific rail tracks, beyond which is the Toyota processing yard and Toyota processing center; to the southeast by the Toyota upper lot; and to the west by the Willamette River. The Schnitzer Steel, Northwest Pipe and Casing, Burgard Industrial Park, and Toyota auto storage area are discussed below.

2.2.5.1 Schnitzer Steel Industries

Schnitzer Steel Industries (Schnitzer), located at 12005 North Burgard Street, borders Terminal 4 on the north. Schnitzer processes, stores, and exports scrap metal (e.g., automobiles, appliances, and ferrous metal products) from its facility. Schnitzer also operates a deep marine terminal for bulk commodities. The property was the site of Oregon Shipbuilding Corporation's shipyard from approximately 1943 through 1945; from the late 1960s through 1972, Schnitzer operated a ship scrapping facility at the property. Schnitzer Steel Industries is listed as DEQ Environmental Cleanup Site Information (ECSI) #2355 and is currently under a Voluntary Cleanup Program (VCP) Agreement for remedial investigation of the site, which is ongoing.

2.2.5.2 Northwest Pipe and Casing

Northwest Pipe and Casing (also known as Northwest Pipe Company), located at 12005 North Burgard Street, borders Terminal 4 on the north. Northwest Pipe and Casing operates a welded steel pipe and coating manufacturing facility. Historically, the Oregon Shipbuilding Corporation shipyard, which operated from

1943 through 1945, extended onto the Northwest Pipe and Casing property. Beall Pipe operated a pipe manufacturing facility on the property from 1945 to 1983. Northwest Pipe and Casing purchased the property in 1983. Northwest Pipe and Casing is listed as DEQ ECSI #138 and is currently under a VCP Agreement for remedial investigation of the site, which is ongoing.

2.2.5.3 Burgard Industrial Park

The portion of the Burgard Industrial Park that is adjacent to the north/northeast of Terminal 4 includes Boydstun Metal Works and Western Machine Works.

Boydstun Metal Works

Boydstun Metal Works (Boydstun), located at 9002 North Sever Court in the Burgard Industrial Park, borders Terminal 4 on the north/northeast. Boydstun fabricates and paints automobile transport trailers. Specific manufacturing activities include cutting steel and aluminum sheets and tubes, welding parts as part of trailer assembly, sandblasting, painting, and installing hydraulics and electrical control systems. Historically, the Oregon Shipbuilding Corporation shipyard, which operated from 1943 to 1945, extended onto the Boydstun property; from the late 1960s through 1972, Schnitzer operated a ship scrapping facility at the property. Boydstun is separately listed as DEQ ECSI #2362; however, the site has been incorporated into the Schnitzer Steel Industries investigation (ECSI #2355), which is ongoing.

Western Machine Works

Western Machine Works, located at 12005 North Burgard Street in the Burgard Industrial Park, borders Terminal 4 on the north/northeast. Western Machine Works fabricates and remanufactures components for the paper and pulp industry. Historically, the Oregon Shipbuilding Corporation shipyard, which operated from 1943 to 1945, extended onto the Western Machine Works property; from the late 1960s through 1972, Schnitzer operated a ship scrapping facility at the property. Western Machine Works is not listed in the DEQ's ECSI database; however, the site is included in the Schnitzer Steel Industries investigation, which is ongoing.

2.2.5.4 Toyota Auto Storage Area

Toyota Motor Sales (Toyota), which occupies properties to the east, south, and southeast of the Terminal 4 Removal Action Area, has held a long-term lease agreement with the Port since 1976 for the storage and processing of automobiles. Historically, Toyota's facilities have been at Terminal 4 and above Terminal 4 on Lombard Street; the facilities are known as the upper and lower lots.

The Toyota area south of the terminal was first developed in 1969 and paved as a large-scale automobile import facility. A floating dock (Berth 417) was constructed in 1969, and a second floating auto dock (Berth 416) was constructed in 1972. In addition, Berths 414 and 415 were completed in 1974 for the handling of steel cargo.

In 1976, Toyota leased the import facility at Berth 416, and the processing plant was expanded in 1979. Berth 417 was relocated to the Port's Terminal 6 and a general cargo auto terminal was constructed there.

In 1986, the Port purchased the St. Johns Auto Wrecking Yard on Lombard Street above Terminal 4. Toyota entered into an agreement with the Port for approximately 69.2 acres of property, buildings, improvements, and dock rights located to the east and south of the Removal Action Area. Toyota exercised an option under the terms of the 1986 lease on October 30, 1989 for an additional 12-acre parcel farther upstream. On April 3, 1990, Toyota exercised another option under the lease for an additional 8.8-acre parcel located on the corner of North Lombard and North Roberts. A recent amendment extending the term of the lease also provided for closure of the "upper property" (east of the terminal) on North Lombard, including removal of the underground fuel tanks.

In 2002, Toyota Motor Sales, U.S.A., Inc. (also known as Toyota; TLS, Logistics) entered into a separate lease agreement for approximately 82 acres south of the Terminal 4 Removal Action Area, which includes a vacated portion of North Bradford Street.

Toyota's current operations include unloading automobiles from ships that dock at Berths 414 and 415, driving the cars to designated yard areas, and storing the vehicles awaiting processing. Processing includes fueling and washing the vehicles, installing accessories, air conditioners, and radios, and making minor repairs to vehicles damaged during shipping.

2.3 Planned Future Land Use

The Port is currently involved in master planning to guide development and redevelopment to the year 2020. Terminal 4 will remain one of the Port's primary marine terminals for the foreseeable future. The Port's planning process is ongoing. This process, which includes discussions with existing and potential future tenants as well as overall consideration of the regional, national, and global business and trade climate, will affect the Port's plans for Terminal 4.

Options under consideration for Terminal 4 generally involve retaining the existing terminal purposes of handling grain, autos, and dry bulk and liquid bulk cargoes. To increase efficiency, most options under consideration include improvements to rail and road access to the terminal. Specific improvements include a loop track for unit trains carrying bulk commodities to the terminal and a vehicle overpass to reduce truck/auto/rail congestion. Most of the alternatives under consideration emphasize the continued use of Slip 3 and deemphasize the use of Slip 1.

2.4 Current Physical Characteristics

The Removal Action Area, located within the Portland Harbor Superfund Site and the Port's Terminal 4, is on the eastern shore of the Willamette River just downstream of the St. Johns Bridge and between River Miles 4 and 5 (see Figures 1-1 and 1-2 for a vicinity map and aerial photograph of the Port's Terminal 4 property). The Removal Action Area's address and boundaries are described in Section 2.1. Upland boundaries, which are depicted on Figure 2-1, are associated with a separate Port project under oversight of the DEQ, as described in Sections 1, 2.2 and 3.3.1.

Owners of property adjacent to Terminal 4 are described in Section 2.2.5. Figure 2-5 shows Port and non-Port ownership within the Removal Action Area. The Removal Action Area encompasses roughly 38 acres, of which Slip 1, Slip 3, and Wheeler Bay make up about 28 acres, while the area from the mouths of the slips to the Harbor Line encompasses approximately 10 acres. Boundaries of the Slip 1 and Slip 3 uplands, which are within Terminal 4 but are not included in the Removal Action Area, are shown on the Removal Action Area site plan on Figure 2-6. These uplands are about 283 acres in area (Parsons Brinkerhoff, 2002), including the Toyota lease areas, and are generally flat in grade in proximity to the slips. The surface covering is primarily asphalt, with minor areas of gravel and/or ballast associated with the rail lines. At present, a relatively large volume of sand is stockpiled within the Slip 1 uplands because of recent grading of the adjacent Toyota facility.

Elevation of Terminal 4 generally ranges from 30 to 35 ft mean sea level (MSL) in proximity to the slips. The river stage (i.e., elevation) is typically between 2 and 10 ft Columbia River Datum (CRD), which equates to 3.7 to 11.7 ft MSL, with the exception of peaks in river stage. This range is generally based on information from the Morrison bridge gage (refer to Figure 2-7 for historical data and note that flood levels for river stage are not reflected in the graph). The diurnal tidal range in the St. Johns area is 2.2 ft at low river stages and becomes progressively less with higher river stages (NOAA, 2003b). East of Terminal 4, the topography is slightly sloping, but somewhat variable. The most notable nearby variation is a gradual rise in the ground surface to an elliptical hill feature about 50 ft MSL. Southeast of Terminal 4, the ground surface rises at 5H:1V or shallower to an elevation of about 100 ft MSL, corresponding to the St. Johns area of Portland. To the west of Terminal 4 and immediately west of the Willamette River channel are the Tualatin Mountains (Portland Hills), with elevation rising relatively steeply at about 1.5H:1V to 3.5H:1V to an elevation of about 1,000 ft MSL. Figure 2-8 shows Terminal 4 relative to surrounding topographic features. Figures 2-9 through 2-16 provide photographs of Slip 1, Wheeler, Bay, and Slip 3 taken during the October 16, 2003 site visit from various vantage points.

Note that the graphical datum conversion on many of the work plan figures is based on datum conversion tables available from the Port of Portland, as well as City of Portland public records. The various datums represented were included in the work plan because consultant reports, public documents, and other published information used for the work plan or the EE/CA could reference bathymetric or topographic vertical positions based on any one of these vertical datums. Therefore, for convenience, the relative positions of these datums have been provided on most figures for quick reference.

The vertical datum for the EE/CA project is the CRD, which is based on an inclined plane from sea level and is referenced according to established river miles along the Columbia River. The North American Vertical Datum (NAVD) 1988 is a "fixed" geodetic datum based on vertical leveling and other techniques that superseded the prior fixed datum, National Geodetic Vertical Datum (NGVD) 1929. The USC&GS 1947 datum is understood to be a local adjustment to NGVD 1929. Mean sea level is a tidal datum determined over a 19-year period of local sea level observations. A more detailed description of vertical datums can be found on the National Oceanic and Atmospheric Administration (NOAA) website at the following links: http://www.ngs.noaa.gov/faq.shtml and http://www.co-ops.nos.noaa.gov. Finally, also reported on the graphical datum conversion is Ordinary High Water (OHW), which is the terminology used in association with the Willamette River stage observations between River Miles 4 and 5. This simply shows the position of OHW referenced to CRD.

2.4.1 Slip 1 Physical Characteristics

Slip 1 is the larger of the two slips (approximately 13 acres) and is infrequently utilized. The mudline elevation ranges from about –34 ft to –38 ft CRD according to the most recent annual bathymetric condition survey by the Port (Port of Portland, 2003).

Embankment slopes above the shoreline were observed during a site visit on October 16, 2003, to be highly variable, generally ranging from very shallow to about 2H:1V or steeper. Where very shallow, the slopes usually transition gradually to a steeper slope some distance from the water – the slope behind the pier at Berth 401 is relatively flat for about 20 to 40 ft, then transitions to a steeper slope (refer to Figure 2-10).

Slope protection consisting of variable-sized rock (having the appearance of 8-inch-minus size) was observed from the shoreline to about mid-slope on the river-facing embankment slopes, which generally have vegetation where no slope protection has been placed (refer to Figure 2-11). On the northern embankment slope near the mouth of Slip 1 are rows of remnant concrete columns from a former pier built in the same manner as the existing piers in the slip. On the embankment slope north of Berth 401 by the Schnitzer Steel property, there are a number of remnant timber piles (and concrete panels lying against the embankment slope). No slope protection is present in this area, and driftwood lines the embankment above the shoreline. More remnant square concrete columns with concrete pile caps exposed occur just south of this area on the embankment slope. The slope includes what appears to be a remnant from a tiered crib wall at the base of the slope. The opposite embankment slope west of Berth 408 does not have slope protection west of the existing pier and is showing signs of erosion in the form of scarps and surficial sloughing (refer to Figure 2-11). Factors that contribute to erosion could include undercutting resulting from propeller wash during former uses of the pier; ongoing forces such as surface currents and wind waves; and possibly cycles of soil wetting and drying that result from tidal and seasonal variations in river stage combined with the relatively steep slope.

Under-pier slopes generally range from 2H:1V to 3H:1V, with the exception of slopes near Berth 408, which range up to around 1H:1V (Port of Portland, 2003).

Two large piers exist within Slip 1, from the head of the slip to about the midpoint, on the north and south sides, providing Berths 405 and 408, respectively. The piers are timber-pile supported with concrete columns and interconnecting concrete framework built from about the shoreline and above as the support structure for the pier deck and associated structures (e.g., warehouses at Berth 405 and stationary crane at Berth 408) as shown on Figure 2-12. These pier structures are in disrepair as characterized in the Port of Portland 2020 Master Plan (Port of Portland, 2002). The Cargill grain elevator is located to the north of Slip 1.

2.4.2 Wheeler Bay Physical Characteristics

Wheeler Bay is the small bay (approximately 3 acres) between Slip 1 and Slip 3. Wheeler Bay was originally to become Slip 2, but Slip 2 was never completed. Wheeler Bay is immediately adjacent to Slip 3, separated by Pier 4.

The embankment slopes above the shoreline at Wheeler Bay are similar to the configuration noted for Slip 1 near Berth 401, with the exception that the very shallow, flat area abruptly transitions to a steeper slope generally 2H:1V or shallower, as observed during the October 16, 2003, site visit (refer to Figure 2-13). The transition to the steeper embankment slope is farther from the shoreline than at Slip 1, ranging from about 5 to 30 ft away. Above the mean higher shoreline, the embankment area is littered with driftwood debris such as tree stumps, logs, and scattered plant matter.

The submerged slopes are very shallow, with mudline elevations generally ranging from –6 ft to –15 ft CRD within the bay, then increasing in slope below Pier 4 to Slip 3 and toward the river.

Remnants from a partially demolished timber pile-supported structure span the relatively shallow embankment slope and remaining timber piles in the bay. Several single timber piles associated with this former structure are present.

The only current structure at Wheeler Bay is Pier 4, which separates the bay from Slip 3. A barge was docked on the Wheeler Bay side during the October 16, 2003 site visit (refer to Figure 2-14).

2.4.3 Slip 3 Physical Characteristics

Slip 3 is the southern and smaller (approximately 12-acre) slip in the Removal Action Area; Slip 3 is very actively used for KMBT soda ash export.

The mudline elevation ranges from about –36 ft to –50 ft CRD (Port of Portland, 2002). The shallower depths occur at the head of the slip. Maintenance dredging of Berths 410 and 411 is performed relatively frequently, and the water depth is from –40 ft to –45 ft CRD adjacent to the pier in Slip 3. The deeper portion of the slip (to –50 ft CRD) consists of a trough that extends from the east side of Pier 4 to the mouth of the slip at its center. This trough appears to be related to erosion caused by the movement of ships out of berth as part of the KMBT operations. The active berthing areas for KMBT are Berths 410 and 411, which are on the north side of Slip 3 (refer to Figure 2-15). The trough widens and deepens near the mouth of the slip.

Under-pier slopes range from about 1.5H:1V to 2.5H:1V or shallower (Port of Portland, 2002). The bathymetry includes the submerged slope at the mouth of the slip, which is about 5H:1V to the deeper channel of the Willamette River.

Embankment slopes above the shoreline and the general locations of slope protection are similar to Slip 1, with the exception that slopes on the south side of Slip 3 (north of the Toyota facility) are generally flat and have less elevation between the shoreline and upland properties. The embankment slope on the south side of Slip 3 has remnant concrete columns from a former pier structure (refer to Figure 2-16).

On the north side of Slip 3 at Berths 410 and Berth 411, a large pier structure, presently used extensively by KMBT, extends to the Harbor Line and visually separates the slip from Wheeler Bay. The structure is similar to the previously described piers, except that the structure foundation apparently included pre-stressed concrete, steel, and timber piles. A large crane is present on the deck of the pier. The remnant of a former pier with construction similar to the piers previously described occurs on the south side of Slip 3; all the above-water portions of the pier have been demolished and the timber piles remain in place, partially visible above the water line.

2.5 Current Ecological Characteristics

2.5.1 General Aquatic and Upland Habitat Potential

No specific studies of ecological conditions at the Terminal 4 Removal Action Area have been conducted. However, some studies addressing general habitat characteristics in the Lower Willamette River have included Terminal 4 (Altman et al., 1997; Ward and Nigro, 1992). In addition, sediment toxicity tests were conducted for the Slip 3 remedial investigation (Hart Crowser, 2000a), and biological tissue samples of fish and crayfish were collected from Terminal 4 during the Round 1 (2002) field investigation for the Portland Harbor Superfund Site. The following discussion summarizes the available information on the biological characteristics of the Terminal 4 Removal Action Area.

The Lower Willamette River from the Portland area to the confluence with the Columbia River is characterized by a maintained navigation channel and shoreline that is extensively modified for industrial and commercial uses. The modification has resulted in deep (>20 ft CRD) open-water habitats in navigation areas, including much of Terminal 4. Such deep-water habitat generally provides feeding habitat for fish and wildlife that feed primarily on water-column species. Adjacent to the deep-water areas are generally shallower areas (<20 ft CRD), usually adjacent to shorelines or other areas outside the navigation channel. The shallower areas generally provide more opportunity for foraging by wading birds and semiaquatic mammals, as well as for aquatic life, including juvenile salmonids, that feeds preferentially in shallower, slack-water areas.

Benthic habitats in the river can be generally divided into three types: (1) unconsolidated sediments (sands and silts) in the deeper water and lower channel slopes; (2) unconsolidated sediments (sands and silts) in shallower areas; and (3) developed under-water structures such as rock riprap, sheet pile, and bulkheads. All three habitat types can be found at the Terminal 4 Removal Action Area. The deeper habitat with typically unconsolidated sediment tends to be in the center of Slips 1 and 3 and the outer portions of Wheeler Bay. Shallow-water areas are found at the margins of the slips and Wheeler Bay, under docks and piers, and in uncovered areas. The shallow areas also typically contain structures that include concrete and wooden pilings, riprap, and other non-native surfaces.

Farr and Ward (1993) sampled extensively in the Lower Willamette River to determine the fish species present. They identified 39 species, 19 of which were exotic. The identified species included federally listed salmon species (see below), white sturgeon, northern pikeminnow, smallmouth bass, and peamouth. During sampling conducted in 2002 to support the Portland Harbor RI/FS, reticulated and prickly sculpin, common carp, and largescale sucker were collected from Terminal 4 for tissue analysis.

Pacific lamprey are a species of concern for investigations in the Lower Willamette River. Surveys for larval ammocoetes were conducted in the Portland Harbor, although not specifically at Terminal 4. No larval or adult lamprey were identified in the harbor during the survey, but additional surveys of greater scope and frequency are needed to confirm the presence or absence of lamprey in the harbor and Terminal 4.

Upland habitat is limited because of surrounding industrial and marine facilities. Vegetated, shallow beach areas are located at the head of Slip 1 and Slip 3 and along much of the Wheeler Bay shoreline. In addition, a shallow cove area with beach shoreline is located just downstream from the mouth of Slip 1. Some revegetation has been conducted in areas at the upstream side of Slip 3.

Although habitats exist in Terminal 4, quality of the habitat is affected by the area's industrial activities. This is especially true for Slip 3, which is one of the Port's busiest berthing areas. Disturbances from ship traffic and the resuspension of sediments by propeller action limit the habitat quality in Slip 3. Far less activity occurs in Slip 1 and Wheeler Bay, but activity in Slip 3 and on adjacent uplands may adversely affect wildlife use in those areas as well.

2.5.2 Special Status Species

Special-status species include federal and state proposed and candidate species, federal species of concern, and state sensitive species. The following summary was taken from the draft RI/FS Programmatic Work Plan for the Portland Harbor Superfund Site. Table 2-6 summarizes the special-status species potentially occurring in the Lower Willamette River.

Table 2-6
Species of Special Interest in the Portland Harbor Area,
Lower Willamette River[1]

Common Name	Scientific Name	Federal Status	State Status
Aquatic plants			
Howell's bentgrass	*Agrostis howellii*	SOC	T
White-topped aster	*Aster curtus*	SOC	T
Wayside aster	*Aster vialis*	SOC	T
Peacock larkspur[a]	*Delphinium pavonaceum*	SOC	E
Willamette daisy[a]	*Erigeron decumbens*	E	E
Howellia[a]	*Howellia aquatilis*	T	-
Bradshaw's lomatium[a]	*Lomatium bradshawii*	E	E
Nelson's sidalcea[a]	*Sidalcea nelsoniana*	T	T
Hitchcock's blue-eyed grass[a]	*Sisyrinchium hitchcockii*	SOC	-
Invertebrates			
Columbia pebblesnail (spire snail)	*Fluminicola fuscus (Fluminicola columbiana)*	SOC	-
Fish			
Pacific lamprey	*Lampetra tridentata*	SOC	SV
River lamprey	*Lampetra ayresi*	SOC	-
Coastal cutthroat trout (Southwestern Washington/ Columbia River ESU)	*Oncorhynchus clarki clarki*	PT	SC
Chum salmon (Lower Columbia River ESU)	*Oncorhynchus keta*	T	SC
Steelhead (Lower Columbia River ESU)	*Oncorhynchus mykiss*	T	SU
Chinook salmon (Lower Columbia River ESU/Upper Willamette River ESU)	*Oncorhynchus tshawytscha*	T	SC
Bull trout	*Salvelinus malma*	T	-
Birds			
Aleutian Canada goose (wintering population)	*Branta canadensis leucopareia*	T	E
Black tern[b]	*Chlidonias niger*	SOC	-
American peregrine falcon	*Falco peregrinus annatum*	Delisted	E
Bald eagle	*Haliaeetus leucocephalus*	T	T
Reptiles/amphibians			
Painted turtle	*Chrysemys picta belli*	-	SC
Cope's giant salamander	*Dicamptodon copei*	-	S
Western toad	*Bufo boreas*	-	S
Tailed frog	*Ascaphus truei*	SOC	S
Northwestern pond turtle	*Clemmys marmorata marmorata*	SOC	SC
Northern red-legged frog	*Rana aurora aurora*	SOC	SU

[1] From Portland Harbor RI/FS Programmatic Work Plan (Lower Willamette Group, 2003).

E – endangered
ESU - evolutionarily significant unit
PT - proposed threatened
S - sensitive
SC - sensitive, critical
SOC - species of concern
SU - sensitive, undetermined status
SV - sensitive, vulnerable
T – threatened

[a] The presence of these species has not been confirmed in the Superfund Site; they have been identified as species present in the Willamette Valley.

[b] This species is also on Oregon Natural Heritage Program's List 4, which contains taxa of conservation concern that require continued monitoring.

2.5.2.1 Invertebrates

The Columbia pebblesnail (also known as the Columbia spire snail) is a freshwater mollusk that may occur in the Lower Willamette River. It is listed as a species of concern by the U.S. Fish and Wildlife Service (USFWS).

2.5.2.2 Fish

Of the seven salmonid species reported to use the Lower Willamette River, five are listed as threatened or proposed threatened (Table 2-6). Coastal cutthroat trout, steelhead, and chum and chinook salmon are also considered sensitive species by the Oregon Department of Fish and Wildlife (ODFW). Pacific lamprey and river lamprey are recognized as species of concern at the federal level, and Pacific lamprey is recognized as a sensitive species at the state level. Pacific lamprey is an anadromous species that occurs in Portland Harbor. Little is known about the presence of river lamprey in the Lower Columbia Basin and the Willamette River. River lamprey have not been observed in these areas in recent years, but it is a rare species and difficult to find in fresh water. River lamprey have been collected in the Lower Columbia River in the vicinity of the Lower Willamette River, but their presence in the Lower Willamette River is unknown (Kostow, 2002).

2.5.2.3 Birds

The status of sensitive aquatic or semiaquatic bird species is listed in Table 2-6. Aleutian Canada geese (*Branta canadensis leucopareia*) are rare but may be observed occasionally along the Lower Willamette River in winter and are considered a federal threatened species. Both Aleutian Canada geese and the American peregrine falcon (*Falco peregrinus annatum*) are protected as state endangered species. Black terns (*Childonias niger)*, a federal listed species of concern, are generally rare in the area, but were common during the summer of 2001 as a result of drought in the eastern part of the state (Nebeker, 2001). Bald eagles are known to use habitat along the Willamette River and are recognized as a threatened species both by USFWS and ODFW. Harlequin duck (*Histrionicus histrionicus*) is considered a federal species of concern, but is uncommon in the Lower Willamette Valley. On rare occasions, these ducks may be observed migrating through the area, but they would not use the area as a foraging ground (Nebeker, 2001). Any of the birds observed in the area have home ranges that extend well beyond the Superfund Site.

Breeding populations of several species present in the Lower Willamette River only during the winter have been given special status by ODFW or are considered sensitive by the Oregon Natural Heritage Program. These species include Barrow's goldeneye (*Bucephala islandica*), bufflehead (*Bucephala albeola*), horned grebe (*Podiceps auritus*), red-necked grebe (*Podiceps grisegena*), long-billed curlew (*Numenius americanus*), and greater sandhill crane (*Grus canadensis*) (ONHP, 2001).

2.5.2.4 Amphibians and Reptiles

Western toad, Cope's giant salamander, tailed frog, northern red-legged frog, northwestern pond turtle, and painted turtle are all considered sensitive species by ODFW. In addition, northwestern pond turtle, tailed frog, and red-legged frog are listed as species of concern by USFWS.

2.5.2.5 Aquatic Plants

Nine wetland plants that occur in the Willamette Valley and may occur within the Superfund Site are special-status species (see Table 2-6). Howell's bentgrass (*Agrostis howellii*), white-topped aster (*Aster curtus*), wayside aster (*Aster vialis*), Peacock larkspur (*Delphinium pavonaceum*), and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) are all counted as species of concern by USFWS. Howellia (*Howellia aquatilis*) and Nelson's sidalcea (*Sidalcea nelsonia*) are federally threatened species, and the Willamette daisy (*Erigeron decumbens*) and Bradshaw's lomatium (*Lomatium bradshawii*) are protected federal endangered species. All of these plant species have state threatened or endangered status as well, with the exception of Howell's bentgrass, howellia, and Hitchcock's blue-eyed grass.

2.6 Current Engineering Characteristics

Terminal 4's current engineering characteristics are summarized below on the basis of information available from previous studies at the facility. Although the Removal Action is concerned with the engineering behavior of sediments in terms of dredging, onsite disposal, and capping, the engineering analysis of the feasibility of Removal Action alternatives requires knowledge of upland soil subsurface conditions and soil engineering properties as well. In general, the following properties of the sediment and upland soils will be used as a basis for the engineering evaluation in the EE/CA:

- density/consistency;
- plasticity characteristics;
- moisture content;
- organic content;
- gradation;
- porosity;
- consolidation characteristics;
- shear strength and "stiffness" characteristics; and
- dynamic (i.e., seismic) characteristics (i.e., shear wave velocity and shear modulus).

The engineering characteristics will be used in the following evaluations (note that other engineering activities not listed here may also be necessary):

- Conceptual designs for each of the Removal Action alternatives, which incorporate:
  - dredging volumes and sediment bulking behavior;
  - dredgeability of sediment;
  - sediment consolidation from capping;
  - slope stability of dredge slopes and under-pier areas;
  - slope stability of potential containment berms (both short-term and long-term seismic conditions); and
  - liquefaction potential and anticipated effects.
- Comparison of Removal Action alternatives, involving comparative evaluations of :
  - implementability (i.e., technical feasibility and constructability);
  - effectiveness; and
  - relative cost of Removal Action alternatives.

Engineering characteristics are available from three primary sources of existing information:

- Geotechnical Borings (or Cone Penetrometer Explorations). Typically available from such prior activities as foundation designs for pier structures and upland buildings and slip-deepening studies.

- Sediment Core or Surface Sediment Analytical Results. Typically available from laboratory testing conducted during previous environmental investigations associated with maintenance dredging or other environmental studies; typically includes grain size and moisture content data.

- Geotechnical Data. Typically available from laboratory testing associated with prior foundation design studies or other geotechnical studies that involve sample collection from borings and subsequent testing. Geotechnical data may include grain size, moisture content, plasticity, density, consolidation, and shear strength.

In addition, the present condition of and planned future uses for existing structures such as piers, utilities, and remnant piles are considered engineering characteristics because they may influence the technical feasibility of Removal Action alternatives. Information on existing structures is available from construction drawings and, in the case of piers, from inspection reports on present conditions.

2.6.1 Available Information Sources

2.6.1.1 Geotechnical Explorations and Monitoring Wells

The Port has assembled a plan that provides the approximate location of all cataloged geotechnical borings performed at Terminal 4 through 2000. These borings provide data on deep subsurface conditions for the Troutdale Formation and typically include laboratory testing results, which provide information about the physical properties of the sediment (or soil). Of these geotechnical borings, which include information from sampling using the standard approach for geotechnical design, i.e., Standard Penetration Testing (SPT), American Society for Testing and Materials (ASTM) Method D 1586, the deep borings have been selected for specific use in identifying data gaps for the EE/CA as shown on Figure 2-17. Existing reports useful for determining currently known engineering characteristics on the basis of prior geotechnical borings and laboratory testing are:

- For Slip 1: Subsurface Conditions Below Piers 1 and 2 (Shannon and Wilson, 1962);
- For Slip 3: Test Pile Program, Including Test Borings (Gerwick, 1959);
- For Slip 3: Remedial Investigation Report (Volume I: Upland, Volume II: Sediment) (Hart Crowser, 2000a); and
- For the upland: Geotechnical Investigation for Planned Bulk Storage Facility (Dames and Moore, 1993).

Logs of geotechnical borings and monitoring wells, including any available site exploration plans and legends from the original report, are provided in Appendix C.

2.6.1.2 Construction Documents

Construction documents for various structures at the Terminal 4 Removal Action Area, such as piers, and at upland properties, such as utilities and building foundations, are available for use in determining the current engineering characteristics of soil and sediment at the Terminal 4 facility. Drawings used to evaluate the condition of existing structures and other engineered aspects of Terminal 4, such as construction details, layout, and elevations for storm and sanitary sewer lines, are documented in Section 9.

2.6.2 Regional Geology/Current Engineering Characteristics

Terminal 4 is included in the Willamette Valley Physiographic Province and is part of the U.S. Geological Survey's (USGS's) Linnton Quadrangle, located at approximately latitude 45.59^{o}, longitude 122.77^{o}.

The Willamette Valley is a broad alluvial plain within a structural basin surrounded by Tertiary marine sedimentary and volcanic rocks of the Coast Range to the west and Tertiary and Quaternary volcanic and pyroclastic rocks of the Cascade Range to the east (O'Connor et al., 2001; Madin, 1990). The Portland Basin is the northern extent of the Willamette Valley. The valley has been a topographic low for millions of years, accumulating thick alluvial deposits and, in recent geologic times, experiencing episodic flooding from glacial Lake Missoula. Faulting and over 1,000 ft of uplift have exposed the Columbia River Basalt Group as the Tualatin Mountains (Portland Hills). The regional geology of the Portland Basin and Willamette Valley is made up of the following major geologic formations, listed from youngest to oldest:

- Unconsolidated Alluvial Deposits. These recent river and historical flood deposits consist of two main units:

  - Recent Alluvium. The deposition processes within the Willamette River for the last several thousand years subsequent to the glacial period have blanketed the low-lying areas in and adjacent to the river. The recent alluvium consists of deposits of silt, sand, and some gravel.

  - Glaciofluvial Flood Deposits. During the Pleistocene, several floods from the Glacial Lake Missoula, which flowed up the Portland Basin and Willamette Valley from the Columbia River, deposited a thick sequence of sand, with layers of gravel, cobbles, and boulders.

- Troutdale Formation. This deposit includes both consolidated and unconsolidated sand, gravel, and cobbles and may be on the order of 100 ft in thickness at the Removal Action Area.

- Sandy River Mudstone Formation. This deposit is predominantly fine-grained, consisting of siltstone and claystone, and thins near the Tualatin Mountains (and the Removal Action Area).

- Columbia River Basalt Group. This consists of a series of basalt flows originating from eastern Washington that spread over large areas of the Pacific Northwest. In the Portland Basin, the reported thickness is up to 1,000 ft, with individual flows ranging from 25 to 200 ft in thickness (Bridgewater Group, 2003).

As shown on Figure 2-18, surficial geology for Terminal 4 consists of recent alluvium and artificial fill. The following sediment units for anticipated depths of interest have been identified from previous studies:

- recent sediment;
- unconsolidated alluvial deposits; and
- Troutdale Formation.

Regarding recent sediment, Table 2-7 provides a tabulation of available information on the grain size distribution from samples collected in the Removal Action Area.

Table 2-7
Grain Size Data

Sample Identification[1]	% Gravel	% Sand	% Silt	% Clay	Depth, ft
HC-S-01	0.1	19.1	65	15.8	<12
HC-S-02	0.3	54.5	33.1	12.1	<12
HC-S-04	0.7	17.7	66.6	15	<12
HC-S-05	0	39.6	45.8	14.6	<12
HC-S-07	0	12.9	68.3	18.8	<12
HC-VC-7-S2	0.1	47.8	36.3	15.8	<12
HC-S-08	0	5.6	73.7	20.7	<12
HC-S-11	0	13.4	69.8	16.8	<12
HC-VC-11-S2	0	47.8	39.7	12.5	<12
HC-S-13	0.1	39.1	46.4	14.4	<12
HC-VC-13-S2	0.1	96.9	2.1	0.9	<12
HC-S-16	0	29.6	55.3	15.1	<12
HC-VC-18-S2	0	96.8	2.3	0.9	<12
HC-S-19	3.7	64.4	24.4	7.5	<12
HC-S-22	0	39	46.9	14.1	<12
HC-S-24	0.7	58.5	30.4	10.4	<12
HC-S-26	0	76.9	17.4	5.7	<12
HC-S-28	0	16	65	19	<12
HC-S-30	0	59.2	30.6	10.2	<12
HC-S-32	0	43.8	38.6	17.6	<12
HC-VC-32-S2	0	96.5	2.6	0.9	<12
HC-S-34	0.1	38.2	47.2	14.5	<12
HC-S-35	0	35.5	50.2	14.3	<12
HC-S-36	0.2	76.4	17.1	6.3	<12
HC-S-39	0	14.9	69.4	15.7	<12
HC-S-42	0	7.1	78.3	14.6	<12

HC-S-44	0	11.2	72	16.8	<12
HC-S-Ref-B	0	0.9	73.6	25.5	<12
HC-S-Ref-C	1.1	79.1	16.6	3.2	<12

Sample Identification[2]	% Sand/Gravel >75 µm	% Silt/Clay <75 µm	Depth, ft
HC-Slip1-01	4.7	95.3	<1
HC-Slip1-02	93.8	6.2	<1
HC-Slip1-03	26.3	73.7	<1
HC-Slip1-04	47.7	52.3	<1
HC-Slip1-05	9.8	90.2	<1
HC-Slip1-06	3.7	96.3	<1
HC-Slip1-07	6.8	93.2	<1
HC-Slip1-08	76.9	23.1	<1
Sample Identification[2]	**% Sand/Gravel >75 µm**	**% Silt/Clay <75 µm**	**Depth, ft**
HC-Slip1-09	87.9	12.1	<1
HC-Slip1-10	70.7	29.3	<1
HC-Slip1-11	16.2	83.8	<1
HC-Slip1-12	4.2	95.8	<1
HC-Slip1-13	90.2	9.8	<1
HC-Slip1-14	11.7	88.3	<1
HC-Slip1-15	16.6	83.4	<1
HC-Slip1-16	14.3	85.7	<1
HC-Slip1-17	10.4	89.6	<1
HC-Slip1-18	16.8	83.2	<1
HC-Slip1-20	24.0	76.0	<1

1 – Hart Crowser, 2000a.
2 – Hart Crowser, 2000b.

2.6.2.1 Slip 1 Engineering Characteristics

Figure 2-19 is a cross section through Slip 1 incorporating available information. The cross section provides a preliminary stratigraphic model that will be refined as supplemental information becomes available from the EE/CA field exploration program. This information has been used in concert with the other geotechnical borings to identify data gaps that will be filled prior to the evaluation of Removal Action alternatives in the EE/CA.

Recent Sediment

Table 2-7 provides surface sediment grain size results, indicating a predominant distribution of silt/clay-sized sediment, though a relatively high sand content is reflected in the data. The sediments in Slip 1 appear to be similar in gradation to Slip 3, though specific percentages of silt versus clay and sand versus gravel were not apparent in the available data. Samples from Slip 1 were taken from a depth of less than 1 foot.

Geotechnical borings are typically not used to sample for or accurately assess the thickness of recent sediment deposits. The sediment in Slip 1 is expected to be thicker than the sediment in Slip 3 (noted to generally range from 2 to 6 ft in thickness) because of relatively infrequent maintenance dredging and ongoing sediment deposition.

Unconsolidated Alluvial Deposits

According to the deep geotechnical borings (Shannon and Wilson, 1962), which spanned the full length of the slip, the alluvial deposits are primarily black, medium dense (occasionally loose), sand to silty sand interbedded in complex layering with gray silt deposits for a depth of 80 to 100 ft below mudline, with exceptions noted below. No interbedding was evident for borings in the western portion of the slip, which could correspond with dredged fill sand placed above the former shoreline, although that could not be determined at this time. Subsurface conditions below the interbedded alluvial deposits consist of black, dense, sand with gravel. Similarly, the nearby upland study (Dames and Moore, 1993) concluded that deep alluvial deposits extend to a depth of about 160 to 180 ft below ground surface. The alluvial soils area is described as loose to medium dense sands and silty sands, to soft to medium stiff sandy to clayey silt and silty clay. The silt and clay were characterized as having moderate compressibility and low shear strength.

Shannon and Wilson (1962) also identified a considerably thicker organic deposit at the head of the slip. The deposits become more silt than sand about half the distance along Berths 405 and 408 near the head of the slip, where the deposits become thicker organic silt. It is expected that this deposit is related to the filling of Gatton's Slough. The deposit is greater than 100 ft in thickness, composed of soft to medium stiff, gray organic silt and clay, with some peat-like debris noted in one or two borings. Sediment plasticity was not determined and is an important data gap with regard to the organics and other fine-grained deposits.

Notably, the subsurface conditions below the mudline from one side of the slip to the other vary, in some cases considerably, which attests to the complexity of the subsurface conditions in the Removal Action Area.

Triaxial shear strength testing yielded the following values:

- medium sand with an internal friction angle equaling 38 degrees;
- silty fine sand with an internal friction angle equaling 33 degrees;
- organic, fine sandy silt with an internal friction angle equaling 31 degrees (cohesion equaling 0.2 ton per square ft); and
- organic clay with an internal friction angle equaling 21 degrees (cohesion equaling 0.2 ton per square ft).

These values are higher than would typically be used for design purposes and should be verified with additional testing.

Troutdale Gravel

The Troutdale Gravel (i.e., Troutdale Formation) was deposited within the ancestral Columbia River channel as a thick "gravel" unit typically characterized as having well-rounded gravel and cobbles derived from the Columbia River Basalt Group. The Troutdale Gravel has been estimated to be 100 ft in thickness at the Removal Action Area (Hart Crowser, 2000a), occurring below the thick sequence of unconsolidated alluvial deposits. The borings in and around Slip 1 encountered dense sandy gravel to silty sandy gravel (Dames and Moore, 1993) below the interbedded layers of sand and silt.

The top of the Troutdale Gravel generally delineates the depth of subsurface conditions of greatest impact to the engineering characteristics of Terminal 4 and will be the focus of engineering data collection to support slope and structure stability evaluations, as well as the feasibility of onsite disposal.

Upland Fill

Adjacent to Slip 1, Dames and Moore (1993) performed two geotechnical borings and several mechanical cone penetrometer explorations, characterizing the fill as 7- to 15-ft-thick loose, brown, silty fine sand.

2.6.2.2 Slip 3 Engineering Characteristics

Recent Sediment

Sediment physical properties in Slip 3 have been characterized (Hart Crowser, 2000a) as very soft to medium stiff, wet, brown, sandy silt to silt and organic silt. From Table 2-7, it can be seen that sediments in Slip 3 are predominantly silt and are also comprised of a lesser amount of sand and clay. Each sample has little to no gravel content. Samples from Slip 3 were taken from a depth of less than 12 feet. Organic debris such as twigs and other plant matter was noted in some of the samples.

In Slip 3, sampling appears to indicate a sediment thickness of 2 to 6 ft, although frequent maintenance dredging occurs here, particularly adjacent to the KMBT pier.

Unconsolidated Alluvial Deposits

Adjacent to Slip 3, Hart Crowser performed 17 monitoring well installations and numerous geoprobes, characterizing the fill as 5- to 40-ft-thick brown, medium sand (i.e., dredge fill), with the greater thickness on the western portion of the area (Hart Crowser, 2000a).

Previous monitoring wells in this same area of Slip 3 were installed by Century West (Hart Crowser, 2000a).

Deep geotechnical borings were performed in Slip 3 by Gerwick (1959) for the City CPD. The borings indicate general similarities to Slip 1, although locally the complexities of the layering and engineering properties could vary considerably.

Troutdale Gravel

The available information for the Troutdale Gravel below Slip 3 is similar to that of Slip 1, and the Troutdale Gravel at Slip 3 is not expected to differ dramatically in engineering properties.

2.6.2.3 Wheeler Bay Engineering Characteristics

No information is available on the engineering characteristics of recent sediment, unconsolidated alluvial deposits, Troutdale Gravel, or upland soil (e.g., fill) near Wheeler Bay. Note that the Troutdale Gravel is not expected to vary considerably from that of Slip 1 or Slip 3.

2.7 Current Hydrogeologic Characteristics

The current hydrogeologic characteristics of the Removal Action Area are summarized in this section based on available information from previous studies at Terminal 4. At present, the only available hydrogeologic information for the Removal Action Area derives from upland studies.

Site-specific hydrogeologic characteristics will be evaluated in conjunction with the upland source control evaluations. Because the Removal Action is proceeding on a separate schedule from the upland investigations, the necessary number of monitoring wells will be installed for this study, but at locations selected in coordination with the upland activities. In the EE/CA, hydrogeologic conditions will be described on both a regional and a site-specific basis.

2.7.1 Available Information Sources

Studies incorporating monitoring well installations and information pertaining to the hydrogeologic conditions of interest are:

- For Slip 3 Upland: Bridgewater Group, Inc., 2003, Portland Harbor Port Facility Groundwater Assessment;

- For Slip 3 Upland: Hart Crowser, 2000c, Remedial Investigation Report (Volume I: Upland, Volume II: Sediment); and

- For Slip 3 Upland: Century West, 1994 (in Hart Crowser, 2000c).

According to these studies, a considerable number of groundwater monitoring wells have been installed at Terminal 4. Most of the monitoring wells are shallow, are located on the Slip 3 uplands, and were installed beginning in early 1993 to define the lateral and vertical extent of contamination from the Union Pacific pipeline. Hart Crowser (2000c) lists the following monitoring well and geoprobe installations:

- Thirty-three geoprobes installed June through October 1998 to depths ranging from 20 to 40 ft below ground surface for groundwater sampling. These explorations were abandoned at the time of the study.

- Seventeen groundwater monitoring wells (including three shallow and deep well clusters) installed in October 1998 to depths ranging from 20 to 45 ft below ground surface. These wells are screened through the upland fill and upper portions of the alluvial deposits from 5 to 20 ft below ground surface; deeper wells are screened from about 30 to 45 ft below ground surface using 5-ft-long well screens. All monitoring wells for this study were installed to evaluate the extent of contamination or to provide groundwater flow characteristics relative to three key features identified as potential sources: the Northern Pipeline Area, the Former Rail Car Fuel Loading Area, and the Hall-Buck Quaker State/Gearlocker Area. The wells were survey-located by a licensed surveyor and referenced to Columbia River Datum.

Prior to the Hart Crowser and Bridgewater Group studies, 20 monitoring wells and 37 soil borings were drilled by Century West. The monitoring wells were installed with screen lengths ranging from 15 to 25 ft.

Figure 2-20 shows the locations of known monitoring wells on Terminal 4 that are potentially available for water-level monitoring for the EE/CA. Additional wells have been installed recently but are not depicted on this figure. A current use inventory of wells at Terminal 4 and on surrounding properties was performed by Hart Crowser (2000c). There are no known current or historical supply wells at Terminal 4. The Hart Crowser inventory identified five wells in use by Northwest Pipe, Schnitzer Steel, and Northwest Container for industrial purposes. Five additional wells installed in the 1940s were identified in the vicinity of Terminal 4. These wells were reportedly installed for industrial use, although their status (whether in use or abandoned) was not determined.

2.7.2 Regional Hydrogeology

Hydrogeologic (i.e., hydrostratigraphic) unit classifications differ from geologic units in that they are not only based on the geologic age and nature of the sedimentary deposit or rock formation, but also are primarily based on the function of the unit as an aquifer (i.e., coarse-grained and capable of supplying water) or confining unit (i.e., fine-grained and generally a low-permeability deposit confining a deeper aquifer). Figure 2-21 provides regional hydrogeologic cross sections near the Removal Action Area, which is located between the two cross sections, slightly closer to Section B on the figure.

Hydrostratigraphic units are categorized as:

- Unconsolidated Sedimentary Aquifer. This aquifer comprises recent alluvial deposits and primarily Pleistocene catastrophic flood deposits that mantle much of the Portland Basin.

- Troutdale Gravel Aquifer. This aquifer is a highly productive sand and gravel deposit, yielding up to 1,000 gallons per minute to wells (Bridgewater, 2003).

- Undifferentiated Fine-Grained Units. This sequence of confining units and aquifers is differentiated farther east of Terminal 4; however, at the western margin of the alluvial deposits near the Tualatin Mountains (i.e., west of Terminal 4), the alluvial deposits' sequence at depth is complicated by the relative depth to older rocks. The following subunits of the undifferentiated unit may occur at depth below the Removal Action Area:

    - Confining Unit 1. This mudstone, siltstone, and claystone unit is considered part of the Troutdale Formation, except where the Troutdale sandstone is not present, which makes it indistinguishable from the Sandy River Formation.

    - Troutdale Sandstone Aquifer. This is a sandstone and conglomerate deposit.

    - Confining Unit 2. This is mudstone, siltstone, and claystone mapped as the Sandy River Formation.

    - Sand and Gravel Aquifer. This is a silty to gravelly sand within the Sandy River Mudstone.

    - Columbia River Basalt Group. This unit is a productive aquifer to the Tualatin Mountain area and Tualatin Basin west of the mountains. Columnar jointing erosional processes between flow events create an extensive interbasalt flow network, and wells are screened at several hundred feet to intersect multiple interflow zones.

The regional drinking water aquifer supplying the City of Portland is the Troutdale Gravel Aquifer (Troutdale Formation) alluvial deposit. It is anticipated that groundwater from higher elevations flows to the Willamette River in deep circular patterns above the fine-grained deposits of the Sandy River Formation, likely creating upward gradient-dominated flow from the Troutdale Gravel Aquifer into the overlying alluvial soils.

The interbedding within the unconsolidated sedimentary aquifer, particularly fine-grained layering of silt and clay, may affect upward flow by causing vertical gradient-dominated flow to dissipate laterally before reaching the recent sediment. This may be supported by the 1999 groundwater elevation data (Hart Crowser, 2000c) at well clusters, suggesting a downward vertical gradient from the upland fill to the underlying shallow alluvial deposits at the time of measurements. However, the deeper wells were completed very shallow within the alluvial soil below the upland fill and may not represent groundwater flow conditions below the surficial unit, such that there may be some hydraulic connection or other factor influencing the result.

2.7.3 Terminal 4 Hydrogeology

In addition to the hydrostratigraphic units described for the regional hydrogeology, Terminal 4 includes an upland fill aquifer. This aquifer is common to the Portland Harbor and Portland Basin in general, involving reclaimed or modified land, which is highly variable in gradation, hydraulic conductivity, and water quality. The upland fill aquifer is used for infiltration of stormwater via two dry wells (Parsons Brinkerhoff, 2002).

Shallow groundwater within the upland fill at Terminal 4 typically ranges from 12 to 20 ft below ground surface to possibly 30 ft below ground surface on the western portion of the Slip 1 upland boundary (i.e., near the Willamette River), and the flow is generally toward the Willamette River from the upland areas of Terminal 4 (Hart Crowser, 2000c). However, Terminal 4's hydrogeology is a complex system influenced by the interaction of the local groundwater regime with the Willamette River hydrology. The most transient aspect of groundwater flow is expected to be the lateral component of groundwater flow, including influences from the following:

- regional groundwater flow to Terminal 4 and Portland Basin;
- seasonal river stage changes, reported to be on the order of 10 ft with short-term tidal fluctuations reported to be about 2 ft at Terminal 4 (Hart Crowser, 2000c); and
- direct precipitation that infiltrates gravel at Terminal 4 and recharges the upland fill. Average annual rainfall in Portland, Oregon is 36.99 inches (Western Regional Climate Center Period 11/1/1941 through 3/31/2003).

Seasonal water-level fluctuations are generally less than 4 ft on the eastern side of the Slip 3 upland boundary to more than 10 ft in wells closer to the river and are likely influenced by the seasonally transient conditions of the river stage.

Hydrologic testing consisting of a pumping test screened through the lower 14 ft of the upland fill has been performed by Century West (Hart Crowser, 2000c). The resulting hydraulic conductivity calculated from the test was 65 ft per day, which was influenced both by the fill and the underlying alluvial soils.

Hydrogeology for Slip 1 is expected to be influenced by the natural ravine (i.e., Gatton's Slough) filled during slip construction. However, this area appears to be in-filled with low-permeability organic silt and clay deposits, which may reduce the possible effect of channeling groundwater into the Slip 1 area.

In additional, the shallow hydrogeology near Slip 3 is expected to be influenced by a west trending depression in the alluvial deposits near Pier 5. This was identified as a preferential pathway for groundwater flow and the migration of light nonaqueous-phase liquid (LNAPL) associated with the former Union Pacific pipeline (Hart Crowser, 2000c).

2.8 Current Hydraulic Characteristics

The hydraulic characteristics of the Willamette River adjacent to the Removal Action Area and the hydraulic characteristics of Slips 1 and 3 are described in this section.

Flow circulation patterns and corresponding sedimentation patterns within Slips 1 and 3 are dominated by the effects of the Willamette River, although sedimentation is also affected by local depositional areas around stormwater outfalls and ship propeller scour patterns. Ship scour that redistributes sediments is an important factor in considering both recontamination potential and requirements for maintenance dredging. Published scientific studies on the bottom shear stresses generated by ship prop wash and tugboat activities will be used to assess the importance of ship scour in Slip 3. In addition, bathymetric survey maps showing localized impacts from ships will be evaluated and used to support conclusions regarding the area and spatial extent of large impacts to the sediment from ships (e.g., scour areas). Also, the near-bottom velocity meters and turbidity sensor data will be evaluated in comparison with shipping activity (times of berthing and departure) to evaluate the effect of vessel movement.

The hydraulic characteristics of the Willamette River that are of particular interest to the Removal Action include the local river bathymetry in the slips and along Terminal 4, the range of river stage fluctuations experienced in the Removal Action Area, and flow patterns, including extent and duration of flow reversals, resulting from fluctuations in the Columbia River water stage.

Recent bathymetric surveys of the Willamette River, including the Removal Action Area, provide a detailed understanding of current bathymetry in the slips and the Willamette River adjacent to Terminal 4 (Striplin Environmental Associates, Inc., 2003). Water depth at the entrance to Slip 1 is approximately 40 ft and water depth at the entrance to Slip 3 is approximately 50 ft (Figure 1-3). The river bathymetry along the Removal Action Area is characterized by steep side slopes and center channel depths of approximately 60 to 70 ft. A deep trough in the river bottom spanning most of the river's width extends from approximately 2,500 ft upstream of Slip 3 downstream to Slip 1 with maximum water depths in the trough greater than 70 ft. Within Slip 3, water depths of between approximately 30 and 40 ft occur over most of the slip with the exception of a deeper channel leading from the river to Berth 411. Within Slip 1, water depth varies between approximately 20 and 30 ft over most of the slip.

A sedimentation study conducted by the Port provides information on the sedimentation patterns and processes of the Port's terminals (Port of Portland, 2002). The ship berths in Terminal 4 experience varying sedimentation. The sedimentation analysis concluded that the two slips have more deposition occurring during lower flow conditions and that the berths running parallel to the river have more deposition occurring during high flow conditions. Although elevated sediment transport occurs during high flows, the long-term effect of low flows (which occur most of the time) can in some cases yield higher long-term deposition rates than high-flow events. High-flow events may also remobilize sediments in circulation eddies within the slips if these sediments are much finer-grained than the sediments near the berths parallel to the river. Comparison of repeat bathymetric survey data reveals local variations in sedimentation patterns along the shoreline as a result of dredging and construction and demolition activities.

The sedimentation analysis included assessment of USGS discharge records available since 1990 for the Willamette River (data primarily from the Portland gage) and the Columbia River (data primarily from the Dalles gage). The Columbia River data were included in the analysis because of the effect of Columbia River flow and stage on hydraulic conditions in the lower Willamette River. Mild flow reversals in the Willamette River occur at times due to rapid stage increases in the Columbia River, although such reversals are typically of short duration. Flows corresponding to a range of exceedance frequencies from 10% to 99% are provided for the Willamette River and Columbia River data in Tables 2-8 and 2-9, respectively, which are derived from Port of Portland, 2002.

Table 2-8
Flow Exceedance Statistics for Willamette River,
USGS Portland Gage, 1990 to 2001

Exceedance (Percent of Time)	Days/Year	Discharge (cfs)
Average	---	36,333
99%	361	6,690
95%	347	7,600
90%	329	8,670
75%	274	11,950
50%	183	22,900
25%	91	45,200
10%	37	83,320
5%	18	118,000
1%	4	180,000

Note: cfs = cubic feet per second
Source: Port of Portland, 2002

Table 2-9
Flow Exceedance Statistics for Columbia River,
USGS Dalles Gage, 1990 to 2001

Exceedance (Percent of Time)	Days/Year	Discharge (cfs)
Average	-	190,058
99%	361	77,935
95%	347	94,900
90%	329	106,000
75%	274	130,072
50%	183	172,000
25%	91	229,000
10%	37	299,000
5%	18	349,000
1%	4	456,530

Note: cfs = cubic feet per second
Source: Port of Portland, 2002

River stage exceedance was also reported for Willamette River stage measured at the Portland gage for the same period (Table 2-10).

Table 2-10
Stage Exceedance Statistics for Willamette River, USGS Portland Gage, 1990 to 2001

Exceedance (Percent of Time)	Days/Year	Stage (CRD)
Average	-	7.4
99%	361	3.4
95%	347	4.1
90%	329	4.5
75%	274	5.4
50%	183	6.7
25%	91	8.6
10%	37	11.4
5%	18	13.2
1%	4	17.6

Note: CRD = Columbia River Datum
Source: Port of Portland, 2002

The exceedance frequencies in Tables 2-8 through 2-10 were used by the Port to assess correlations between dredge prism volumes and the cumulative number of days where flows or stage exceeded various exceedance values (for example, the number of days for which flow was greater than a specific flow, such as the 20th percentile). The results of the Port's sedimentation analysis for each berth and slip are briefly summarized below, along with interpretation of spatial deposition patterns shown in survey-to-survey bathymetric changes mapped by the Port in Appendix D of the sedimentation analysis report (Port of Portland, 2002).

In Berth 401, sedimentation is reported to have occurred during high flow periods and net erosion is reported to have occurred during low flow periods. Comparison of the 1998 and 2001 bathymetric data indicates greater deposition in deeper areas away from the dock than near the dock.

In Slip 1, sedimentation rates are reported to be related to the 3% flow exceedance. Deposition is reported during low flow periods with little change or some scour during periods when high flows occurred. Spatial deposition patterns based on comparison of 2000 and 2001 bathymetric survey data were mapped by the Port. Comparison of these data indicates deposition along the downstream side of the mouth of the slip, along the center axis of the slip, and in localized areas near the southeast and northeast corners of the slip in areas corresponding to stormwater outfall locations. In particular, the area of deposition adjacent to Berth 408 appears to reflect a local deposition footprint characteristic of that produced by an outfall. The bathymetric survey comparison maps for the periods 1997 to 1998, 1998 to 1999, 1999 to 2000, and 2000 to 2001 show a consistent pattern of slope sloughing along the western half of the south shoreline of Slip 1. The bank is slowly eroding and collapsing to a more gradual slope along this section of the slip. This is apparently due to prior demolition of a berth (Port of Portland, 2002).

In Slip 3, sedimentation rates are reported to show less correlation to the 3% flow exceedance than in Slip 1. Dredge prism volumes do not show any discernable pattern over time and reported conclusions regarding flow dependency are tenuous due to the nature of the data for Slip 3. Comparison of the bathymetry changes mapped by the Port based on the May 1994 and December 1994 bathymetric surveys shows a localized area of sedimentation in the southeast corner of the slip. This area is near two stormwater outfalls, and this deposition could be related to the outfalls. A localized depositional delta from a stormwater outfall is also apparent in the middle of the eastern shoreline of Slip 3 in comparison of the April/May 1998 survey and the June 1999 survey. Deposition due to the outfalls along the southeastern portion of Slip 1 is not evident in this survey, suggesting either that stormwater management was improved for these outfalls or that sediment sources from the outfalls are episodic (e.g., as would occur if discharges were related to periodic construction activity in the outfall drainage area).

Comparison of surveys conducted in January 1995 following a dredging event and in January 1996 indicates broader depositional areas along the southeast and northeast portions of the slip; however, the very high rates of deposition are typical of results caused by horizontal positioning error (USACE, 2002). Similarly, comparison of the January 1996 survey and the December 1997 survey shows high rates of erosion along the northeast portion of the slip on the steep slope area. These results are also suspect due to possible survey error. Another result that appears possibly affected by survey error is the June 2000 and May 2001 survey comparison, which indicates widespread erosion throughout Slip 1. Error in vertical datum control is suspected. Other survey comparisons presented by the Port for Slip 3 indicate modest rates of deposition throughout the slip.

Sediment grain size distribution in Slips 1 and 3 also provides a means to assess sedimentation patterns. Grain size measurements available for 19 surface sediment samples collected in Slip 1 indicate that the sediments are predominantly fine-grained (Hart Crowser, 2000a). Percent fines in these samples range from 96% to 6.2%, with only five samples having less than 50% fines and eight samples having greater than 85% fines. The spatial distribution of the fines shows that deposition of fines is greater at the eastern end of Slip 1 than near the mouth of the slip. The data also indicate that, in general, the sediments in the deeper portions of the slip are finer than sediments along the sides of the slip.

Twenty-nine grain size measurements available for Slip 3 show that sediments in Slip 3 also consist of predominantly fine material (Hart Crowser, 2000a). (These grain size data were derived from a NOAA database; see Section 4 for a discussion of that database.) Percent fines in these samples range from 23% to 94.5% with an average of 67% and standard deviation of 22%. Overall, Slip 3 sediments appear to contain slightly less fine-grained material than do sediments in Slip 1. The spatial distribution of percent fine values in Slip 3 does not reveal any discernable pattern, although percent fine values are generally higher in deeper areas than in shallow areas. This suggests that deposition and flow circulation patterns in Slip 3 may be quite variable under different river conditions.

2.9 Terminal 4 Stormwater Utilities

Stormwater runoff to the Terminal 4 Removal Action Area is derived from 15 catchment basins as illustrated in Figures 2-22 and 2-23. Figure 2-22 depicts the Terminal 4 facility-wide stormwater drainage patterns, while Figure 2-23 provides a close-up view of the Removal Action Area to illustrate details of piping, outfalls, and other specifics of the stormwater drainage system. Most of the areas represented in the figures are paved with grading to direct surface water to catch basins shown on the figures. Of these catchment basins, five drain into Slip 1, three drain into Slip 3, one drains into Wheeler Bay, and the remaining six drain into the Willamette River adjacent to the Removal Action Area site.

A total of six stormwater outfalls are located in Slip 1. As evident in Figure 2-23, the following characteristics are associated with the outfalls:

- One outfall drains stormwater runoff in a 15-inch pipe from a 17.8 acre area around the grain elevators on the former Cargill property.
- One outfalls drains stormwater runoff in an 18-inch pipe from a 13.3-acre area around the I.R.M. property to the south of Slip 1.
- Two outfalls drain stormwater runoff in 21-inch pipes from a 5.5 acre area directly east of Slip 1.
- One outfall drains a 3.6-acre piece of land just south of the previously mentioned area in a 6-inch pipe.
- The sixth outfall (52c) in Slip 1 is for the City of Portland pipeline. This 36-inch pipeline receives runoff from a 23.4-acre stormwater drainage basin approximately 1,500 feet east of Slip 1 in the Toyota Processing Yard area. On the east end of the 23.4-acre drainage basin, undetermined off-site sources of stormwater runoff exist, denoted on Figure 2-22 with a dashed line.

Slip 3 also contains a total of six stormwater outfalls. The following characteristics are associated with those outfalls, which can be seen in Figure 2-23:

- One outfall drains a 1.5-acre area at the east end of the piers in Slip 3 on the Kinder Morgan property.
- Two outfalls drain a building and the 2.6-acre area around it to the east of Slip 3.
- Three outfalls drain the 16.8-acre area south of Slip 3. An additional outfall in this area drains into the Willamette River. Two other outfalls previously drained this area into the Willamette River, but they have since been plugged and/or abandoned. Apparently, one of the two outfalls was associated with roof drainage from a former building. The building no longer exists. The abandoned outfall can be inferred to have been associated with a building from the limited distance and area coverage of piping between the outfall and terminating points of the lines.

Wheeler Bay contains one outfall which drains a 30.2-acre area, consisting of a large portion of the Kinder Morgan property as well as many of the rail lines at the site, in a 21-inch pipe.

Two outfalls drain the 16.3-acre area on the former Cargill property to the north of Slip 1 in 10-inch and 21-inch pipes, respectively. These outfalls flow into the Willamette River.

3. Potential Sources of Contamination

This section presents information showing how various activities and operations that took place at and near Terminal 4 may have been sources of contamination to the Removal Action Area. Existing information is generally believed to be sufficient to characterize the nature of Removal Action Area sources for the EE/CA. However, any additional or superseding information on Terminal 4 activities and contaminant sources that is developed during ongoing studies, such as those described in Sections 1, 2.2, and 3.3.1 and the Portland Harbor Superfund Site remedial investigation, will be incorporated into the EE/CA. These investigations may reveal potential contaminant sources on uplands adjacent to Terminal 4, as well as potential sources of contamination to the Willamette River, such as industrial facilities upstream and downstream from Terminal 4 and agricultural lands well upstream from Terminal 4.

3.1 Terminal 4 and Adjacent Property Potential Contaminant Sources

Potential sources of contamination to the Removal Action Area consist of activities and operations that have occurred or are occurring within the Removal Action Area; on Terminal 4, including Slip 1 and Slip 3 uplands; on property adjacent to Terminal 4; and on the Willamette River and property up and down river from the Removal Action Area. These activities have been described in detail in Section 2. They are summarized as potential contamination sources in Table 3-1, along with the substances potentially released by each activity. Known spills or releases associated with the activities are also included in Table 3-1, although the list is drawn only from readily available information and is not considered comprehensive. Known spills not yet associated with a particular activity are described in the text following Table 3-1.

Potential sources outside Terminal 4 include release or resuspension and transport of contaminants from upstream sediments in the river and any contaminated tributary sediments, stormwater and non-point source runoff and contributions from the urban area of Portland, runoff from other facilities along the waterfront, and point source discharges. Specific potential sources of contamination to the Willamette River currently under consideration by DEQ (Jim Anderson, personal communication, 11/5/03) include the facilities listed below. Contaminated sediments associated with these facilities could be mobilized, particularly in high flow events, and redeposited in the Removal Action Area at Terminal 4.

- Cascade General/Portland Ship Yard;
- Triangle Park – Reidel site;
- McCormick and Baxter site;
- Willamette Cove;
- Arco;
- Exxon/Mobil;
- Gasco;
- Wacker Siltronic;
- Atofina; and
- Gunderson.

DEQ has determined that the Terminal 4 auto storage area is not a source of contamination to the Willamette River. This determination is pending USEPA's concurrence.

Table 3-1
Summary of Potential Contamination Sources
for the Terminal 4 Removal Action Area[1]

Potential Contaminant Source	Substances Potentially Released	Known Spills or Releases
Potential Contaminant Sources Located at Terminal 4 (including Slip 1 and Slip 3 Uplands)		
Cargill hydraulic oil release at Conveyor Building (C-10) [2]	Hydraulic oil	• Remediation of impacted soils initiated at Building C-10 but not complete. Excavations exposed during June 2003 site walk. 11/2003 excavation left contaminated soil onsite due to inaccessibility. • PAH and TPH constituents confirmed in verification samples.
Reported Cargill releases to Slip 1[2]	Gear grease	• In 1984, Cargill had a release of gear grease to Slip 1; cleanup was conducted by Riedel. • In September 1993, approx. ½ gallon of hydraulic oil was released to Slip 1; cleanup was conducted by Riedel.
Cargill Fuel Storage and Handling Area near Building 152[2]	Petroleum constituents	Area groundwater discovered to contain oil in 1992. This area drains to the head of Slip 1.
Cargill fuel oil UST (T4-22) [1]	Fuel oil	None known.
Former Cargill fuel/ oil UST (T4-85) [2]	Used oil	None known.
Former Cargill diesel AST (T4-45) [2]	Diesel	Cat litter observed on ground near tank during October 2003 walk-through indicates past fuel spills have occurred.
Former Cargill diesel AST (T4-47 & 48) [2]	Diesel/used oil	Cargill discovered oil on groundwater in this area in 1992. The area drains to the head of Slip 1.
Cargill hydraulic pumps (west of Railcar Tipper) [2]	Hydraulic oil (staining around units observed)	None known.
Cargill pesticide and rodenticide applications[2]	Weed control chemicals, poisoned bait for rodent control, malathion, phostoxin, weevilcide (liquid form, including carbon tetrachloride and carbon disulfide)	Weed control chemicals applied to ground.
Multiple Cargill sumps[2]	Waste oil, hydraulic oil	• Sump in work pit beneath Railcar Tipper contained discolored and odorous liquid during October 2003 walk-through. • In 01/1989, Spencer Environmental removed 475 gallons of waste oil pumped from the Truck Dump sump (Cargill drawing shows a hose in the Truck Dump broke). • Between 1990 and 1999, Spencer pumped and disposed of approx. 2,045 gallons of oil for recycling and 32 gallon

Potential Contaminant Source	Substances Potentially Released	Known Spills or Releases
		garbage cans of hydraulic oil-soaked wheat and absorbent pads.
Cargill Maintenance Shop[2]	Hydraulic oil, lube oils, lubricants, paints, thinners, solvents, antifreeze, aluminum fiberglass coating, soluble oil, industrial cleaners, epoxies, gear grease, transmission fluid, and motor oils	None known.
Former Cargill Transformer Building[2]	Polychlorinated biphenyls	None known.
Former Cargill Diesel Tanks (T4-23)[2]	Diesel	None known.
Waste piles[2]	Waste piles containing tires, scrap metal, railroad ties, and debris observed during the October 2003 walk-through	None known.
Cargill deep water well[2]	Unknown oil	• Well filled in 1992; field notes indicated 7 feet of oil on top of water between 27 and 34 feet below ground surface. • Spencer Environmental removed 307 gallons of "product" from the well (PCB tests were negative).
Former Cargill Machinery Shop[2]	Chemical storage	None known.
Cargill former Blacksmith Shop[2,4]	Chemical storage	None known.
Cargill "Bull Pen" [2]	Trichloroethylene, primer, paint wastes	Cleanup of bull pen reportedly conducted by Van Waters and Rogers in February 1998.
Cargill Rail Trackage between Rail Track Shed and Berth 401[2]	Contaminants associated with locomotive maintenance operations	Stained soils observed during October 2003 walk-through and reflected in Cargill exit audit of area. Rail area drains to Slip 1.
Rogers AST[3]		Soil staining was observed at the base of the AST in 1989.
IRM Fertilizer AST (T4-79) [3]	Liquid fertilizer	A liquid fertilizer spill from the AST located within the tank containment area occurred around 1984. In 1996, samples taken in the area of the spill revealed that nitrate levels in the soil were non-detect or below 1 mg/kg in all samples.
IRM Boiler Fuel UST (T4-17) [3]	Boiler Fuel	None known.
Former ASTs at Port Maintenance Facility (T4-81, T4-82, T4-83) [4]	Diesel, used oil	None known.
Former USTs at Port Maintenance Facility (T4-16, T4-26, T4-44) [4]	Diesel, gasoline	None known.

Potential Contaminant Source	Substances Potentially Released	Known Spills or Releases
KMBT UST North of Rail Dump Building (T4-43) [4]	Diesel	None known.
Former Tank Car Cleaning Pit at Liquid Bulk Facility[4]	Unknown	None known.
Ore/Concentrate Handling Areas[4]	Metals	None known.
Former Fumigation Plant[4]	Pesticides	None known.
Former USATS Disinfestation Plant[4]	Pesticides	None known.
Former USATS Salvage Yard[4]	Unknown	None known.
Former USATS gasoline fueling station along Carroll Road[4]	Petroleum constituents	None known.
Hazardous material storage at gearlockers and maintenance buildings[4]	Unknown	None known.
Hazardous material storage at former Blacksmith Shop and former Machinery Shop[4]	Unknown	None known.
Former below-ground gas line and fueling station at Boiler House[4]	Petroleum constituents	None known.
Union Pacific Pipeline[4]	Oils, fuels	• 1970 release from leaking valve seal on the Union Pacific pipeline; Standard Oil recovered about 200 gallons of diesel fuel from an overflowing manhole; four sections of piping along the northern pipeline replaced, presumably due to leaks. • Five oil leaks discovered in the original Union Pacific pipeline on November 13 and December 6, 12, and 15, 1970. December 15, 1970, leak occurred during Union Pacific's pipeline repairs when oil flowed through the sand and escaped into the water. • 1971 oil seep into Willamette River from southern bank of Slip 3. Union Pacific recovered some of this oil by digging a

Potential Contaminant Source	Substances Potentially Released	Known Spills or Releases
		trench along the bank of Slip 3 at the place where the oil seepage occurred. Union Pacific also pumped oil out of the ground from several wells that it dug at Terminal 4.
Slip 3 slicks and seeps, possibly associated with Union Pacific pipeline[4]	Oils	• In late 1972 and early 1973, oil slicks began appearing at the head, or eastern end, of Slip 3 • Oil seeping from the head of Slip 3 discovered in 1991.
Former Pencil Pitch Handling[4]	Polycyclic aromatic hydrocarbons.	• Between 1979 and 1988, 25 illegal discharges allegedly occurred through stormwater and directly to the Willamette River when pencil pitch was unloaded by clam shell from ship holds. The Dravo clamshell's outloader protective tents were replaced in 1986. Hall-Buck modified Dravo mechanism in 1988 to better control spillage and wash water. • In 1992 Jones Oregon Stevedoring Co. complained of uncontrolled pencil pitch dust generated by unloading of MV Agness on February 25; dust settled on break-bulk cargo facilities operated by Jones Oregon and interfered with ship unloading. Hall-Buck responded by improving a rear section of the loading hopper enclosure and installing a top cover. • Port warned Hall-Buck in 1996 about repeated pencil pitch spills. Hall-Buck asserts existence of settling sump for capture of contaminated stormwater.
Oil Release at in Slip 3[5]	Oil	• According to the National Response Center, an unknown quantity of oil was released in the vicinity of Berths 410, 415, and 416 on March 18, 1985. No additional information was available.
Diesel Release to Willamette River[5]	Diesel	• According to the National Response Center, approximately 15 gallons of diesel was released to the Willamette River at Terminal 4 on May 2, 1985. No additional information was available.
Vessel Sinking at Slip 1[5]	Unknown	• According to the U.S. Coast Guard, a vessel sinking at Pier 2 on April 14, 1996 caused a sheen on the water in Slip 1. No additional information was available.
Vessel Astypalea, at Slip 1	Oil	• In April 2001, approximately 50 gallons of oil were released when the Astypalea was moored at Slip 1. The U.S. Coast Guard responded and the oil was

Potential Contaminant Source	Substances Potentially Released	Known Spills or Releases
		cleaned up using absorbent materials. The Astypalea was carrying liquid fertilizer (Port of Portland, 2001).
Stormwater Discharges	Unknown	• Permitted stormwater discharges from Port-owned stormwater systems at Slip 1 and Slip 3. • Stormwater discharges from City of Portland-owned stormwater system at Slip 1 (outfall 52c).
Terminal 4 Railyard Operations	Unknown	• Not yet evaluated.
Potential Contaminant Sources on Upland Property Adjacent to Terminal 4		
Schnitzer Steel	Unknown	• Not yet evaluated.
Electrical Substation	Unknown	• Not yet evaluated.
Crown Cork and Seal	Unknown	• Not yet evaluated.
Former Union Carbide site	Unknown	• Not yet evaluated.
Light industrial area (Port marine facility, ChemCentral, Borden, Flint Ink)	Unknown	• Not yet evaluated.
Toyota facility	Unknown	• Not yet evaluated.
Union Pacific auto rail yard	Unknown	• Not yet evaluated.
Harvest Homes	Unknown	• Not yet evaluated.
Various wrecking yards	Unknown	• Not yet evaluated.
Potential Contaminant Sources on the Willamette River and Property Up and Down River from the Removal Action Area		
Cascade General/ Portland Ship Yard	Unknown	• Not yet evaluated.
Triangle Park – Reidel site	Unknown	• Not yet evaluated.
McCormick and Baxter site	PAH	• Not yet evaluated.
Willamette Cove	Unknown	• Not yet evaluated.
Arco	Unknown	• Not yet evaluated.
Exxon/Mobil	Unknown	• Not yet evaluated.
Gasco	Unknown	• Not yet evaluated.
Wacker Siltronic	Unknown	• Not yet evaluated.
Atofina	DDT	• Not yet evaluated.
Gunderson	Unknown	• Not yet evaluated.

Notes:

1 – As is true for the information discussed in Section 2.2, the information in this table is based on the best information available at the time this work plan was prepared. However, this table should be viewed as a work in progress. Additional research, such as that being conducted as part of the upland source control activities described in Sections 1, 2.2, and 3.3.1, may uncover new findings that will augment or supersede the information presented here. Such new information will be incorporated into the EE/CA.

2 – ATC Associates, Inc., 2003.

3 – Port of Portland, 2000.
4 – Slip 1 Upland Area RI Scoping Process.
5 – Lower Willamette Group, 2003.

3.1.1 Known In-Water Spills Not Yet Associated with a Particular Activity or Source

As described in Section 1, the Port is working with DEQ to identify contaminant sources in the Slip 1 and Slip 3 uplands and to perform appropriate source control activities. DEQ is the lead agency for such work pursuant to the Memorandum of Understanding (MOU) that the USEPA, DEQ, and other government agencies signed with regard to the Superfund Site after it was added to the NPL.

3.2 Completed Terminal 4 Investigative and Remedial Actions

The Port has been investigating the nature and extent of contamination at Terminal 4 since 1988. These investigations have been initiated by the Port or tenants in response to historical activities, ongoing operations, or spills of hazardous substances. A number of site investigations and remedial actions have been completed for both the upland and sediment portions of the Terminal 4 facility. Completed investigations and remedial activities for Slip 1 and Slip 3 uplands and sediments are summarized in Tables 3-2, 3-3, and 3-4. More information can be obtained about specific events from the documents referenced in the tables.

Table 3-2
Chronology of Completed Slip 1 Upland and Sediment Investigations and Remedial Activities, 1998 to Present

Year	Event	Reference
1998	• Sediment sampling to provide preliminary dredge prism characterization to support permitting process for the dredging of the Willamette River navigational channel. • Portland Harbor study included three sediment samples from Slip 1 area and one sediment sample from Berth 401.	• Volume 1: Sediment Characterization Study of Local Sponsor's Berths; Columbia and Willamette River Navigation Channel Deepening; Longview and Kalama, Washington, and Portland, Oregon (Hart Crowser, 1999) • Portland Harbor Sediment Investigation Report (Roy F. Weston Inc., 1998)
2000	• Limited sediment characterization study. • Preliminary assessment prepared by Port of Portland for Slip 1 uplands and submitted to DEQ. • Portland Harbor Superfund Site listing for sediments.	• Terminal 4 – Slip 1 and Berth 401 Sediment Characterization Study (Hart Crowser, 2000e) • Preliminary Assessment, Port of Portland, Terminal 4 – Slip 1 (Port of Portland, 2000) • USEPA Administrative Order on Consent for Remedial Investigation/Feasibility Study (USEPA, 2001a)
2003	• Port entered into VCP agreement with DEQ for Slip 1 uplands (VCP investigation and remedial work is ongoing).	• Voluntary Agreement for Remedial Investigation, Source Control Measures, and Feasibility Study (Oregon DEQ, 2003a)

Year	Event	Reference
2003	• Cargill terminates lease of Port property.	• Environmental Site Assessment of CLD Pacific Grain/Cargill Facility (ATC Associates, Inc., 2003)

Table 3-3
Chronology of Completed Slip 3 Upland Investigations and Remedial Activities, 1991 to Present

Year	Event	Reference
1991	• Waste oil UST decommissioning and soil removal at gearlocker facility.	• Underground Storage Tank Decommissioning, Port of Portland Terminal 4 – OTC Gear Locker Building (Hahn and Associates, Inc., 1991)
1993-1994	• Investigation of potential oil seep sources along the former Union Pacific pipeline and Quaker State/gearlocker areas. • Oil-absorbing booms placed in Slip 3 to capture seepage along the bank. • Interim product recovery system installed and pumped groundwater and product from a well to an oil/water separator. Separated water was treated by carbon filtration and discharged to the Willamette River.	• Remedial Investigation Report, Terminal 4, Port of Portland (Century West Engineering Corporation, 1994)
1995	• Soil investigation at former waste oil UST location at gearlocker facility. No Further Action letter issued by DEQ.	• OTC Gear Locker Facility, Port of Portland (Century West Engineering Corporation, 1995)
1996	• Diesel and gasoline UST decommissioning and soil removal at gearlocker facility.	• Report of Underground Storage Tank Decommissioning, Terminal Four – Gear Locker Facility (GeoEngineers, Inc., 1996)
1997	• Investigations at Quaker State site and Union Pacific pipeline to assess whether former operations contributed to subsurface contamination in the vicinity of Slip 3 oil seep. • Union Pacific began manually pumping product from wells and installed a 1-ft-deep interceptor trench along the eastern edge of Slip 3. • Absorbent booms and pads were used to intercept seeping product.	• Former Quaker State Bottling Facility, Port of Portland – Terminal 4 (Kennedy/Jenks Consultants, Inc., 1997) • Site Investigation, Port of Portland – Marine Terminal 4 (Pacific Environmental Group, 1997a) • Additional Subsurface Investigation, Port of Portland – Marine Terminal 4 (Pacific Environmental Group, 1997b) • Status of Interim Activities and Remedial Schedule, Port of Portland - Marine Terminal 4 (Pacific Environmental Group, 1997c)
1998	• DEQ prepared Preliminary Assessment Equivalent/Strategy Recommendation for Slip 3. The facility is given a high priority for further action. • Sections of Union Pacific pipeline were drained and removed. Soil sampling was conducted. Additional soil and groundwater investigations conducted.	• Preliminary Assessment Equivalent/Strategy Recommendation, Port of Portland Terminal 4 (Oregon DEQ, 1998, DEQ Site Assessment Program) • Remedial Investigation/Feasibility Study Work Plan, Terminal 4 Slip 3, Upland (Hart Crowser, 1998)

Year	Event	Reference
1999	• Startup of Interim Action to limit migration of petroleum hydrocarbons with groundwater to the slip. The interim action consists of pumping soil vapor, free-phase liquid petroleum hydrocarbons, and groundwater containing dissolved-phase petroleum hydrocarbons. • Activities of RI work plan, initiated in 1998, concluded.	
2000	• RI report finalized and human health risk assessment and Level 1 scoping ecological risk assessment completed.	• Remedial Investigation Report Terminal 4, Slip 3 Upland (Hart Crowser, 2000c) • Human Health and Ecological Baseline Risk Assessment, Terminal 4, Slip 3 Upland (Hart Crowser, 2000d)
2002	• Port entered into VCP agreement for Slip 3 uplands (VCP work is ongoing).	• Voluntary Agreement for Feasibility Study (Oregon DEQ, 2002)
2002	• Feasibility study report completed.	• Feasibility Study Report, Terminal 4, Slip 3 Upland (Hart Crowser, 2002)
2003	• DEQ issued Record of Decision for Slip 3 upland. The remedy includes: o Removal and offsite disposal of shallow soil in the former Quaker State tank farm area. o Groundwater pumping to remove LNAPL associated with the diesel fuel pipeline release, evaluation of dual-phase (vacuum-enhanced) LNAPL extraction, removal and offsite disposal of contaminated soil at the Slip 3 riverbank, and groundwater monitoring. o An institutional control that identifies residual petroleum hydrocarbon-contaminated areas in the Slip 3 uplands and the need for appropriate contaminated soil or groundwater management.	• Record of Decision, Port of Portland, Terminal 4 Slip 3 Upland, 2003 (Oregon DEQ, 2003b)
2003	• Port entered into VCP Agreement for Slip 1 uplands.	• Voluntary Agreement for Remedial Investigation, Source Control, and Feasibility Study (Oregon DEQ, 2003a).

Table 3-4
Chronology of Completed Slip 3 Sediment Investigations and Remedial Activities, 1988 to Present

Year	Event	Reference
1986	• Vacuum sweeper used to clean up 75%, or about 6-8 cubic yards, of spilled pencil pitch.	
1988	• Sediment investigation included surface grabs and subsurface cores. Sediment was analyzed for pencil	• Sediment Quality Report, Sediment Test Results from Terminal 4 Slip 3, Berths 410, 411, and 412 (Port of Portland, 1994)

Year	Event	Reference
	pitch, polycyclic aromatic hydrocarbons (PAHs), metals, pesticides, oil and grease, grain size, and polychlorinated biphenyls (PCBs).	
1993 – 1994	• USEPA and State of Oregon issue Consent Decree under the Clean Water Act and state law that requires cessation of non-permitted discharges of pencil pitch and remediation of sediment above 0.5% dry weight of pencil pitch. • Additional sampling conducted to delineate the depth distribution of contaminants.	• Federal Consent Decree, Case Number CV 930267 RE (USEPA, 1993a)
1994 - 1995	• Port dredges and disposes of approximately 35,000 cubic yards of sediments containing greater than 0.5% pencil pitch from Slip 3 pursuant to the 1993 consent decree between Port, USEPA and Oregon. In 1995, USEPA determines Port has met its obligations under the consent decree.	• Water Quality Monitoring During Dredging and Disposal of Sediments from Terminal 4 Slip 3 in Portland Harbor – Final Report (Hartman Associates, Inc., 1995)
1997-1998	• Sediment characterization study conducted as part of maintenance dredging requirements for Berth 410. • A clamshell bucketful of pencil pitch containing an estimated 50 to 1,000 pounds of pencil pitch was spilled in the vicinity of Berth 411. Two rounds of dredging, at least one by Hall-Buck, were conducted to remove pencil pitch-contaminated sediments. DEQ provided oversight of the second round of dredging; pencil pitch handling at Terminal 4 ends with the decommissioning of the Dravo equipment. • As part of the Portland Harbor study, DEQ and USEPA conducted a harbor-wide sediment characterization study that included Terminal 4. • DEQ prepares Preliminary Assessment Equivalent/Strategy Recommendation for Slip 3. The facility is given a high priority for further action. • Sediment sampling conducted at Slip 3 as part of a remedial investigation conducted by the Port with oversight from DEQ under the VCP.	• Sediment Characterization Study, River Terminal 4, Slip 3 (Hart Crowser, 1997a) • Pencil Pitch Removal Oversight and Sediment Characterization Report, Terminal 4 Slip 3, Berth 411 (Hart Crowser, 1997b) • Portland Harbor Sediment Investigation Report (Roy F. Weston Inc., 1998) • Preliminary Assessment Equivalent/Strategy Recommendation, Port of Portland Terminal 4 (Oregon DEQ, 1998, DEQ Site Assessment Program) • Remedial Investigation Report, Terminal 4, Slip 3 Sediments (Hart Crowser, 2000a)
2000	• Portland Harbor Superfund Site listing.	• USEPA Administrative Order on Consent for Remedial Investigation/ Feasibility Study (USEPA, 2001a)

3.3 Ongoing Terminal 4 Investigative and Remedial Actions

3.3.1 Upland Source Control Work

An MOU regarding the Portland Harbor Superfund Site was signed by USEPA, DEQ, and other government agencies after the Site was added to the NPL. The MOU designates DEQ as the lead agency for upland source identification and control. The Port is working with DEQ to identify sources in the Slip 1 and Slip 3 uplands and, where appropriate, to perform necessary source control activities.

3.3.1.1 Slip 1

In 2003, the Port and DEQ entered into a Voluntary Agreement for Remedial Investigation, Source Control Measures, and Feasibility Study (Oregon DEQ, 2003a) regarding the Terminal 4 Slip 1 uplands (see Figure 2-1 for upland area boundaries). This agreement requires the Port to investigate the property, conduct a risk assessment and a feasibility study, and identify and evaluate source control measures. Work under this agreement began in late 2003 and will be ongoing during the work specified in this work plan. The Port has arranged for close coordination between the project teams so that new information from either effort will be conveyed to the other in a timely manner.

3.3.1.2 Slip 3

In June 2002, the Port and DEQ entered into a Voluntary Agreement to perform a feasibility study (Oregon DEQ, 2002) at the Slip 3 Upland Area (Figure 2-1). This agreement required the Port to conduct a feasibility study of the Slip 3 Upland Area portion of Terminal 4 to address petroleum contamination in subsurface soil and groundwater. In April 2003, DEQ issued a Record of Decision (Oregon DEQ, 2003b) requiring various cleanup actions to be performed on the Slip 3 uplands to address historical petroleum spills. These actions were to include:

- Quaker State Tank Farm excavation;
- pumping of LNAPL;
- dual-phase extraction;
- riverbank excavation and backfill;
- groundwater monitoring and compliance evaluation; and
- institutional control.

Investigation performed since the Record of Decision was issued indicates that local soil and groundwater conditions, as well as the extent of LNAPL contamination, may be different than previously assumed. Additional investigation is ongoing to assess these conditions and suggests that the volume of LNAPL may be smaller than originally reported. This new information will be incorporated into the design of the remediation system. Work under this agreement began in late 2003 and will be ongoing during the work specified in this work plan. The Port has arranged for close coordination between the project teams so that new information from either effort will be conveyed to the other in a timely manner.

3.3.2 Port of Portland Stormwater Management Program

The Port owns and operates its own storm sewer system at Terminal 4. This system discharges into Slip 1, Slip 3, and the Willamette River either directly or through the City of Portland's storm sewer system. Drainage areas at Terminal 4 are shown on Figure 2-22. The current configuration of the stormwater system at Terminal 4 is shown on Figure 2-23.

Marine terminal stormwater is managed through a variety of regulatory mechanisms, policies and best management practices. National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit No. 101314 (Municipal Permit), on which the Port and the City of Portland are co-permittees, is the foundation permit for stormwater management. The MS4 covers discharges of stormwater from the MS4 within the City of Portland Urban Service Boundary. The DEQ regulates stormwater runoff from Port properties through this permit. As co-permittees, the Port and the City of Portland are authorized to discharge stormwater to public waters while implementing a stormwater management program (SWMP) to reduce the contribution of pollutants in stormwater to the maximum extent practicable. The SWMP consists of a variety of best management practices (BMPs), such as Employee Education, Spill Prevention and Response Planning, Control of Illicit Discharges, Erosion and Sediment Control, and Landscape Maintenance Practices.

The Port's dry season monitoring effort is part of the Illicit Discharge Detection and Removal Program and is designed to detect non-stormwater discharges from Port outfalls. Dry season monitoring of Port-owned outfalls occurs on a 5-year rotation with certain priority outfalls being monitored annually. If a discharge is observed from an outfall, a sample is collected and sent to an independent laboratory for analysis. The Port uses the results of the analysis, combined with observed field conditions, to identify the discharge source and to assess associated risks.

In addition, the Port manages stormwater through Ordinance 361 Storm Water Regulation; through various environmental policies such as Commission Policy No. 6.1.11 Environmental Policy and Environmental Water Resource Policy No. 7.4.16; and through Marine Tenant Program BMPs. Marine terminal tenants are required to comply with the Port's Municipal Permit if they discharge into the system. Sources that discharge waste water to surface water, typically conveyed through the storm sewer system, must obtain an NPDES industrial wastewater permit. Sources not eligible for a general permit must apply for an individual permit. Most marine terminal tenants hold additional industrial permits. Table 3-5 lists the Terminal 4 tenants and their water quality permits.

Table 3-5
Terminal 4 Tenants – Water Quality Permits

Tenant Name	Permit Type
Kinder Morgan Bulk Terminals	NPDES-IND (App No. 988139, File No. 100025) NPDES-IW-O (Permit No. 102446)
International Raw Materials	1200-Z (Permit No. 16055, File No. 110170)
Cargill	MS4 Permit No. 101314
Cereal Food Processors	MS4 Permit No. 101314
Foss Maritime	MS4 Permit No. 101314
Rogers Stevedoring	MS4 Permit No. 101314
Toyota Logistics Services, Inc.	1200-Z (Permit No. 11208, File No. 100726)
Port of Portland	1500-A

The 1200-Z permits are required for point source discharges and are based on a facility's SIC code. These permits are managed through preparation and implementation of a stormwater pollution control plan (SWPCP).

The SWPCP contains a site description and site controls such as BMPs, spill prevention and response procedures, preventive maintenance procedures, and employee education requirements. The 1200-Z permits contain benchmark guideline concentrations. Sampling is required twice a year and visual monitoring is required monthly. An exceedance of benchmarks triggers a requirement to check the SWPCP and implement additional BMPs, as necessary. Table 3-6 describes the benchmarks for the required sampling parameters for the 1200-Z general industrial permits.

Table 3-6
1200-Z Benchmarks

Parameters	Benchmark
TSS	130 mg/L
pH	5.5 - 9 S.U.
Oil and Grease	10 mg/L
Total Copper	0.1 mg/L
Total Lead	0.4 mg/L
Total Zinc	0.6 mg/L
Floating Solids	No Visible
Oil/Grease Sheen	No Visible

Evaluation of stormwater at Terminal 4 is included in the Voluntary Agreement for the Terminal 4 Slip 1 Upland Facility and is being addressed as part of the remedial investigation. The approach to stormwater evaluation will be included in the remedial investigation work plan, which is anticipated for submittal to DEQ in May 2004.

3.3.3 City Stormwater Investigation

In early 2000, the City of Portland and DEQ entered into a Voluntary Cleanup Letter Agreement to address stormwater outfalls owned and operated by the City. This agreement (Oregon DEQ, 2000) requires the City to complete a preliminary assessment of certain outfalls, including Outfall 52C, which drains into Slip 1. The preliminary assessment includes the following:

- a summary of readily available current or historical information on the outfall;
- the results of database searches for facilities within the catchment area of the outfall;
- screening of existing sediment quality results in proximity to the outfall; and
- other steps to evaluate discharges from the outfall and develop priorities and recommendations for future study.

The results of this preliminary assessment were presented in July 2000 (City of Portland, 2000). Metals including cadmium, lead, and zinc as well as PAHs were detected in sediment samples immediately adjacent to outfall 52c.

The City and DEQ also entered into an Intergovernmental Agreement for Remedial Investigation and Source Control (Oregon DEQ, 2003c). This agreement requires the City to evaluate the potential for sediment contamination to result from City-owned outfalls. Work under this agreement is ongoing.

3.4 Summary of Potential Sources of Contamination

Sources of sediment contamination at Terminal 4 are generally understood and include various aspects of past in-river and Terminal 4 operations, including the handling of ore, ore concentrate, pencil pitch, petroleum products, and other cargo. Sediment contamination sources also include activities on the Terminal 4 and adjacent uplands which likely contributed to sediment contamination through spills, stormwater runoff, or groundwater contamination. In many cases, activities that likely contributed to sediment contamination have been discontinued. Potential ongoing sources — from ongoing operations at Terminal 4 or adjacent properties, from residual surface or subsurface contamination at Terminal 4 or adjacent properties, or from sources of contamination in the Willamette River — are currently under investigation. These sources and potential sources are considered in light of existing sediment quality data presented in Section 4 and further discussed in the preliminary conceptual model for the Removal Action Area in Section 5.

4. Summary of Existing Data on Sediment Quality and Toxicity

The Port has been investigating the nature and extent of sediment contamination at Terminal 4 since 1988. Other organizations, including the U.S. Army Corps of Engineers (USACE), the USEPA, and DEQ, have investigated the nature and extent of sediment contamination in the Willamette River and have collected sediment samples from Terminal 4 as part of their investigations. The purpose of this section is to describe the existing body of sediment quality data collected at Terminal 4 through these various projects and to provide context regarding the spatial area likely to require remediation. Table 4-1 summarizes the sediment investigations that have produced data relevant to Terminal 4 sediments. Figures provided by NOAA depict surface and subsurface sediment quality exceedances for copper, lead, zinc, total polycyclic aromatic hydrocarbons (PAHs), DDT, and polychlorinated biphenyls (PCBs) (Appendix D). Because maintenance dredging has occurred periodically in Slip 1 and Slip 3 to maintain operational draft depths at the berths, data from the dredge prisms (i.e., sediment that was dredged and is no longer present at Terminal 4) are not included in Table 4-1 and are not discussed in this work plan.

Sediment chemistry data from the investigations summarized in Table 4-1 were obtained from the NOAA Query Manager 2.51 database for Terminal 4 of the Willamette River. They represent published sediment data collected in the Terminal 4 area for a variety of purposes and include different analytical detection limits and analyte lists. Different classes of constituents were analyzed in each investigation. These differences, however, are generally minor and do not limit the data set for the purposes intended here. Sufficient data exist in each analyte class and for each important constituent to evaluate fundamental statistics such as detection frequency, maximum detected concentration, and minimum detected concentration.

The Port did not compare the data in the database with data in the original reports to assess possible data entry errors. The data in the database are assumed to be entered correctly. Available sediment chemistry data consist only of bulk sediment analytical results. No analytical results are available for sediment leachates or elutriates. On the basis of a database search performed by Striplin Environmental Associates (Berger, 2003), seven subsurface sediment samples were removed from the Terminal 4 sediment database because their locations have been dredged and the data are therefore not representative of existing sediment conditions. The data removed from the Terminal 4 database are:

- For Slip 1, data associated with locations WLCT4L93T408-IT40801, WLCT4L93T408-2T40802, and WLCT4L93T408-3T40803; and
- For Slip 3, data associated with locations WR-WS198SD0290, WR-WS198SD0320, WLCDRE87.5S410.5S410, and WLCDRE87.5S412.5S412.

The remaining surface and subsurface sediment samples in the database are believed to represent sediment that has not been dredged.

This discussion of existing sediment data is categorized by surface and subsurface sediment. Under-pier sediment represents a separate category for discussion; however, no existing sediment quality data were located for under-pier samples. “Surface sediment” refers to sediment samples collected from 0 to 1 ft below mudline. The majority of surface sediment samples from the NOAA database were collected from 0 to 0.33 ft below mudline, although some were collected from 0 to 0.5 ft below mudline. “Subsurface sediment” refers to sediment samples collected below 1 ft below the mudline. The discussion of existing sediment data is further categorized by Slip 1 and Slip 3. For the purposes of this discussion, "Slip 1" includes Slip 1 and Berth 401, and "Slip 3" includes Slip 3, Wheeler Bay, and Pier 5.

Existing sediment chemistry data, along with sediment chemistry data to be collected for the EE/CA (as discussed in Section 7.7), will be used to delineate the horizontal and vertical extent of contaminated sediment that will require removal. The SOW requires that existing sediment chemistry data be compared to the following existing sediment quality guidelines (SQGs) representing a range of levels, including low or no effects, which are:

- Threshold Effects Concentration (TEC) (MacDonald et al., 2000);
- Threshold Effects Level (TEL) (Smith et al., 1996); and
- Effects Range Low (ERL) (Long and Morgan, 1990).

In addition, the existing sediment chemistry data are to be compared to SQGs representing levels at which probable effects are expected:

- Probable Effects Concentration (PEC) (MacDonald et al., 2000);
- Probable Effects Level (PEL) (Smith et al., 1996); and
- Effects Range Medium (ERM) (Long and Morgan, 1990).

Although not required by the SOW, the existing sediment chemistry data were compared to the PELs to make the overall comparison of existing data to SQGs consistent. For example, PECs are the probable effects counterpart to the low effects TECs, and ERMs are the probable effects counterpart to the low effects ERL. The PELs were therefore included because they are the probable effects counterpart to the low effects TEL.

These SQGs are all toxicity-based SQGs. Bioacumulation-based SQGs are not widely available. The specific nature of the bioaccumulation evaluation will be identified after the removal alternatives have been through the conceptual design phase.

Existing sediment chemistry data were compared to these SQGs to evaluate the horizontal and vertical extent of contaminated sediment that requires removal. This comparison was made to fulfill requirements of the SOW and is not intended to imply that the SQGs should be used as cleanup levels for the Removal Action Area. The outcome of the comparison of existing sediment chemistry data to SQGs is discussed in Section 4.4.

4.1 Sediment Quality

In accordance with the SOW, existing sediment chemistry data were also reviewed to establish whether the data fall into the Category 1 or Category 2 data categories used in the Portland Harbor RI/FS Revised Draft Final Programmatic Work Plan protocols (Lower Willamette Group, 2003). Note that this document is being revised based on USEPA comments. The categories are defined as:

- Category 1 data are of known quality and are considered to be acceptable for use in decision making for the RI/FS. There is sufficient information on these data sets to confidently verify that the data, along with associated data qualifiers, accurately represent chemical concentrations present at the time of sampling.

- Category 2 data are of generally unknown or suspect quality. The quality assurance/quality control information shows that data quality is poor or suspect or that essential quality assurance/quality control data (e.g., surrogate recoveries, matrix spike/matrix spike duplicates recoveries) are either incomplete or lacking.

The classification of data into Category 1 and Category 2 is a data quality metric used to evaluate data quality and the appropriateness of using data for decision-making. Data collected as part of the EE/CA work plan will undergo data validation, making it Category 1 data. Ten to twenty percent of the data collected as part of the EE/CA work plan will undergo Level IV data validation, and the remainder will undergo Level III data validation, in accordance with the USEPA's Functional Guidelines (USEPA, 1999, 2002). The data validation classifications of Level III and Level IV are derived from the USEPA contract laboratory program (CLP) (USEPA, 1987). Level III data validation consists of reviewing chains of custody; holding times; field, trip, and method blanks; surrogate, matrix spike/matrix spike duplicate, and laboratory control sample/laboratory control sample duplicate recoveries; field duplicate, laboratory duplicate, matrix spike/matrix spike duplicate, and laboratory control sample/laboratory control sample duplicate relative percent differences; and reporting limits. Level IV data validation consists of a full data validation, including a review of raw data.

Level III data validation is comparable to the Puget Sound Dredge Disposal Analysis quality assurance 1 (QA1) data review, and Level IV data validation is comparable to the Puget Sound Dredge Disposal Analysis quality assurance 2 (QA2) data review (Washington State Department of Ecology, 1989). For consistency with the chemistry analytical work that will be performed in accordance with CLP protocols, data collected as part of the EE/CA work plan will also be validated in accordance with CLP, i.e., Level III and Level IV data validation will be performed.

Table 4-1 identifies the data categories determined for existing sediment quality data.

The Portland Harbor RI/FS Revised Draft Final Programmatic Work Plan states that:

> *Analyses upon which project decisions will be based will utilize Category 1 data. As examples, the ecological and human health risk assessments will use Category 1 data in the risk calculations, and the definition of sediment management areas will rely on Category 1 sediment data. Category 2 data will be used during project scoping. For example, Category 2 tissue data were used to help identify chemicals of interest, and Category 2 sediment data were used in the initial assessment of trends in chemical concentrations, which was useful for defining the site characterization sampling program.*

Category 1 and Category 2 data will be used similarly for the EE/CA. Category 1 and Category 2 data are used in this section to evaluate existing sediment quality. However, additional sediment chemistry data will be collected for the EE/CA, and primarily Category 1 data will be used to delineate the horizontal and vertical extent of contaminated sediment. If existing data will be used in the Removal Action alternatives analysis, the Port will evaluate whether the existing data validation is sufficient or additional data validation is warranted.

Detection limits for the existing sediment data were evaluated, and the results of that evaluation are incorporated into the discussions that follow for each analyte group. Detection limits were evaluated for their appropriateness for the EE/CA (i.e., for delineating the horizontal and vertical extent of contaminated sediment that will require removal). Elevated detection limits could cause data to be unusable for the EE/CA. For example, if an analyte is reported as "not detected" at an elevated detection limit, there may be doubt over whether that analyte was present or not. The reported detection limits for the existing data were considered acceptable for the purposes of the EE/CA; however, as explained below, the EE/CA work plan proposes additional sediment collection to further evaluate the surface and subsurface sediment conditions in the Removal Action Area.

4.2 Surface Sediment

General observations of the existing surface sediment data, based on frequency of detections, range of detected concentrations, and spatial trends in concentrations, are as follows:

- Concentrations of metals, PAHs, and bis(2-ethylhexyl)phthalate (BEP) generally decreased from the head of the slip to the mouth in Slips 1 and 3.
- Concentrations of total PCBs tended to decrease from the head to the mouth of Slip 1.

The existing surface sediment data for Slips 1 and 3 are discussed in greater detail below. The data are presented by constituent class (i.e., metals, PAHs, semivolatile organic compounds, pesticides and PCBs, miscellaneous organics, volatile organic compounds, butyltins, and conventionals), as taken from the NOAA Query Manager 2.51 database. No changes were made to NOAA's categorization of particular compounds into particular constituent classes. The term "miscellaneous organics" is not meant to diminish the potential importance of compounds in that class; it simply means that those compounds were not included in other constituent class categories.

4.2.1 Slip 1 Surface Sediment

Twenty-six surface sediment samples were collected from throughout Slip 1, with three samples located in the vicinity of Berth 401. Figure 4-1 shows Slip 1 surface sediment sample locations. Slip 1 surface sediment sample dates and depths are presented in Table 4-2. These samples were analyzed for at least some of the following constituents: metals, PAHs, semivolatile organic compounds (SVOCs), pesticides, PCBs, miscellaneous organics, volatile organic compounds (VOCs), butyltins including tributyltin (TBT), and conventionals, including total solids, total organic carbon (TOC), and grain size. Different classes of constituents were analyzed in each investigation for Slip 1 surface sediment. Table 4-3 presents the list of constituents for which Slip 1 surface sediment samples were analyzed and summarizes Slip 1 surface sediment chemistry data, including number of samples, number of detections, minimum and maximum detected concentrations, average detected concentration, and minimum and maximum detection limit for each compound analyzed.

4.2.1.1 Metals Results

Slip 1 surface sediment samples were analyzed for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, titanium, vanadium, and zinc. However, not all Slip 1 surface sediment samples were analyzed for this full list of metals. Some Slip 1 surface sediment samples were analyzed for a subset of the full list. Table 4-3 presents the frequency of analysis for each metal. All of the metals for which the Slip 1 surface sediment samples were analyzed were detected at least once except selenium, which was not detected in any of the 15 surface sediment samples analyzed. Cadmium, chromium, copper, lead, and zinc concentrations displayed spatial trends in Slip 1 surface sediment. The maximum concentrations of cadmium, chromium, copper, and zinc occurred in the surface sediment samples collected near the head of Slip 1. The maximum concentration of lead occurred in the surface sediment sample collected near Berth 408. Surface sediment concentrations of cadmium, chromium, copper, lead, and zinc decreased from the head to the mouth of Slip 1. For the remaining metals, no spatial trend was apparent in surface sediment concentrations at Slip 1.

Metals detection limits in Slip 1 surface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 surface sediment samples will be collected and analyzed for a select list of metals to further delineate the horizontal extent of contaminated sediment, as discussed in Section 7.7.

4.2.1.2 PAH Results

Table 4-3 summarizes the individual PAH compounds analyzed in Slip 1 surface sediment samples and their frequency of analysis. All of the PAH compounds for which Slip 1 surface sediment samples were analyzed were detected at least once except 2-nitroaniline, 3,3-dichlorobenzidine, 3-nitroaniline, 4-nitroaniline, and nitrobenzene, which were not detected. Maximum total PAH concentrations were generally observed in surface sediment samples collected at the head of Slip 1. Total PAH surface sediment concentrations tended to decrease from the head to the mouth of Slip 1.

Some detection limits for Slip 1 surface sediment results were elevated, with detection limits ranging from 10 to 35,000 µg/kg for all PAHs. The elevated detection limits for PAHs resulted from sample dilution to obtain concentrations for certain PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, PAH detection limits for Slip 1 surface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 surface sediment samples will be collected and analyzed for a select list of PAHs to further delineate the horizontal extent of contaminated sediment, as discussed in Section 7.7.

4.2.1.3 SVOC Results

Table 4-3 summarizes the individual SVOCs analyzed in Slip 1 surface sediment samples and their frequency of analysis. Six SVOCs (4-methylphenol, benzoic acid, BEP, butylbenzyl phthalate, di-n-octyl phthalate, and di-n-butyl phthalate) were detected in Slip 1 surface sediment samples. The remaining SVOCs for which the samples were analyzed were not detected. Benzoic acid and 4-methylphenol were detected in one of 13 samples and two of 13 samples, respectively, at concentrations slightly above the detection limits. Phthalates, particularly BEP, were more frequently detected. The maximum BEP and butylbenzyl phthalate concentrations were observed in surface sediment samples from the head of Slip 1. Surface sediment concentrations of BEP decreased from the head to the mouth of Slip 1. BEP is a commonly occurring laboratory contaminant related to the use of plastics and may not represent environmental contamination.

The SVOC detection limits for some Slip 1 surface sediment results were elevated, with detection limits ranging from 0.24 to 35,000 µg/kg for all SVOCs. The elevated detection limits for SVOCs resulted from sample dilution to obtain concentrations for PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, SVOC detection limits for surface sediment samples from Slip 1 are acceptable for the purposes of the EE/CA. Additional Slip 1 surface sediment samples will be collected and analyzed for a select list of SVOCs to further delineate the horizontal extent of contaminated sediment, as discussed in Section 7.7.

4.2.1.4 Pesticide and PCB Results

Table 4-3 summarizes the individual pesticides and PCBs analyzed in Slip 1 surface sediment samples and their frequency of analysis. The pesticide total DDT (tDDT, which includes 2,4'-DDD, 2,4'-DDE, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) was detected in 16 of 23 samples in Slip 1 surface sediment samples. The maximum tDDT concentrations occurred in surface sediment samples from Berth 401. There was no apparent spatial trend in tDDT concentrations in Slip 1 surface sediment samples. The pesticides aldrin, alpha-chlordane, gamma-chlordane, endosulfan sulfate, and beta-hexachlorocyclohexane were detected infrequently at concentrations slightly above the detection limit. The remaining pesticides for which the samples were analyzed were not detected.

The PCB compounds Aroclors 1242, 1254, and 1260 were detected in nine, five, and 12 samples, respectively, in Slip 1 surface sediment. Aroclor 1248 was detected in one sample. Maximum concentrations of Aroclors 1242 and 1254 were observed in a surface sediment sample collected from Berth 401. The maximum concentration of Aroclor 1260 was observed near Berth 408. Surface sediment concentrations of total PCB (tPCB, which is the sum of all available PCB data) generally decreased from the head to the mouth of Slip 1.

The pesticide detection limits for Slip 1 surface sediment samples are acceptable for the purposes of the EE/CA. PCB detection limits were elevated for five surface sediment samples collected at the head of Slip 1, with detection limits ranging from 100 to 500 µg/kg for all the Aroclors. Because these elevated detection limits resulted from sample dilution and other important constituents, such as PAHs and metals are detected, they are acceptable for purposes of the EE/CA. Additional Slip 1 surface sediment samples will be collected and analyzed for a select list of pesticides and PCBs to further delineate the horizontal extent of contaminated sediment, as discussed in Section 7.7.

4.2.1.5 Miscellaneous Organic and Butyltin Results

Table 4-3 summarizes the individual miscellaneous organic and butyltin compounds analyzed in Slip 1 surface sediment samples and their frequency of analysis. Dibutyltin dichloride, which was detected in all four of the samples analyzed, was the only miscellaneous organic compound detected in Slip 1 surface sediment samples. In addition, the butyltin compounds monobutyltin chloride and TBT were detected in Slip 1 surface sediment samples. The remaining butyltins were not detected in Slip 1 surface sediment samples. There was no apparent spatial pattern in butyltin surface sediment concentrations in Slip 1.

Some miscellaneous organic detection limits for Slip 1 surface sediments were elevated, with detection limits ranging from 5 to 5,000 µg/kg. In all cases, the elevated detection limits for miscellaneous organics resulted from sample dilution to obtain concentrations for PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, miscellaneous organic detection limits for surface sediment samples from Slip 1 are acceptable for the purposes of the EE/CA. Butyltin detection limits in Slip 1 surface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 surface sediment samples will be collected and analyzed for petroleum hydrocarbons to further delineate the horizontal extent of contaminated sediment, as discussed in Section 7.7.

4.2.1.6 VOC Results

Table 4-3 summarizes the individual VOCs analyzed in Slip 1 surface sediment samples and their frequency of analysis. The VOCs methylene chloride, toluene, and m,p-xylene were each detected once in Slip 1 surface sediment samples. The methylene chloride detection may be an artifact of laboratory method blank contamination, based on the data qualifier. Toluene and m,p-xylene were detected in a surface sediment sample collected at the head of Slip 1. The remaining VOCs for which the samples were analyzed were not detected in Slip 1 surface sediment samples.

One Slip 1 surface sediment sample had elevated detection limits for VOCs ranging from 100 to 2,000 µg/kg as a result of sample dilution to obtain concentrations for toluene and m,p-xylene within the calibration range. Because the elevated detection limits resulted from sample dilution, VOC detection limits for Slip 1 surface sediment samples are acceptable for the purposes of the EE/CA.

4.2.2 Slip 3 Surface Sediment

Fifty-four surface sediment samples were collected throughout Slip 3, with six surface sediment samples collected in Wheeler Bay and four collected near Berth 414. Figure 4-1 shows Slip 3 surface sediment sample locations. Slip 3 surface sediment sample dates and depths are presented in Table 4-2. These samples were analyzed for at least some of the following constituents: metals, PAHs, SVOCs, pesticides, PCBs, miscellaneous organics, VOCs, and conventionals (e.g., ammonia, total solids, total sulfide, total volatile solids, TOC, and grain size). Different classes of constituents were analyzed in each investigation for Slip 3 surface sediment. Table 4-4 presents the list of constituents for which Slip 3 surface sediment samples were analyzed and summarizes Slip 3 surface sediment chemistry data.

Because of sediment resuspension and redistribution resulting from propeller scour and other wave actions, existing surface sediment data for Slip 3 may not represent current sediment quality in the specific location where a given sample was collected. However, the data are likely representative of general surface sediment conditions in Slip 3.

4.2.2.1 Metals Results

Slip 3 surface sediment samples were analyzed for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, titanium, vanadium, and zinc. However, not all Slip 3 surface sediment samples were analyzed for this full list of metals. Some Slip 3 surface sediment samples were analyzed for a subset of the full list. Table 4-4 presents the frequency of analysis for each metal. All of the metals for which the Slip 3 surface sediment samples were analyzed were detected at least once except selenium, which was not detected in the eight samples analyzed. Cadmium, copper, lead, and zinc surface sediment concentrations displayed spatial trends, generally decreasing from the head to the mouth of Slip 3. Copper, lead, and zinc surface sediment concentrations also tended to decrease from north to south in Slip 3.

The detection limits for metals analyzed in Slip 3 surface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 surface sediment samples will be collected and analyzed for a select list of metals to confirm existing surface sediment quality, as discussed in Section 7.7.

4.2.2.2 PAH Results

Table 4-4 summarizes the individual PAHs analyzed in Slip 3 surface sediment samples and their frequency of analysis. The only PAHs not detected in Slip 3 surface sediment samples were 2-nitroaniline, 3,3-dichlorobenzidine, 3-nitroaniline, 4-nitroaniline, and nitrobenzene. Total PAH surface sediment concentrations generally decreased from the head to the mouth of Slip 3. In Wheeler Bay, PAH concentrations tended to be highest in the southeast corner of the bay. There also appears to be a total PAH maximum adjacent to Pier 5.

Some PAH detection limits for Slip 3 surface sediment samples were elevated, with detection limits ranging from 19 to 20,000 µg/kg for all PAHs. The elevated detection limits resulted from sample dilution to obtain concentrations for certain PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, PAH detection limits for surface sediment samples from Slip 3 are acceptable for the purposes of the EE/CA. Additional Slip 3 surface sediment samples will be collected and analyzed for a select list of PAHs to confirm existing surface sediment quality, as discussed in Section 7.7.

4.2.2.3 SVOC Results

Table 4-4 summarizes the individual SVOCs analyzed in Slip 3 surface sediment samples and their frequency of analysis. Of the SVOCs for which the samples were analyzed, only phenols, benzoic acid, and phthalates were detected in Slip 3 surface sediment samples. Surface sediment concentrations of BEP generally decreased from the head to the mouth of Slip 3. The remaining detected SVOCs were not detected with enough frequency to evaluate spatial trends.

Some SVOC detection limits for Slip 3 surface sediment results were elevated, with detection limits ranging from 2 to 100,000 µg/kg for all SVOCs. The elevated detection limits for SVOCs resulted from sample dilution to obtain concentrations for PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, SVOC detection limits for surface sediment samples from Slip 3 are acceptable for the purposes of the EE/CA. Additional Slip 3 surface sediment samples will be collected and analyzed for a select list of SVOCs to confirm existing surface sediment quality, as discussed in Section 7.7.

4.2.2.4 Pesticide and PCB Results

Table 4-4 summarizes the individual pesticides and PCBs analyzed in Slip 3 surface sediment samples and their frequency of analysis. The only pesticides detected in Slip 3 surface sediment samples were DDD, DDE, and DDT. However, the data density for DDD, DDE, and DDT in Slip 3 surface sediment samples is not adequate for an evaluation of spatial trends.

Aroclor 1260, the only Aroclor detected in Slip 3 surface sediment samples, was detected in one sample. Data density is insufficient to evaluate spatial trends.

Some pesticide detection limits for surface sediment samples from Slip 3 were elevated, with detection limits ranging from 0.97 to 20,000 µg/kg for all pesticides. Some of the elevated detection limits (e.g., hexachlorobenzene with a maximum detection limit of 20,000 µg/kg) resulted from sample dilution to obtain concentrations for PAHs within the calibration range. One Slip 3 surface sediment sample from the northeast portion of Slip 3 had elevated detection limits for MCPA (2-methyl-4-chlorophenoxyacetic acid) of 3,300 µg/kg and for MCPP (2-[2-methyl-4-chlorophenoxy] propionic acid) of 4,600 µg/kg. Because these elevated detection limits resulted from sample dilution and other important constituents, such as PAHs and metals are detected, they are acceptable for purposes of the EE/CA. PCB detection limits in Slip 3 surface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 surface sediment samples will be collected and analyzed for a select list of pesticides and PCBs to confirm existing surface sediment quality, as discussed in Section 7.7.

4.2.2.5 Miscellaneous Organic Results

Table 4-4 summarizes the individual miscellaneous organics analyzed in Slip 3 surface sediment samples and their frequency of analysis. Miscellaneous organic compounds and mixtures, including diesel, lube oil, pencil pitch, phytane, and pristane, were analyzed and detected in Slip 3 surface sediment samples.

Diesel detection limits for Slip 3 surface sediment samples were elevated, ranging from 25,000 to 250,000 µg/kg. The elevated detection limits for diesel resulted from sample dilution to obtain concentrations for pencil pitch within the calibration range. Because the elevated detection limits resulted from sample dilution, miscellaneous organic detection limits for Slip 3 surface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 surface sediment samples will be collected and analyzed for petroleum hydrocarbons to confirm existing surface sediment quality, as discussed in Section 7.7.

4.2.2.6 VOC Results

Table 4-4 summarizes the individual VOCs analyzed in Slip 3 surface sediment samples and their frequency of analysis. No VOCs were detected in Slip 3 surface sediment samples. Detection limits for VOCs in Slip 3 surface sediment samples are acceptable for the purposes of the EE/CA.

4.3 Under-Pier Sediment

No existing data were located for under-pier sediment.

4.4 Subsurface Sediment

General observations of the existing subsurface sediment data, based on frequency of detections, range of detected concentrations, and vertical trends in concentrations, are as follows:

- Concentrations of lead and zinc generally increased from surface to subsurface.
- Concentrations of total PAHs tended to be greater in the surface than in the subsurface.

The existing subsurface sediment data for Slips 1 and 3 are discussed in greater detail below.

4.4.1 Slip 1 Subsurface Sediment

Five subsurface sediment cores were collected in and near Slip 1: one core in the southeast end of Slip 1, two cores outside the Removal Action Area in the vicinity of Berth 401, and two cores outside the Removal Action Area at the southwest end of the slip. Six subsurface sediment samples were collected from the five cores; the subsurface samples generally extended to between 2 and 6 ft below mudline and represented whole core composites. Three of the six samples included surface sediment (i.e., the top of the sample was at 0 ft below the mudline). Those three samples were neither distinctly surface nor distinctly subsurface sediment, but rather a combination of both. For the purposes of this work plan, the samples are treated as subsurface sediment samples. Figure 4-2 shows Slip 1 subsurface sediment sample locations. Slip 1 subsurface sediment sample dates and depths are presented in Table 4-2. These samples were analyzed for metals, PAHs, SVOCs, pesticides, PCBs, miscellaneous organics, and conventionals (e.g., ammonia, total solids, total sulfide, total volatile solids, TOC, acid volatile sulfides, and grain size). Different classes of constituents were analyzed in each investigation for Slip 1 subsurface sediment. Table 4-5 summarizes Slip 1 subsurface sediment chemistry data and presents the list of constituents for which Slip 1 subsurface sediment samples were analyzed.

4.4.1.1 Metals Results

Slip 1 subsurface sediment samples were analyzed for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc. However, not all Slip 1 subsurface sediment samples were analyzed for this full list of metals. Some Slip 1 subsurface sediment samples were analyzed for a subset of the full list. Table 4-5 presents the frequency of analysis for each metal. All of the metals for which Slip 1 subsurface sediment samples were analyzed were detected at least once except thallium, which was not detected in the one sample analyzed. A sediment core collected in the vicinity of Berth 408 contained the maximum subsurface concentrations of cadmium, chromium, copper, lead, and zinc. Subsurface concentrations of lead tended to be greater than in surface sediment samples from Slip 1.

The metals detection limits in Slip 1 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 subsurface sediment samples will be collected and analyzed for a select list of metals to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.1.2 PAH Results

Table 4-5 summarizes the individual PAHs analyzed in Slip 1 subsurface sediment samples and their frequency of analysis. All of the PAHs for which Slip 1 subsurface sediment samples were analyzed were detected at least once except 2-nitroaniline, 3,3-dichlorobenzidine, 3-nitroaniline, 4-nitroaniline, and nitrobenzene, which were not detected. Generally, total PAH concentrations in Slip 1 subsurface sediment samples tended to be less than in surface sediment samples.

Some PAH detection limits for Slip 1 subsurface sediment samples were elevated, with detection limits ranging from 19 to 200 µg/kg for all PAHs. The elevated detection limits resulted from sample dilution to obtain concentrations for certain PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, PAH detection limits for subsurface sediment samples from Slip 1 are acceptable for the purposes of the EE/CA. Additional Slip 1 subsurface sediment samples will be collected and analyzed for a select list of PAHs to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.1.3 SVOC Results

Table 4-5 summarizes the individual SVOCs analyzed in Slip 1 subsurface sediment samples and their frequency of analysis. The SVOCs 4-methylphenol, BEP, and butylbenzyl phthalate were the only SVOCs detected in Slip 1 subsurface sediment samples. Butylbenzyl phthalate and 4-methylphenol were detected in one and two samples, respectively, at concentrations slightly above the detection limits. BEP was detected in one of three samples; the sample was collected near Berth 408.

Some SVOC detection limits for Slip 1 subsurface sediment samples were elevated, with detection limits ranging from 1 to 1,000 µg/kg for all SVOCs. The elevated detection limits resulted from sample dilution to obtain concentrations for PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, SVOC detection limits for Slip 1 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 subsurface sediment samples will be collected and analyzed for a select list of SVOCs to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.1.4 Pesticide and PCB Results

Table 4-5 summarizes the individual pesticides and PCBs analyzed in Slip 1 subsurface sediment samples and their frequency of analysis. The pesticides methoxychlor and tDDT were detected in Slip 1 subsurface sediment samples. Methoxychlor was detected in one sample at an estimated concentration below the detection limit. Total DDT was detected in all three subsurface samples analyzed. The maximum concentration of tDDT was detected in the vicinity of Berth 401. Pesticide detection limits in Slip 1 subsurface sediment samples are acceptable for the purposes of the EE/CA.

Aroclor 1260 was detected in subsurface sediment samples collected near Berth 401 and at the southwest end of Slip 1. The remaining Aroclors were not detected in Slip 1 subsurface sediment samples. PCB detection limits for Slip 1 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 subsurface sediment samples will be collected and analyzed for a select list of pesticides and PCBs to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.1.5 Miscellaneous Organic Results

Table 4-5 summarizes the individual miscellaneous organics analyzed in Slip 1 subsurface sediment samples and their frequency of analysis. Miscellaneous organics were not detected in Slip 1 subsurface sediment samples. Miscellaneous organic detection limits for Slip 1 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 1 subsurface sediment samples will be collected and analyzed for petroleum hydrocarbons to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.2 Slip 3 Subsurface Sediment

Ten subsurface sediment cores were collected throughout the Slip 3 area, with one core located in Wheeler Bay and one core located north of Berth 414. Nineteen subsurface sediment samples were collected from the 10 cores; the subsurface sediment samples generally extended to between 2 and 4 ft below the mudline and were generally sampled in 2-ft intervals (e.g., surface to 2 ft and 2 to 4 ft below mudline). Nine of the 10 cores were collected in 1998 (Hart Crowser, 2000a). The core barrels were 14 ft long. The cores generally contained good (i.e., greater than 10 ft) recovery. However, although long cores were collected, only two samples from each core representing the top 4 ft were analyzed for chemistry. Figure 4-2 shows Slip 3 subsurface sediment sample locations. Slip 3 subsurface sediment sample dates and depths are presented in Table 4-2. These samples were analyzed for metals, PAHs, SVOCs, pesticides, miscellaneous organics, VOCs, and conventionals (e.g., ammonia, total solids, total sulfide, total volatile solids, TOC, and grain size). Different classes of constituents were analyzed in each investigation for Slip 3 subsurface sediment. Table 4-6 summarizes Slip 3 subsurface sediment chemistry data and presents the list of constituents for which Slip 3 subsurface sediment samples were analyzed.

4.4.2.1 Metals Results

Slip 3 subsurface sediment samples were analyzed for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc. However, not all Slip 3 subsurface sediment samples were analyzed for this full list metals. Some Slip 3 subsurface sediment samples were analyzed for a subset of the full list. Table 4-6 presents the frequency of analysis for each metal. All of the metals for which Slip 3 subsurface sediment samples were analyzed were detected at least once except thallium, which was not detected in the one sample analyzed. Lead and zinc concentrations tended to be greater in the Slip 3 subsurface sediment samples than in Slip 3 surface sediment.

The metals detection limits in Slip 3 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 subsurface sediment samples will be collected and analyzed for a select list of metals to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.2.2 PAH Results

Table 4-6 summarizes the individual PAHs analyzed in Slip 3 subsurface sediment samples and their frequency of analysis. All of the PAHs for which Slip 3 subsurface sediment samples were analyzed were detected at least once except 2-nitroaniline, 3,3-dichlorobenzidine, 3-nitroaniline, 4-nitroaniline, acenaphthylene, and nitrobenzene, which were not detected. Generally, subsurface concentrations of total PAHs tended to be less than in surface sediment. No consistent trend was observed in total PAH subsurface sediment concentrations in the cores. The highest total PAH concentration occurred sometimes in the 0- to 2-ft interval and sometimes in the 2- to 4-ft interval. The cores containing the highest total PAH concentrations in the 2- to 4-ft interval were collected throughout Slip 3 (i.e., not located within a distinct area).

Some PAH detection limits for Slip 3 subsurface sediment samples were elevated, with detection limits ranging from 20 to 4,000 µg/kg for all PAHs. The elevated detection limits resulted from sample dilution to obtain concentrations for certain PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, PAH detection limits for Slip 3 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 subsurface sediment samples will be collected and analyzed for a select list of PAHs to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.2.3 SVOC Results

Table 4-6 summarizes the individual SVOCs analyzed in Slip 3 subsurface sediment samples and their frequency of analysis. The only SVOC detected in Slip 3 subsurface sediment samples was BEP, which was detected in three of the 19 samples analyzed. Two of the three detections of BEP were at concentrations slightly above the detection limit. Because BEP is a common laboratory contaminant, it is possible that the low concentrations of BEP resulted from laboratory contamination of the samples with plasticware, such as gloves or bags.

Some SVOC detection limits for Slip 3 subsurface sediment samples were elevated, with detection limits ranging from 5 to 20,000 µg/kg for all SVOCs. The elevated detection limits resulted from sample dilution to obtain concentrations for PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, SVOC detection limits for Slip 3 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 subsurface sediment samples will be collected and analyzed for a select list of SVOCs to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.2.4 Pesticide Results

Table 4-6 summarizes the individual pesticides analyzed in Slip 3 subsurface sediment samples and their frequency of analysis. Hexachlorobenzene, hexachlorocyclopentadiene, and isophorone are the only pesticides for which Slip 3 subsurface sediment samples were analyzed. These three compounds were not detected.

Some pesticide detection limits for Slip 3 subsurface sediment samples were elevated, with detection limits ranging from 20 to 4,000 µg/kg for all pesticides. The elevated detection limits resulted from sample dilution to obtain concentrations for PAHs within the calibration range. Because the elevated detection limits resulted from sample dilution, pesticide detection limits for Slip 3 subsurface sediment samples are acceptable for the purposes of the EE/CA. Additional Slip 3 subsurface sediment samples will be collected and analyzed for a select list of pesticides to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.2.5 Miscellaneous Organic Results

Table 4-6 summarizes the individual miscellaneous organics analyzed in Slip 3 subsurface sediment samples and their frequency of analysis. Pencil pitch was the only miscellaneous organic analyte detected in Slip 3 subsurface sediment samples. The highest concentrations of pencil pitch were observed in cores from the head of Slip 3 and from the southeastern portion of Wheeler Bay.

Diesel detection limits for Slip 3 subsurface sediment samples were elevated, ranging from 25,000 to 100,000 µg/kg. The elevated detection limits resulted from sample dilution to obtain concentrations for pencil pitch within the calibration range. Because the elevated detection limits resulted from sample dilution, miscellaneous organic detection limits for subsurface sediment samples from Slip 3 are acceptable for the purposes of the EE/CA. Additional Slip 3 subsurface sediment samples will be collected and analyzed for petroleum hydrocarbons to delineate the horizontal and vertical extent of contaminated sediment, as discussed in Section 7.7.

4.4.2.6 VOC Results

Table 4-6 summarizes the individual VOCs analyzed in Slip 3 subsurface sediment samples and their frequency of analysis. The only VOC detected in Slip 3 subsurface sediment samples was m,p-xylene, which was detected at the detection limit in one sample from the southeast end of Wheeler Bay. Detection limits for VOCs in Slip 3 subsurface sediment samples are acceptable for the purposes of the EE/CA.

4.5 Constituents of Potential Concern

Existing sediment chemistry data, along with sediment chemistry data collected for the EE/CA (as discussed in Section 7.7), will be used to delineate the horizontal and vertical extent of contaminated sediment that requires removal. To evaluate the extent of sediment that requires removal, existing sediment chemistry data were compared to the SQGs stated in the SOW (i.e., TEC, TEL, ERL, PEC, PEL, and ERM). Use of these SQGs does not imply that the SQGs should be used as cleanup levels for the Removal Action Area.

The SQGs fall into two categories: low (i.e., threshold) effects guidelines (TEC, TEL, and ERL) and probable effects guidelines (PEC, PEL, and ERM). The TEC, TEL, and ERL represent concentrations below which toxicity effects are unlikely to be observed. The PEC, PEL, and ERM represent concentrations above which toxicity effects are likely to be observed. However, these generic SQGs were developed over a variety of conditions and using mixtures of contaminants. Removal Action Area-specific conditions will determine the actual effects likely to occur. Removal Action Area sediments exhibiting concentrations below the low effects SQGs are unlikely to cause toxicity and should not require removal. Sediment chemistry concentrations that fall between the low effects and probable effects SQGs represent a gray area in which toxicity effects may occur; therefore, sediments containing chemistry concentrations above the low effects and below the probable effects SQGs may cause toxicity and may need removal. Sediments containing chemistry concentrations above the probable effects SQGs require further delineation and investigation to determine whether they are likely to cause toxicity and likely require removal. Further delineation will include a cost analysis to compare the cost of possibly dredging the sediment that contains chemistry concentrations in the "gray area" versus the cost of capping these sediments.

These SQGs are all toxicity-based. Bioaccumulation-based SQGs are not widely available. The specific nature of the bioaccumulation evaluation will be identified after the removal alternatives have been through the conceptual design phase. The maximum, minimum, and average concentrations of existing Slip 1 surface sediment, Slip 3 surface sediment, Slip 1 subsurface sediment, and Slip 3 subsurface sediment data were compared to the TEC, TEL, ERL, PEC, PEL, and ERM SQGs. This comparison is illustrated on Figures 4-3 and 4-4 for surface and subsurface chemistry, respectively. Figures 4-3 and 4-4 present the SQG comparison for a select list of constituents that, based on site history and sediment chemistry, are likely constituents of potential concern (COPCs) for the site. On the figures, the SQGs are represented by the lowest sediment quality guideline (i.e., the lowest low effects SQG) and the highest sediment quality guideline (i.e., the highest probable effects SQG).

Figure 4-3 shows that the maximum concentrations of metals and PAHs in Slip 1 surface sediment samples exceed the probable effects SQGs and that Slip 3 surface sediment samples contain average and maximum metals and PAH concentrations above the probable effects SQGs. Total DDT and tPCB results fall between the low and probable effects SQGs for Slip 1 and Slip 3 surface sediment samples.

Figure 4-4 shows that the maximum metals concentration in Slip 1 subsurface sediment samples exceeds the probable effects SQGs. PAHs, tDDT, and tPCB concentrations fall between the low effects and probable effects SQGs for Slip 1 subsurface sediment samples. However, the number of Slip 1 subsurface sediment samples analyzed for these compounds is limited. For Slip 3 subsurface sediment samples, the maximum and average metals and PAH concentrations are above the probable effects SQGs. Slip 3 subsurface sediment samples were not analyzed for tDDT and tPCB.

Compounds that were not detected or were detected only infrequently at concentrations slightly above the detection limits—e.g., pesticides except for tDDT, SVOCs except for phthalates, and miscellaneous organics except for pencil pitch—were not carried forward as COPCs. Compounds that were occasionally detected, such as VOCs and TBT, were also not carried forward as COPCs because of the low probability that these constituents are present in sediment at concentrations of concern. The VOCs were infrequently detected; petroleum products known to have been handled at Terminal 4, such as diesel fuel, lube oil, and Bunker C fuel, generally do not contain the range of petroleum hydrocarbons that includes the VOCs. Similarly, butyltin compounds (e.g., TBT) are not expected to be common contaminants in the Removal Action Area sediments given the site history. Because TBT is an antifouling agent used in marine ship-hull paint, it is often detected in shipyard sediments impacted by paint chips from shipbuilding and ship repair. The available history indicates that shipyard activities have not occurred at Terminal 4. Although TBT may leach from ship-hull paint and become entrained in the sediment column, such an effect is not considered a likely ongoing source of contamination to sediment in the Removal Action Area because the International Maritime Organization has banned TBT antifoulants in marine paint; the ban will take effect in 2008 (http://www.imo.org/home.asp). The low frequency of detection and the low detected concentrations of pesticides (except tDDT), SVOCs (except phthalates), miscellaneous organics (except pencil pitch), VOCs, and butyltins indicate they are unlikely contaminants in the Removal Action Area and they will not drive cleanup.

Based on the existing data, metals, PAHs, phthalates, tDDT, tPCB, and petroleum hydrocarbons are the COPCs for sediment in the Removal Action Area. These COPCs were determined on the basis of frequency of detection, range of detected concentrations, lateral and vertical trends in concentrations, comparison to sediment quality guidelines, site uses, and sources. The list of COPCs may be revised when additional data proposed for collection in this work plan have been reviewed.

4.6 Summary of Sediment Toxicity Testing Data

Sediment toxicity testing data are available for the Removal Action Area from the Slip 3 Remedial Investigation Report (Hart Crowser, 2000a). Sixteen sediment samples from Slip 3 and the immediate vicinity were tested: 14 from Slip 3, one from Wheeler Bay, and one from the Pier 5 area just upstream of the Slip 3 mouth (Figure 4-5). In addition, two reference area samples were collected from the Columbia River downstream of the Willamette River confluence. Two reference samples were needed to account for the range in grain size of the Slip 3 sediment samples. Test sediments with less than 59.5% fines were compared to reference sample Ref-C; those with greater than 59.5% fines were compared to reference sample Ref-B. The study area and reference sampling locations were approved by DEQ.

The toxicity tests were conducted according to standard test protocols (USEPA, 1994b; ASTM, 1995). The tests employed were:

- acute 10-day amphipod survival test (*Hyallela azteca*);
- acute 10-day midge survival test (*Chironomus tentans*); and
- chronic 10-day midge growth test (*Chironomus tentans*).

Results of the tests are shown in Tables 4-7, 4-8, and 4-9 as they appeared in Hart Crowser (2000a). Decision criteria were based on the Dredge Management Evaluation Framework for the Lower Columbia River Management Area (USACE et al., 1998). For amphipod survival, tests were considered to fail if the mortality in the test samples exceeded that of reference samples by more than 15% and results in test samples were statistically different from reference (alpha $\leq$ 0.05). Similarly, midge survivorship bioassays failed if mortality in test samples exceeded reference samples by more than 20% and test sample results were statistically different from reference (alpha $\leq$ 0.05). The midge growth test failed if test sample biomass was less than 60% of reference and test sample results were statistically different from reference (alpha $\leq$ 0.05).

Tests were conducted in two phases. Phase I used samples from areas of low to moderate contamination. Phase II was conducted with samples from more contaminated areas. In general, samples from the outer (i.e., riverward) half of Slip 3 did not fail any toxicity tests (samples HCS26, HCS28, HCS30, HCS35, HCS36, HCS39, and HCS42). Six of nine (HCS01, HCS04, HCS05, HCS07, HCS16, and HCS22) samples tested from the inland half of Slip 3 failed at least one of the toxicity tests. Although correlation with contaminant concentrations were difficult to discern, test failures were more frequent in the more contaminated areas of Slip 3.

Table 4-1
Summary of Existing Sediment Investigation Reports for Terminal 4

Date	Reference	Activity	Number of Surface Sediment Samples		Number of Subsurface Sediment Samples		Data Category (a)
			Slip 1	Slip 3	Slip 1	Slip 3	
1987	USACE, 1987b. Proposal for PCB/metal tests in Columbia/Willamette sediments.	Surface sediment samples collected in the Willamette River.	1	2	0	0	2
1988	USACE, 1988. Willamette River Raw Data1986-1988.	Subsurface sediment samples.	0	0	2	0	2
1995	Hartman Associates / Fishman Environmental Services, 1995. Chemical Characterization of Sediments Adjacent to Storm Water Discharges in the Willamette River Near Portland.	Surface sediment samples collected in the Willamette River to characterize the impact of stormwater discharge to surface sediment quality.	5	0	0	0	1
1997	Roy F. Weston, Inc., 1998. Portland Harbor Sediment Investigation Report, Multnomah County, Oregon.	As part of the Portland Harbor Study, USEPA and DEQ conducted a harbor-wide sediment characterization study that included Terminal 4.	5	7	1	1	1,2 (b)
1998	Hart Crowser, 1999. Volume 1: Sediment Characterization Study of Local Sponsor's Berths; Columbia and Willamette River Navigation Channel Deepening; Longview and Kalama, Washington, and Portland, Oregon.	Sediment sampling event to provide preliminary dredge prism characterization to support permitting process for the dredging of the Willamette River Navigational Channel.	0	0	2	0	1
1998	Hart Crowser, 2000a. Remedial Investigation Report, Terminal 4, Slip 3 Sediments, Portland, Oregon, April 18, 2000.	Sediment sampling conducted at Terminal 4, Slip 3 as part of a remedial investigation conducted by the Port with oversight from DEQ under the Voluntary Cleanup Program.	0	44	0	9	1
1999	USACE, 1999. Willametter River Sediment Data - 1997 CRCD Project.	Subsurface sediment samples.	0	0	1	0	1,2 (c)
2000	Hart Crowser, 2000e. Terminal 4 –Slip 1 and Berth 401 Sediment Characterization Study, May 31, 2000.	Limited sediment characterization study.	10	0	0	0	2
2002	Unknown	Round 1 sediment sampling of Portland Harbor.	5	1	0	0	1 (d)

a. Data categories from the Portland Harbor RI/FS Work Plan. See Section 4 for a discussion of data categories.
b. Chlorinated phenoxy herbicides were classified as Category 2. The remaining data are Category 1.
c. Grain size and total volatile solids were classified as Category 2. The remaining data are Category 1.
d. These data were not classified in the Portland Harbor RI/FS Work Plan. However, since this work was done for the Portland Harbor RI/FS, it was assumed the data are Category 1.

Table 4-2
Existing Sediment Sample Depths

Database Station ID (a)	Database Sample ID (a)	Sample Date	Upper Sample Depth (ft)	Lower Sample Depth (ft)	Sample ID from Original Report	Source of Data (a)
Slip 1 Surface Samples						
28001	2801	12/1/1982	0.00	0.50	87.2/5.2.2/5.2	USACE, 1987b
51001	5101	11/19/1999	0.00	0.33	99lip101lip101	Hart Crowser, 2000e
51003	5101	11/19/1999	0.00	0.33	99lip103lip103	Hart Crowser, 2000e
51005	5101	11/19/1999	0.00	0.33	99lip105lip105	Hart Crowser, 2000e
51006	5101	11/19/1999	0.00	0.33	99lip106lip106	Hart Crowser, 2000e
51007	5101	11/19/1999	0.00	0.33	99lip107lip107	Hart Crowser, 2000e
51011	5101	11/19/1999	0.00	0.33	99lip111lip111	Hart Crowser, 2000e
51012	5101	11/19/1999	0.00	0.33	99lip112lip112	Hart Crowser, 2000e
51014	5101	11/19/1999	0.00	0.33	99lip114lip114	Hart Crowser, 2000e
51016	5101	11/19/1999	0.00	0.33	99lip116lip116	Hart Crowser, 2000e
51018	5101	11/19/1999	0.00	0.33	99lip118lip118	Hart Crowser, 2000e
75011	7501	7/18/1994	0.00	0.33	94J16PPA438221	Hartman Associates / Fishman Environmental Services, 1995
75012	7501	7/18/1994	0.00	0.33	94J16PPB438222	Hartman Associates / Fishman Environmental Services, 1995
75013	7501	7/18/1994	0.00	0.33	94J16PPC438223	Hartman Associates / Fishman Environmental Services, 1995
75014	7501	7/18/1994	0.00	0.33	94J16PPD438224	Hartman Associates / Fishman Environmental Services, 1995
75015	7501	7/18/1994	0.00	0.33	94J16PPE438225	Hartman Associates / Fishman Environmental Services, 1995
76016	7601	9/18/1997	0.00	0.33	WR-WSI98SD0160	Roy F. Weston, Inc., 1998
76021	7601	9/18/1997	0.00	0.33	I98SD0210000CC	Roy F. Weston, Inc., 1998
76021	7602	9/18/1997	0.00	0.33	I98SD021000CCD	Roy F. Weston, Inc., 1998
76022	7601	9/18/1997	0.00	0.33	WR-WSI98SD0220	Roy F. Weston, Inc., 1998
76023	7601	9/18/1997	0.00	0.33	WR-WSI98SD0230	Roy F. Weston, Inc., 1998
03R004SD	C11	10/18/2002	0.00	0.50	3R004SDS015C11	Round 1 Sediment Sampling 2002 of Portland Harbor
03R004SD	C12	10/18/2002	0.00	0.50	3R004SDS015C12	Round 1 Sediment Sampling 2002 of Portland Harbor

Table 4-2
Existing Sediment Sample Depths

Database Station ID (a)	Database Sample ID (a)	Sample Date	Upper Sample Depth (ft)	Lower Sample Depth (ft)	Sample ID from Original Report	Source of Data (a)
03R004SD	C20	10/18/2002	0.00	0.50	3R004SDS015C20	Round 1 Sediment Sampling 2002 of Portland Harbor
03R004SD	C30	10/18/2002	0.00	0.50	3R004SDS015C30	Round 1 Sediment Sampling 2002 of Portland Harbor
04R003SD	C00	10/24/2002	0.00	0.50	4R003SDS015C00	Round 1 Sediment Sampling 2002 of Portland Harbor
Slip 3 Surface Samples						
28002	2801	12/1/1982	0.00	0.50	87.5S410.5S410	USACE, 1987b
28003	2801	7/1/1983	0.00	0.50	87.5S412.5S412	USACE, 1987b
50001	5001	10/13/1998	0.00	0.33	4J98HCS01HCS01	Hart Crowser, 2000
50002	5001	10/13/1998	0.00	0.33	4J98HCS02HCS02	Hart Crowser, 2000
50003	5001	10/13/1998	0.00	0.33	4J98HCS03HCS03	Hart Crowser, 2000
50004	5001	10/13/1998	0.00	0.33	4J98HCS04HCS04	Hart Crowser, 2000
50005	5001	10/13/1998	0.00	0.33	4J98HCS05HCS05	Hart Crowser, 2000
50006	5001	10/13/1998	0.00	0.33	4J98HCS06HCS06	Hart Crowser, 2000
50007	5002	10/13/1998	0.00	0.33	4J98HCS07HCS07	Hart Crowser, 2000
50008	5001	10/13/1998	0.00	0.33	4J98HCS08HCS08	Hart Crowser, 2000
50009	5001	10/13/1998	0.00	0.33	4J98HCS09HCS09	Hart Crowser, 2000
50010	5001	10/14/1998	0.00	0.33	4J98HCS10HCS10	Hart Crowser, 2000
50011	5001	10/14/1998	0.00	0.33	4J98HCS11HCS11	Hart Crowser, 2000
50012	5001	10/14/1998	0.00	0.33	4J98HCS12HCS12	Hart Crowser, 2000
50013	5003	10/14/1998	0.00	0.33	4J98HCS13HCS13	Hart Crowser, 2000
50014	5001	10/14/1998	0.00	0.33	4J98HCS14HCS14	Hart Crowser, 2000
50015	5001	10/14/1998	0.00	0.33	4J98HCS15HCS15	Hart Crowser, 2000
50016	5001	10/14/1998	0.00	0.33	4J98HCS16HCS16	Hart Crowser, 2000
50017	5001	10/14/1998	0.00	0.33	4J98HCS17HCS17	Hart Crowser, 2000
50018	5001	10/15/1998	0.00	0.33	4J98HCS18HCS18	Hart Crowser, 2000
50019	5001	10/15/1998	0.00	0.33	4J98HCS19HCS19	Hart Crowser, 2000
50020	5001	10/15/1998	0.00	0.33	4J98HCS20HCS20	Hart Crowser, 2000
50021	5001	10/15/1998	0.00	0.33	4J98HCS21HCS21	Hart Crowser, 2000
50022	5002	10/14/1998	0.00	0.33	4J98HCS22HCS22	Hart Crowser, 2000
50023	5001	10/14/1998	0.00	0.33	4J98HCS23HCS23	Hart Crowser, 2000

Table 4-2
Existing Sediment Sample Depths

Database Station ID (a)	Database Sample ID (a)	Sample Date	Upper Sample Depth (ft)	Lower Sample Depth (ft)	Sample ID from Original Report	Source of Data (a)
50024	5001	10/14/1998	0.00	0.33	4J98HCS24HCS24	Hart Crowser, 2000
50025	5001	10/14/1998	0.00	0.33	4J98HCS25HCS25	Hart Crowser, 2000
50026	5001	10/14/1998	0.00	0.33	4J98HCS26HCS26	Hart Crowser, 2000
50027	5003	10/14/1998	0.00	0.33	4J98HCS27HCS27	Hart Crowser, 2000
50028	5001	10/14/1998	0.00	0.33	4J98HCS28HCS28	Hart Crowser, 2000
50029	5001	10/14/1998	0.00	0.33	4J98HCS29HCS29	Hart Crowser, 2000
50030	5001	10/15/1998	0.00	0.33	4J98HCS30HCS30	Hart Crowser, 2000
50031	5001	10/15/1998	0.00	0.33	4J98HCS31HCS31	Hart Crowser, 2000
50032	5002	10/14/1998	0.00	0.33	4J98HCS32HCS32	Hart Crowser, 2000
50033	5001	10/14/1998	0.00	0.33	4J98HCS33HCS33	Hart Crowser, 2000
50034	5001	10/15/1998	0.00	0.33	4J98HCS34HCS34	Hart Crowser, 2000
50035	5001	10/14/1998	0.00	0.33	4J98HCS35HCS35	Hart Crowser, 2000
50036	5001	10/15/1998	0.00	0.33	4J98HCS36HCS36	Hart Crowser, 2000
50037	5001	10/14/1998	0.00	0.33	4J98HCS37HCS37	Hart Crowser, 2000
50038	5001	10/15/1998	0.00	0.33	4J98HCS38HCS38	Hart Crowser, 2000
50039	5002	10/15/1998	0.00	0.33	4J98HCS39HCS39	Hart Crowser, 2000
50040	5001	10/15/1998	0.00	0.33	4J98HCS40HCS40	Hart Crowser, 2000
50041	5001	10/15/1998	0.00	0.33	4J98HCS41HCS41	Hart Crowser, 2000
50042	5001	10/15/1998	0.00	0.33	4J98HCS42HCS42	Hart Crowser, 2000
50043	5001	10/15/1998	0.00	0.33	4J98HCS43HCS43	Hart Crowser, 2000
50044	5001	10/15/1998	0.00	0.33	4J98HCS44HCS44	Hart Crowser, 2000
76025	7601	9/18/1997	0.00	0.33	WR-WSI98SD0250	Roy F. Weston, Inc., 1998
76027	7601	9/18/1997	0.00	0.33	WR-WSI98SD0270	Roy F. Weston, Inc., 1998
76029	7601	9/18/1997	0.00	0.33	WR-WSI98SD0290	Roy F. Weston, Inc., 1998
76031	7601	9/18/1997	0.00	0.33	WR-WSI98SD0310	Roy F. Weston, Inc., 1998
76032	7601	9/18/1997	0.00	0.33	WR-WSI98SD0320	Roy F. Weston, Inc., 1998
76033	7601	9/18/1997	0.00	0.33	WR-WSI98SD0330	Roy F. Weston, Inc., 1998
76034	7601	9/18/1997	0.00	0.33	WR-WSI98SD0340	Roy F. Weston, Inc., 1998
04R002SD	C00	10/16/2002	0.00	0.50	4R002SDS015C00	Round 1 Sediment Sampling 2002 of Portland Harbor

Table 4-2
Existing Sediment Sample Depths

Database Station ID (a)	Database Sample ID (a)	Sample Date	Upper Sample Depth (ft)	Lower Sample Depth (ft)	Sample ID from Original Report	Source of Data (a)
Slip 1 Subsurface Samples						
45003	4501	9/14/1998	0.00	3.00	98B401C1B401C1	Hart Crowser, 1999
45004	4501	9/14/1998	3.00	5.02	98B401C2B401C2	Hart Crowser, 1999
60005	6001	3/23/1988	2.01	3.02	R04884.3R4.3RB	USACE, 1988
60005	6002	3/23/1988	0.99	2.01	R04884.3R4.3RM	USACE, 1988
65034	6501	7/22/1997	0.00	6.01	97WRGC18RGC18A	USACE, 1999
76023	7602	10/17/1997	0.00	2.97	SI98SD0230000A	Roy F. Weston, Inc., 1998
Slip 3 Subsurface Samples						
50007	5001	10/12/1998	0.00	1.98	J98HCS07VC07S1	Hart Crowser, 2000
50007	5003	10/12/1998	1.98	4.22	J98HCS07VC07S2	Hart Crowser, 2000
50011	5002	10/12/1998	0.00	2.11	J98HCS11VC11S1	Hart Crowser, 2000
50011	5003	10/12/1998	2.11	3.99	J98HCS11VC11S2	Hart Crowser, 2000
50013	5001	10/12/1998	1.98	3.99	J98HCS13VC13S2	Hart Crowser, 2000
50013	5002	10/12/1998	0.00	1.98	J98HCS13VC13S1	Hart Crowser, 2000
50018	5002	10/12/1998	0.00	2.21	J98HCS18VC18S1	Hart Crowser, 2000
50018	5003	10/12/1998	2.21	3.99	J98HCS18VC18S2	Hart Crowser, 2000
50022	5001	10/12/1998	0.00	1.98	J98HCS22VC22S1	Hart Crowser, 2000
50022	5003	10/12/1998	1.98	3.99	J98HCS22VC22S2	Hart Crowser, 2000
50027	5001	10/12/1998	1.88	3.50	J98HCS27VC27S2	Hart Crowser, 2000
50027	5002	10/12/1998	0.00	1.88	J98HCS27VC27S1	Hart Crowser, 2000
50032	5001	10/12/1998	0.00	1.78	J98HCS32VC32S1	Hart Crowser, 2000
50032	5003	10/12/1998	1.78	3.99	J98HCS32VC32S2	Hart Crowser, 2000
50039	5001	10/12/1998	0.00	1.98	J98HCS39VC39S1	Hart Crowser, 2000
50039	5003	10/12/1998	1.98	3.99	J98HCS39VC39S2	Hart Crowser, 2000
50042	5002	10/12/1998	1.98	3.99	J98HCS42VC42S2	Hart Crowser, 2000
50042	5003	10/12/1998	0.00	1.98	J98HCS42VC42S1	Hart Crowser, 2000
76031	7602	10/17/1997	0.00	2.97	SI98SD0310000A	Roy F. Weston, Inc., 1998

a. Data from NOAA Query Manager 2.51 for Terminal 4 of the Willamette River.

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Metals (mg/kg)							
Aluminum	10	10	16,400	44,000	31,150	NA	NA
Antimony	25	7	0.4	11	8.8	2.3 U	10 U
Arsenic	25	22	3	7	4.3	5 U	5 U
Barium	5	5	184	198	193	NA	NA
Beryllium	10	5	0.7	0.7	0.7	1 U	1 U
Cadmium	25	17	0.25	4	0.94	0.3 U	1 U
Calcium	5	5	8,030	9190	8,512	NA	NA
Chromium	25	25	16	165	44	NA	NA
Cobalt	5	5	18.8	19.4	19	NA	NA
Copper	25	25	15	151	44	NA	NA
Iron	5	5	42,600	48,000	45,140	NA	NA
Lead	25	25	11	223	58	NA	NA
Magnesium	5	5	7,040	7,440	7,264	NA	NA
Manganese	5	5	653	792	736	NA	NA
Mercury	15	8	0.06	0.2	0.09	0.1 U	0.2 U
Nickel	25	25	15	40	23	NA	NA
Potassium	5	5	1,320	1,500	1,432	NA	NA
Selenium	15	0	ND	ND	ND	0.3 U	6 U
Silver	25	20	0.06	0.8	0.34	2 U	2 U
Sodium	5	5	1,050	1,370	1,180	NA	NA
Thallium	10	5	6	10	8	1 U	1 U
Titanium	2	2	1,850	2,030	1,940	NA	NA
Vanadium	5	5	102	114	108	NA	NA
Zinc	25	25	66.5	655	201	NA	NA
PAHs (ug/kg)							
2-Methylnaphthalene	25	3	36	80	61	10 U	5,000 U
2-Nitroaniline	15	0	ND	ND	ND	96 U	35,000 U
3,3-Dichlorobenzidine	15	0	ND	ND	ND	96 U	35,000 U
3-Nitroaniline	15	0	ND	ND	ND	120 U	35,000 U
4-Nitroaniline	15	0	ND	ND	ND	96 U	35,000 U

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Acenaphthene		25	14	29	970	218	10 U	5,000 U
Acenaphthylene		25	4	51	63	58	10 U	5,000 U
Anthracene		25	18	22	1,400	278	10 U	5,000 U
Benzo(a)anthracene		25	24	60	17,000	2,304	3,000 U	3,000 U
Benzo(a)pyrene		25	24	79	19,000	2,786	3,000 U	3,000 U
Benzo(b)fluoranthene		25	24	80	21,000	2,822	3,000 U	3,000 U
Benzo(b+k)fluoranthene		20	19	145	33,000	6,091	3,000 U	3,000 U
Benzo(g,h,i)perylene		25	22	23	10,000	1,781	300 U	3,000 U
Benzo(k)fluoranthene		25	24	65	12,000	2,153	3,000 U	3,000 U
Carbazole		10	7	16	420	133	19 U	20 U
Chrysene		25	24	93	19,000	2,750	3,000 U	3,000 U
Dibenzo(a,h)anthracene		25	13	44	2,300	544	10 U	5,000 U
Dibenzofuran		25	7	30	290	119	10 U	5,000 U
Fluoranthene		25	24	120	28,000	3,800	3,000 U	3,000 U
Fluorene		25	14	22	600	143	10 U	5,000 U
Indeno(1,2,3-cd)pyrene		25	24	28	17,000	2,207	3,000 U	3,000 U
Naphthalene		25	9	21	140	67	10 U	5,000 U
Nitrobenzene		15	0	ND	ND	ND	19 U	5,000 U
Total PAH	(d,e)	15	14	603	118,000	14,859	3,000 U	3,000 U
Total PAH reported	(f)	20	19	894	178,000	32,196	3,000 U	3,000 U
Total HPAH	(e,g)	15	14	512	106,000	13,133	3,000 U	3,000 U
Total HPAH reported	(f)	20	19	894	166,000	29,687	3,000 U	3,000 U
Total LPAH	(e,h)	15	13	91	12,000	1,859	300 U	3,000 U
Total LPAH reported	(f)	20	17	110	12,000	2,804	10 U	3,000 U
Phenanthrene		25	22	69	12,000	1,772	10 U	3,000 U
Pyrene		25	24	130	23,000	3,363	3,000 U	3,000 U
Semivolatile Organic Compounds (ug/kg)								
1,2,4-Trichlorobenzene		13	0	ND	ND	ND	19 U	5,000 U
1,2-Dichlorobenzene		13	0	ND	ND	ND	19 U	5,000 U
1,3-Dichlorobenzene		13	0	ND	ND	ND	19 U	5,000 U
1,4-Dichlorobenzene		13	0	ND	ND	ND	19 U	5,000 U

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
2,3,4,5-Tetrachlorophenol	3	0	ND	ND	ND	96 U	98 U
2,3,4,6-Tetrachlorophenol	3	0	ND	ND	ND	96 U	98 U
2,3,5,6-Tetrachlorophenol	3	0	ND	ND	ND	96 U	98 U
2,4,5-Trichlorophenol	13	0	ND	ND	ND	96 U	5,000 U
2,4,6-Trichlorophenol	13	0	ND	ND	ND	96 U	5,000 U
2,4-Dichlorophenol	13	0	ND	ND	ND	58 U	5,000 U
2,4-Dimethylphenol	13	0	ND	ND	ND	19 U	5,000 U
2,4-Dinitrophenol	12	0	ND	ND	ND	190 U	35,000 U
2,4-Dinitrotoluene	13	0	ND	ND	ND	96 U	5,000 U
2-Chloronaphthalene	13	0	ND	ND	ND	19 U	5,000 U
2-Chlorophenol	13	0	ND	ND	ND	19 U	5,000 U
2-Methylphenol	13	0	ND	ND	ND	19 U	5,000 U
2-Nitrophenol	13	0	ND	ND	ND	96 U	5,000 U
4-Bromylphenyl phenyl ether	13	0	ND	ND	ND	19 U	5,000 U
4-Chloro-3-methylphenol	13	0	ND	ND	ND	38 U	5,000 U
4-Chloroaniline	13	0	ND	ND	ND	58 U	5,000 U
4-Chlorophenyl phenyl ether	13	0	ND	ND	ND	19 U	5,000 U
4-Methylphenol	13	2	29	41	35	19 U	5,000 U
4-Nitrophenol	13	0	ND	ND	ND	96 U	35,000 U
Aniline	8	0	ND	ND	ND	19 U	15,000 U
Benzoic acid	13	1	200	200	200	190 U	35,000 U
Benzyl alcohol	13	0	ND	ND	ND	19 U	5,000 U
Bis(2-chloroethoxy)methane	13	0	ND	ND	ND	19 U	5,000 U
Bis(2-chloroethyl)ether	13	0	ND	ND	ND	38 U	5,000 U
Bis(2-ethylhexyl)phthalate	23	16	170	38,000	4,428	130 U	3,000 U
Butylbenzyl phthalate	23	5	31	3,000	766	10 U	5,000 U
Di-n-octyl phthalate	23	3	39	190	94	10 U	5,000 U
Di-n-butyl phthalate	23	2	27	61	44	10 U	5,000 U
Diethyl phthalate	23	0	ND	ND	ND	10 U	5,000 U
Dimethyl phthalate	23	0	ND	ND	ND	10 U	5,000 U
Dinitro-o-cresol	12	0	ND	ND	ND	190 U	35,000 U
Dinoseb	3	0	ND	ND	ND	3.1 U	3.2 U

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Hexachlorobutadiene		13	0	ND	ND	ND	0.24 U	5,000 U
Hexachloroethane		13	0	ND	ND	ND	19 U	5,000 U
N-nitrosodi-N-propylamine		13	0	ND	ND	ND	38 U	5,000 U
N-nitrosodimethylamine		8	0	ND	ND	ND	96 U	35,000 U
N-nitrosodiphenylamine		13	0	ND	ND	ND	19 U	5,000 U
Pentachlorophenol		13	0	ND	ND	ND	96 U	35,000 U
Phenol		13	0	ND	ND	ND	19 U	5,000 U
Pesticides and PCBs (ug/kg)								
2,4,5-T		5	0	ND	ND	ND	1.6 U	2.6 U
2,4-DB		5	0	ND	ND	ND	31 U	33 U
2,4-D		5	0	ND	ND	ND	6.2 U	6.5 U
Aldrin		23	1	1	1	1	0.19 U	10 U
Aroclor 1016		22	0	ND	ND	ND	3.9 U	100 U
Aroclor 1221		22	0	ND	ND	ND	7.7 U	100 U
Aroclor 1232		22	0	ND	ND	ND	3.9 U	100 U
Aroclor 1242		22	9	12	240	86	3.9 U	100 U
Aroclor 1248		22	1	12	12	12	3.9 U	500 U
Aroclor 1254		22	5	18	83	54	10 U	500 U
Aroclor 1260		22	12	11	110	46	10 U	500 U
Cis and trans-chlordane		6	0	ND	ND	ND	39 U	100 U
Alpha-chlordane		17	2	1.1	2.1	1.6	0.25 U	10 U
Gamme-chlordane		12	4	2.5	5.8	3.4	1 U	10 U
Trans-chlordane		5	0	ND	ND	ND	0.2 U	1 U
Total DDT reported	(f)	18	11	7.3	28.4	17	2 U	20 U
Total DDT	(e,i)	5	5	6.6	39.7	18	NA	NA
Dalapon		5	0	ND	ND	ND	16 U	69 U
Dicamba		5	0	ND	ND	ND	3 U	3 U
Dieldrin		23	0	ND	ND	ND	1 U	20 U
Endosulfan sulfate		23	1	12	12	12	0.39 U	20 U
Alpha-endosulfan		22	0	ND	ND	ND	0.19 U	10 U
Beta-endosulfan		22	0	ND	ND	ND	0.39 U	16 U

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Endrin		23	0	ND	ND	ND	0.39 U	10 U
Endrin aldehyde		22	0	ND	ND	ND	0.39 U	17 U
Endrin ketone		17	0	ND	ND	ND	0.39 U	52 U
Heptachlor		23	0	ND	ND	ND	0.19 U	10 U
Heptachlor epoxide		22	0	ND	ND	ND	0.19 U	10 U
Hexachlorobenzene		15	0	ND	ND	ND	0.24 U	5000 U
Alpha-hexachlorocyclohexane		22	0	ND	ND	ND	0.19 U	10 U
Beta-hexachlorocyclohexane		22	1	2.1	2.1	2.1	1 U	30 U
Delta-hexachlorocyclohexane		22	0	ND	ND	ND	0.19 U	10 U
Gamma-hexachlorocyclohexane		22	0	ND	ND	ND	0.2 U	10 U
Hexachlorocyclopentadiene		15	0	ND	ND	ND	96 U	5000 U
Isophorone		15	0	ND	ND	ND	19 U	5000 U
MCPA		5	0	ND	ND	ND	3100 U	3300 U
MCPP		5	0	ND	ND	ND	3100 U	5100 U
Methoxylchlor		22	0	ND	ND	ND	1 U	70 U
Mirex		5	0	ND	ND	ND	0.39 U	1.4 U
Trans-nonachlor		5	0	ND	ND	ND	0.39 U	0.39 U
Oxychlordane		5	0	ND	ND	ND	0.39 U	3.1 U
Total PCB	(e,j)	13	6	51	369	225	39 U	500 U
Total PCB reported	(f)	17	8	11	135	63	20 U	500 U
Silvex		5	0	ND	ND	ND	1.6 U	1.9 U
Toxaphene		23	0	ND	ND	ND	19 U	2000 U
Cis-nonachlor		5	0	ND	ND	ND	0.39 U	1.8 U
o,p'-DDD		5	0	ND	ND	ND	0.54 U	1.5 U
o,p'-DDE		5	0	ND	ND	ND	0.39 U	32 U
o,p'-DDT		5	0	ND	ND	ND	0.39 U	0.65 U
p,p'-DDD		22	10	2.6	12	6.0	1 U	10 U
p,p'-DDE		23	11	3.3	15	7.2	2 U	10 U
p,p'-DDT		23	9	1.2	11	6.1	2 U	20 U

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Miscellaneous Organics (ug/kg)							
Trans-1,2-dichloroethene	5	0	ND	ND	ND	5 U	100 U
2,2'-Oxybis(1-chloropropane)	15	0	ND	ND	ND	19 U	5,000 U
2,6-Dinitrotoluene	15	0	ND	ND	ND	96 U	5,000 U
Azobenzene	5	0	ND	ND	ND	19 U	20 U
Dibutyltin dichloride	4	4	12	56	34	NA	NA
Dichloroprop	5	0	ND	ND	ND	6.2 U	62 U
Trichlorofluoromethane	5	0	ND	ND	ND	10 U	200 U
Trichlorotrifluoroethane	5	0	ND	ND	ND	10 U	200 U
Cis-1,2-dichloroethene	5	0	ND	ND	ND	5 U	100 U
Volatile Organic Compounds (ug/kg)							
1,1-Dichloroethane	5	0	ND	ND	ND	5 U	100 U
1,1-Dichloroethene	5	0	ND	ND	ND	5 U	100 U
1,1,1-Trichloroethane	5	0	ND	ND	ND	5 U	100 U
1,1,2,2,-Tetrachloroethane	5	0	ND	ND	ND	5 U	100 U
1,1,2-Trichloroethane	5	0	ND	ND	ND	5 U	100 U
1,2-Dichloroethane	5	0	ND	ND	ND	5 U	100 U
1,2-Dichloropropane	5	0	ND	ND	ND	5 U	100 U
Trans-1,3-dichloropropene	5	0	ND	ND	ND	5 U	100 U
2-Butanone	5	0	ND	ND	ND	100 U	2,000 U
2-Chloroethylvinyl ether	5	0	ND	ND	ND	10 U	200 U
Acetone	5	0	ND	ND	ND	100 U	2,000 U
Benzene	5	0	ND	ND	ND	5 U	100 U
Bromodichloromethane	5	0	ND	ND	ND	5 U	100 U
Bromoform	5	0	ND	ND	ND	5 U	100 U
Bromomethane	5	0	ND	ND	ND	10 U	200 U
Carbon disulfide	5	0	ND	ND	ND	100 U	2000 U
Carbon tetrachloride	5	0	ND	ND	ND	5 U	100 U
Chlorobenzene	5	0	ND	ND	ND	5 U	100 U
Chloroethane	5	0	ND	ND	ND	10 U	200 U
Chloroform	5	0	ND	ND	ND	5 U	100 U

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Chloromethane	5	0	ND	ND	ND	10 U	200 U
Dibromochloromethane	5	0	ND	ND	ND	5 U	100 U
Ethylbenzene	5	0	ND	ND	ND	5 U	100 U
Methyl butyl ketone	5	0	ND	ND	ND	50 U	1,000 U
Methyl isobutyl ketone	5	0	ND	ND	ND	50 U	1,000 U
Methylene chloride	5	1	11	11	ND	5 U	100 U
Styrene	5	0	ND	ND	ND	5 U	100 U
Tetrachloroethene	5	0	ND	ND	ND	5 U	100 U
Toluene	5	1	600	600	600	5 U	10 U
Trichloroethene	5	0	ND	ND	ND	5 U	100 U
Vinyl acetate	5	0	ND	ND	ND	50 U	1,000 U
Vinyl chloride	5	0	ND	ND	ND	10 U	200 U
m,p-Xylene	5	1	190	190	190	5 U	10 U
Cis-1,2-dichloropropene	5	0	ND	ND	ND	5 U	100 U
Butyltins (ug/kg)							
Butyltin ion	2	0	ND	ND	ND	5.9 U	5.9 U
Dibutyltin ion	2	0	ND	ND	ND	5.9 U	5.9 U
Monobutyltin chloride	4	3	8.2	28	15	NA (k)	NA (k)
Tetrabutyltin	6	0	ND	ND	ND	5.8 U	5.9 U
Tributyltin (as TBT cation)	6	6	20	63	41	NA	NA
Tributyltin chloride	4	4	23	64	36	NA	NA

Table 4-3
Summary of Slip 1 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Conventionals								
Total Solids	(%)	20	20	27.2	77.1	53	NA	NA
Total Organic Carbon	(%)	21	21	1.17	4.72	1.9	NA	NA

ND = All sample results were non-detect. There is no maximum, minimum, or average detected concentration.
NA = All sample results were detected. There is no maximum or minimum detection limit.
U = All results non-detect. Average concentration is average of detection limits.
a. Data from NOAA Query Manager 2.51 database for Terminal 4 of the Willamette River.
b. The average detected concentration calculation includes detected results only. Non-detect results are not included.
c. The maximum and minimum detection limits are for non-detect results only.
d. In the database, total PAH is the sum of total LPAH and total HPAH.
e. In the database, total concentrations were calculated using the detected values or the highest non-detect detection limit if all results were non-detect. If the highest non-detect detection limit was greater than the summed detected values, then the non-detect detection limit was used.
f. Total reported concentrations (total reported PAH, HPAH, LPAH, DDT, and PCB) were provided with the original study data.
g. Total HPAH is presented in the database and is the sum of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, perylene, and pyrene.
h. Total LPAH is presented in the database and is the sum of acenaphthene, anthracene, biphenyl, naphthalene, 2,6-dimethylnaphthalene, fluorene, 1-methylnaphthalene, 2-methylnaphthalene, 1-methylphenanthrene, and phenanthrene.
i. Total DDT is presented in the database and is the sum of o,p'-DDD, o,p'-DDE, o,p'-DDT, p,p'-DDD, p,p'-DDE, and p,p'-DDT.
j. Total PCB is presented in the database and is the sum of the Aroclors. It appears that the same Aroclors were used for the total PCB sum in each study.
k. Three of the four samples analyzed contained detected concentrations of monobutyltin chloride. The monobutyltin chloride result in the fourth sample was rejected.

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Metals (mg/kg)							
Aluminum	8	8	26,000	43,400	38,788	NA	NA
Antimony	33	26	0.1	13	3.2	0.1 U	0.2 U
Arsenic	33	28	3	14	6.1	5 U	6 U
Barium	7	7	167	188	179	NA	NA
Beryllium	7	7	0.6	0.7	0.68	NA	NA
Cadmium	33	33	0.2	6.6	1.6	NA	NA
Calcium	7	7	7,620	8,530	8,104	NA	NA
Chromium	33	33	14	43	28	NA	NA
Cobalt	7	7	18	20	19	NA	NA
Copper	33	33	15	134	52	NA	NA
Iron	7	7	41,100	45,400	42,557	NA	NA
Lead	33	33	13	1,160	228	NA	NA
Magnesium	7	7	6,910	7,810	7,307	NA	NA
Manganese	7	7	642	751	707	NA	NA
Mercury	33	33	0.02	0.34	0.1	NA	NA
Nickel	33	33	12	56	26	NA	NA
Potassium	7	7	1,240	1,570	1,386	NA	NA
Selenium	8	0	ND	ND	ND	0.3 U	7 U
Silver	33	33	0.1	2.1	0.62	NA	NA
Sodium	7	7	1,090	1,490	1,241	NA	NA
Thallium	7	4	8	12	9.3	5 U	7 U
Titanium	1	1	1,870	1,870	1,870	NA	NA
Vanadium	7	7	103	111	107	NA	NA
Zinc	33	33	82	1,330	349	NA	NA
PAHs (ug/kg)							
2-Methylnaphthalene	8	5	26	540	238	19 U	98 U
2-Nitroaniline	8	0	ND	ND	ND	95 U	540 U
3,3-Dichlorobenzidine	8	0	ND	ND	ND	95 U	540 U
3-Nitroaniline	8	0	ND	ND	ND	110 U	650 U

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
4-Nitroaniline		8	0	ND	ND	ND	95 U	540 U
Acenaphthene		41	39	23	14,000	1,361	10,000 U	20,000 U
Acenaphthylene		41	20	20	3,600	316	19 U	20,000 U
Anthracene		41	39	27	12,000	1,712	10,000 U	20,000 U
Benzo(a)anthracene		41	41	170	81,000	13,713	NA	NA
Benzo(a)pyrene		41	41	180	94,000	16,216	NA	NA
Benzo(b)fluoranthene		41	41	150	83,000	13,922	NA	NA
Benzo(b+k)fluoranthene		40	40	248	156,000	24,302	NA	NA
Benzo(g,h,i)perylene		41	41	96	55,000	10,639	NA	NA
Benzo(k)fluoranthene		41	41	98	76,000	11,349	NA	NA
Carbazole		8	8	25	10,000	2,213	NA	NA
Chrysene		41	41	170	78,000	14,045	NA	NA
Dibenzo(a,h)anthracene		41	37	50	25,000	2,260	19 U	20,000 U
Dibenzofuran		41	27	23	1,300	224	19 U	20,000 U
Fluoranthene		52	52	280	130,000	19,910	NA	NA
Fluorene		41	36	22	14,000	920	20 U	20,000 U
Indeno(1,2,3-cd)pyrene		41	41	160	110,000	17,600	NA	NA
Naphthalene		41	33	22	2,200	313	19 U	20,000 U
Nitrobenzene		8	0	ND	ND	ND	19 U	110 U
Total PAH	(d,e)	41	41	1,493	585,000	102,528	NA	NA
Total PAH reported	(f)	40	40	2,235	868,000	167,247	NA	NA
Total HPAH	(e,g)	41	41	1,250	471,000	89,942	NA	NA
Total HPAH reported	(f)	40	40	1,976	765,000	155,065	NA	NA
Total LPAH	(e,h)	41	41	233	114,000	12,586	NA	NA
Total LPAH reported	(f)	40	40	233	114,000	12,182	NA	NA
Phenanthrene		41	41	150	74,000	8,682	NA	NA
Pyrene		41	41	300	110,000	22,122	NA	NA
Semivolatile Organic Compounds (ug/kg)								
1,2,4-Trichlorobenzene		8	0	ND	ND	ND	19 U	110 U
1,2-Dichlorobenzene		40	0	ND	ND	ND	5 U	110 U

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
1,3-Dichlorobenzene	40	0	ND	ND	ND	5 U	110 U
1,4-Dichlorobenzene	40	0	ND	ND	ND	5 U	110 U
2,3,4,5-Tetrachlorophenol	1	0	ND	ND	ND	540 U	540 U
2,3,4,6-Tetrachlorophenol	1	0	ND	ND	ND	540 U	540 U
2,3,5,6-Tetrachlorophenol	1	0	ND	ND	ND	540 U	540 U
2,4,5-Trichlorophenol	8	0	ND	ND	ND	95 U	540 U
2,4,6-Trichlorophenol	8	0	ND	ND	ND	95 U	540 U
2,4-Dichlorophenol	8	0	ND	ND	ND	57 U	330 U
2,4-Dimethylphenol	41	3	7	31	16	6 U	6,000 U
2,4-Dinitrophenol	8	0	ND	ND	ND	190 U	1,100 U
2,4-Dinitrotoluene	7	0	ND	ND	ND	95 U	540 U
2-Chloronaphthalene	8	0	ND	ND	ND	19 U	110 U
2-Chlorophenol	8	0	ND	ND	ND	19 U	110 U
2-Methylphenol	41	2	17	51	34	6 U	6,000 U
2-Nitrophenol	8	0	ND	ND	ND	95 U	540 U
4-Bromylphenyl phenyl ether	8	0	ND	ND	ND	19 U	110 U
4-Chloro-3-methylphenol	8	0	ND	ND	ND	38 U	220 U
4-Chloroaniline	8	0	ND	ND	ND	57 U	330 U
4-Chlorophenyl phenyl ether	8	0	ND	ND	ND	19 U	110 U
4-Methylphenol	41	6	20	130	45	19 U	20,000 U
4-Nitrophenol	8	0	ND	ND	ND	95 U	540 U
Aniline	1	0	ND	ND	ND	110 U	110 U
Benzoic acid	41	1	110	110	110	100 U	100,000 U
Benzyl alcohol	41	0	ND	ND	ND	6 U	6,000 U
Bis(2-chloroethoxy)methane	8	0	ND	ND	ND	19 U	110 U
Bis(2-chloroethyl)ether	8	0	ND	ND	ND	38 U	220 U
Bis(2-ethylhexyl)phthalate	41	29	50	550	327	91 U	20,000 U
Butylbenzyl phthalate	41	7	20	110	47	19 U	20,000 U
Di-n-octyl phthalate	41	2	40	100	70	19 U	20,000 U
Di-n-butyl phthalate	41	1	43	43	43	19 U	20,000 U
Diethyl phthalate	41	1	25	25	25	19 U	20,000 U

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Dimethyl phthalate		41	0	ND	ND	ND	19 U	20,000 U
Dinitro-o-cresol		8	0	ND	ND	ND	190 U	1,100 U
Dinoseb		1	0	ND	ND	ND	3.3 U	3.3 U
Hexachlorobutadiene		41	0	ND	ND	ND	2 U	20,000 U
Hexachloroethane		8	0	ND	ND	ND	19 U	220 U
N-nitrosodi-N-propylamine		8	0	ND	ND	ND	38 U	220 U
N-nitrosodimethylamine		1	0	ND	ND	ND	540 U	540 U
N-nitrosodiphenylamine		41	0	ND	ND	ND	12 U	12,000 U
Pentachlorophenol		41	0	ND	ND	ND	60 U	60,000 U
Phenol		41	2	55	110	83	19 U	20,000 U
Pesticides and PCBs (ug/kg)								
2,4,5-T		1	0	ND	ND	ND	1.6 U	1.6 U
2,4-DB		1	0	ND	ND	ND	33 U	33 U
2,4-D		1	0	ND	ND	ND	6.5 U	6.5 U
Aldrin		9	0	ND	ND	ND	0.97 U	20 U
Aroclor 1016		2	0	ND	ND	ND	3.9 U	19 U
Aroclor 1221		2	0	ND	ND	ND	7.9 U	39 U
Aroclor 1232		2	0	ND	ND	ND	3.9 U	19 U
Aroclor 1242		2	0	ND	ND	ND	3.9 U	19 U
Aroclor 1248		2	0	ND	ND	ND	7.3 U	19 U
Aroclor 1254		2	0	ND	ND	ND	19 U	22 U
Aroclor 1260		2	1	66	66	66	19 U	19 U
Cis and trans-chlordane		2	0	ND	ND	ND	14 U	450 U
Alpha-chlordane		7	0	ND	ND	ND	0.97 U	20 U
Gamme-chlordane		6	0	ND	ND	ND	0.97 U	20 U
Trans-chlordane		1	0	ND	ND	ND	2 U	2 U
Total DDT reported	(f)	8	6	1.2	39	16	12 U	159 U
Total DDT	(e.i)	1	1	6.8	6.8	6.8	NA	NA
Dalapon		1	0	ND	ND	ND	23 U	23 U
Dicamba		1	0	ND	ND	ND	3.3 U	3.3 U

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Dieldrin		9	0	ND	ND	ND	1.9 U	20 U
Endosulfan sulfate		9	0	ND	ND	ND	1.9 U	23 U
Alpha-endosulfan		7	0	ND	ND	ND	0.97 U	20 U
Beta-endosulfan		7	0	ND	ND	ND	1.9 U	20 U
Endrin		9	0	ND	ND	ND	1.9 U	20 U
Endrin aldehyde		7	0	ND	ND	ND	1.9 U	20 U
Endrin ketone		7	0	ND	ND	ND	3.9 U	20 U
Heptachlor		9	0	ND	ND	ND	0.97 U	20 U
Heptachlor epoxide		7	0	ND	ND	ND	0.97 U	20 U
Hexachlorobenzene		41	0	ND	ND	ND	2 U	20,000 U
Alpha-hexachlorocyclohexane		7	0	ND	ND	ND	0.97 U	20 U
Beta-hexachlorocyclohexane		7	0	ND	ND	ND	0.97 U	20 U
Delta-hexachlorocyclohexane		7	0	ND	ND	ND	0.97 U	20 U
Gamma-hexachlorocyclohexane		7	0	ND	ND	ND	0.97 U	20 U
Hexachlorocyclopentadiene		8	0	ND	ND	ND	95 U	540 U
Isophorone		8	0	ND	ND	ND	19 U	110 U
MCPA		1	0	ND	ND	ND	3,300 U	3,300 U
MCPP		1	0	ND	ND	ND	4,600 U	4,600 U
Methoxylchlor		7	0	ND	ND	ND	10 U	40 U
Mirex		1	0	ND	ND	ND	3.9 U	3.9 U
Trans-nonachlor		1	0	ND	ND	ND	3.9 U	3.9 U
Oxychlordane		1	0	ND	ND	ND	3.9 U	3.9 U
Total PCB	(e,j)	4	2	55	95	75	39 U	45 U
Total PCB reported	(f)	1	0	ND	ND	ND	39 U	39 U
Silvex		1	0	ND	ND	ND	1.6 U	1.6 U
Toxaphene		9	0	ND	ND	ND	23 U	300 U
Cis-nonachlor		1	0	ND	ND	ND	3.9 U	3.9 U
o,p'-DDD		1	0	ND	ND	ND	3.9 U	3.9 U
o,p'-DDE		1	0	ND	ND	ND	3.9 U	3.9 U
o,p'-DDT		1	0	ND	ND	ND	3.9 U	3.9 U
p,p'-DDD		9	5	1	8	5.6	1.9 U	99 U

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
p,p'-DDE	9	5	1.2	5	3.2	3.9 U	20 U
p,p'-DDT	9	4	3	26	12	1.9 U	159 U
Miscellaneous Organics (ug/kg)							
2,2'-Oxybis(1-chloropropane)	8	0	ND	ND	ND	19 U	110 U
2,6-Dinitrotoluene	8	0	ND	ND	ND	95 U	540 U
Azobenzene	1	0	ND	ND	ND	110 U	110 U
Dichloroprop	1	0	ND	ND	ND	6.5 U	6.5 U
Diesel	44	10	230,000	2,100,000	657,000	25,000 U	200,000 U
Lube oil	44	7	160	1,100	479	100 U	100 U
Pencil pitch	44	37	310	14,000	2,274	100 U	300 U
Phytane	44	11	500	6,100	1782	500 U	1,000 U
Pristance	44	15	500	7,000	1620	500 U	500 U
Volatile Organic Compounds (ug/kg)							
Benzene	32	0	ND	ND	ND	5 U	25 U
Ethylbenzene	32	0	ND	ND	ND	5 U	25 U
Tetrachloroethene	32	0	ND	ND	ND	5 U	25 U
Toluene	32	0	ND	ND	ND	5 U	25 U
Trichloroethene	32	0	ND	ND	ND	5 U	25 U
m,p-Xylene	32	0	ND	ND	ND	5 U	25 U
o-Xylene	32	0	ND	ND	ND	5 U	25 U

Table 4-4
Summary of Slip 3 Surface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Conventionals								
Ammonia	(mg/kg)	32	32	12	224	93	NA	NA
Total Solids	(%)	45	45	30	78	47	NA	NA
Total Sulfide (S2)	(mg/kg)	32	32	1.6	1,830	139	NA	NA
Total Volatile Solids	(%)	33	33	1.8	13	6.7	NA	NA
Total Organic Carbon	(%)	42	42	0.42	3.7	1.9	NA	NA

ND = All sample results were non-detect. There is no maximum, minimum, or average detected concentration.
NA = All sample results were detected. There is no maximum or minimum detection limit.
U = All results non-detect. Average concentration is average of detection limits.
a. Data from NOAA Query Manager 2.51 database for Terminal 4 of the Willamette River.
b. The average detected concentration calculation includes detected results only. Non-detect results are not included.
c. The maximum and minimum detection limits are for non-detect results only.
d. In the database, total PAH is the sum of total LPAH and total HPAH.
e. In the database, total concentrations were calculated using the detected values or the highest non-detect detection limit if all results were non-detect. If the highest non-detect detection limit was greater than the summed detected values, then the non-detect detection limit was used.
f. Total reported concentrations (total reported PAH, HPAH, LPAH, DDT, and PCB) were provided with the original study data.
g. Total HPAH is presented in the database and is the sum of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, perylene, and pyrene.
h. Total LPAH is presented in the database and is the sum of acenaphthene, anthracene, biphenyl, naphthalene, 2,6-dimethylnaphthalene, fluorene, 1-methylnaphthalene, 2-methylnaphthalene, 1-methylphenanthrene, and phenanthrene.
i. Total DDT is presented in the database and is the sum of o,p'-DDD, o,p'-DDE, o,p'-DDT, p,p'-DDD, p,p'-DDE, and p,p'-DDT.
j. Total PCB is presented in the database and is the sum of the Aroclors. It appears that the same Aroclors were used for the total PCB sum in each study.

Table 4-5
Summary of Slip 1 Subsurface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Metals (mg/kg)							
Aluminum	1	1	40,700	40,700	40,700	NA	NA
Antimony	3	2	0.03	6	3	0.02 U	0.02 U
Arsenic	4	3	1	4.5	2.3	4 U	4 U
Barium	1	1	191	191	191	NA	NA
Beryllium	1	1	0.56	0.56	0.56	NA	NA
Cadmium	4	4	0.14	2.8	0.89	NA	NA
Calcium	1	1	8,330	8,330	8,330	NA	NA
Chromium	4	4	11	41	25	NA	NA
Cobalt	1	1	19	19	19	NA	NA
Copper	4	4	14	64	34	NA	NA
Iron	1	1	42,600	42,600	42,600	NA	NA
Lead	4	4	10	222	67	NA	NA
Magnesium	1	1	7,100	7,100	7,100	NA	NA
Manganese	1	1	495	495	495	NA	NA
Mercury	4	4	0.08	0.21	0.13	NA	NA
Nickel	4	4	15	32	22	NA	NA
Potassium	1	1	1,300	1,300	1,300	NA	NA
Selenium	1	1	6	6	6	NA	NA
Silver	4	4	0.12	1.3	0.47	NA	NA
Sodium	1	1	1,200	1,200	1,200	NA	NA
Thallium	1	0	ND	ND	ND	4 U	4 U
Vanadium	1	1	107	107	107	NA	NA
Zinc	4	4	53	535	197	NA	NA
PAHs (ug/kg)							
2-Methylnaphthalene	2	2	53	170	112	NA	NA
2-Nitroaniline	1	0	ND	ND	ND	97 U	97 U
3,3-Dichlorobenzidine	1	0	ND	ND	ND	97 U	97 U
3-Nitroaniline	1	0	ND	ND	ND	120 U	120 U
4-Nitroaniline	1	0	ND	ND	ND	97 U	97 U
Acenaphthene	4	4	38	210	132	NA	NA

Table 4-5
Summary of Slip 1 Subsurface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Acenaphthylene		4	1	10	10	10	19 U	200 U
Anthracene		4	4	46	250	127	NA	NA
Benzo(a)anthracene		4	4	74	690	384	NA	NA
Benzo(a)pyrene		4	4	81	960	493	NA	NA
Benzo(b)fluoranthene		4	4	63	830	373	NA	NA
Benzo(b+k)fluoranthene		4	4	121	1,500	700	NA	NA
Benzo(g,h,i)perylene		4	4	56	560	284	NA	NA
Benzo(k)fluoranthene		4	4	58	670	327	NA	NA
Carbazole		1	1	99	99	99	NA	NA
Chrysene		4	4	90	860	470	NA	NA
Dibenzo(a,h)anthracene		4	2	11	200	106	20 U	200 U
Dibenzofuran		4	2	42	85	64	20 U	200 U
Fluoranthene		4	4	217	2,200	962	NA	NA
Fluorene		4	3	27	133	84	200 U	200 U
Indeno(1,2,3-cd)pyrene		4	4	55	580	306	NA	NA
Naphthalene		4	4	84	290	175	NA	NA
Nitrobenzene		1	0	ND	ND	ND	19 U	19 U
Total PAH	(d,e)	4	4	1,761	8,890	4,641	NA	NA
Total PAH reported	(f)	4	4	2,003	10,590	5,921	NA	NA
Total HPAH	(e,g)	4	4	688	7,040	3,500	NA	NA
Total HPAH reported	(f)	4	4	920	8,740	4,790	NA	NA
Total LPAH	(e,h)	4	4	466	1,850	1,142	NA	NA
Total LPAH reported	(f)	4	4	466	1,850	1,131	NA	NA
Phenanthrene		4	4	260	1,100	590	NA	NA
Pyrene		4	4	215	2,700	1,139	NA	NA
Semivolatile Organic Compounds (ug/kg)								
1,2,4-Trichlorobenzene		1	0	ND	ND	ND	19 U	19 U
1,2-Dichlorobenzene		3	0	ND	ND	ND	1 U	19 U
1,3-Dichlorobenzene		3	0	ND	ND	ND	1 U	19 U
1,4-Dichlorobenzene		3	0	ND	ND	ND	1 U	19 U
2,4,5-Trichlorophenol		1	0	ND	ND	ND	97 U	97 U

Table 4-5
Summary of Slip 1 Subsurface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
2,4,6-Trichlorophenol	1	0	ND	ND	ND	97 U	97 U
2,4-Dichlorophenol	1	0	ND	ND	ND	58 U	58 U
2,4-Dimethylphenol	3	0	ND	ND	ND	6 U	60 U
2,4-Dinitrophenol	1	0	ND	ND	ND	190 U	190 U
2,4-Dinitrotoluene	1	0	ND	ND	ND	97 U	97 U
2-Chloronaphthalene	1	0	ND	ND	ND	19 U	19 U
2-Chlorophenol	1	0	ND	ND	ND	19 U	19 U
2-Methylphenol	3	0	ND	ND	ND	6 U	60 U
2-Nitrophenol	1	0	ND	ND	ND	97 U	97 U
4-Bromylphenyl phenyl ether	1	0	ND	ND	ND	19 U	19 U
4-Chloro-3-methylphenol	1	0	ND	ND	ND	39 U	39 U
4-Chloroaniline	1	0	ND	ND	ND	58 U	58 U
4-Chlorophenyl phenyl ether	1	0	ND	ND	ND	19 U	19 U
4-Methylphenol	3	2	23	26	25	200 U	200 U
4-Nitrophenol	1	0	ND	ND	ND	97 U	97 U
Benzoic acid	3	0	ND	ND	ND	100 U	1,000 U
Benzyl alcohol	3	0	ND	ND	ND	6 U	60 U
Bis(2-chloroethoxy)methane	1	0	ND	ND	ND	19 U	19 U
Bis(2-chloroethyl)ether	1	0	ND	ND	ND	39 U	39 U
Bis(2-ethylhexyl)phthalate	3	1	380	380	380	20 U	200 U
Butylbenzyl phthalate	3	1	240	240	240	19 U	20 U
Di-n-octyl phthalate	3	0	ND	ND	ND	19 U	200 U
Di-n-butyl phthalate	3	0	ND	ND	ND	19 U	200 U
Diethyl phthalate	3	0	ND	ND	ND	19 U	200 U
Dimethyl phthalate	3	0	ND	ND	ND	19 U	200 U
Dinitro-o-cresol	1	0	ND	ND	ND	190 U	190 U
Hexachlorobutadiene	3	0	ND	ND	ND	19 U	200 U
Hexachloroethane	1	0	ND	ND	ND	19 U	19 U
N-nitrosodi-N-propylamine	1	0	ND	ND	ND	39 U	39 U
N-nitrosodiphenylamine	3	0	ND	ND	ND	12 U	120 U
Pentachlorophenol	3	0	ND	ND	ND	61 U	610 U
Phenol	3	0	ND	ND	ND	19 U	200 U

Table 4-5
Summary of Slip 1 Subsurface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Pesticides and PCBs (ug/kg)								
Aldrin		3	0	ND	ND	ND	1.7 U	2 U
Aroclor 1016		3	0	ND	ND	ND	10 U	10 U
Aroclor 1221		3	0	ND	ND	ND	10 U	10 U
Aroclor 1232		3	0	ND	ND	ND	10 U	10 U
Aroclor 1242		3	0	ND	ND	ND	10 U	10 U
Aroclor 1248		3	0	ND	ND	ND	10 U	10 U
Aroclor 1254		3	0	ND	ND	ND	10 U	25 U
Aroclor 1260		3	3	12	32	21	NA	NA
Cis and trans-chlordane		1	0	ND	ND	ND	10 U	10 U
Alpha-chlordane		2	0	ND	ND	ND	1.7 U	2 U
Gamme-chlordane		2	0	ND	ND	ND	1.7 U	1.7 U
Total DDT reported	(f)	3	3	4.8	480	163	NA	NA
Total DDT	(i)							
Dieldrin		3	0	ND	ND	ND	2 U	2 U
Endosulfan sulfate		1	0	ND	ND	ND	2 U	2 U
Alpha-endosulfan		1	0	ND	ND	ND	2 U	2 U
Beta-endosulfan		1	0	ND	ND	ND	2 U	2 U
Endrin		1	0	ND	ND	ND	2 U	2 U
Endrin aldehyde		1	0	ND	ND	ND	2 U	2 U
Heptachlor		3	0	ND	ND	ND	1.7 U	2 U
Heptachlor epoxide		1	0	ND	ND	ND	2 U	2 U
Hexachlorobenzene		3	0	ND	ND	ND	19 U	200 U
Alpha-hexachlorocyclohexane		1	0	ND	ND	ND	2 U	2 U
Beta-hexachlorocyclohexane		1	0	ND	ND	ND	2 U	2 U
Delta-hexachlorocyclohexane		1	0	ND	ND	ND	2 U	2 U
Gamma-hexachlorocyclohexane		3	0	ND	ND	ND	2 U	2 U
Hexachlorocyclopentadiene		1	0	ND	ND	ND	97 U	97 U
Isophorone		1	0	ND	ND	ND	19 U	19 U
Methoxylchlor		1	1	1	1	1	NA	NA
Total PCB	(e,j)	3	3	12	32	21	NA	NA

Table 4-5
Summary of Slip 1 Subsurface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Total PCB reported	(f)	3	3	12	32	21	NA	NA
Toxaphene		1	0	ND	ND	ND	40 U	40 U
p,p'-DDD		3	3	2	14	7.0	NA	NA
p,p'-DDE		3	2	2	5.8	3.9	2.3 U	2 U
p,p'-DDT		3	2	0.8	460	230	6.7 U	7 U
Miscellaneous Organics (ug/kg)								
2,2'-Oxybis(1-chloropropane)		1	0	ND	ND	ND	19 U	19 U
2,6-Dinitrotoluene		1	0	ND	ND	ND	97 U	97 U

Table 4-5
Summary of Slip 1 Subsurface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Conventionals								
Ammonia	(mg/kg)	2	2	154	209	182	NA	NA
Total Solids	(%)	3	3	53	70	59	NA	NA
Total Sulfide (S2)	(mg/kg)	2	2	28	32	30	NA	NA
Total Volatile Solids	(%)	2	2	2.6	6	4.4	NA	NA
Total Organic Carbon	(%)	4	4	0.53	2.3	1.6	NA	NA
Acid Volatile Sulfides	(mg/kg)	1	1	17.9	17.9	18	NA	NA

ND = All sample results were non-detect. There is no maximum, minimum, or average detected concentration.
NA = All sample results were detected. There is no maximum or minimum detection limit.
U = All results non-detect. Average concentration is average of detection limits.
a. Data from NOAA Query Manager 2.51 database for Terminal 4 of the Willamette River.
b. The average detected concentration calculation includes detected results only. Non-detect results are not included.
c. The maximum and minimum detection limits are for non-detect results only.
d. In the database, total PAH is the sum of total LPAH and total HPAH.
e. In the database, total concentrations were calculated using the detected values or the highest non-detect detection limit if all results were non-detect. If the highest non-detect detection limit was greater than the summed detected values, then the non-detect detection limit was used.
f. Total reported concentrations (total reported PAH, HPAH, LPAH, DDT, and PCB) were provided with the original study data.
g. Total HPAH is presented in the database and is the sum of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, perylene, and pyrene.
h. Total LPAH is presented in the database and is the sum of acenaphthene, anthracene, biphenyl, naphthalene, 2,6-dimethylnaphthalene, fluorene, 1-methylnaphthalene, 2-methylnaphthalene, 1-methylphenanthrene, and phenanthrene.
i. Total DDT was not included in the database for Slip 1 subsurface sediment.
j. Total PCB is presented in the database and is the sum of the Aroclors. It appears that the same Aroclors were used for the total PCB sum in each study.

Table 4-6
Summary of Slip 3 Subsurface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Metals (mg/kg)							
Aluminum	1	1	40,900	40,900	40,900	NA	NA
Antimony	15	8	0.2	8	1.5	0.1 U	0.1 U
Arsenic	15	15	2	15	5.4	NA	NA
Barium	1	1	185	185	185	NA	NA
Beryllium	1	1	0.54	0.54	0.54	NA	NA
Cadmium	15	14	0.1	3.3	1.2	0.1 U	0.1 U
Calcium	1	1	7,930	7,930	7,930	NA	NA
Chromium	15	15	9	41	22	NA	NA
Cobalt	1	1	20	20	20	NA	NA
Copper	15	15	13	103	47	NA	NA
Iron	1	1	44,100	44,100	44,100	NA	NA
Lead	15	15	3	576	165	NA	NA
Magnesium	1	1	7,010	7,010	7,010	NA	NA
Manganese	1	1	684	684	684	NA	NA
Mercury	15	13	0.02	0.18	0.09	0.02 U	0.02 U
Nickel	15	15	15	37	22	NA	NA
Potassium	1	1	1,410	1,410	1,410	NA	NA
Selenium	1	1	6	6	6	NA	NA
Silver	15	11	0.2	1.6	0.72	0.1 U	0.1 U
Sodium	1	1	1,230	1,230	1,230	NA	NA
Thallium	1	0	ND	ND	ND	5 U	5 U
Vanadium	1	1	106	106	106	NA	NA
Zinc	15	15	37	656	246	NA	NA
PAHs (ug/kg)							
2-Methylnaphthalene	1	1	240	240	240	NA	NA
2-Nitroaniline	1	0	ND	ND	ND	240 U	240 U
3,3-Dichlorobenzidine	1	0	ND	ND	ND	240 U	240 U
3-Nitroaniline	1	0	ND	ND	ND	290 U	290 U
4-Nitroaniline	1	0	ND	ND	ND	240 U	240 U
Acenaphthene	19	3	30	2,200	913	20 U	4,000 U

Table 4-6
Summary of Slip 3 Subsurface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Acenaphthylene		19	0	ND	ND	ND	20 U	4,000 U
Anthracene		19	6	21	1,700	550	20 U	4,000 U
Benzo(a)anthracene		19	17	190	20,000	6,334	20 U	20 U
Benzo(a)pyrene		19	17	240	24,000	7,685	20 U	20 U
Benzo(b)fluoranthene		19	17	180	21,000	6,430	20 U	20 U
Benzo(b+k)fluoranthene		19	17	350	36,000	11,824	20 U	20 U
Benzo(g,h,i)perylene		19	17	110	16,000	4,876	20 U	20 U
Benzo(k)fluoranthene		19	17	170	17,000	5,394	20 U	20 U
Carbazole		1	1	1,800	1,800	1,800	NA	NA
Chrysene		19	17	190	20,000	6,369	20 U	20 U
Dibenzo(a,h)anthracene		19	4	23	4,400	1,126	20 U	4,000 U
Dibenzofuran		19	1	340	340	340	20 U	4,000 U
Fluoranthene		19	17	350	28,000	8,929	20 U	20 U
Fluorene		19	1	830	830	830	20 U	4,000 U
Indeno(1,2,3-cd)pyrene		19	17	190	32,000	8,504	20 U	20 U
Naphthalene		19	1	440	440	440	20 U	4,000 U
Nitrobenzene		1	0	ND	ND	ND	48 U	48 U
Total PAH	(d,e)	19	17	1,481	124,000	40,925	20 U	20 U
Total PAH reported	(f)	19	17	2,181	208,000	66,115	20 U	20 U
Total HPAH	(e,g)	19	17	1,373	115,000	37,531	20 U	20 U
Total HPAH reported	(f)	19	17	2,073	198,000	62,735	20 U	20 U
Total LPAH	(e.h)	19	16	108	13,010	3,605	20 U	4,000 U
Total LPAH reported	(f)	19	16	108	12,770	3,590	20 U	4,000 U
Phenanthrene		19	16	87	10,000	3,134	20 U	4,000 U
Pyrene		19	17	320	24,000	7,949	20 U	20 U
Semivolatile Organic Compounds (ug/kg)								
1,2,4-Trichlorobenzene		1	0	ND	ND	ND	48 U	48 U
1,2-Dichlorobenzene		19	0	ND	ND	ND	5 U	48 U
1,3-Dichlorobenzene		19	0	ND	ND	ND	5 U	48 U
1,4-Dichlorobenzene		19	0	ND	ND	ND	5 U	48 U
2,4,5-Trichlorophenol		1	0	ND	ND	ND	240 U	240 U

Table 4-6
Summary of Slip 3 Subsurface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
2,4,6-Trichlorophenol	1	0	ND	ND	ND	240 U	240 U
2,4-Dichlorophenol	1	0	ND	ND	ND	140 U	140 U
2,4-Dimethylphenol	19	0	ND	ND	ND	6 U	1,200 U
2,4-Dinitrophenol	1	0	ND	ND	ND	480 U	480 U
2,4-Dinitrotoluene	1	0	ND	ND	ND	240 U	240 U
2-Chloronaphthalene	1	0	ND	ND	ND	48 U	48 U
2-Chlorophenol	1	0	ND	ND	ND	48 U	48 U
2-Methylphenol	19	0	ND	ND	ND	6 U	1,200 U
2-Nitrophenol	1	0	ND	ND	ND	240 U	240 U
4-Bromylphenyl phenyl ether	1	0	ND	ND	ND	48 U	48 U
4-Chloro-3-methylphenol	1	0	ND	ND	ND	96 U	96 U
4-Chloroaniline	1	0	ND	ND	ND	140 U	140 U
4-Chlorophenyl phenyl ether	1	0	ND	ND	ND	48 U	48 U
4-Methylphenol	19	0	ND	ND	ND	20 U	4,000 U
4-Nitrophenol	1	0	ND	ND	ND	240 U	240 U
Benzoic acid	19	0	ND	ND	ND	100 U	20,000 U
Benzyl alcohol	19	0	ND	ND	ND	6 U	1,200 U
Bis(2-chloroethoxy)methane	1	0	ND	ND	ND	48 U	48 U
Bis(2-chloroethyl)ether	1	0	ND	ND	ND	96 U	96 U
Bis(2-ethylhexyl)phthalate	19	3	36	420	212	20 U	4,000 U
Butylbenzyl phthalate	19	0	ND	ND	ND	20 U	4,000 U
Di-n-octyl phthalate	19	0	ND	ND	ND	20 U	4,000 U
Di-n-butyl phthalate	19	0	ND	ND	ND	20 U	4,000 U
Diethyl phthalate	19	0	ND	ND	ND	20 U	4,000 U
Dimethyl phthalate	19	0	ND	ND	ND	20 U	4,000 U
Dinitro-o-cresol	1	0	ND	ND	ND	480 U	480 U
Hexachlorobutadiene	19	0	ND	ND	ND	20 U	4,000 U
Hexachloroethane	1	0	ND	ND	ND	48 U	48 U
N-nitrosodi-N-propylamine	1	0	ND	ND	ND	96 U	96 U
N-nitrosodiphenylamine	19	0	ND	ND	ND	12 U	2,400 U
Pentachlorophenol	19	0	ND	ND	ND	60 U	12,000 U
Phenol	19	0	ND	ND	ND	20 U	4,000 U

Table 4-6
Summary of Slip 3 Subsurface Sediment Chemistry Data

Compounds (a)	Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Pesticides and PCBs (ug/kg)							
Hexachlorobenzene	19	0	ND	ND	ND	20 U	4,000 U
Hexachlorocyclopentadiene	1	0	ND	ND	ND	240 U	240 U
Isophorone	1	0	ND	ND	ND	48 U	48 U
Miscellaneous Organics (ug/kg)							
2,2'-Oxybis(1-chloropropane)	1	0	ND	ND	ND	48 U	48 U
2,6-Dinitrotoluene	1	0	ND	ND	ND	240 U	240 U
Diesel	3	0	ND	ND	ND	25,000 U	100,000 U
Lube oil	3	0	ND	ND	ND	100 U	100 U
Pencil pitch	16	16	21	2,300	703	NA	NA
Phytane	3	0	ND	ND	ND	500 U	500 U
Pristance	3	0	ND	ND	ND	500 U	500 U
Volatile Organic Compounds (ug/kg)							
Benzene	18	0	ND	ND	ND	5 U	10 U
Ethylbenzene	18	0	ND	ND	ND	5 U	10 U
Tetrachloroethene	18	0	ND	ND	ND	5 U	10 U
Toluene	18	0	ND	ND	ND	5 U	10 U
Trichloroethene	18	0	ND	ND	ND	5 U	10 U
m,p-Xylene	18	1	5	5	5	5 U	10 U
o-Xylene	18	0	ND	ND	ND	5 U	10 U

Table 4-6
Summary of Slip 3 Subsurface Sediment Chemistry Data

Compounds (a)		Number of Samples	Number of Detections	Minimum Detected Concentration	Maximum Detected Concentration	Average Detected Concentration (b)	Minimum Detection Limit (c)	Maximum Detection Limit (c)
Conventionals								
Ammonia	(mg/kg)	18	18	1.4	327	133	NA	NA
Total Solids	(%)	18	18	49	81	63	NA	NA
Total Sulfide (S2)	(mg/kg)	12	12	2	796	135	NA	NA
Total Volatile Solids	(%)	18	18	1.7	11	5.5	NA	NA
Total Organic Carbon	(%)	19	19	0.03	3.0	1.4	NA	NA

ND = All sample results were non-detect. There is no maximum, minimum, or average detected concentration.
NA = All sample results were detected. There is no maximum or minimum detection limit.
U = All results non-detect. Average concentration is average of detection limits.
a. Data from NOAA Query Manager 2.51 database for Terminal 4 of the Willamette River.
b. The average detected concentration calculation includes detected results only. Non-detect results are not included.
c. The maximum and minimum detection limits are for non-detect results only.
d. In the database, total PAH is the sum of total LPAH and total HPAH.
e. In the database, total concentrations were calculated using the detected values or the highest non-detect detection limit if all results were non-detect. If the highest non-detect detection limit was greater than the summed detected values, then the non-detect detection limit was used.
f. Total reported concentrations (total reported PAH, HPAH, and LPAH) were provided with the original study data.
g. Total HPAH is presented in the database and is the sum of benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, perylene, and pyrene.
h. Total LPAH is presented in the database and is the sum of acenaphthene, anthracene, biphenyl, naphthalene, 2,6-dimethylnaphthalene, fluorene, 1-methylnaphthalene, 2-methylnaphthalene, 1-methylphenanthrene, and phenanthrene.

Table 4-7 - Summary of Sediment Bioassay Results - Amphipod Bioassay (Hyallela azteca)
Port of Portland, Terminal 4 - Slip 3

Sample Identification	Test Mean Mortality (M_T) in percent	Reference Mean Mortality (M_R) in percent	M_T-M_R	P-Value	Single-Hit Criteria [1] (M_T - M_R > 15%)	Two-Hit Criteria [2] (significant diff. btwn M_T and M_R)	Overall Result [3]
PHASE 1							
HC-S-26	7.5	1.3	6.2	0.04	Pass	yes	**Pass**
HC-S-28	16.3	3.8	12.5	0.01	Pass	yes	**Pass**
HC-S-35	5.0	3.8	1.2	-	Pass	no	**Pass**
HC-S-36	3.8	1.3	2.5	-	Pass	no	**Pass**
HC-S-39	6.3	3.8	2.5	-	Pass	no	**Pass**
HC-S-42	7.5	3.8	3.7	-	Pass	no	**Pass**
Ref B	3.8	-	-	-	-	-	**-**
Ref C	1.3	-	-	-	-	-	**-**
Neg. Control	1.3	-	-	-	-	-	**-**
PHASE 2							
HC-S-01	35.0	13.8	21.2	0.003	Fail	yes	Fail
HC-S-04	37.5	13.8	23.7	0.002	Fail	yes	Fail
HC-S-05	28.8	13.8	15	0.04	Pass	yes	Fail
HC-S-07	20.0	13.8	6.2	-	Pass	no	Fail
HC-S-11	18.8	13.8	5	-	Pass	no	Pass
HC-S-16	27.5	13.8	13.7	0.04	Pass	yes	Fail
HC-S-19	16.3	26.3	-10	-	Pass	no	Pass
HC-S-22	30.0	13.8	16.2	0.01	Fail	yes	Fail
HC-S-24	33.8	26.3	7.5	-	Pass	no	Pass
HC-S-30	12.5	26.3	-13.8	-	Pass	no	Pass
Ref B	13.8	-	-	-	-	-	-
Ref C	26.3	-	-	-	-	-	-
Neg. Control	15.0	-	-	-	-	-	-

Source: Hart Crowser, 2000.

Notes:

[1] One Hit Required to Fail Bioassay

[2] Two Hits Required to Fail Bioassay

[3] A test fails if either of the following is true:
"Fail" of the single-hit criteria for the corresponding sample from any of the toxicity tests.
"Yes" for any two-hit criteria for the corresponding sample from any of the toxicity tests.

Table 4-8 - Summary of Sediment Bioassay Results - Midge Acute Bioassay (Chironomus tentans)
Port of Portland, Terminal 4 - Slip 3

Sample Identification	Test Mean Mortality (M_T) in percent	Reference Mean Mortality (M_R) in percent	M_T-M_R	P-Value	Single-Hit Criteria [1] (M_T - M_R > 20%)	Two-Hit Criteria [2] (significant diff. btwn M_T and M_R)	Overall Result [3]
PHASE 1							
HC-S-26	27.5	20.0	7.5	-	Pass	no	**Pass**
HC-S-28	40.0	28.8	11.2	-	Pass	no	**Pass**
HC-S-35	35.0	28.8	6.2	-	Pass	no	**Pass**
HC-S-36	26.3	20.0	6.3	-	Pass	no	**Pass**
HC-S-39	41.3	28.8	12.5	0.03	Pass	yes	**Pass**
HC-S-42	28.8	28.8	0	-	Pass	no	**Pass**
Ref B	28.8	-	-	-	-	-	**-**
Ref C	20.0	-	-	-	-	-	**-**
Neg. Control	15.0	-	-	-	-	-	**-**
PHASE 2							
HC-S-01	47.5	12.5	35	0.00001	Fail	yes	Fail
HC-S-04	30.0	12.5	17.5	0.03	Pass	yes	Fail
HC-S-05	31.3	12.5	18.8	0.04	Pass	yes	Fail
HC-S-07	25.0	12.5	12.5	-	Pass	no	Fail
HC-S-11	26.3	12.5	13.8	-	Pass	no	Pass
HC-S-16	17.5	12.5	5	-	Pass	no	Fail
HC-S-19	12.5	21.3	-8.8	-	Pass	no	Pass
HC-S-22	33.8	12.5	21.3	0.007	Fail	yes	Fail
HC-S-24	30.0	21.3	8.7	-	Pass	no	Pass
HC-S-30	8.6	21.3	-12.7	-	Pass	no	Pass
Ref B	12.5	-	-	-	-	-	-
Ref C	21.3	-	-	-	-	-	-
Neg. Control	3.8	-	-	-	-	-	-

Source: Hart Crowser, 2000.

Notes:

[1] One Hit Required to Fail Bioassay

[2] Two Hits Required to Fail Bioassay

[3] A test fails if either of the following is true:
"Fail" of the single-hit criteria for the corresponding sample from any of the toxicity tests.
"Yes" for any two-hit criteria for the corresponding sample from any of the toxicity tests.

Table 4-9 - Summary of Sediment Bioassay Results - Midge Chronic Bioassay (Chironomus tentans)
Port of Portland, Terminal 4 - Slip 3

Sample Identification	Test Mean Individual Biomass (B_T) in mg	Reference Mean Individual Biomass (B_R) in mg	B_T/B_R*100	P-Value	Single-Hit Criteria [1] (B_T/B_R < 60%)	Two-Hit Criteria [2] (significant diff. btwn B_T and B_R)	Overall Result [3]
PHASE 1							
HC-S-26	2.01	1.73	116.2	-	Pass	no	**Pass**
HC-S-28	1.32	1.60	82.5	-	Pass	no	**Pass**
HC-S-35	1.71	1.60	106.9	-	Pass	no	**Pass**
HC-S-36	1.50	1.73	86.7	-	Pass	no	**Pass**
HC-S-39	1.64	1.60	102.5	-	Pass	no	**Pass**
HC-S-42	1.46	1.60	91.3	-	Pass	no	**Pass**
Ref B	1.60	-	-	-	-	-	**-**
Ref C	1.73	-	-	-	-	-	**-**
Neg. Control	1.69	-	-	-	-	-	**-**
PHASE 2							
HC-S-01	0.19	1.15	16.5	0.00002	Fail	yes	Fail
HC-S-04	0.37	1.15	32.2	0.00001	Fail	yes	Fail
HC-S-05	0.51	1.15	44.3	0.00002	Fail	yes	Fail
HC-S-07	0.59	1.15	51.3	0.0003	Fail	yes	Fail
HC-S-11	0.81	1.15	70.4	0.009	Pass	yes	Pass
HC-S-16	0.74	1.15	64.3	0.002	Pass	yes	Fail
HC-S-19	1.09	1.37	79.6	-	Pass	no	Pass
HC-S-22	1.02	1.15	88.7	-	Pass	no	Fail
HC-S-24	0.96	1.37	70.1	0.08	Pass	yes	Pass
HC-S-30	0.95	1.37	69.3	0.01	Pass	yes	Pass
Ref B	1.15	-	-	-	-	-	-
Ref C	1.37	-	-	-	-	-	-
Neg. Control	1.46	-	-	-	-	-	-

Source: Hart Crowser, 2000.

Notes:

[1] One Hit Required to Fail Bioassay

[2] Two Hits Required to Fail Bioassay

[3] A test fails if either of the following is true:
"Fail" of the single-hit criteria for the corresponding sample from any of the toxicity tests.
"Yes" for any two-hit criteria for the corresponding sample from any of the toxicity tests.

5. Preliminary Conceptual Model of the Removal Action Area

The existing sediment quality data were evaluated in concert with the ownership and operations chronology (see Section 2.2.3) and the information about known historical and potential ongoing sources (see Section 3) in order to create a preliminary model of the general relationship between the sources and contaminated sediment in Terminal 4. The discussion of sources that follows is broken into primary and secondary sources and is organized by slip. For this discussion, Slip 1 includes Slip 1 and Berth 401 and Slip 3 includes Slip 3, Wheeler Bay, and Berth 414.

Constituents of potential concern in the Removal Action Area sediment are metals, PAHs, phthalates, tDDT, tPCBs and petroleum hydrocarbons. Although other constituents, such as VOCs and butyltins, were occasionally detected in the Removal Action Area sediment, they tend to be detected infrequently and at concentrations near the detection limit (see Section 4). For that reason, the discussion of primary and secondary sources of contamination focuses on metals, PAHs, phthalates, tDDT, and tPCBs. TPH will be dealt with by individual PAH compounds.

Based on the ownership and operations history, the known physical configuration of Terminal 4, and the existing human use and ecology of the Removal Action Area, a preliminary conceptual model was developed to establish the potential linkages between known and suspected sources of contamination (see Section 3), transport mechanisms, and receptors. A pictorial representation of this preliminary conceptual model is provided on Figure 5-1.

The following discussion refers to contaminant sources and transport with respect to the in-water portion of Terminal 4 only (Removal Action Area). This perspective is necessary to focus the EE/CA on sediments, sources of contamination to the sediments, and the environmental consequences that result from sediment contamination in the Removal Action Area. In some cases, exposures may result from multiple primary or secondary sources of contamination. For example, exposure of some receptors at Terminal 4 may be affected by contaminated sediments when sediments are resuspended by propeller scour or other forces. Sediment removal would alleviate this source of adverse effect on surface water quality. However, these receptors may also be affected by other sources, including stormwater, direct spills from over-water operations, and influx of contaminated groundwater. Sediment removal in the Removal Action Area would not address exposures from such sources.

Other sources of contamination are being addressed through separate programs, such as the Upland Source Control Projects for Terminal 4 under DEQ agreements, stormwater assessment and management programs, and voluntary cleanup agreements with the DEQ. In addition, offsite sources in the Willamette River are being addressed through the Portland Harbor Superfund Site remedial investigation/feasibility study, which is providing comprehensive ecological and human health risk assessments for the river in Portland Harbor and, when completed, will result in a USEPA-sponsored plan to remediate sediments and manage risks. Figure 5-2 presents a comprehensive conceptual model for the Terminal 4 Removal Action Area. The color coding of sources and transport pathways on Figure 5-2 identifies the general programs by which various aspects are being addressed.

5.1 Primary Sources of Contamination

In the context of the EE/CA, primary sources of contamination are original sources from which contaminants are or were released into the environment. Each primary source is associated with a primary release mechanism by which contaminants enter the environment. Primary sources and release mechanisms include spills from ship loading and unloading, spills and leaks from historical upland operations that reach the river at Terminal 4 through runoff or leaching, leaks from petroleum storage tanks or pipelines that enter groundwater, and the range of contamination sources to the Willamette River outside the Removal Action Area.

5.1.1 Slip 1 Sediment

Possible primary sources of metals to Slip 1 sediment include historic spills associated with ore handling at Slip 1 and spills and releases from upland activities that drained into Slip 1 through stormwater outfalls located at the east end of Slip 1. Ore and concentrate handling occurred in the southeast area of Slip 1, including at Berth 408, from approximately 1955 to 1971. Ores that were handled at Terminal 4 include alumina bauxite; chrome ore; ferrophosphorous iron ore; and copper, lead, manganese, nickel, silver, and zinc concentrate. Surface sediment concentrations of cadmium, chromium, copper, lead, and zinc decrease from east to west. Lead concentrations in subsurface sediment tend to be greater than in surface sediment, suggesting that the source of lead to Slip 1 is historical, not ongoing.

The primary sources of phthalates, tDDT, and tPCBs to Slip 1 sediment have not been specifically identified. However, phthalates are often associated with stormwater outfalls; tDDT has multiple sources in the area, including historical application and manufacturing; and tPCB sources are abundant in the industrialized corridor.

5.1.2 Slip 3 Sediment

Possible primary sources of metals to Slip 3 sediment include historic spills associated with ore handling at Slip 3 and spills and releases from upland activities that drained into Slip 3 through stormwater outfalls located at the east end of Slip 3. Ore and concentrate handling occurred in the southern portion of Slip 3 from approximately 1921 to 1961. From approximately 1961 to 1988, ore handling occurred at Berths 410 and 411. Ores that were handled at Terminal 4 include alumina bauxite; chrome ore; ferrophosphorous iron ore; and copper, lead, manganese, nickel, silver, and zinc concentrate. Surface sediment concentrations of cadmium, copper, lead, and zinc decrease from east to west. Lead and zinc concentrations in subsurface sediment are generally greater than in surface sediment, suggesting that the source of lead and zinc to Slip 3 is historical, not ongoing.

Possible primary sources of PAHs to Slip 3 sediment include the activities associated with petroleum product and pencil pitch handling at Terminal 4, as well as upstream sources in the Willamette River. Petroleum-related activities at Slip 3 included the oil-supply dock, St. Johns Tank Farm, the Union Pacific pipeline, Quaker State operations, the auxiliary oil pipeline, waste oil USTs, and diesel and gasoline USTs. Pencil pitch handling at Terminal 4 occurred from approximately 1978 to 1998, generally at Berth 411. Spills of oils and pencil pitch have been documented. Possible sources to the Willamette River outside Terminal 4 include the McCormick and Baxter Superfund Site, Gasco, Arco, Mobil, and general urban stormwater runoff. These primary sources affect the sediments in Terminal 4 through secondary sources and transport. PAH concentrations in surface sediment generally decrease from east to west.

The primary sources of phthalates, tDDT, and tPCBs to Slip 3 sediment are the same as those cited for Slip 1.

5.2 Secondary Sources of Contamination

Secondary sources of contamination are generally environmental media that have become contaminated as a result of transport from upgradient sources and that then serve as secondary reservoirs for further release and transport or as exposure points. Examples of secondary sources and associated release mechanisms include contaminated groundwater that slowly discharges a contaminant load to surface water or sediment, upland surfaces such as parking lots or soils that release contaminants through stormwater runoff, deposition of suspended sediment from offsite sources, including the Willamette River, and sediment resuspension within Terminal 4.

5.2.1 Slip 1 Sediment

Possible secondary sources of metals to Slip 1 sediment include offsite, in-river sources. The trend of decreasing (from east to west) surface sediment concentrations of cadmium, chromium, copper, lead, and zinc supports the possibility that stormwater outfalls caused metals to contaminate Slip 1 sediments. As noted in Section 2.8, depositional patterns at the head of the slip appear to be typical of outfalls. In addition, the head (east end) of the slip is likely a lower-energy environment than the mouth of the slip, which is probably a higher-energy environment because of river flow and ship wake. Particulates could preferentially settle out of the water column in a lower-energy environment.

Potential secondary sources of PAHs to Slip 1 sediment include groundwater transport, stormwater, and offsite, in-river sources. Groundwater may become contaminated by migrating through soil contaminated with petroleum hydrocarbons. The contaminated groundwater may then migrate through the sediment and contaminate the sediment prior to discharging to the surface water. Stormwater may become contaminated as it encountered spilled or residual materials on the pavement surface before draining to catch basins and flowing to the Removal Action Area. Offsite releases of phthalates, tDDT, and tPCBs have resulted in contamination of sediment in the Willamette River. These sediments act as a secondary source to Slip 1 when resuspended, transported to the slip, and deposited.

5.2.2 Slip 3 Sediment

Possible secondary sources of metals to Slip 3 sediment include offsite, in-river sources. As in the case of Slip 1, depositional patterns appear to be influenced by sedimentation from current and historical outfalls. Deposition of sediment resulting from flow into the slip from the river is also likely.

Potential secondary sources of PAHs to Slip 3 sediment include groundwater transport, stormwater, and in-river sources. Groundwater may become contaminated by migrating through soil contaminated with petroleum hydrocarbons. The contaminated groundwater may then migrate through the sediment and contaminate the sediment prior to discharging directly to the surface water (i.e., below the waterline or through seeps that discharge onto the ground surface and flow into the water). Stormwater may become contaminated as it encountered spilled or residual materials on the pavement surface before draining to catch basins and flowing to the Removal Action Area. Offsite releases of phthalates, tDDT, and tPCBs have resulted in contamination of sediment in the Willamette River. These sediments act as a secondary source to Slip 1 when resuspended, transported to the slip, and deposited.

No existing data were located for under-pier sediment. It is unknown whether sediment contamination is present under the piers.

5.3 Pathways and Receptors

The focus of the EE/CA is on sediments and the exposures and risks that may result from direct or indirect contact with sediment contaminants. Sources of contamination to groundwater and surface water, and any associated exposure risks not associated with sediments, are being addressed through other activities or orders, such as those described in Sections 1, 2.2 and 3.3.1.

Exposure pathways describe the mechanisms by which a receptor becomes exposed to contaminants. At a minimum, a “complete” exposure pathway must include a source, a release mechanism, and a transport pathway (route of exposure) to the receptor. If any component is missing, the exposure pathway is likely to be incomplete. The sources, release mechanisms, and transport pathways have been described above. The following discussion identifies the exposure pathways and the receptors that may be exposed to sediment-related contaminants in the Removal Action Area. In this discussion, “sediment” is used to refer to both the solid and liquid (porewater) components of bulk sediment.

5.3.1 Relevant Exposure Pathways and Receptors

For human and ecological receptors, exposure to sediment contaminants may be direct or indirect. Direct exposure results from contact with contaminated sediment. Indirect exposure results from contact with contaminants that have been transferred from sediments to another exposure medium, such as water or biota.

Relevant direct exposure pathways include:

- contact between receptors’ external surfaces and contaminated bed sediment, including porewater;
- ingestion of contaminated sediment by receptors, either incidentally during drinking or eating or as part of the feeding process (e.g., filter feeders); and
- contact between the receptor and resuspended sediment (e.g., ventilation of gill surfaces).

Relevant indirect exposure pathways include:

- ingestion of food that has become contaminated through contact with sediment contaminants; and
- ingestion of or contact with surface water that has become contaminated through the transfer of contaminants into the dissolved or colloidal phases.

For humans and avian/mammalian wildlife, exposure to contaminants via dermal contact with sediments is typically considered minor compared to the ingestion pathways. However, external contact with sediment (including porewater) can be important for fish and aquatic invertebrates. Figure 5-2 illustrates the exposure pathways, as well as representative ecological receptors and human receptor types.

Bioconcentration and biomagnification are processes that affect exposure, especially in aquatic-based foodwebs. Bioconcentration is the increase in concentration of a chemical in an organism resulting from tissue absorption levels exceeding the rate of metabolism and excretion. Metals and organic compounds may bioconcentrate. Biomagnification occurs when concentrations of a chemical in biota increase with successive trophic levels. Biomagnification is best known with regard to persistent organic chemicals such as DDT and PCBs, but can also occur for organically transformed metals.

As noted previously, the focus of the Terminal 4 Removal Action is in-water contaminated sediment. Therefore, the risk analysis for Terminal 4 will focus on pathways related to the effect that contaminated sediment may have on other media, such as surface water and biota. Other exposure pathways are being addressed under other regulatory programs. Exposure to beach sediment and potential exposure to shorebirds are being addressed in the harborwide RI/FS baseline risk assessment. Likewise, exposure to surface water that may have been contaminated by pathways other than Terminal 4 contaminated sediment is also being addressed for humans and ecological receptors in the harborwide RI/FS.

5.3.1.1 Human Receptors

Human receptors potentially exposed at the site include (1) persons who fish in Terminal 4 and consume the fish that they catch and (2) persons engaged in activities during which they may contact sediments or surface water affected by sediments in Terminal 4. Specific receptor groups for which risk analysis will be conducted will be identified after the identification of Removal Action alternatives. Such receptor groups will probably include dockside workers and fishers/consumers (including recreational fishers, Native American fishers, and non-tribal fishers). Dockside workers could be exposed to in-water sediment-related contaminants if they contact contaminated sediment during work activities. Fishers of any group could be exposed to contaminants if they ingest fish that have absorbed contaminants from the sediment, as well as by contact with the sediment during fishing activities.

Currently, fishing exposures are assumed to occur aboard boats because federally mandated security measures for shipping ports prohibit access to the Terminal 4 shoreline and because the Port anticipates marine use of Terminal 4 for the foreseeable future. If land use of Terminal 4 changes in the future, additional risk analysis may be required, such as analysis of exposure to beach and nearshore sediment by fishers, transients or other waterfront users.

5.3.1.2 Ecological Receptors

Ecological receptors potentially exposed to sediment contaminants in the Removal Action Area are listed below. The list generally follows that developed for the Portland Harbor remedial investigation/feasibility study for the entire Lower Willamette River. Because of limited habitat quality, especially in the upland adjacent to the Removal Action Area, not all of the receptor types listed here are necessarily represented in the Removal Action Area or immediate vicinity. However, the list is provided to identify the scope of species that may occur at the Removal Action Area or in the Willamette River near the Removal Action Area.

- Benthic Infauna and Epibenthic Organisms. These receptors are in intimate contact with bed sediment. Many species of infauna are also filter feeders or otherwise process sediment during feeding.

- Benthic Fish. Fish such as sculpin, catfish, and sturgeon often reside on or near the river bottom, have direct contact with sediment, and may ingest sediment as they forage. Larval lamprey (i.e., ammocoetes) live in the sediments and filter food from ingested sediments. The presence of ammocoetes has not been confirmed in Portland Harbor, but, if present, the larvae would be exposed to contaminated sediment.

- Water-Column Fish. Fish such as smallmouth bass, northern pikeminnow, and juvenile salmonids feed in the water column and so have little contact with bed sediment, but may ingest contaminated food items.

- Amphibians. Amphibians may deposit eggs on or near sediments, and adults often burrow into sediments or live in direct contact with sediments. Adults and larvae may also ingest sediments as they feed on vegetation or prey.

- Waterfowl. Waterfowl include several feeding guilds that may have contact with contaminated sediments as a result of feeding. Dabbling ducks such as mallards may be directly exposed through incidental ingestion of sediment and indirectly exposed through ingestion of contaminated prey or vegetation during feeding. Diving ducks such as mergansers may be directly exposed through incidental ingestion of sediment and indirectly exposed through ingestion of fish or amphibians that have become contaminated.

- Wading Birds. Sandpipers and related wading birds may directly ingest sediment as they probe beaches and shallow sediment for invertebrates. They may be indirectly exposed through ingestion of contaminated prey species.

- Raptors. Aquatic-feeding raptors such as osprey and bald eagles may be indirectly exposed as they ingest contaminated fish from the water column. Direct exposure through ingestion of contaminated sediments by such species is limited to the sediment contained in the gastrointestinal tract of the prey species.

- Aquatic-Feeding Mammals. Raccoons, muskrats, and river otters are examples of mammals that feed on fish, invertebrates, and amphibians from aquatic habitats. Such receptors may be indirectly exposed through ingestion of contaminated prey and directly exposed through incidental ingestion of sediments.

6. Data Gaps and Data Quality Objectives

This section evaluates whether existing data are sufficient to develop Removal Action alternatives and to allow evaluation of the Removal Action alternatives for their ability to meet the Removal Action Objectives (RAOs). If the data are found insufficient in some regard, then a data gap has been identified and must be filled. At that point, data quality objectives (DQOs) are established to ensure that new data collected to fill data gaps are of appropriate quantity and quality. In the following discussion, this process is applied to evaluate data gaps and identify DQOs in the areas of history, cultural resources, and land use; physical characteristics; ecological and human health risk characteristics; engineering characteristics; hydrogeologic characteristics; recontamination source characteristics; sediment quality characteristics; dredged sediment quality characteristics; and hydraulics and sedimentation characteristics.

6.1 Evaluation Process

The steps in this evaluation are to:

- introduce preliminary RAOs;
- introduce proposed Removal Action alternatives and technologies;
- assess the data needs of for each alternative and technology;
- evaluate whether the existing data are sufficient both in quantity and quality to adequately perform a comparative evaluation of the Removal Action alternatives; and
- develop DQOs for any new data that need to be collected.

6.2 Rationale for Data Gap Assessment

6.2.1 Removal Action Objectives

The RAOs for the Terminal 4 Removal Action are to:

- Reduce ecological and human health risks associated with sediment contamination within the Removal Action Area to acceptable levels.

- Reduce the likelihood of recontamination of sediments within the Removal Action Area.

The Port proposes to achieve the RAOs while allowing continued use of the marine terminal and minimizing disruption of operations.

6.2.2 Removal Action Alternatives and Technologies

In accordance with the USEPA guidance (USEPA, 1993b) for Non-Time-Critical Removal Actions (NTCRAs), "only the most qualified technologies that apply to the media or source of contamination" need to be considered for the development, comparative evaluation, and selection of Removal Action alternatives. On the basis of prior experience with a number of contaminated sediment projects in the Pacific Northwest, the technologies identified as likely to qualify for consideration in the EE/CA include:

- dredging of contaminated sediments, which will be followed by some or all of the following additional, auxiliary technologies:
  - transport of dredged sediments;
  - treatment of dredged sediments; and
  - disposal of dredged sediments, either onsite or offsite; and
- in-situ capping of contaminated sediments.

It is plausible to assume that the alternatives for the Terminal 4 Removal Action will include a combination of some or all of these main technology types. The technology of no action and natural attenuation are not likely to be applied in wide areas of the Removal Action Area but may be applicable to marginal areas.

Certain site-specific information is required for each of these technologies before they can be developed as Removal Action alternatives in enough detail to evaluate how each would address the RAOs and fare in a comparative evaluation of their success at meeting the criteria of effectiveness, implementability, and cost. For each of these technologies, the most important data needs are:

- Dredging

  - chemical characteristics of sediment contamination;
  - lateral extent of contamination;
  - vertical extent of contamination;
  - sediment volume to be addressed;
  - engineering properties of sediment;
  - stability of neighboring structures;
  - impacts to water quality during dredging;
  - resuspension potential of sediment;
  - remobilization of chemicals;
  - presence and nature of underwater debris;
  - disposal methodology;
  - future berth configuration considerations;
  - impacts to current tenants and operations;
  - impacts to cultural resources; and
  - impacts to environment.

- Transport

  - dredging methodology (mechanical or hydraulic);
  - sediment volume to be transported;
  - water content of sediment;
  - sediment particle size, affecting its suitability for gravity dewatering;
  - the need and type of flocculating additives to enhance gravity dewatering; and
  - distance of transport.

- Treatment

  - volume of sediment to be treated;
  - homogeneity and uniformity of sediment;
  - sediment water content;

- sediment chemical composition;
- residual sediment characteristics;
- sediment leaching potential;
- availability of site for treatment; and
- landfill waste acceptance criteria.

- Onsite disposal in a confined disposal facility (CDF)

  - strength and compressibility of subsurface sediment/soil;
  - strength of containment berm aggregate;
  - settling characteristics of dredged sediment;
  - leaching potential of sediment;
  - hydrogeological parameters;
  - hydrogeological parameters of containment berm and enclosed sediment;
  - impacts to cultural resources; and
  - impacts to environment.

- Offsite disposal

  - water acceptance criteria at disposal facility;
  - sediment chemical composition;
  - leaching potential of contaminants with respect to waste acceptance criteria;
  - sediment volume and mass;
  - water content of sediment;
  - type of transport (truck, rail, or barge);
  - impact of transport on Port operations;
  - impact of transport on community; and
  - noise and air emissions during transport.

- Capping

  - strength and compressibility of sediment;
  - sediment leaching potential;
  - hydraulic gradient across cap;
  - bioturbation depth;
  - periodic loads on cap, including seismic load, erosion (current, tides, floods), and outfall scour;
  - operational loads and impacts including spuds, anchors, and propeller-induced scour and erosion;
  - impacts to cultural resources; and
  - impacts to environment.

Along with the specific data needs mentioned above, the operational requirements of the Terminal 4 facility will factor into the analysis of technologies and Removal Action alternatives. These operational requirements include present and future vessel types, facility maintenance (pile driving, maintenance dredging) requirements, spill control and response, and debris removal.

6.2.3 Introduction of Data Quality Objectives Process

This section presents the procedure for a focused assessment of the gaps in existing data in terms of what is needed to evaluate the removal technologies for their effectiveness, implementability, and cost. The data needs in turn will drive the general objectives of the Removal Action Area characterization through the DQO process in accordance with USEPA guidance (USEPA, 2000). The development of DQOs for the Removal Action is outlined in detail in Table 6-1 and, for the reader's convenience, discussed briefly below. Specific methodologies for executing the Removal Action Area characterization are then outlined in Section 7.

As shown in Table 6-1, DQOs are developed through a logical process comprising the following steps:

- Step 1: State the problem.

- Step 2: Identify the decision (i.e., identify the questions that must be answered to address the problem statement).

- Step 3: Identify inputs to the decision (i.e., identify the data types required to formulate decisions to address the problem).

- Step 4: Define the boundaries of the study (i.e., define the boundaries of the data collection efforts).

- Step 5: Develop a decision rule (i.e., describe the data uses and objectives for the information needed to make the required decision).

- Step 6: Specify tolerable limits on decision errors (i.e., specify how the data will be evaluated against accepted standards, where applicable).

- Step 7: Optimize the design for data acquisition (i.e., develop data collection activities that achieve specific DQOs and can be optimized to meet multiple DQOs).

For the Terminal 4 Removal Action, the process outlined above was employed to establish DQOs and identify data gaps in nine knowledge areas:

- history, cultural resources, and land use (Section 6.3);
- physical characteristics (Section 6.4);
- ecological and human health risk assessment characteristics (Section 6.5);
- engineering characteristics (Section 6.6);
- hydrogeologic characteristics (Section 6.7);
- recontamination source characterization (Section 6.8);
- sediment quality characteristics (Section 6.9);
- dredged sediment quality characteristics (Section 6.10); and
- hydraulics and sedimentation (Section 6.11).

6.3 History, Cultural Resources, and Land Use

The history of Terminal 4 is sufficiently understood to allow an evaluation for purposes of the EE/CA of how terminal operations have influenced the nature and extent of contamination in the Removal Action Area. No additional data collection regarding the history of Terminal 4 is anticipated, but additional data will be incorporated into the overall data set as they become available.

Existing cultural resources information, subject to acceptance by the Tribes, is sufficient to perform the work specified for the EE/CA. However, additional cultural resources information, in the form of oral histories, will be gathered by others, independent of the Terminal 4 Removal Action. Sediment and soil samples, boreholes, and cores will also be examined during sample collection for artifacts or other archaeological deposits (see Appendix A1 for details).

No data gaps exist in the understanding of current land uses. Future land uses at Terminal 4 will remain related to marine operations. Details regarding tenants, their operations, and the Port's actions to support those operations may change. As such information becomes available, it will be incorporated into the overall data set and will be considered during the Terminal 4 Removal Action.

6.4 Physical Characteristics

Existing information provides a thorough understanding of the Removal Action Area's physical characteristics, with one exception: topographic information for embankment slopes above the water line; more specifically, topography from the upper extent of the June 2003 hydrographic conditions survey (Port of Portland, 2003) to the top-of-slope. (Upland topographic data are available above the top-of-slope.) Filling this data gap is necessary for characterizing embankment slope stability and stability of a slope cap or under-pier cap.

The field work to address the data gap will include:

- a topographic grid survey on slopes at low river stage conducted by a licensed surveyor; and
- a lead-line survey below piers on a 100-ft grid.

6.5 Ecological and Human Health Risk Characteristics

6.5.1 Ecological Risk Assessment

The ecological risk evaluation for the EE/CA will consist of two components. In the first component, data on existing conditions of sediment contamination and toxicity will be summarized to help in the preliminary design of Removal Action alternatives. The first component will be completed using existing data on sediment contamination and toxicity, as well as data that will be collected during the EE/CA field program. The purpose of the first component is to identify the contaminants, potentially complete exposure pathways, and exposure points and receptors in the Removal Action Area. Assessment of risk in this component will be limited to a comparison of sediment data to SQGs, where available.

The second component will be specific characterization of the residual risk for each of the Removal Action alternatives proposed in the EE/CA. This characterization will be used to demonstrate each alternative's protectiveness of the environment and to compare the relative protectiveness of the alternatives. To the extent practicable, residual risks will be evaluated by comparing SQGs to sediment chemistry data. However, if risk calculations being developed by the Lower Willamette Group are approved by the USEPA and its partners during this process, those values will be used instead of SQGs. The specific methodology for the risk analyses will be determined in consultation with USEPA personnel after specific Removal Action alternatives have been identified. The methodology for evaluating residual risk will be documented during the Technical Briefing that will initiate the EE/CA process.

The conceptual site model (Section 5) shows potentially complete pathways for exposure of aquatic and terrestrial receptors to contaminated sediments in the Removal Action Area (Figure 5-2). Past data from Slip 3 show toxicity to test organisms in standard sediment toxicity tests (Hart Crowser, 2000d). Data from Slip 1, Slip 3, and Wheeler Bay indicate concentrations of COPCs (e.g., PAHs, zinc, and DDT) in surface sediments that exceed commonly used SQGs. Therefore, data from the Removal Action Area (sediment suggest that unacceptable risk exists in Slip 3 and is likely in Slip 1 and Wheeler Bay. Ecological risk evaluation is necessary to (1) help in designing preliminary Removal Action alternatives and (2) evaluate and compare the environmental protectiveness of the Removal Action alternatives.

For comparison of sediment chemistry to SQGs, the Removal Action Area data needs include:

- historical surface and subsurface data on sediment chemistry;
- data from the EE/CA field program documenting existing surface sediment chemistry;
- data on subsurface chemistry to (a) help in the design of Removal Action alternatives and (b) determine risks associated with Removal Action alternatives that may result in exposure of currently buried sediment horizons; and
- data from sediment elutriate testing to evaluate the effects of resuspended bed sediment on water quality.

6.5.2 Human Health Risk Assessment

The conceptual model introduced in Section 5 shows potentially complete pathways for exposure of humans to sediment contaminants at the Removal Action Area (Figure 5-2). Exposure pathways include direct exposure to sediments (i.e., incidental ingestion, dermal absorption) and indirect exposure through ingestion of surface water, fish, or shellfish that may have absorbed contaminants. While available information is insufficient to assess whether associated risks are acceptable, elevated concentrations of contaminants have been documented for the Removal Action Area. Data are needed for each Removal Action alternative to help determine whether residual risk to human health will acceptable after implementation of the Removal Action.

The approach to assessing human health risks includes two components. The first component focuses on existing conditions and is limited to identifying complete exposure pathways from sediment to humans and areas where elevated contaminant concentrations are known. Historical data and data from the EE/CA field program will be used in this assessment. Results will be used to help identify Removal Action alternatives that eliminate potentially complete pathways for exposure to humans.

As with the ecological risk assessment, the second component will evaluate the residual human health risks specific to each Removal Action alternative for the ingestion of biota and direct contact with in-water sediments. The specific risk questions and method for accomplishing this cannot be identified until the characteristics of each alternative have been identified. To the extent necessary, risk analysis procedures for human health will be consistent with those being used in the Portland Harbor Superfund Site remedial investigation/feasibility study.

The specific methods will be developed in consultation with USEPA risk assessors and formally documented in the Technical Briefing.

The information needed to support these decisions will include existing and new data on contaminant concentrations in surface and subsurface sediments; estimates of post-Removal Action concentrations; and, if bioaccumulation-based SQGs are not available, estimates of contaminant intake from fish or shellfish using existing data. However, information needs beyond sediment chemistry cannot be identified at this time.

The anticipated sediment chemistry data needs for the human health risk assessment are similar to those anticipated for the ecological risk assessment:

- historical surface and subsurface data on sediment chemistry;
- data from the EE/CA field program documenting existing surface sediment chemistry; and
- data on subsurface chemistry to (a) help in the design of Removal Action alternatives and (b) determine risks associated with Removal Action alternatives that may result in exposure of currently buried sediment horizons.

Additional data needs will be identified once Removal Action alternatives have been characterized and specific risk assessment methods have been approved.

6.6 Engineering Characteristics

Engineering characteristics of the Removal Action Area should be understood sufficiently well so that the Removal Action alternatives can be adequately developed and comparatively evaluated. Only a certain number of Removal Action technologies and alternatives will be considered to achieve the RAOs. These technologies have unique data needs. Data needs for engineering characteristics fall into three categories:

- Capping/dredging data needs
  - laboratory testing of sediments from core samples generally collected from soil strata near the surface and surface samples for engineering properties; and
  - additional information, such as the refusal depth for coring and other behaviors noted during the sampling process.

- Onsite disposal data needs
  - laboratory testing of sediments from core samples generally collected from soil strata near the surface and surface samples for engineering properties;
  - laboratory testing of sediments from core samples collected from soil strata at greater depth;
  - Standard Penetration Testing (SPT) blow counts in accordance with ASTM D 1586-99;
  - structure details and properties of structural elements;
  - monitoring wells installed using SPT sampling methodology;
  - seismic cone penetrometer tests (SCPT) or other CPT technology in accordance with ASTM D 5778-95 (2000);
  - seismic testing (e.g., shear wave velocity profile); and
  - additional information, such as the refusal depth for coring and other behaviors noted during the sampling process.

- Slope and adjacent structure stability data needs

- laboratory testing of sediments from core samples collected from soil strata at greater depth;
- SPT blow counts in accordance with ASTM D 1586-99;
- structure details and properties of structural elements;
- monitoring wells installed using SPT sampling methodology;
- SCPT or other CPT technology in accordance with ASTM D 5778-95 (2000); and
- seismic testing (e.g., shear wave velocity profile).

Figure 2-17 shows the locations of existing over-the-water geotechnical explorations. As the figure indicates, some geotechnical data are available, but not to the extent in quantity and distribution that would be sufficient to develop and compare the Removal Action alternatives. Although not shown on the figure, shallow upland borings and monitoring wells performed using SPT methodology are available and will be used during the EE/CA to the extent practical.

To locate additional exploration locations, design cross sections have been developed (Figure 6-1) and will likely be utilized during the development and evaluation of the Removal Action alternatives. These cross sections identify the most efficient number and locations of geotechnical explorations for gathering sufficient data. Field activities to fill data gaps will include:

- installing five geotechnical borings;
- installing 10 seismic cone penetrometer explorations; and
- installing one seismic properties boring.

The specific locations of and methodology for executing the data collection are described in Section 7.4.

6.7 Hydrogeologic Characteristics

Available information regarding hydrogeologic characteristics is summarized in Section 2.7. Additional data needs revolve around the following analysis requirements:

- development of a general hydrogeologic model for the Terminal 4 Removal Action Area; and
- support groundwater flow and contaminant transport modeling.

Activities to fill data gaps and support the EE/CA will include:

- installing three monitoring well clusters near the Willamette River, screened within each hydrostratigraphic unit influencing contaminant transport characteristics for sediments residing at the base of the slips;
- installing one intermediate/shallow well cluster at the Gatton's Slough organic silt/clay in Slip 1, with one screen in lower elevations of recent alluvial deposits at or slightly below elevation of Slip 3, the other within the Gatton's Slough soils if a saturated sand layer is encountered;
- installing two monitoring well clusters upgradient of the slips screened within each hydrostratigraphic unit; and
- surveying monitoring well top-of-casing elevations and ground surface elevations.

Subsequent data collection and testing will include:

- performing laboratory testing of long-term sediment leaching characteristics using thin-column leaching tests (TCLTs);
- performing laboratory testing of sediment sorption/desorption characteristics to provide site-specific values for contaminant transport modeling if TCLT results indicate that contaminant mass loading from sediment to surface water would occur;
- performing a limited groundwater monitoring study that incorporates extrapolated data on seasonal trends and existing data from Hart Crowser, 2000c and includes pressure transducers to measure real-time variation in water level, with periodic monitoring of conventional parameters; and
- performing grain-size testing for correlations to determine hydrogeologic parameters.

6.8 Recontamination Source Characterization

Potential sources of recontamination should be understood sufficiently well so that their impact can be incorporated in the development and comparative evaluation of the Removal Action alternatives.

A conceptual model for potential sources of sediment recontamination at the Terminal 4 Removal Action Area is shown on Figure 6-2. Sources at Terminal 4, such as ongoing operations, stormwater, and groundwater, will be considered. Sources outside Terminal 4 and the Removal Action Area, such as neighboring upland facilities, discharges or releases to the river, and sediment transport from elsewhere in the river, will also be considered.

The Port has, under the DEQ Voluntary Cleanup Program, established two initiatives to address the upland sources of contamination at Terminal 4: one for the Slip 1 area and one for the Slip 3 area specifically aimed at nonaqueous-phase liquid contamination. The Port's efforts, which are summarized in Section 3 and include remedial investigation, feasibility study, source control measures evaluation, and remedial action, will likely identify and control remaining sources at Terminal 4. The Port has also established a detailed stormwater management program for the entire Terminal 4 facility. Details of the Port's stormwater program are discussed in Section 3.3.2. Finally, the Port is a member of the Lower Willamette Group, which is the PRP group to address the contaminated sediment issues for the entire Portland Harbor Superfund Site.

Information from these efforts should provide the foundation for evaluation of source control and recontamination. In particular, the following information is expected:

- estimates of groundwater-related flux of contaminants to the Removal Action Area;
- estimates of the stormwater-related flux of contaminants into the Removal Action Area; and
- sediment quality and grain size measurements in Willamette River sediments near the Removal Action Area.

The approach to acquisition of these data is discussed in Section 7.7.

6.9 Sediment Quality Characteristics

The sediment quality characteristics of the Removal Action Area should be sufficiently well understood so that the lateral and vertical extent (area and volume) of sediment requiring remediation can be established in order to develop and evaluate the Removal Action alternatives.

Sediment quality data needs required for evaluation of Removal Action alternatives are:

- nature and lateral extent of contamination;
- under-pier sediment quality; and
- nature and vertical extent of contamination.

These sediment quality data needs are generally associated with the sediment in its **present place** and relate primarily to assist in establishing the extent of the sediment to be remediated. These data will also be used to estimate residual contamination (if any) and thus will serve as important inputs to the streamlined ecological and human health risk assessments to be performed as part of the evaluation of the long-term effectiveness of the Removal Action alternatives.

Different sediment characteristics data will be needed to describe sediment behavior for dredging and transportation to onsite or offsite disposal. These sediment quality data needs are discussed in the following sections.

6.9.1 Nature and Lateral Extent of Contamination

Surface sediment chemistry data will be used to evaluate the nature and lateral extent of contamination in the Removal Action Area. Insufficient surface sediment data are currently available for Slip 1 to allow delineation of the lateral extent of contamination, so additional surface sediment samples will be collected. Information for Slip 3 is insufficient to evaluate the lateral extent of contamination. Because bathymetry data from Slip 3 indicate that surface sediment may be resuspended and deposited in different areas as a result of propeller scour, additional surface sediment samples will be collected in Slip 3 to confirm surface sediment quality. Section 7.8.2 describes the number and locations of surface sediment samples that will be collected and the analyses to be performed.

6.9.2 Under-Pier Sediment Quality

Surface sediment chemistry data from under the piers is needed to determine whether action is required under the piers, as well as to determine the potential lateral extent of contamination under the piers. There are no available under-pier sediment data; therefore, under-pier sediment samples will be collected. There are no data available for the sediment in the pilings of the former Pier 5. Under-pier sediment samples will also be collected from this area. Section 7.8.3 describes the number and locations of under-pier surface sediment samples and the analyses to be performed.

6.9.3 Nature and Vertical Extent of Contamination

Subsurface sediment chemistry data will be used to determine the nature and vertical extent of contamination in the Removal Action Area. Insufficient subsurface sediment data are currently available to allow evaluation of the vertical extent of contamination in Slips 1 and 3, so additional subsurface sediment samples will be collected in Slips 1 and 3 to evaluate the vertical extent of contamination. Section 7.8.4 describes the number of cores, the locations of the cores, and the subsampling scheme for the cores, as well as the analyses to be performed.

6.10 Dredged Sediment Quality Characteristics

Dredged sediment quality characteristics should be understood sufficiently well to assist in the development and evaluation of Removal Action alternatives that involve dredging, i.e., the removal of sediment from its present place and subsequent transportation and onsite or offsite disposal of the sediment.

These data needs include the following:

- data needed to assess impacts to water quality during dredging;
- data needed to assess onsite disposal; and
- data needed to assess offsite disposal.

6.10.1 Water Quality Impacts During Dredging

Dredging elutriate data will be required to assess the water quality impacts during dredging so that the short-term effectiveness of Removal Action alternatives involving dredging can be evaluated. Dredge elutriate data will be collected from composite (surface and subsurface) sediment samples. No dredge elutriate data are currently available for the sediments that may require dredging. Therefore, composite samples will be collected for laboratory dredging elutriate tests.

Section 7.8.2 details the number of dredging elutriate tests that will be performed. The dredging elutriate samples will be analyzed for the same list of constituents as surface and subsurface sediment samples.

6.10.2 Sediment Quality Characteristics Impacting Onsite Disposal

Certain sediment quality characteristics need to be understood sufficiently well so that Removal Action alternatives involving onsite disposal can be adequately developed and evaluated. These characteristics are:

- settling velocity of the dredged material;
- short-term water quality impacts from a CDF; and
- long-term water quality impacts from a CDF.

No such data are currently available, so column settling, modified elutriate, and column leachate data will be collected from composite (surface and subsurface) sediment samples. Settling velocities will be evaluated with column settling tests, short-term water quality impacts will be evaluated with modified elutriate tests, while long-term water quality impacts will be evaluated with thin-column leaching tests. Section 7.8.3 discusses the number of composite sediment samples, their composition, and the analyses to be performed.

6.10.3 Sediment Quality Characteristics Impacting Offsite Disposal in a Subtitle D Landfill

Certain sediment quality characteristics need to be understood sufficiently well so that Removal Action alternatives involving offsite disposal can be adequately developed and evaluated. These data needs include:

- chemical data with respect to hazardous waste determination;

- chemical data with respect to Toxic Substances Control Act (TSCA) waste determination; and
- chemical and physical data with respect to landfill acceptance criteria.

The assessment of offsite disposal of dredged sediment assumes that the dredged sediment is suitable for disposal at a Subtitle D landfill. The assessment will be performed using the following landfill acceptance criteria:

- hazardous waste determination;
- toxicity characteristics leaching procedure (TCLP) testing;
- a TSCA determination;
- data on the generation and loss of free liquid; and
- any additional landfill-specific acceptance criteria.

Because existing data are insufficient for this analysis, new surface and subsurface sediment chemistry data and composite (surface and subsurface) sediment samples will also be collected. Section 7.8.4 details the number of samples, their composition, and the analyses to be performed.

6.11 Hydraulics and Sedimentation

The degree to which the Terminal 4 shoreline and local bathymetry influence river stage in the Willamette River should be sufficiently well understood so that potential changes to river flood stages as a result of berth modification necessitated by a Removal Action alternative can be adequately evaluated.

The data types of interest are:

- basin hydrology data;
- water stage measurements and corresponding flow measurements;
- upstream flow data; and
- any available velocity measurements or model computations in the river reach of interest.

Basin hydrology data such as monthly flow statistics, the effect of any upstream dams on flow, and similar information will allow an assessment of the range of flow conditions that might be experienced during the Removal Action.

Specific data needs include:

- cross-sectional river velocity measurements to calibrate a local hydrodynamic model;
- velocity measurements at several locations within the slip areas to characterize eddy circulation and differentiate between the following situations:
  - low or moderate river flow and no vessel activity;
  - high river flow and no vessel activity; and
  - vessel activity.
- river stage measurements at the Removal Action Area and near the mouth of the Willamette River or at some downstream location during high flow periods that can be correlated in time to USGS flow measurements; and
- characterization of the river bottom over the model domain.

The methodology and procedures for gathering and using these data are presented in Section 7.10.

Table 6-1
Data Quality Objectives Development

Data Type	Problem Statement	Required Decision	Decision Inputs	Study Boundaries	Decision Rule	Decision Error Limits	Design for Obtaining Data
History	The history of Terminal 4 should be sufficiently understood to evaluate for EE/CA purposes the influence of Terminal 4 operations on the nature and extent of contamination in the Removal Action Area.	Determine what activities could have contributed contamination and where.	Decision will require understanding of Terminal 4 history.	Terminal 4 property.	Terminal 4 history should be understood well enough to leave no substantial gaps in chronological continuity.	Not applicable.	None required. Existing information is sufficient.
Cultural Resources	The history of Terminal 4 should be sufficiently understood to evaluate the potential impact of the removal action on cultural resources within the Removal Action Area.	Determine what operational or spatial controls might be necessary during implementation of the removal action.	Decision will require understanding of Terminal 4 history.	Terminal 4 property.	Terminal 4 history should be understood well enough to leave no substantial gaps in chronological continuity.	Not applicable.	Oral histories may be required and would be gathered by others, independently from the Terminal 4 Removal Action. Samples, boreholes, and cores will be examined during collection for artifacts.
Land Use	The current and potential future land use of Terminal 4 should be understood well enough to identify potential constraints on the removal action.	Determine if current and potential future Terminal 4 land use could limit the type or location of removal action planned.	Decision will require a planning-level understanding of potential future land use and a thorough understanding of current land use at Terminal 4.	Terminal 4 property.	Current and potential future land use at Terminal 4 should be understood well enough to avoid conflicts with the removal action.	Not applicable.	Current Port operations and potential future Terminal 4 uses are subject to ongoing business planning processes.
Physical Characteristics	The physical configuration of the Removal Action Area should be sufficiently understood to safely and effectively explore the area and propose a removal action.	Determine the dimensions and other physical parameters of the Removal Action Area.	The decision will require bathymetric, topographic, geologic, and built structure information.	The Removal Action Area and the immediately adjacent slopes and upland areas.	The physical configuration of the Removal Action Area will need to be known well enough to support alternative evaluation and ultimately design.	Standard survey limits will apply.	Existing topography and bathymetry are sufficient for EE/CA except topographic information for above water line embankment slopes to be gained by topographic surveys.

Data Type	Table 6-1 Data Quality Objectives Development						
	Problem Statement	**Required Decision**	**Decision Inputs**	**Study Boundaries**	**Decision Rule**	**Decision Error Limits**	**Design for Obtaining Data**
Ecological Health	The potential exposure pathways from sediment to ecological receptors should be sufficiently understood to confirm that they will be sufficiently attenuated by the removal action or, if not, that residual risk is acceptable.	Slip 3 and Wheeler Bay: Determine whether post-removal action risks are acceptable. Slip 1: Determine (1) extent of removal action needed in slip and (2) whether post-removal action risks are acceptable.	For the analysis of alternatives in the EE/CA, comparison will require data on the projected surface sediment chemistry to relevant sediment criteria. Once the selected Removal Action has been implemented, but prior to closure, confirmation sampling will be used to assess the actual residual risk.	Removal Action Area.	Benthos and Fish: UCL95 for mean post-action surface sediment concentration in each unit, or other appropriate exposure unit, should not exceed chemical-specific SQGs. Upper Trophic Level Consumers: Aggregate exposure from T4 sediment should not exceed chemical- and receptor-specific LOAEL-based reference dose. (Based on UCL95 exposure point concentrations).	Implied error rate is 5% or less chance that mean exposure will exceed relevant criterion.	Evaluation of existing habitat data and coordination with collection and evaluation of sediment chemistry data.
Human Health	The potential exposure pathways from sediment to human users should be sufficiently understood to confirm that they will be sufficiently attenuated by the removal action or, if not, that residual risk from sediment is acceptable.	Determine whether post-removal action risk is acceptable for removal action alternatives.	Decision will require (1) data on surface sediment chemistry (projected post-Removal Action), AND (2) data on other exposure parameters (bioaccumulation, intake parameters, etc.) OR site-specific SQGs from harborwide risk assessment if available.	Removal Action Area	Remediate contaminated sediment to ensure that contaminant levels are not above ARARS or above risk-based goals when ARARS are not available or are not protective. Other factors (e.g., detection limits, background) and uncertainties may also be considered. For carcinogenic effects in humans, USEPA's Superfund program uses 10^{-6} to 10^{-4} as an acceptable cancer risk range; for non-cancer effects, the goal is to limit exposures to levels below the RfD. Protective is defined as a cancer risk of less than or equal to 10^{-4}; for non-cancer effects, protective is defined as exposures equal to or less than the RfD.	Implied error rate is 5% or less chance that mean exposure will exceed relevant criterion.	Sediment sampling and development of exposure scenarios appropriate to removal action alternatives.

Data Type	Table 6-1 Data Quality Objectives Development						
	Problem Statement	**Required Decision**	**Decision Inputs**	**Study Boundaries**	**Decision Rule**	**Decision Error Limits**	**Design for Obtaining Data**
Engineering Characteristics	The engineering properties of the sediments should be sufficiently understood to evaluate short-term effectiveness of removal actions such as capping or dredging.	Determine if the sediments in the Removal Action Area can be effectively dredged using available equipment and/or capped using accepted technology.	Decision will require knowledge of physical properties of the sediments including standard penetration test, grain size, moisture content, Atterberg limits, organic content, bulk density, specific gravity, consolidation, and shear strength.	Removal Action Area.	The engineering properties of the sediments should be known at a level consistent with standard of practice in the Pacific Northwest for sediment remediation and other shoreline projects.	Accuracy of the individual geotechnical tests is set forth in the appropriate ASTM.	For sediment, utilize 10% to 20% of all vibracore sampling locations to obtain samples. Drill 3 geotechnical borings over the water. Perform 7 seismic cone penetrometer tests (SCPT) in-water. Laboratory testing to be comprised of particle size distribution test, Atterberg limits test, moisture content test, specific gravity test, organic content, triaxial testing (shear strength), and consolidation testing (compressibility). Obtain tip resistance, sleeve friction and pore pressure parameters as well as shear wave profiles from SCPTs.
Engineering Characteristics	The properties of sediments within the Removal Action Area and the properties of soils in the vicinity of the Removal Action Area should be sufficiently understood to evaluate the interaction of sediments and nearby slopes, structures and fixtures caused by removal action.	Determine the maximum practical dredging elevation adjacent to existing slopes and structures.	Decision will require geotechnical borings and related standard penetration tests as well as index testing of selected samples.	The Removal Action Area and immediately adjacent slopes and upland areas.	The engineering properties of the soils on the margins of the Removal Action Area should be known at a level consistent with the standard of practice for evaluation of slope stability using models such as Plaxis.	Accuracy of the individual geotechnical tests is set forth in the appropriate ASTM.	Drill boreholes at 6 locations. These boreholes will be completed as clustered monitoring wells. Drill 1 deep geotechnical boring for upland shear wave velocity profile testing. Drill 2 geotechnical borings. Laboratory testing to be comprised of particle size distribution test, Atterberg limits test, moisture content, specific gravity test, organic content, triaxial testing (shear strength), and consolidation testing (compressibility).
Engineering Characteristics	The Removal Action Area itself should be sufficiently understood to evaluate the feasibility of onsite disposal of contaminated sediments.	Determine the feasibility of construction of a disposal facility within the Removal Action Area.	Decision will require geotechnical borings and related standard penetration tests as well as index testing of selected samples.	The Removal Action Area in general and critical areas such as those where closure berms or adjacent structures could present feasibility limitations for onsite disposal.	The engineering properties of the sediments within the Removal Action Area and in immediately adjacent areas should be known to a level consistent with the standard of practice for evaluation of onsite disposal.	Accuracy of the individual geotechnical tests is set forth in the appropriate ASTM.	Utilize 10% to 20% of samples at vibracore locations. Drill 2 geotechnical borings. Perform 7 SCPT within the slips and 3 SPCT in front of the slips. Collect in-situ soil parameters using the SPT test. Laboratory testing to be comprised of particle size distribution test, Atterberg limits test, moisture content test, specific gravity test, organic content, triaxial testing (shear strength), and consolidation testing (compressibility). Obtain tip resistance, sleeve friction and pore pressure parameters as well as shear wave profiles from SCPTs.
Hydrogeologic Characteristics	The Removal Action Area should be sufficiently understood to evaluate the feasibility of onsite disposal or in-situ capping of contaminated sediments.	Will contaminated sediments disposed of onsite be effectively contained for the long term?	Decision will require knowledge of hydrogeologic regime and groundwater quality.	Terminal 4 property surrounding Removal Action Area as necessary.	Hydrogeologic regime and groundwater quality information should be sufficiently understood to provide inputs to typical models such as ModFlow and MT3D.	Accuracy based on appropriate laboratory standards.	Perform elutriate testing to assess partitioning of absorbed contaminants into liquid phase during removal action. Perform TCLT laboratory testing to assess the long-term leaching potential of sediment to be disposed at disposal facilities or capped in situ.

Data Type	Problem Statement	Required Decision	Decision Inputs	Study Boundaries	Decision Rule	Decision Error Limits	Design for Obtaining Data
	Table 6-1 **Data Quality Objectives Development**						
Recontamination Source Characterization	Sources within and immediately adjacent to Removal Action Area could contribute contaminants in sufficient mass to ultimately recontaminate the Removal Action Area.	Determine if sources on or immediately adjacent to the Removal Action Area may result in recontamination.	Decision will require knowledge of contaminant mass loading from sources such as stormwater and groundwater.	Terminal 4 property surrounding the Removal Action Area as necessary.	Mass loadings should be sufficiently understood to assess the potential for recontamination using models such as WASP, if necessary, or more simple approaches, if possible.	Mass loadings will need to be quantified such that analysis of recontamination within a 50- to 100-year design life will be possible.	Collect stormwater samples from outfalls, install monitoring wells and collect groundwater quality samples. (Note: these samples to be collected by others under Terminal 4 Slip 1 upland study.)
	Other sources of contamination to the river could contribute contaminants in sufficient mass to ultimately recontaminate the Removal Action Area.	Determine if other sources will result in contamination.	Decision will require knowledge of contaminant mass loading from offsite sources such as nearby facilities, upriver industrial and agricultural sources.	The Willamette River upstream and in the vicinity of Terminal 4.	Mass loadings should be sufficiently understood to assess the potential for recontamination using models such as WASP, if necessary, or more simple approaches, if possible.	Mass loadings will need to be quantified such that analysis of recontamination within a 50- to 100-year design life will be possible.	Analyze existing information for river water quality, analyze existing information on Willamette River sedimentation and sediment chemistry, and analyze suspended and bedload transport rates. Collect additional chemistry information on suspended sediment.
	Historical and existing sources of contaminants may be declining and future recontamination potential could be significantly lower than historical or present day potential.	Evaluate historical concentration trends in sediment to determine whether or not sources are declining and whether or not present-day measured recontamination potential will be representative of the future trends.	Determination will require obtaining data on historical sediment concentration trends from sediment core profiles.	Removal Action Area.	Sediment cores must be obtainable from long-term depositional areas in the removal action area. Detailed core chemistry profiles will also be needed.	Approximately +/- 2 ft vertically.	Qualitatively evaluate core chemistry profiles for better determination of change in sediment concentrations with depth.
Sediment Quality	The areal extent of surface sediment contamination should be delineated to determine the areal extent of sediment that requires remediation.	Determine areal extent of surface sediment contamination.	Decision will require evaluation of existing surface sediment chemistry data and collection of surface sediment samples for chemistry analysis to provide adequate coverage of the Removal Action Area.	Removal Action Area.	Surface sediment quality should be sufficiently understood to assess the areal extent of sediment contamination.	Approximately +/- 50 to 100 ft horizontally, the assumed length and width of a dredge sub-prism.	Collect surface sediment samples in the Removal Action Area and analyze for chemistry.
	The quality of surface sediment under the piers should be evaluated to determine if remediation is required for under-pier sediment.	Determine under-pier surface sediment quality.	Decision will require collection of under-pier surface sediment samples for chemistry analysis.	Under-pier areas within Removal Action Area.	Under-pier surface sediment quality should be sufficiently understood to assess the need for under-pier sediment remediation.	Approximately +/- 50 to 100 ft horizontally.	Collect under-pier surface sediment samples in the Removal Action Area and analyze for chemistry.
	The vertical extent of subsurface sediment contamination should be delineated to determine the depth and volume of sediment that requires remediation.	Determine vertical extent of subsurface sediment contamination.	Decision will require evaluation of existing subsurface sediment chemistry data and collection of subsurface sediment samples for chemistry analysis to provide adequate coverage of the Removal Action Area.	Removal Action Area.	Subsurface sediment quality should be sufficiently understood to assess the vertical extent of sediment contamination.	Approximately +/- 1 ft vertically, the assumed allowable amount of overdredge.	Collect subsurface sediment samples in the Removal Action Area and analyze for chemistry.

Table 6-1
Data Quality Objectives Development

Data Type	Problem Statement	Required Decision	Decision Inputs	Study Boundaries	Decision Rule	Decision Error Limits	Design for Obtaining Data
Dredged Sediment Transport and Disposal	The onsite transport and disposal characteristics of the sediments within the Removal Action Area should be understood.	Determine the effectiveness of onsite transport and disposal technologies.	Decision will require physical and chemical analysis of the contaminated sediments.	Removal Action Area.	Settling behavior, elutriate concentration, and leaching behavior should be understood at a level necessary to evaluate on-site disposal technologies.	Corps of Engineers protocols will apply.	Sediment samples will be tested for settling velocity, dredging and modified elutriate behavior, and column leaching behavior.
	The offsite transport and disposal characteristics of the sediments within the Removal Action Area should be understood.	Determine the effectiveness of offsite transport and disposal technologies.	Decision will require physical and chemical analysis of the contaminated sediments.	Removal Action Area.	Dewatering behavior, water treatment requirements, and disposal facility-specific testing requirements should be understood at a level sufficient to evaluate offsite disposal.	Facility-specific.	Sediment samples will be tested for generation and loss of free liquids, pore water quality, and disposal facility-specific tests.
Hydraulics and Sedimentation	Velocity and associated bed shear stress patterns in the Removal Action Area will likely control sedimentation rates important to evaluating recontamination potential.	Identify what areas will be most subject to sedimentation and how sedimentation will vary spatially in the Removal Action Area.	Decision will require an understanding of the spatial (two-dimensional) variation in flow velocities and associated bed shear stresses for a range of flow conditions.	Terminal 4 project area and section of Willamette River bounded by the project area.	Velocity patterns (location, direction and magnitude) and bed shear stresses (location and magnitude) should be measured and/or computed on a grid or scale of sufficient resolution to resolve the main flow circulation pathways and bathymetric variations.	Desired accuracy of velocity predictions or measurements - approximately +/- 0.2 ft/sec.	Measure velocity profiles along transects within Slips 1 and 3 of the Terminal 4 project area and across the Willamette River at the upstream, mid point, and downstream boundary of the removal area. Compute velocities and shear stresses using the RMA2 hydrodynamic model, utilizing measured values for model calibration.
	The degree to which the Terminal 4 shoreline and local bathymetry influence river stage should be understood so that potential changes to river flood stages as a result of berth modifications can be predicted.	Determine if flood stage will be appreciably impacted by activities in the Removal Action Area.	Decision will require flood stage simulations for existing conditions and post-remediation conditions (and potentially during remediation of local flow constrictions are put in place such as sheet pile).	Main channel of the Willamette River to a distance upstream where changes in the local river geometry can be shown to have a minimal impact on river stage.	Terminal 4 modifications as a result of remediation action should not have any appreciable impact on upstream or downstream flood stage.	Predicted flood stage for existing conditions and modified conditions using a river hydraulics model with accuracy of at least +/- 0.5 ft, or equal to accuracy of existing, accepted flood stage models for the Willamette River.	Obtain model inputs for existing flood stage simulations for the Willamette River, simulate existing conditions for the 100-yr flood, and modify river cross sections to reflect remedial actions at the Terminal 4 area and then repeat the 100-yr flood simulation. Compare water surface elevation predictions for each case.

7. Removal Action Area Characterization Activities

This section describes the methodologies, procedures, and protocols to be used in collecting data to fill the data gaps identified in Section 6. Filling these data gaps will provide the additional information needed to complete the Removal Action Area characterization.

7.1 Summary of Data Sufficiency

Available data in several areas were found to be insufficient to adequately develop and evaluate Removal Action alternatives, as summarized below.

- History, Cultural Resources, and Land Use — available data, subject to acceptance by the Tribes, are sufficient;
- Physical Characteristics — available data are nearly sufficient;
- Ecological and Human Health Risk Characteristics — available data are insufficient, additional data required;
- Engineering Characteristics — available data are insufficient, additional data required;
- Hydrogeologic Characteristics — available data are insufficient, additional data required;
- Recontamination Source Characterization — available data are insufficient, additional data required;
- Sediment Quality Characteristics — available data are insufficient, additional data required;
- Dredged Sediment Quality Characteristics — available data are insufficient, additional data required; and
- Hydraulics and Sedimentation Characteristics — available data are insufficient, additional data required.

7.2 History, Cultural Resources, and Land Use

No additional data collection regarding Terminal 4 is required in the knowledge areas of history, cultural resources, and land use; existing information is sufficient, subject to the Tribes' acceptance. Oral histories, while not necessary for the EE/CA, will be gathered by others independent of the Removal Action project. Historical Terminal 4 data that become available will be incorporated into the EE/CA.

7.3 Physical Characteristics

The physical characteristics data gaps for the Removal Action Area consist only of topographic information on the embankment slopes above the water line, from the upper extent of the available hydrographic surveys to top-of-slope, above which upland topographic surveys are available. The field work will consist of a topographic grid survey on slopes at low river stage and a lead-line survey below piers on a 100-ft spacing.

Once the grid survey is performed for the embankment slope to the top-of-slope, the information will be converted to CRD and incorporated into the base map for the Removal Action Area prior to analysis of cross sections. The lead line surveys will be indicated as numeric elevation values (i.e., CRD) shown on the correction horizontal position according to digital global positioning system measurements taken during data collection activities.

7.4 Ecological and Human Health Risk Characteristics

An important motivation for performing the Removal Action is the known unacceptable ecological risk as evidenced in some sediment samples that show toxicity to benthic organisms and contaminant concentrations that exceed risk-based SQGs. A streamlined risk evaluation will be conducted for the EE/CA to aid in selection of a Removal Action alternative for the Removal Action Area. In accordance with USEPA guidance for NTCRAs (USEPA, 1993b), the risk assessment will be streamlined to identify exposure pathways of potential concern and provide a screening-level assessment of potential risk associated with complete pathways.

The overall EE/CA risk analysis approach includes two components. The first component is intended to simply identify the contaminants, potentially complete exposure pathways, and exposure points in the Removal Action Area and compare sediment data to SQGs to provide a preliminary characterization of risk. The first component will be completed using existing data on sediment contamination and toxicity, as well as data that will be collected during the EE/CA field program. The results will be used to aid in preliminary design of alternatives to help ensure that exposure pathways of interest are addressed.

The second component will be specific characterization of the residual risk for each of the Removal Action alternatives proposed in the EE/CA. As noted above, this characterization will be used to demonstrate the protectiveness of human health and the environment for each alternative and to compare the relative protectiveness of the alternatives. Once Removal Action alternatives have been identified, risk analysis procedures that are specific to assessing residual risks for each alternative will be proposed in the Technical Briefing on Removal Action Alternatives (Technical Briefing) to be submitted for USEPA review and approval prior to the EE/CA report.

Section 5 describes the preliminary conceptual model for the site, including the important sources and media to which human and ecological receptors may be exposed. The risk analyses will focus on the pathways relevant to each receptor type.

7.4.1 Human Health Risk Assessment

As noted above, the human health risk assessment (HHRA) will have two components. The first component will focus on identifying potential exposure pathways currently existing at the Removal Action Area and the human uses of the Removal Action Area that might result in exposure. Data on contaminant concentrations in sediment will be used to identify the areal extent of potential exposures. Removal Action alternatives will then be developed to address the areas of exposure.

The objective of the second component is a specific analysis of residual human health risk associated with each Removal Action alternative. Proposed methods for the analysis will be documented in the Technical Briefing document and submitted to USEPA for review and approval. The extent of the analysis will depend on the nature of the Removal Action. For example, if Slip 3 alternatives prescribe pathway elimination (e.g., through extensive capping with clean materials), the remaining surface that is not capped will be the focus of the analysis.

The HHRA is expected to include one or more exposure scenarios reflecting expected human use of the Removal Action Area following the Removal Action. The scenarios will allow identification of the appropriate frequency and duration of exposure. To the extent applicable, the scenarios will be consistent with those to be used in the Portland Harbor Superfund Site RI/FS. Human uses that result in potentially complete exposure pathways are expected to include fishers that consume fish caught in and around Terminal 4, occupational exposures for dock workers, and trespasser/transient scenarios. The exposures are expected to include consumption of fish and, therefore, will include assessment of bioaccumulative compounds as appropriate. This may require use of SQGs based on bioaccumulation. If agency-approved bioaccumulative SQGs are available from the Portland Harbor RI/FS, they will be used in the EE/CA process. If not available, site-specific SQGs may be developed if necessary to support removal decisions. Direct contact with in-river sediments will also be considered for scenarios for which it is applicable. The long-term plans for land use at Terminal 4 will be used to adjust the frequency and intensity of exposures considered in the risk analyses. For example, marine operations and security measures may minimize access to the water from land at Terminal 4, reducing fishing opportunities and catch. Ongoing marine activities may limit Terminal 4 as a significant source of food to subsistence fishers.

As noted, specific methods for exposure analysis will be consistent with those used for the Portland Harbor Superfund Site RI/FS. However, the EE/CA field data collection is not expected to include fish or invertebrate tissue beyond that collected for the RI. Therefore, assumptions regarding exposure may be adopted, including use of data on fish species that are not normally important in human consumption and use of biota-sediment accumulation factors (BSAFs) to estimate uptake into consumed fish and invertebrate species. Exposure and risk calculations will be consistent with USEPA guidance.

7.4.2 Ecological Risk Assessment

The following discussion presents general ecological characteristics of the Removal Action Area followed by an approach for the risk evaluation for Slip 1, Slip 3, and Wheeler Bay. Because the approach will utilize SQGs to evaluate risk potentials, a discussion of the SQGs is also presented. As for the HHRA, specific ecological risk analysis processes will be proposed in the Technical Briefing once Removal Action alternatives have been identified. However, SQGs for evaluating potential toxicity to benthic invertebrates and fish are available for use in preliminary risk characterization during alternative development. SQGs will be used to provide a preliminary estimate of ecological risk for Terminal 4 sediments.

7.4.2.1 Ecological Characterization

The Removal Action Area consists of a highly modified habitat; its quality is limited by past and present industrial and maritime land uses, and it has been modified by dredging and shoreline development for marine operations. No native habitat or shoreline currently exists in the Removal Action Area. Some shallow-water habitat (<20 ft) does exist at edges and margins of the Removal Action Area, both under piers and in open water. Wheeler Bay has the most extensive uncovered, nearshore shallows, with beach areas where wildlife can feed. Some shoreline and upland areas have been replanted at the north side of Slip 3. Given the past operations at Terminal 4 and the current understanding of habitat characteristics, no additional habitat characterization is needed to support Removal Action decisions.

Threatened and Endangered Species

A search of the existing literature to determine the presence of threatened and endangered species will be conducted. This will include the general scientific literature, information obtained from the USFWS, the DEQ, and other federal, state, and local agencies. Table 2-6 summarizes the results of a recent search conducted for the Portland Harbor Superfund Site RI/FS. As required, a complete biological assessment will be performed (see Section 8.6.2) to evaluate the effects of the preferred Removal Action alternative on any threatened or endangered species that may be present in the Removal Action Area.

Benthic Resources

Because the sediment in Slips 1 and 3 is of a highly disturbed nature as the result of maritime operations and maintenance dredging, the development of benthic communities in some areas of the slips may be limited. However, Sediment Profile Imaging (SPI) showed a functional benthic community in Slip 3 and at the head of Slip 1. Benthic organisms may exist in the shallow-water habitat within the slips and in Wheeler Bay.No specific, added studies will be conducted to characterize benthic communities in Terminal 4. Benthic resources will be addressed in the ecological risk assessment through the use of specific SQGs for benthic organisms.

Fish Resources

Due to the size of Terminal 4 and the highly mobile nature of fish resources in the Willamette River, it is unlikely that fish resources in the harbor will be significantly affected by actions identified in the EE/CA. Fish resources in Terminal 4 probably include resident species (e.g., sculpin) as well as species that may spend only a portion of their time there (e.g., smallmouth bass, juvenile salmonids). Individual fish in Terminal 4 could be adversely affected by sediment contamination. However, it is unlikely that contamination in Terminal 4 would by itself significantly affect fish populations in the Lower Willamette River. Risks to fish will be evaluated through the use of SQGs to address food-chain effects for the post-Removal Action analysis; water-column effects (i.e., through resuspension of sediment) will be addressed for possible risks as part of the evaluation of long-term effectiveness during the Removal Action (see Section 8.5.1.5).

Other Ecological Receptors

Additional ecological resources present in the Removal Action Area, such as amphibians, birds, and small mammals, will be evaluated in the ecological risk assessment through use of SQGs (see Section 8.5.1.5).

7.4.2.2 Ecological Risk Assessment Approach

As noted above, the ecological risk assessment will have two components. The first is primarily intended to characterize existing conditions through comparison of sediment quality data to SQGs for the contaminants relevant to the EE/CA. This process has been initiated with the comparison of existing sediment data to SQGs and the summary of toxicity testing data, both presented in Section 4 of this work plan. Additional characterization of existing conditions will be conducted using surface sediment and surface water data collected during the EE/CA field program. This information will be used to help design Removal Action alternatives and will be presented in the EE/CA report.

The second component will focus on evaluating residual risks associated with each of the Removal Action alternatives. The approach will also be primarily based on comparison of sediment chemistry data to SQGs. For each alternative, the analysis will focus on the surface conditions expected following implementation. This includes evaluation of:

- newly exposed sediment that may result from dredging operations;
- existing surface sediment conditions that may be left undisturbed; and
- risks that may be associated with potential sources of recontamination to surface materials.

The analysis will include the SQGs presented in Section 4. However, subject to approval from USEPA, Portland Harbor-specific SQGs that become available from the Portland Harbor Superfund Site RI/FS will be substituted for literature-based SQGs where applicable. This will help ensure consistency of the Terminal 4 Removal Action with the harbor-wide remedial action(s) that will be identified in the Record of Decision. Use of such criteria may be adopted at several points in the EE/CA process, including assessment of residual risk and/or final identification of Removal Action areas. Where such criteria are not available, specific risk-analysis procedures will be proposed in the Technical Briefing.

Supplemental information is also available for risk analysis if needed to support Removal Action decisions. These data include contaminant concentrations in a few fish species and some crayfish samples that are available from harbor-wide sampling for the RI/FS (Lower Willamette Group, 2003). Much of the available data are from Slip 1, with fewer samples available from Wheeler Bay and Slip 3. These data may aid in evaluating risk from sediments that would remain undisturbed by Removal Action alternatives or in assessing the relative importance of offsite sources to risk in the Removal Action Area.

In addition to the residual long-term risks associated with each alternative, the short-term risks during alternative implementation will be assessed. Of primary concern is the resuspension of bed sediments during dredging or other disturbances. The effects of suspended sediment on water quality will be evaluated using results of elutriate testing and other analyses.

7.5 Engineering Characteristics

As discussed in Section 6.6, available information is insufficient to adequately develop and evaluate Removal Action alternatives. Therefore, additional geotechnical explorations are proposed with associated laboratory testing. The following sections discuss the methodology, protocols, and procedures of the exploration and laboratory testing. The methodology of sampling and testing somewhat depends on the analytical tools to be used for the development and evaluation of the Removal Action alternatives. Therefore, where this is the case, the analytical method is also presented and its special data input needs are discussed.

7.5.1 Geotechnical Field Exploration

Six geotechnical borings and 10 SCPTs are proposed to address engineering characteristics. Geotechnical borings will be completed in accordance with OAR 690 Division 240 Construction, Maintenance, Alternation, Conversion and Abandonment of Monitoring Wells, Geotechnical Holes, and Other Holes in Oregon. Hollow-stem auger borings will be completed for geotechnical borings and monitoring wells in general accordance with ASTM D 1452, Standard Practice for Soil Investigation and Sampling by Auger Drilling. SCPT technology involves a less invasive, temporary installation of a probe that is grouted upon retraction. SCPT explorations will be performed in general accordance with ASTM D 5778, Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils. The proposed locations of these explorations are shown on Figure 7-1.

The field sampling plan provides additional details pertaining to the geotechnical explorations (both borings and SCPTs). Details for the proposed geotechnical borings, including anticipated depths and number of samples, are shown in Table 7-1, which indicates laboratory testing to be performed for the combined purposes of engineering and hydrogeologic characterization. Testing will be performed in accordance with the ASTM standards indicated in Table 7-1.

Regarding analysis of engineering characteristics, this section further elaborates on the analysis methods and models that will be used in the EE/CA. The analyses described in this section will either be completed to support the screening of technologies during development of Removal Action alternatives or performed after the technologies have been assembled into Removal Action alternatives to aid in determining technical feasibility.

7.5.2 Sediment Physical Properties

Laboratory testing of sediment physical properties will provide input to the assessment of sediment engineering characteristics. Sediment physical properties can be generally categorized into the following subgroups:

- Physical properties (for characterization of sediment and upland soil)
  - moisture content;
  - grain size;
  - organic content; and
  - specific gravity.

- Consolidation properties (for characterization of sediment and upland soil)
  - 1-dimensional consolidation; and
  - Atterberg limits.

- Shear strength properties (for testing of deep “sediment” and upland soil)
  - UU triaxial test. This is a rapid shear test (unconsolidated, undrained) that gives a general idea of the undrained strength characteristics of the sample in its disturbed condition following extrusion from a thin-walled sample liner.

  - CU triaxial test. This is a more representative and time-consuming shear strength test that involves consolidating the soil to its in-situ stress conditions (i.e., compressed axially and laterally to represent in-situ stress regime, then sheared undrained). The test allows an approximation of the drained shear strength properties of the sediment/soil by measuring pore-pressure during the shear.

Seismic properties will not be determined based on laboratory testing. Alternatively, SCPT and the seismic properties borings will also provide shear wave velocity profiles that will become inputs for the analysis of seismic stability and liquefaction potential.

7.5.3 Slope Stability Assessment Methodology

A commercially available software package, SLOPE/W v5.0 (GEO-SLOPE, 2002) will be used to assess the stability of slopes affected by the Removal Action. This software package is based on the limit equilibrium method and the Spencer’s calculation methodology commonly used in geotechnical engineering practice for slope stability analyses. Its use has been accepted and approved for contaminated sediment remediation projects by USEPA Region 10.

Cross sections 1 through 7 shown on Figure 7-1 will be used to select representative analysis sections for evaluating slope stability of potential containment berms (i.e., cross sections 1, 2, and 3) and impact to adjacent structures from dredging and stability of under-pier slopes subject to capping (i.e., cross sections 4, 5, 6, and 7). From subsurface information, “worst-case” soil conditions profiles will be modeled for slope stability using conventional means (i.e., SLOPE/W). Engineering properties obtained either directly or by empirical correlations/published values will be used to develop input parameters for the analyses.

Analysis conditions to be tested in the modeling, depending upon the Removal Action alternative, will consist of the following (to be further discussed in the EE/CA):

- Short-term (undrained). Represents conditions during or immediately after construction of the Removal Action alternative.
- Long-term (drained). Represents the long-term, static equilibrium condition long after construction of the Removal Action alternative.
- Pseudo-static. Represents a quasi-seismic evaluation methodology that adds an inertial horizontal force to simulate the increase driving force from earthquake shaking.
- Post-liquefaction (residual shear strength). Represents the case where applicable sediments/soils have liquefied and undergone loss of shear strength following the liquefaction event.

To assess the additional complexity of determining “impacts to adjacent structures” from dredging adjacent to piers, as well as the additional complexity of seismic stability of potential containment berms, Plaxis v8 will be used in the EE/CA as needed. Plaxis will supplement SLOPE/W to support the determination of technical feasibility and cost of a particular Removal Action alternative. Plaxis v8 (Plaxis, 2002) is a finite element model capable of simulating the interaction of soil and structures subject to changed loading and/or stress state conditions, including the capability to consider a number of construction steps and the incremental effects on stability. Rather than predicting a factor of safety, this model provides output indicating the deformation characteristics of the soil and resulting stress/moment conditions and deflection of the adjacent structure elements. This analysis will be needed for evaluating dredging immediately next to the piers. Dredging will likely require the addition of a sheet pile wall to maintain the stability of under-pier slopes and the stability of the pier itself (depending on the nature and extent of contamination to be removed and the Port’s planned facility use). The representative size and type of structural reinforcement will be needed to establish a reasonably representative and comparable cost for the EE/CA.

7.5.4 Settlement and Consolidation Assessment Methodology

Settlement (elastic compression and consolidation) below caps, under-pier caps, and containment berms may be severe enough to limit the effectiveness or even nullify the technical feasibility of Removal Action alternatives. The EE/CA will include analyses using both standard 1-Dimensional Consolidation Theory and the USACE’s ADDAMS model PSDDF (Primary-Secondary Consolidation, and Desiccation of Dredged Fill) (Stark, 1996). The latter will be used only as part of the assessment of effectiveness of onsite disposal. For PSDDF, a portion (or all) of cross sections 8 through 11 (particularly 10 and 11), shown on Figure 6-1, could be modeled for consolidation behavior. The settlement and consolidation behavior of the Removal Action Area will not only involve the amount (i.e., magnitude) of settlement, but also the length of time (i.e., time rate) of settlement, which will likely factor into the evaluation process.

7.5.5 Liquefaction Potential/Seismic Strength Assessment Methodology

The behavior of the Removal Action Area or a Removal Action alternative in response to earthquake effects may be severe enough to limit the effectiveness or nullify the technical feasibility of a given Removal Action alternative. Liquefaction analyses will be performed based on the standard of practice approach by Seed et al. (1985) and the National Center for Earthquake Engineering Research Workshop (NCEER, 1996) to define the extent of liquefaction predicted and potential impacts to the Removal Action alternatives. To accomplish this analysis, the shear wave velocity profiles collected during the field program will be used to perform a ProSHAKE (or equivalent) analysis, which calculates a site-specific peak ground acceleration that may occur for a particular representative set of seismic conditions. For liquefaction, a portion (or all) of cross sections 8 through 11 (particularly 10 and 11), shown on Figure 6-1, could be modeled for this condition when evaluating Removal Action alternatives.

The peak ground acceleration determined from ProSHAKE (or equivalent) will also be used as an input to the pseudo-static seismic stability analyses. Additionally, post-liquefaction residual shear strength to support the slope stability analyses will be determined from methods presented in Kramer (1996) and Seed and Harder (1990).

7.6 Hydrogeologic Characteristics

As discussed in Section 6.7, available information is insufficient to adequately develop and evaluate Removal Action alternatives. Therefore, additional hydrogeologic investigations are proposed with associated laboratory testing. The following sections discuss the methodology, protocols, and procedures of the hydrogeologic data collection.

Six monitoring well clusters are proposed to address hydrogeologic characteristics. Monitoring wells will be completed in accordance with OAR 690 Division 240 Construction, Maintenance, Alternation, Conversion and Abandonment of Monitoring Wells, Geotechnical Holes, and Other Holes in Oregon and in conformance with DEQ guidance (see http://www.deq.state.or.us/wmc/tank/documents/monwell.pdf). The field sampling plan provides additional details pertaining to well completion and well development. Details for the proposed monitoring wells (anticipated depths and number of samples) are provided in Table 7-1, which indicates laboratory testing to be performed for the combined purposes of engineering and hydrogeologic characterization. Grain size tests will be used to determine hydrologic parameters based on empirical relationships and published values in the technical literature. Testing will be performed in accordance with relevant ASTM standards. The locations of the proposed explorations are shown on Figure 7-2.

Monitoring well clusters will comprise shallow, intermediate, and deep intervals, corresponding to the three primary hydrogeologic units to be characterized, which were introduced in Section 2. The exception to this may be the MW03 series of wells, which is specifically for monitoring groundwater flow conditions associated with Gatton's Slough. All three depths of the cluster are indicated, but based on a geotechnical study (Shannon and Wilson, 1962) of Slip 1, which discovered organic clay and silt that may be associated with Gatton's Slough in-filling, there may be limited flow through these fine-grained deposits with low hydraulic conductivity. Unless layers of saturated sand are encountered within the in-filled deposits that would justify a well, the deep location will be completed as the sole well below the in-filled soils. Each well within a cluster will be completed within 10 to 20 ft of an adjacent well for predicting vertical gradients. Wells will be screened within the zone of interest using 10-ft screens or 5-ft screens if applicable for thin layers.

As described in Section 6, a limited groundwater monitoring study will be performed within the data collection time frame allowed by the EE/CA schedule and will be extrapolated based on historical trends to infer seasonal characteristics.

Regarding hydrogeologic characteristics relevant to the analysis of disposal technologies, the following tasks will be performed:

- Develop conceptual site hydrogeologic model (in coordination with the Port's Upland Source Control Project where applicable, primarily for shallow wells).

- Determine hydraulic connectivity of upland fill aquifer to recent alluvial deposits (may differ from Slip 1 to Slip 3).

- Determine groundwater contour maps for each of three units (upland fill; recent alluvial deposits; Troutdale Gravel).

- Determine seasonal changes within each of the three units by water-level monitoring by extrapolating data collected within the EE/CA data collection period based on seasonal trends and existing data from Hart Crowser, 2000a. This activity includes field monitoring of pH, temperature, specific conductance, and dissolved oxygen.

- Determine vertical groundwater flow gradients between hydraulically separate units (and horizontal flow gradients).

- Determine groundwater flow characteristics of in-filled Gatton's Slough.

- Verify upland gradients from Troutdale Gravel Aquifer.

- Develop groundwater flow model using Visual MODFLOW, which includes each hydrostratigraphic unit encountered in explorations.

- Assess the effectiveness of onsite disposal and capping of sediment. Both require that contaminated sediment remain in place. Modeling of contaminant transport through sediment using MT3D will be used in conjunction with the results of laboratory testing described in Section 7.9 to assess sediment leaching characteristics.

7.7 Recontamination Source Characterization

7.7.1 Sources at Terminal 4

Work to be conducted pursuant to the Port's Terminal 4 Slip 1 source control agreement (Oregon DEQ, 2003b) includes installation of groundwater monitoring wells and sampling of stormwater. Details of these proposed studies will be provided separately.

7.7.2 Sources Outside Terminal 4

Sources outside Terminal 4 include contaminants transported in dissolved phase, attached to suspended particles, or attached to bed load sediment particles. Dissolved phase transport is not of high concern for the Removal Action Area, as sediment recontamination will be governed by deposition of particle-bound contaminants. Assessment of recontamination potential resulting from offsite, in-river sources should include:

- quantification of levels of contaminants in recently deposited sediments;
- characterization of the uncertainty range about the quantifications;
- estimation of the time trend in historical and current sources for projections into the future; and
- estimation of the amount of deposition likely to occur in the Removal Action Area of particles borne by the upstream flow .

There are several possible approaches to assessing recontamination potential associated with current offsite, in-river sources, including direct measurement of the sources (e.g., outfalls or tributaries), measurement of water quality or sediment quality transported to the Removal Action Area from offsite, and estimation based on available data. Recontamination potential can be assessed by assuming that the highest concentrations measured in the river will be transported without dilution to the boundary of the Removal Action Area. An estimate of the potential impact of current sources can be obtained by measuring water quality and transported sediment quality (suspended sediment and bed load sediment) immediately outside the Removal Action Area.

In-river source characterization activities will include:

- measurement of particle-phase concentrations of constituents of interest on sediments collected through deployment of sediment traps and bed load samplers; and
- measurement of contaminant concentrations in water quality samples collected upstream of the Removal Action Area during stormwater runoff events.

Sediment trap and bed load sampling will also provide an indication of sediment transport rates. Once in-river source characterization activities are completed, recontamination potential will be assessed by estimating sediment deposition in the Removal Action Area. For example, if the suspended sediment concentration is X, the deposition rate is Y, and the bioturbated sediment layer is Z, the time rate of recontamination of the surface sediment layer can be estimated. The deposition rate can be estimated based on the sediment trap data, or computed with the SED2D model.

7.8 Sediment Quality Characteristics

As discussed in Section 6.9, available sediment quality information is insufficient to adequately develop and evaluate Removal Action alternatives. Therefore, additional sediment chemistry sampling and analysis are proposed. The following sections discuss the methodology, protocols, and procedures of the sediment sampling and analysis.

The sediment quality data required for evaluation of Removal Action alternatives are:

- nature and lateral extent of contamination;
- under-pier sediment quality; and
- nature and vertical extent of contamination.

The lateral extent of contamination will be evaluated with surface sediment chemistry data. Under-pier surface sediment quality will be assessed to determine whether removal is required for under-pier sediment. Subsurface sediment chemistry data will be used to determine the vertical extent (i.e., depth) of contamination.

7.8.1 Sampling Methods and Data Validation

Sediment samples will be collected in accordance with USEPA's Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual (USEPA, 2001b). Sediment chemistry analyses will be performed in accordance with CLP or equivalent methods, such as SW-846, Test Methods for Evaluating Solid Waste (USEPA, 1994). Laboratories performing chemistry analyses will be certified by the National Environmental Laboratory Accreditation Program (NELAP). Analytical methods, target detection limits, and sample requirements for chemical analyses are specified in the QAPP (Appendix A). All analytical results will undergo data quality validation performed by an independent third party; approximately 90% of analytical results will undergo a Level III data quality validation, and 10 to 20% of the results will undergo a Level IV data quality validation (CLP). Data quality validation will be performed in accordance with USEPA Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review (USEPA, 1999, 2002).

The proposed sampling design is stratified. Samples from Slip 1 and Slip 3, as well as Wheeler Bay and the Willamette River portion of the Removal Action Area will be obtained. A high degree of judgment has been applied to the particular sampling locations within each strata.

7.8.2 Surface Sediment Chemistry

Thirty-two surface sediment samples will be collected for the EE/CA: 17 in Slip 1 and 15 in Slip 3. Proposed surface sediment sampling locations are shown on Figure 7-3. Sampling locations were selected based on the existing data and to provide adequate coverage to evaluate the nature and lateral extent of contamination. Surface sediment samples will be collected from the top 1.0 ft in accordance with the surface sediment interval used for the Portland Harbor Superfund Site surface sediment sampling protocol. Surface sediment samples will be analyzed for metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), SVOCs (including PAHs and phthalates), tDDT, PCBs (as Aroclors), total petroleum hydrocarbons (TPH), TOC, and grain size. Although pesticides, besides DDT, are not COPCs, a contingency plan has been developed at the request of USEPA for the possible analysis of a few sediment samples from Slip 1 for pesticides. Sediment samples for tDDT will be extracted and analyzed for the list of pesticides presented in Table A2-1 of the QAPP but only DDT will be reported. DDT and PCB results will be evaluated in Slip 1 for possible reporting of the full suite of pesticides. If elevated tDDT is observed in sediment samples from Slip 1, a select number of samples from Slip 1 will have the full pesticide list reported. Figure 7-4 outlines the sediment sample handling and analytical framework for the EE/CA.

7.8.3 Under-Pier Sediment Chemistry

Fifteen under-pier surface sediment samples will be collected for the EE/CA. Proposed under-pier surface sediment sampling locations are shown on Figure 7-3. Sample locations were selected to provide adequate coverage to evaluate the nature and lateral extent of potential contamination. Under-pier surface sediment samples will be collected by SCUBA divers using hand-held core tubes. Divers will target any available surface sediment under the piers. Under-pier surface sediment samples will be analyzed for metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), SVOCs (including PAHs and phthalates), tDDT, PCBs (as Aroclors), TPH, TOC, and grain size. In addition, the divers will probe the surface sediment within the pilings of the former Pier 5 to evaluate the depth of soft sediment as opposed to riprap. Figure 7-4 outlines the sediment sample handling and analytical framework for the EE/CA.

7.8.4 Subsurface Sediment Chemistry

Thirty-two sediment cores will be collected for the EE/CA: 17 cores in Slip 1 and 15 cores in Slip 3. Proposed core locations are shown on Figure 7-5. Sample locations were selected based on the existing data and to provide adequate coverage to evaluate the extent of contamination. Cores will be collected with a vibracore. Target core length will be 15 ft or the point of refusal. The top 1 ft of each core will be collected for the surface sediment sample. The remainder of the core will be subdivided into 2-ft intervals (i.e., 1 to 3 ft below mudline, 3 to 5 ft, 5 to 7 ft, 7 to 9 ft, 9 to 11 ft, 11 to 13 ft, and 13 to 15 ft). Each interval will be homogenized and subsampled for analysis The subsamples representing the top 11 ft of sediment below the mudline will be submitted for analysis of metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), SVOCs (including PAHs and phthalates), tDDT, PCBs (as Aroclors), TPH, TOC, and grain size. Although pesticides, besides DDT, are not COPCs, a contingency plan has been developed at the request of USEPA for the possible analysis of a few sediment samples from Slip 1 for pesticides. Sediment samples for tDDT will be extracted and analyzed for the list of pesticides presented in Table A2-1 of the QAPP but only DDT will be reported. DDT and PCB results will be evaluated in Slip 1 for possible reporting of the full suite of pesticides. If elevated tDDT is observed in sediment samples from Slip 1, a select number of samples from Slip 1 will have the full pesticide list reported. A representative subsample of each remaining core section will be placed in a frozen archive for possible future analysis. Where necessary, analytical groups (e.g., organic analyses) will be extracted and the extract held in archive for future analysis. The archived samples may be submitted for analysis depending on the chemistry results for the top 11 ft of each core. Figure 7-4 outlines the sediment sample handling and analytical framework for the EE/CA.

7.9 Dredged Sediment Quality Characteristics

As discussed in Section 6.10, available information is insufficient to adequately develop and evaluate Removal Action alternatives. Therefore additional sediment quality characteristics pertaining to the dredging and subsequent transport and disposal of the dredged sediment are proposed. The following sections discuss the methodology, protocols, and procedures of the exploration and laboratory testing.

The data needs include:

- data to assess impact to water quality during dredging;
- data to assess onsite disposal; and
- data to assess offsite disposal.

Potential water quality impacts during dredging will be evaluated using dredging elutriate data. Settling velocity, modified elutriate, and column leachate data will be used to assess onsite disposal in a CDF. The assessment of offsite disposal in a Subtitle D landfill will be performed with landfill-specific acceptance criteria. These criteria may include hazardous waste determination, TCLP tests, TSCA determinations, data on the generation and loss of free liquid, and other landfill-specific acceptance criteria.

7.9.1 Water Quality Data Need

Assessment of water quality impacts for the implementation of dredging technologies will be performed with dredging elutriate data. The dredging elutriate test (DRET) simulates the release of sediment-bound and porewater constituents into the receiving water column at the point of dredging. Two DRETs will be performed for the EE/CA in accordance with Dredging Elutriate Test (DRET) Development (DiGiano et al., 1995). Two composite sediment samples will be created for the DRETs: one composite of the cores collected from Slip 1 and the other of the cores from Slip 3 (Slips 1 and 3 core sampling locations are discussed in Section 7.8). The composite sediment samples will consist of representative subsamples of the top 11 ft (i.e., 0 to 11 ft below mudline) of each core. Figure 7-4 outlines the sediment sample handling and analytical framework for the EE/CA. The DRET samples will be analyzed for the same list of constituents as surface and subsurface sediment samples (metals, SVOCs, tDDT, PCBs, and TPH). Additionally, elutriate ammonia and hydrogen sulfide content will be measured in each sample.

7.9.2 Sediment Quality Characteristics Impacting Onsite Disposal

Data needed to evaluate the onsite disposal of dredged material include:

- settling velocity of dredged material placed in a CDF;
- short-term water quality impacts from a CDF; and
- long-term water quality impacts from a CDF.

A column settling test (CST) will be performed to evaluate the settling velocity of dredged material placed in a CDF. The CST simulates the settling chacteristics of hydraulically transported and placed sediment. The CST will be performed in accordance with Confined Disposal of Dredged Material (USACE, 1987). The CST will be performed on a composite sediment sample consisting of the cores from Slip 3. Figure 7-4 summarizes the sediment sample handling and analytical framework for the EE/CA. The composite sediment sample will consist of the 0- to 11-ft below mudline length of each core. Column settling samples will analyzed for total suspended solids.

A modified elutriate test (MET) will be performed to evaluate short-term water quality impacts from a CDF. The MET simulates the release of sediment-bound and porewater constituents. The MET will be performed in accordance with Environmental Effects of Dredging, Technical Notes, Interim Guidance for Predicting Quality of Effluent Discharged from Confined Dredged Material Disposal Areas—Test Procedures (Palermo, 1985). The MET will be performed on a composite sediment sample consisting of cores from Slip 3. The composite sediment sample will consist of the 0- to 11-ft below mudline length of each core. The MET elutriate will be analyzed for metals, SVOCs, tDDT, and PCBs.

A thin-column leaching test (TCLT) will be performed to evaluate long-term water quality impacts from a CDF. The TCLT will be performed in accordance with Leachate Testing and Evaluation for Estuarine Sediments (Myers et al., 1996). The TCLT will be performed on a composite sediment sample consisting of cores from Slip 3. The composite sediment sample will consist of the 0- to 11-ft below mudline length of each core. The TCLT leachate will be analyzed for metals, SVOCs, tDDT, and PCBs. Figure 7-4 outlines the sediment sample handling and analytical framework for the EE/CA.

7.9.3 Sediment Quality Characteristics Affecting Offsite Disposal

Two composite sediment samples will be analyzed for hazardous waste determination, TCLP, generation and loss of free liquid, and landfill-specific acceptance criteria. One composite sediment sample will consist of the cores collected from Slip 1, and the other will consist of the cores from Slip 3. The composite sediment samples will consist of the 0- to 11-ft below mudline length of each core.

For hazardous waste determination, the two composite sediment samples will be analyzed for ignitability, corrosivity, and reactivity. TCLP tests will be performed on the two composite sediment samples and the TCLP leachate will be analyzed for metals, pesticides, herbicides, VOCs, and SVOCs. The two composite sediment samples will also undergo paint filter tests to evaluate the generation and loss of free liquid.

The existing and new surface and subsurface sediment PCB data will be evaluated as part of the TSCA determination. The new surface and subsurface sediment TPH data will be evaluated against landfill TPH acceptance criteria. Figure 7-4 outlines the sediment sample handling and analytical framework for the EE/CA.

7.9.4 Sampling Methods and Data Validation

Sediment samples will be collected in accordance with USEPA's Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual (USEPA, 2001b). Laboratories performing chemistry analyses will be certified by NELAP. Elutriate, leachate, and other tests will be performed in accordance with the methods specified above. All analytical results will undergo data quality validation; 90% of analytical results will undergo a Level III data quality validation, and 10% of the results will undergo a Level IV data quality validation (CLP). Data quality validation will be performed in accordance with USEPA Contract Laboratory Program National Functional Guidelines for Organic and Inorganic Data Review (USEPA, 1999, 2002).

7.10 Hydraulics and Sedimentation Characteristics

As discussed in Section 6.11, available information is insufficient to adequately develop and evaluate Removal Action alternatives. Therefore, additional hydraulic and hydrodynamic data collection is proposed. The following sections discuss the methodology, protocols, and procedures of the data collection.

The interaction between river and berth hydraulics in the Removal Action Area will be simulated with the RMA-2 two-dimensional hydrodynamic model to predict flow circulation and sedimentation patterns. Simulation will be performed for a range of conditions, including high and low flow scenarios, to assess the spatial variation in velocity and bed shear stresses. Flow velocity and bed shear stress patterns will be mapped for each scenario. Sedimentation patterns will be simulated using the SED2D model, which is designed to directly use the hydrodynamic simulation results obtained from RMA-2.

The data required to successfully run the RMA-2 and SED2D models include bathymetric data, river elevations and flow rates for simulation conditions, and suspended sediment concentrations carried by the river. Calibration data are also needed, including velocity data, water surface elevations, and sedimentation measurements. The calibration data can also be used to empirically assess sedimentation behavior outside of the modeling analysis.

The following data collection activities will be conducted to support evaluation of river and berth hydraulics and sedimentation patterns:

- Three rounds of velocity measurements will be collected along eight transects running halfway across the river adjacent to the Terminal 4 Removal Action Area and along four transects across Slip 1 and Slip 3 using a boat-mounted Acoustic Doppler Current Profiler (ADCP).

- Four moored oceanographic arrays consisting of an Acoustic Doppler Current Meter (ADCM), turbidity sensor, and tubular sediment traps will be deployed as vertical in-line arrays within each slip to collect time series near-bottom velocity, turbidity, and sedimentation data.

- Willamette River water surface elevations will be measured with three tide gages deployed near Berth 414 and at an upstream and a downstream location. The upstream gage will be installed near the St.

Johns Bridge. The downstream gage will be installed at a location approximately 3 miles downstream of the Removal Action Area near the confluence with the Columbia River to provide a downstream elevation for the hydrodynamic model.

7.10.1 Transect Velocity Measurements

Cross-sectional river velocity measurements will be obtained from measurement of velocity depth profiles along eight transects running part way across the river from the Terminal 4 shoreline and across each of the slips. These measurements will provide “snapshots” of the magnitude and direction of flow velocities adjacent to the terminal and within the slips that can be used to calibrate the hydrodynamic model simulations of flow and circulation patterns in the river and adjacent slips.

These data will be collected by a qualified hydrographic surveying contractor using RD Instrument’s 1,200 kHz ADCP (or comparable) positioned below a differential global positioning system (DGPS) receiver using trackline control instrumentation. The transects will be run from the Terminal 4 shoreline halfway across the river (i.e., to the channel midpoint). Three transects will be run in Slip 3, two in the Wheeler Bay area, and three in Slip 1. ADCP transect lines in the Slip 3 area will take off from the upstream end of Slip 3 (at the shoreline corner entering the slip), from the midpoint of the eastern edge of the slip, and from the downstream edge of the slip (from the shoreline corner at the mouth of the slip). ADCP transect lines in the Wheeler Bay area will take off from the midpoint of the eastern shoreline of Wheeler Bay and from the downstream edge of Wheeler Bay. The transects in Slip 1 will take off from the upstream edge, midpoint of the eastern edge, and the downstream edge (similar to Slip 3). The trackline and measurement points for each transect will be recorded using DGPS equipment.

Transects will also be run north-south in the slips. Three north-south transects will be run in Slip 3 (from the head, midpoint, and mouth of the slip). Three north-south transects will be run in Slip 1 (from the head, midpoint, and mouth of the slip).

7.10.2 Moored Arrays

Four arrays consisting of a near-bottom ADCM will be moored within the slips. One array will be placed near the mouth of Slip 1, two arrays will be placed within Slip 3, and one array will be placed just upstream of the Removal Action Area. The arrays will be deployed as in-line vertical moorings composed of an anchor, a sufficient length of jacketed wire cable, and a subsurface floatation buoy. A surface buoy will be linked to the top of the subsurface sphere with a tether. The two moorings in Slip 3 will include a single sediment trap mounted 2 to 3 ft above the sediments and a Nortek Aquadopp® (or comparable) sensor mounted 3 ft above the sediment trap. The remaining two arrays will just have Aquadopp® sensors. The Aquadopp® sensors will record turbidity and current velocity. Sediment traps of typical design will be constructed or purchased. Sediment traps will generally consist of a series of three tubes capped on one end and positioned around the vertical mooring cable. A hexcel baffle composed of numerous individual cells will placed in the opening of each tube or cone to reduce turbulence around the mouth of the trap.

The array in Slip 1 will be situated approximately 30% of the distance from the mouth of the slip to the eastern end at approximately the east-west centerline of the slip. The two arrays in Slip 3 will be positioned, with one array positioned at one-third of the distance from the mouth of the slip to the eastern end of the slip; and the other array at a distance approximately two-thirds of the distance from the mouth of the slip to the eastern end. This configuration is designed to provide information on flow circulation and sedimentation patterns caused by eddies in the slip from the Willamette River flow.

The sensors may also record influences of vessel movement and ship propellers. Kinder Morgan, the tenant of Slip 3, will be contacted in order to prepare a schedule of vessel movement in and out of Slip 3 during the sampling time frame. Our current understanding is that approximately 100 ships per year, typically of the 50,000-ton class and never more than one ship at a time, are serviced at Slip 3. Ships are berthed bow toward the river and are maneuvered with tugboat tenders during berthing and departure. When sensor readings are made, the time of vessel movement, type and size of vessel, and other pertinent information will also be recorded, and the relationship of this information to the sensor readings will be evaluated.

Sampling locations will be recorded using DGPS equipment and marked with high-visibility buoys to minimize disruption by ship traffic. Prior to array deployment, ship activities will be reviewed with the Port and, if necessary, locations will be adjusted and/or diver installation and retrieval of the arrays will be used to avoid placing buoys in ship traffic.

Following installation, the arrays will be retrieved at 30 days and 60 days for data collection. Data will be downloaded each time and samples retrieved from the sediment traps for analysis.

In addition to the collected data, published scientific studies on the bottom shear stresses generated by ship prop wash and tugboat activities will be used to assess the importance of ship scour in Slip 3. Bathymetric survey maps showing localized impacts from ships will be evaluated and used to support conclusions regarding the areas and spatial extent of large impacts to the sediment from ships (e.g., scour areas).

7.10.3 Stage Recorders

Water surface elevations will be recorded with tide gages installed near the downstream end of Slip 3 and approximately 1.25 miles downstream of the Removal Action Area.

The gage locations will be established to the Columbia River datum, which will be programmed into the gages so that water depth measurements recorded by gage are automatically converted and stored as elevation. Water level recording will be initiated after the gage elevations have been established through field survey with accuracy to at least 0.1 ft.

The gages will be installed for a 60-day period and data downloads will be conducted at 20 days, 30 days, and 60 days following installation. Water levels will be recorded at 15-minute intervals.

Table 7-1
Estimated Number and Type of Engineering (and Hydrogeologic) Characteristics Explorations and Laboratory Tests

Exploration ID	Anticipated Depth, Ft.[1]	Anticipated No. (Disturbed) SPT Samples	Anticipated No. ("Undisturbed") Piston Samples	Anticipated No. of Surface/Subsurface Sediment Samples	Composited Sample (Core Samples Only)	Moisture Content, ASTM D 2216	Grain Size, ASTM D 422	Atterberg Limits, ASTM D 4318	Organic Content, ASTM D 2974	Specific Gravity, ASTM D 854	Consolidation, ASTM D 2435 or 4186	Sample Bulk Density (Coordinated with Laboratory)	UU Triaxial Test (Shear Strength), ASTM D 2850	CU Triaxial Test (Shear Strength), ASTM D 4767
G01W	120	27	4	N/A	N/A	27	5	5	1	2	2	4	4	1
G02W	80	21	2	N/A	N/A	21	4	4	1	1	1	2	0	0
G03L	160	26	4	N/A	N/A	26	5	5	1	0	0	4	0	0
G04L	90	18	4	N/A	N/A	18	4	4	1	0	0	4	4	1
G05W	140	29	4	N/A	N/A	29	6	6	1	2	2	4	4	1
G06W	70	19	2	N/A	N/A	19	4	4	1	1	1	2	0	0
MW01S	30	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW01I	60	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW01D[4]	180	28	0	N/A	N/A	28	6	6	1	0	0	0	0	0
MW02S	30	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW02I	60	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW02D	180	28	0	N/A	N/A	28	6	6	1	0	0	0	0	0
MW03I	80	16	0	N/A	N/A	16	3	3	1	0	0	0	0	0
MW03D[5]	130	23	0	N/A	N/A	23	5	5	1	0	0	0	0	0
MW04S	30	6	1	N/A	N/A	6	1	1	1	0	0	0	0	0
MW04I	80	16	2	N/A	N/A	16	3	3	1	0	0	0	0	0
MW05S	30	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW05I	60	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW05D	180	28	0	N/A	N/A	28	6	6	1	0	0	0	0	0
MW06S	30	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW06I	60	1	0	N/A	N/A	1	1	0	1	0	0	0	0	0
MW06D	180	28	0	N/A	N/A	28	4	4	1	0	0	0	0	0

Notes:
(1) Anticipated depths are presently estimated. These will be refined before the field program and further altered depending on the conditions encountered in the field.
(2) Number of laboratory tests indicate represent approximate values to be verified based on conditions encountered in the field.
(3) This table does not include proposed Seismic Cone Penetrometer explorations, as these do not involve sample collection.
(4) For monitoring well series explorations, the deep boring of a cluster will be sampled at the interval specified in the Field Sampling Plan. Shallow and Intermediate wells will only be sampled in the screened interval for the purpose of grain size analysis, etc.
(5) This well is not intended for installation into the Troutdale Gravel, but for installation in a permeable unit below Gatton Slough fine-grained organic silt/clay soils.

8. Removal Action Evaluation Approach

This section describes how Removal Action alternatives will be developed and how the alternatives will then be compared and ranked to assess their relative performance at meeting specific objectives associated with the evaluation criteria of effectiveness, implementability, and cost. This section also describes how the preferred Removal Action alternative will be identified, as well as the steps that will be taken to conduct a biological assessment of the effects of the preferred alternative on species listed and proposed for listing under the Endangered Species Act.

8.1 Removal Action Objectives

The RAOs were introduced in Section 6.1 and are repeated here in accordance with the NTCRA guidance (USEPA, 1993b). RAOs for the Terminal 4 Removal Action Area are to:

- Reduce ecological and human health risks associated with sediment contamination within the Removal Action Area to acceptable levels.

- Limit the likelihood of recontamination of sediments within the Removal Action Area.

The Port proposes to achieve the RAOs while allowing continued use of the marine terminal and minimizing disruption of operations.

8.2 Potential ARARs and TBCs

Federal and Oregon potentially applicable or relevant and appropriate requirements (ARARs) will be compiled and used as one element in the Removal Action evaluation. On-Site actions (i.e., those taken within the Portland Harbor Superfund Site) must comply with the substantive requirements of any identified ARARs, to the extent practical considering the circumstances of the situation, or receive an ARAR waiver allowed by USEPA guidance under certain circumstances. On-Site actions do not have to comply with the corresponding procedural ARAR requirements, such as permit applications, reporting obligations, and record keeping requirements. Off-Site actions must comply with all substantive and procedural ARAR requirements.

Potential ARARs are divided into the following categories:

- Chemical-Specific Requirements. These are health- or risk-based concentration limits or ranges for specific hazardous substances, pollutants, or contaminants in various environmental media. An example is the maximum contaminant levels established by USEPA as safe levels in drinking water.

- Action-Specific Requirements. These are controls or restrictions on particular types of activities such as hazardous waste management or wastewater treatment. Examples of action-specific requirements are state and federal air emissions standards as applied to an in-situ extraction treatment unit.

- Location-Specific Requirements. These are restrictions on activities based on the characteristics of a site or its immediate environment. The restrictions on work performed in wetlands or wetland buffers provide an example. In this example, the location-specific requirements may require restoration of wetlands.

The potential chemical- and location-specific ARARs are summarized in Table 8-1, which provides citations and brief synopses of the ARARs. Chemical- and location-specific ARARs will be reevaluated subsequent to data collection described in this work plan. Action-specific ARARs will be identified after Removal Action alternatives and cleanup technologies are chosen for analysis in the EE/CA. However, evaluation and tracking of certain action-specific ARARs, such as the Flood Insurance Act and related cut and fill issues, will be undertaken prior to development of Removal Action alternatives to allow for an appropriate level of analysis. A complete list of potential chemical-, location-, and action-specific ARARs and To Be Considereds (TBCs) will be developed following the selection of Removal Action alternatives for the EE/CA.

8.3 Screening of Technologies

In accordance with the USEPA guidance (USEPA, 1993b) for NTCRAs, "only the most qualified technologies that apply to the media or source of contamination" need to be considered for the development, comparative evaluation, and selection of Removal Action alternatives. On the basis of prior experience with a number of contaminated sediment projects in the Pacific Northwest, the technologies identified as likely to qualify for consideration in the EE/CA include:

- Dredging, followed by additional, auxiliary technologies:
  - transport of dredged sediments;
  - treatment of dredged sediments; and
  - disposal of dredged material onsite or offsite; and
- In-situ capping of contaminated sediment.

8.3.1 Dredging Technologies

Dredging technologies are used to remove contaminated sediment from its original place for subsequent treatment, transportation, or disposal. Dredging removes the sediment and associated contamination, thereby reducing or eliminating its volume and toxic effects.

The EE/CA will briefly review dredging technologies (primarily grouped as either mechanical or hydraulic) and introduce a range of dredging equipment that is both available and potentially suitable for the Removal Action. The screening criteria that will be used to narrow a presumably broad range of dredging technologies to those most practical and qualified for the Removal Action will include, but not be limited to:

- resuspension of sediment during dredging;
- dredging accuracy;
- production rate;
- volume of water generated while dredging;
- equipment availability;
- type of and need for supporting equipment;
- ability to handle underwater obstructions, logs, riprap, boulders, and other debris; and
- site constraints, slopes, including water depths, slip size, and presence of piers (i.e., access).

Following this screening, a short list of dredging technologies will be developed and will serve as the basis for developing Removal Action alternatives.

8.3.2 Dredge Material Handling Technologies

The following is a brief summary of technologies likely to be considered for the handling, transportation, and disposal of dredged sediment.

8.3.2.1 Transport Technologies

The EE/CA will discuss the various alternatives for dredged material transport and their applicability to the Removal Action. Transport methods such as pipelines, barges (of various types and configurations), and transloading to truck and rail will be reviewed. A table or flowchart illustrating the relationship of the transport technologies to the dredging and disposal technologies will be developed to demonstrate the interrelationships among the various transport, dredging, and capping technologies, which are closely linked.

8.3.2.2 Treatment Technologies

The USEPA guidance for conducting NTCRAs (USEPA, 1993b) indicates that, to the extent practicable, EE/CA alternatives should consider the CERCLA preference for treatment over containment or land disposal. The EE/CA will identify technologies, process options, and alternatives for evaluation that include treatment of contaminated sediments. Based on a preliminary evaluation, treatment of sediment may include:

- Physical or chemical treatment; or
- Thermal treatment.

Physical treatment involves operations in which change to the medium is brought about by means of or through the application of physical forces (e.g., separation technologies such as gravity separation or filtration).

Chemical treatment brings about change to the sediment by means of or through chemical reaction. Chemical treatment is typically used in conjunction with physical treatment to enhance contaminant removal, immobilization, or degradation. Physical/chemical treatment technologies likely to be considered potentially applicable to the Removal Action Area sediments include:

- Sediment Washing. Sediment washing is a physical or physical/chemical process that reduces the volume of material requiring further treatment or disposal by separating and/or removing organic contaminants that adhere to organic matter and fine particles within a soil/sediment matrix. The water used in sediment washing normally requires additional handling and treatment to meet applicable discharge criteria.

- Stabilization/Solidification. Stabilization/solidification is a treatment process that immobilizes contaminants in sediments using chemical treatment (addition of cement, pozzolanic material) while potentially improving the handling characteristics of the material.

Thermal treatment technologies use heat as the primary mechanism for removal/volatilization and/or destruction of chemical compounds in sediments. Thermal treatment technologies include:

- Incineration. Incineration is a treatment technology that uses a controlled, high-temperature combustion process to destroy contaminants, reducing the volume and/or toxicity of the contaminated sediments.

- Thermal Desorption. Thermal desorption is a treatment technology that separates the contaminants from the sediment matrix at a lower temperature than incineration, causing the contaminants to volatilize.

On the basis of past experience with sediment remediation projects in the Northwest (and elsewhere), it is anticipated that treatment will consist only of dewatering.

8.3.3 Disposal Technologies

Sediment dredged from the Removal Action Area may be disposed of onsite or offsite. The onsite disposal of dredged sediment is typically implemented by the construction of a nearshore confined disposal facility (CDF). Nearshore CDFs are essentially lagoons surrounded by berms into which the dredged sediment is placed. The berms are designed and constructed to reduce the likelihood of migration of leachable contaminants into the groundwater or to the adjacent water body. After a CDF is filled, it is capped with an engineered layer that prevents the infiltration of precipitation and other surface water and that can also facilitate the use of the CDF area for beneficial purposes. Upland CDFs were not considered because sufficient land is not available at the Terminal 4 facility.

Offsite disposal of the sediment dredged from the Removal Action Area will likely be implemented via disposal at a Subtitle D solid waste landfill. Typically, disposing of dredged material in this manner requires that the dredged material be dewatered, loaded, and transported for disposal. Loading into a barge, railcar, or truck may occur at the Removal Action Area or loading into a railcar or truck could occur at another location, depending on the disposal facility selected. Transport to the disposal facility may be by barge, truck, railcar, or a combination, depending on the disposal facility selected. The selected disposal facility must be permitted to accept the types and concentrations of contaminants found in the dredged material.

Pacific Northwest landfills have developed several approaches to managing the relatively high water content found in dredged material. Landfills may apply for a research, development, and demonstration (RD&D) permit or may add a byproduct to the dredged material to dry the waste. An RD&D permit waives specific requirements (such as the paint filter test) for municipal solid waste landfills in order to promote innovative landfill technologies and operating processes. The landfill operator must demonstrate that these technologies and operating processes will not result in increased risk to human health and the environment. Under this program, certain landfills may accept liquid wastes for disposal to enhance waste decomposition. Liquid wastes are wastes that do not pass the paint filter test (USEPA Method 9095). Alternatively, a landfill operator may add a byproduct to dry the waste so that the waste will meet the permit conditions of the landfill (i.e., pass the paint filter test).

The EE/CA will summarize the disposal technologies determined to be most practical for the sediment in the Removal Action Area, as well as the waste disposal requirements and current and projected capacities of the likely upland disposal facilities.

8.3.4 Capping Technologies

Capping technologies isolate contaminated sediment in place, thereby reducing the mobility of contaminants, i.e., the ability of contaminants to reach ecological and human receptors and the water body.

The EE/CA will briefly review capping technologies, including caps constructed using earthen materials, such as sand and gravel, and caps constructed using man-made materials, such as reinforced mattresses, concrete filled mattresses, and armoring. The advantages and disadvantages of the capping technologies will be described. The EE/CA will also discuss the various placement techniques that can be used to install caps. The screening criteria that will be used to narrow a presumably broad range of capping technologies to those most practical and qualified for the Removal Action will include, but not be limited to:

- strength and compressibility of sediments;
- stability of sediment slopes to be capped;
- impacts to water quality during cap placement;
- the presence of underwater debris;
- potential interference of the cap with navigation;
- the presence of piers, piles, and under-pier areas to be capped; and
- periodic external loads on the cap, including seismic forces, erosion, propeller wash, and ice, as appropriate.

Following this screening, a short list of capping technologies will be developed and will serve as the basis for developing Removal Action alternatives.

8.3.5 Technology Summary

The EE/CA will summarize the limited number of dredging technologies (including auxiliary treatment, transport, and disposal technologies), capping technologies, options, and facilities that will be considered in developing Removal Action alternatives. In accordance with NTCRA guidance, “only the most qualified technologies that apply to the media or source of contamination” (USEPA, 1993b) will be evaluated in the EE/CA.

8.4 Development of Alternatives

The EE/CA will introduce a limited number of Removal Action alternatives based on the short list of technologies discussed in Section 8.3. In compliance with the National Contingency Plan, a No Action alternative will be used as a baseline for evaluating and comparing the alternatives. The alternatives will be built on the selected technologies, the results of the Removal Action Area characterization, the RAOs, and future land use requirements.

It is likely that different removal technologies will be considered for Slip 1, Slip 3, and Wheeler Bay. Therefore, the alternatives likely will include a combination of technologies.

Anticipated alternatives to be developed in the EE/CA include:

- No Action;
- removal by dredging (either mechanical or hydraulic), followed by onsite disposal;
- removal by dredging (either mechanical or hydraulic), followed by upland disposal; and
- capping in place.

A flow chart of the development of these alternatives using the various technologies introduced above is shown on Figure 8-1.

So that each alternative can be considered for further evaluation, the following information will be provided in the EE/CA:

- a brief summary of the rationale behind development of the alternative;
- the alternative's removal scope;
- the alternative's removal schedule; and
- a brief description of the technologies involved and planned removal activities, including:
    - quantification of the volume or areal extent of sediment to be addressed with the technology(ies);
    - a general description of the type of equipment to be used for in-water work;
    - a general description of shoreline equipment for the handling, pre-treatment, treatment, and hauling of sediment (as applicable); and
    - requirements for an onshore staging area and access to support implementation of the technology(ies).

It is envisioned that each Removal Action alternative will be introduced at a conceptual design level (approximately 15% completion), with figures and tables (as necessary) to support the narrative description.

The EE/CA will also evaluate the developed alternatives against the criteria of effectiveness, implementability, and cost, as discussed below.

In the assessment of effectiveness, each alternative will be evaluated for:

- how well it meets RAOs, i.e., protects the public health and the environment and provides a permanent, long-term solution;
- whether and to what extent it meets the ARARs;
- whether and to what extent it meets the criteria of reducing mobility, volume, and toxicity of contaminants; and
- whether and how it provides safety to workers, the public, and the environment during implementation.

In the assessment of implementability, each alternative will be evaluated with regard to its technical feasibility, the availability of the necessary resources to support the alternative, and its administrative feasibility.

The cost of the alternatives will be determined by establishing the present worth of each alternative's implementation by looking at capital costs and the costs of post-removal control (if any). The capital costs include direct and indirect capital costs. Typical cost considerations include:

- Direct capital costs
    - construction costs;
    - mobilization and demobilization costs;
    - equipment and material expenses;
    - land and site acquisition costs;

- buildings, services, utilities, and relocation costs;
- treatment costs;
- transport and disposal costs;
- analytical costs; and
- contingency.

- Indirect capital costs
  - engineering and design fees;
  - legal fees, permits and licenses; and
  - startup and shakedown costs.

- Annual post-Removal Action control costs
  - operational costs;
  - maintenance;
  - auxiliary materials and energy;
  - monitoring costs;
  - disposal of residuals;
  - support cost; and
  - insurance and other risk-related cost.

The accuracy of EE/CA-level cost estimates is in the range of -30% to +50%, in accordance with USEPA guidance (USEPA, 1993b).

The Port may also factor in other financial considerations including but not limited to risk management, insurance costs, and costs associated with interruptions in marine operations.

8.5 Comparative Evaluation of Alternatives

The EE/CA will present a comparative evaluation of the relative performance of each alternative in relation to the evaluation criteria. The purpose of the comparative evaluation is to identify the advantages and disadvantages of each alternative so that key tradeoffs affecting selection of the Removal Action alternative can be identified. In this evaluation, the No Action alternative will be used as a baseline.

In the comparative evaluation, the alternatives will be scored (ranked) for how well each meets each criterion. Alternatives that meet all the requirements of a criterion will be ranked "high." Alternatives that meet most, but not all, the requirements of a criterion will be ranked "medium." Alternatives that meet only some of the requirements of a criterion will be ranked "low." Alternatives that do not meet the requirements of a criterion will be ranked "does not meet."

For example, when evaluating alternatives from the aspect of the "reduction of mobility, volume, and toxicity of contaminants," a capping alternative that achieves the RAOs by isolating the contaminated sediment and so meets only the reduction of mobility component of the criterion may be scored as "medium." This alternative may then be compared to another alternative, such as dredging followed by treatment and upland disposal, that achieves the RAOs and meets all the criterion's requirements by reducing mobility, volume, and toxicity, thereby receiving a score of "high."

The EE/CA will also discuss the process used to evaluate the criteria and to develop a comparative ranking of the Removal Action alternatives, as outlined below.

8.5.1 Effectiveness

Under this criterion, the Removal Action alternatives will be comparatively evaluated against the factors discussed below.

8.5.1.1 Overall Protection of Public Health and the Environment

This evaluation will assess the extent and effectiveness of controls at managing the risk posed by exposure to residual sediment contaminants and untreated wastes in the Removal Action Area. The following factors will be considered:

- the extent to which the alternative addresses potentially complete and significant exposure pathways for human and ecological risk;
- the magnitude of residual risk, i.e., the effectiveness of the alternative and the residual risk from waste and residuals remaining after the Removal Action. This factor also looks at whether the alternative contributes to future cleanup objectives. Since the Removal Action is the last action anticipated for the Removal Action Area, the magnitude of the risk will be fully evaluated; and
- the adequacy and reliability of controls, i.e., the need for, extent of, and effectiveness of post-removal controls, if required.

Exposure and risk calculations as described in Section 7.4 will be used to estimate relative exposure and risk for the alternatives. As noted in Section 7.4, the specific methods to be used in estimating human health risk will be proposed when the Removal Action alternatives have been identified. For ecological risk, the analysis will depend primarily on a comparison of contaminant concentrations in sediments to SQGs appropriate to the pathways and receptors identified. However, if risk calculations being developed by the Lower Willamette Group are approved by the USEPA and its partners during this process, those values will be used instead of SQGs.

8.5.1.2 Compliance with ARARs

The evaluation criteria will include potential location-, chemical-, and action-specific ARARs and TBCs. The comparative evaluation and ranking of the Removal Action alternatives will assess whether and to what extent the alternatives meet the potential ARARs and TBCs.

As part of the evaluation of ARARs, each alternative will be evaluated for compliance with the standards and criteria of Clean Water Act Section 404 (b) (1). The criteria and standards are outlined in 40 CFR 230 Subparts B-H. This information will be included as an appendix to the EE/CA report and will fulfill the Scope of Work requirement for "a draft memorandum that provides sufficient information to demonstrate compliance with substantive requirements of Section 404 (b) (1) of the Clean Water Act."

The highest score will be assigned to those Removal Action alternatives that meet all potential ARARs and TBCs.

8.5.1.3 Short-Term Effectiveness

The evaluation criteria for short-term effectiveness will include:

- worker health and safety;
- public health and safety;
- impacts to water quality;
- impacts to quality of life in terms of noise, vibrations, dust, emissions, and odor;
- impacts to offsite aquatic and terrestrial biota during implementation; and
- impacts on the ongoing operations of Terminal 4 and general navigation.

The highest score will be assigned to those Removal Action alternatives that represent the least risk to workers and will have the fewest impacts on water quality, quality of life, biota, and Terminal 4 operations.

8.5.1.4 Reduction of Mobility, Volume, and Toxicity of Contaminants

The evaluation criteria for reduction of mobility, volume, and toxicity of contaminants will include:

- the alternative's effectiveness at reducing the ability of contaminants to move by advection or diffusion;
- the alternative's effectiveness at reducing the volume of contaminated sediment in the Removal Action Area upon implementation; and
- the alternative's effectiveness at reducing the harmful effects (i.e., toxicity) of contaminants in the sediment on ecological or human receptors.

In making this evaluation, the following factors will be considered:

- the process (if any) by which the mobility, volume, and toxicity of contaminants in the sediment are affected;
- the extent to which the mobility, volume, and toxicity of contaminants will be reduced;
- the degree to which the effect on mobility, volume, and toxicity of the contaminants is irreversible;
- the type and quantity of residuals that will remain after implementation of the alternative; and
- whether the alternative will satisfy the CERCLA preference for treatment.

The highest score will be assigned to those Removal Action alternatives that provide the greatest reduction (collectively) in the mobility, volume, and toxicity of contaminants.

8.5.1.5 Long-Term Effectiveness – Residual Risk Assessment Approach

The long-term effectiveness of the Removal Action alternatives will be evaluated by assessing factors such as permanence of the actions proposed, the stability of the sediments, and the potential for recontamination from offsite sources.

NTCRA guidance (USEPA, 1993b) identifies two basic components to this evaluation: (1) the magnitude of (residual) risk and (2) the adequacy and reliability of controls.

An assessment of the magnitude of risk that is residual to the action is necessary to characterize the effectiveness of the action at reducing risk and protecting public health and the environment. The Terminal 4 Removal Action is being performed as an interim measure and as part of the overall cleanup of Portland Harbor. However, the extent of the action is intended to represent the final action in the Removal Action Area. In this respect, the effectiveness of the alternatives at addressing health risks will be compared using the risk analysis framework that will be developed once the alternatives have been identified. As noted in Section 7.4, the USEPA-approved framework will be documented in the Technical Briefing on Proposed Removal Alternatives as required by the AOC. For both human health and ecological receptors, risk-based sediment criteria established for the Portland Harbor Superfund Site remedial investigation/feasibility study will be used where available and applicable to ensure consistency with the site-wide remedy. Where Removal Action Area-specific risk analyses are necessary, the Technical Briefing on Proposed Removal Alternatives will describe methods and data needs.

The adequacy and reliability of controls will be compared based on whether the alternatives provide a permanent, irreversible technical solution or whether the alternatives carry the risk that protectiveness will deteriorate.

The highest score will be assigned to those Removal Action alternatives that provide irreversible, permanent protectiveness and result in the least residual risk to human and ecological receptors.

8.5.2 Implementability

Under this criterion, the Removal Action alternatives will be comparatively evaluated against the factors discussed below.

8.5.2.1 Technical Feasibility

The EE/CA will assess the ability of the technology components to implement the Removal Action alternative. Three principal aspects of the technical feasibility will be assessed:

- Construction and Operational Considerations. The alternatives will be compared from the aspect of assembling, staffing, and operating within the time allotted by the Removal Action schedule.

- Demonstrated Performance. The alternatives will be compared from the aspects of technical maturity, prior use under similar conditions, reliability, and possible issues related to difficulty or complexity of their implementation at the Removal Action Area. In addition, the technology components of each alternative will be evaluated for their availability from multiple sources on a competitive basis.

- Schedule. The overall schedule for implementing each alternative will be carefully considered taking into account the potential for shutdowns, since technical problems may adversely affect the schedule.

The highest score will be assigned those the Removal Action alternatives that exhibit the most successful project performance, are available from multiple vendors, and offer the highest reliability and the least risk of delay.

8.5.2.2 Administrative Feasibility

The EE/CA will address the activities needed to coordinate with other offices and agencies prior to and during the implementation of a Removal Action alternative, including any offsite permits, adherence to non-environmental laws, and concerns of other regulatory agencies; for example, ecological considerations for threatened and endangered species. Other factors to be considered include easements, right-of-way agreements, and zoning requirements.

Since the Removal Action is funded by the Port, the statutory limits otherwise applicable to agency-funded NTCRAs are not applicable.

The highest score will be assigned to those Removal Action alternatives that require the least amount of agency coordination and the least amount of additional regulatory action (e.g., building permit, zoning, right-of-way).

8.5.2.3 Availability

The EE/CA will assess whether and to what extent the technology components of the Removal Action alternatives are available within a time frame that maintains the Removal Action schedule. The availability of funds to meet the requirements of the post-removal controls will also be assessed. Important availability factors include:

- the availability of the technologies, as well as the availability of labor, skilled labor, and professional labor to implement the alternatives;
- the capacity, adequacy, and availability of offsite disposal facilities (if required for an alternative), with special emphasis on certain waste disposal requirements (e.g., all wastes from the Removal Action Area are considered CERCLA wastes, the potential for PCB-contaminated waste streams, and the high moisture content of the waste stream);
- the availability of necessary laboratory services and onsite facilities such as light, electricity, sewer, and other utilities; and
- the time frame required to implement full-scale use of an innovative, prospective technology (if required for an alternative), including pilot-scale studies or demonstrations.

The highest score will be assigned to those Removal Action alternatives that are readily available, preferably from multiple vendors and suppliers; for which the need for labor, laboratory services, and onsite services can readily be met in the vicinity of Terminal 4; and that can be implemented in the shortest time.

8.5.2.4 State and Tribal Acceptance

During preparation of the EE/CA, the concerns of DEQ and tribal entities will be solicited and carefully considered. The Removal Action alternatives will be compared as to whether and to what extent DEQ and tribal concerns can be addressed by implementing an alternative.

The highest score will be assigned to those Removal Action alternatives that best address DEQ and tribal concerns.

8.5.2.5 Public Acceptance

During preparation of the EE/CA, the Port will implement a community outreach program to actively seek input from members of the community and gather their concerns. The Removal Action alternatives will be compared as to whether and to what extent community concerns can be addressed by implementing an alternative.

The highest score will be assigned to those Removal Action alternatives that best address community concerns.

8.5.3 Cost

The Removal Action alternatives will be compared with respect to their projected full implementation costs, including the costs of mitigation, disposal, and long-term monitoring. The costs for individual alternatives will be established based on the present worth method, so that alternatives with significantly different implementation time frames can be compared.

The highest score will be assigned to those Removal Action alternatives that have the lowest present worth implementation cost.

8.5.4 Ranking of Alternatives

The EE/CA will summarize the results of the comparative evaluation. A table will be prepared to summarize the comparison and scoring. A narrative will discuss the tradeoffs associated with implementation of the various Removal Action alternatives. The Removal Action alternative that best satisfies the evaluation criteria will be identified, as will the justification for its selection.

8.6 Preferred Alternative

8.6.1 Description of the Preferred Alternative

The EE/CA will describe the preferred Removal Action alternative, i.e., the alternative determined to best satisfy the evaluation criteria.

The preferred Removal Action alternative will be described in some detail, providing a basis for preparation of the Action Memorandum and a more detailed presentation to the public, the State, tribal entities, and other stakeholders, as well as providing a foundation document for development of the biological assessment and the Clean Water Act, Section 401.b.1 evaluation. It is envisioned that the preferred alternative will be described at the 20% to 25% level of design detail.

8.6.2 Biological Assessment of the Preferred Alternative

A professional biologist will complete a biological assessment (BA) of the effects of the preferred alternative on species listed and proposed for listing under the Endangered Species Act. The BA will analyze the potential direct, indirect, and cumulative effects of the preferred Removal Action alternative on species and their habitat. The best available scientific and commercial data and reports will be used for the BA, including agency species reviews, basin assessments, and species narratives.

Preparation of the BA will require a field review and compilation and review of all existing habitat and species information relevant to the Removal Action Area. It is likely that no primary data collection will be necessary. The BA will include the following information:

- Introduction and Background
  - purpose of the BA, including legal and other directions;
  - project setting and legal description of the Removal Action Area;
  - a summary of listed species and their habitats; and
  - other species present.

- Consultation to Date
  - information on the analysis to be used in the BA; and
  - documentation of field reviews, meetings with agencies, and other efforts to support the analysis and conclusions contained in the BA.

- Preferred Alternative
  - all details of the preferred Removal Action alternative, including mitigation measures and all measures to be used to minimize adverse effects to species and their habitats.

- Species Account
  - a general species account, including life history and biological requirements;
  - known current limiting factors for the species; and
  - species presence in the Removal Action Area or location relative to the Removal Action Area.

- Existing Habitat Conditions/Environmental Baseline
  - formal habitat designations (federal and State) in the Removal Action Area;
  - environmental baseline of habitat (defined as conditions at the time of listing), current conditions, limiting factors, and habitat capabilities in the context of existing conditions; and
  - the relative contribution or value of habitat in the Removal Action Area.

- Effects of the Preferred Alternative
  - effects of the preferred Removal Action alternative, organized using accepted indicators of habitat quality including water quality, channel physical attributes, streambank conditions, and riparian conditions; and
  - discussion of potential direct, indirect, and cumulative effects to species and their habitats for each indicator.

- Determination
  - succinct conclusions regarding the effects of the preferred Removal Action alternative on species and their habitats.

- References
  - a complete list of references used to support the BA's analysis and conclusions.

- Appendices
  - a project area map;
  - maps of species distribution; and
  - a checklist summarizing the effects of the preferred Removal Action alternative.

9. References

9.1 References Cited

Altman, B.C., M. Henson, and I.R. Waite, 1997. Summary of information on aquatic biota and their habitats in the Willamette Basin, Oregon, through 1995. U.S. Geological Survey. Water Resources Investigations Report 97-4023. 85 pp. + Appendices.

American Society for Testing and Materials (ASTM), 1995. Standard Test Methods for Measuring the Toxicity of Sediment-associated Contaminants with Fresh Water Invertebrates. E1706-95.

Archaeological Investigations Northwest, Inc. (AINW), 2003. A Cultural Resources Reconnaissance Survey of the Port of Portland's Terminal 4, Portland, Oregon (Final Draft). April 11, 2003.

ATC Associates, Inc., 2003. Environmental Site Assessment of CLD Pacific Grain/Cargill Facility, Port of Portland – Terminal 4, December 4, 2003.

Berger, S. 2003. Email from S. Berger of Striplin Environmental Associates to P. Spadaro of BBL.

Bridgewater Group, Inc. (in association with Hart Crowser), 2003. Portland Harbor and Port Facility Groundwater Assessment. May.

Caldwell, J.M., and Doyle, M.C., 1995. Sediment Oxygen Demand in the Lower Willamette River, Oregon, 1994: U.S. Geological Survey Water-Resources Investigations Report 95-4196, 14 p.

Century West Engineering Corporation, 1994. Remedial Investigation Report, Terminal 4, Port of Portland, January 1994.

Century West Engineering Corporation, 1995. OTC Gear Locker Facility, Port of Portland, September, 1995.

City of Portland Commission of Public Docks (City CPD), 1923. Commission of Public Docks Annual Report.

City of Portland Commission of Public Docks (City CPD), 1927. Commission of Public Docks Annual Report.

City of Portland Commission of Public Docks (City CPD), 1931. Commission of Public Docks Annual Report.

City of Portland Commission of Public Docks (City CPD), 1947. Commission of Public Docks Annual Report.

City of Portland Commission of Public Docks (City CPD), 1949. Minutes, Vol. 12, p. 428.

City of Portland, 2000. Preliminary Evaluation of City Outfalls, Portland Harbor Study Area, Environmental Services, City of Portland, Notebook 1, Factshore Stormwater and CSO Outfalls, July 2000.

Dames & Moore, 1993. Geotechnical Investigation, Planned Bulk Storage Facility, Port of Portland, Terminal 4, Portland, Oregon. December 15, 1993

Dickson, Gladys N., 1976. St. Johns Heritage. Compiled by the St. Johns Historical Association. No pagination. St. Johns Historical Association, Portland, Oregon.

DiGiano, F. A., C. T. Miller, and J. Yoon, 1995. Dredging Elutriate Test (DRET) Development. Prepared for the U.S. Army Corps of Engineers, Waterways Experiment Station. Contract Report D 95-1. August.

Donovan and Associates, 1997. Historic Documentation Pier 1, Terminal 4, Portland, Oregon.

Drucker, Philip, 1934. Clackamas Notes. Ms. 4516(78), Archives of the Bureau of American Ethnology, Smithsonian Institute, Washington, D.C.

Farr, R.A., and D.L. Ward, 1993. Fishes of the Lower Willamette River, near Portland, Oregon. Northwest Science, Vol. 67. No. 1.

French, David H., and Katherine S. French, 1998. Wasco, Wishram, and Cascades. In *Plateau*, edited by Deward E. Walker, Jr., pp. 360-377. Handbook of North American Indians, Vol. 12, W.C. Sturtevant, general editor, Smithsonian Institute, Washington, D.C.

GeoEngineers, Inc., 1996. Report of Underground Storage Tank Decommissioning, Terminal Four – Gear Locker Facility, September 1996.

GEO-SLOPE, 2002. SLOPE/W Version 5 Slope Stability Computer Model, Limit Equilibrium Analysis Using Method of Slices.

Gerwick, 1959. Report to the City of Portland, Commission of Public Docks, March 5, 1959. Pier 4, Terminal No. 4 Test Pile Records.

Hahn and Associates, Inc., 1991. Underground Storage Tank Decommissioning, Port of Portland Terminal 4 – OTC Gear Locker Building, July 1991.

Harrison, H.E., Anderson, C.W., Rinella, F.A., Gasser, T.M., and Pogue, Jr., T.R., 1995. Analytical Data from Phases I and II of the Willamette River Basin Water Quality Study, Oregon, 1992-94. U.S. Geological Survey Open-File Report 95-373, 171 p. – potential source of upstream water quality data, including TSS, and organic carbon content of TSS.

Hart Crowser, 1997a. Sediment Characterization Study, River Terminal 4, Slip 3. Willamette River, Portland, Oregon, August 29, 1997.

Hart Crowser, 1997b. Pencil Pitch Removal Oversight and Sediment Characterization Report, Terminal 4 Slip 3, Berth 411, Portland, Oregon, September 25, 1997.

Hart Crowser, 1998. Remedial Investigation/Feasibility Study Work Plan, Terminal 4 Slip 3, Upland. Port of Portland, Portland, Oregon, August 18, 1998.

Hart Crowser, 1999. Volume 1: Sediment Characterization Study of Local Sponsor's Berths; Columbia and Willamette River Navigation Channel Deepening; Longview and Kalama, Washington, and Portland, Oregon.

Hart Crowser, 2000a. Remedial Investigation Report, Terminal 4, Slip 3 Sediments (Volume I) with tables, figures, and Appendices A through E, Port of Portland, Portland, Oregon (available in hard copy and electronically), April 18, 2000.

Hart Crowser, 2000b. Memo to the Port of Portland (Pad Quinn) regarding Terminal 4 – Slip 1 and Berth 401 Sediment Characterization Study, May 31, 2000.

Hart Crowser, 2000c. Remedial Investigation Report Terminal 4, Slip 3 Upland, Port of Portland, Portland, Oregon, January 21, 2000.

Hart Crowser, 2000d. Human Health and Ecological Baseline Risk Assessment, Terminal 4, Slip 3 Upland. Portland, Oregon, October 18, 2000.

Hart Crowser, 2000e. Terminal 4 –Slip 1 and Berth 401 Sediment Characterization Study, May 31, 2000.

Hart Crowser, 2002. Feasibility Study Report, 2002. Terminal 4, Slip 3 Upland, Port of Portland, Portland, Oregon, July 5, 2002.

Hartman Associates, Inc., 1994. Technical Memorandum regarding Terminal 4, Pencil Pitch, Propeller Scour/Deposition Patterns. June 22, 1994.

Hartman Associates, Inc., 1995. Water Quality Monitoring during Dredging and Disposal of Sediments from Terminal 4 Slip 3 in Portland Harbor, Final Report. April 28, 1995.

Hartman & Associates, Inc. and Fishman Environmental Services, 1995. Chemical Characterization of Sediments Adjacent to Storm Water Discharges in the Willamette River Near Portland. Submitted to United States Environmental Protection Agency, Region 10, Seattle, Washington. February 20, 1995.

Kennedy/Jenks Consultants, Inc., 1997. Former Quaker State Bottling Facility, Port of Portland – Terminal 4, April 1997.

Kostow, D., 2002. Oregon Lampreys: natural history, status, and analysis of management issues. Oregon Department of Fish and Wildlife.

Kramer, Steven L., 1996. Geotechnical Earthquake Engineering. Publisher: Prentice-Hall, Inc., Upper Saddle River, NJ.

Lee, K.K., and Risley, J.D., 2001. Estimates of ground-water recharge, base flow, and stream reach gains and losses in the Willamette River Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 01-4215, 52 p. – groundwater recharge is a recontamination mechanism, also the flow study data may contain useful summary statistics or other info.

Long and Morgan, 1990. The Potential for Biological Effects of Sediment-sorbed Contaminants Tested in the National Status and Trends Program.

Lower Willamette Group, 2003. Portland Harbor RI/FS, Revised Draft Final Programmatic Work Plan. November 13.

MacDonald, D. D., C. G. Ingersoll, and T. A. Berger, 2000. Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems. *Archives of Environmental Contamination and Toxicology* 39: 20-31.

Madin, 1990. Earthquake-Hazard Geologic Maps of the Portland, Oregon Metropolitan Area, Oregon – Text and map explanation: Oregon Department of Geology and Mineral Industries Open-File Report 0-90-2, pp.

McFarland, W.D. and Morgan D.S., 1998. Description of the Ground-water Flow System in the Portland Basin, Oregon and Washington.

Merchants Exchange Journals, 1932. Journal for Fiscal Year 1931-1932, p. 5.

Minkler, Laura, 1976. More St. Johns History. In *St. Johns Heritage*, compiled by the St. Johns Historical Association. No pagination. St. Johns Historical Association, Portland, Oregon.

Moulton, Gary E. (editor), 1990. The Journals of the Lewis and Clark Expedition. Vol. 6: November 2, 1805 - March 22, 1806. University of Nebraska Press, Lincoln, Nebraska and London.

Moulton, Gary E. (editor), 1991. The Journals of the Lewis and Clark Expedition, Vol. 7; March 23-June 9, 1806. University of Nebraska Press, Lincoln, Nebraska and London.

Myers, T. E., J. M. Brannon, B. A. Tardy, and D. M. Townsend, 1996. Leachate Testing and Evaluation for Estuarine Sediments. Prepared for the U.S. Army Corps of Engineers, Waterways Experiment Station. Technical Report D-96-1. March.

National Center for Earthquake Engineering Research (NCEER) Workshop, 1996. Summary Report, 1-40 pp.

National Oceanic and Atmospheric Administration (NOAA), 2003. U.S. Department of Commerce, September 2003. Willamette River Data and Maps, Query Manager 2.5, Marplot 3.3 (on CD).

National Oceanic and Atmospheric Administration (NOAA), 2003b. Navigation Chart for the Port of Portland, Charts on Demand Number 18526 by OceanGraphix.

Nebeker, M., 2001. Personal communication (telephone conversation with Berit Bergquist, Windward Environmental, Seattle, WA). Manager, Sauvie Island Wildlife Area, Oregon Department of Fish and Wildlife, Clackamas, OR. December 6.

O'Connor, J.E., A. Sarna-Wojcicki, K.C. Wozniak, D. J. Polette, and R. J. Fleck, 2001. Origin, Extent, and Thickness of Quaternary Geologic Units in the Willamette Valley, Oregon: U.S. Geological Survey Professional Paper 1620, 52 p.

Oregon Natural Heritage Program (ONHP), 2001. Rare, threatened and endangered plants and animals of Oregon. Oregon Natural Heritage Program, Portland, OR.

Oregon Department of Environmental Quality (Oregon DEQ), 1998. DEQ Site Assessment Program. Preliminary Assessment Equivalent/Strategy Recommendation, Port of Portland Terminal 4. May 29, 1998.

Oregon Department of Environmental Quality (Oregon DEQ), 2000. Voluntary Cleanup Letter Agreement, City of Portland Outfalls, Portland Harbor. March 30, 2000.

Oregon Department of Environmental Quality (Oregon DEQ), 2002. Voluntary Agreement for Feasibility Study between Oregon Department of Environmental Quality and the Port of Portland, DEQ No. LQVC-NWR-02-11.

Oregon Department of Environmental Quality (Oregon DEQ), 2003a. Voluntary Agreement for Remedial Investigation, Source Control Measures, and Feasibility Study, Port of Portland – Terminal 4 Slip 1 Upland Facility. December 4, 2003.

Oregon Department of Environmental Quality (Oregon DEQ), 2003b. Record of Decision, Port of Portland, Terminal 4, Slip 3 Upland, ECSI # 272. April 21, 2003.

Oregon Department of Environmental Quality (Oregon DEQ), 2003c. Intergovernmental Agreement for Remedial Investigation and Source Control Measures between City of Portland, Bureau of Environmental Services and Oregon Department of Environmental Quality, DEQ No. LQVC-NWR-03-10, August 13, 2003.

Orzol, L.L., K.C. Wozniak, T.R. Meissner, and D.B. Lee, 2000. Ground-water and water-chemistry data for the Willamette Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 99-4036, 141 p.

Pacific Environmental Group, 1997a. Site Investigation, Port of Portland – Marine Terminal 4. May 1997.

Pacific Environmental Group, 1997b. Additional Subsurface Investigation, Port of Portland – Marine Terminal 4. October 1997.

Pacific Environmental Group, 1997c. Status of Interim Activities and Remedial Schedule, Port of Portland - Marine Terminal 4. October 1997.

Palermo, M. R. 1985. Environmental Effects of Dredging, Technical Notes, Interim Guidance for Predicting Quality of Effluent discharged from Confined Dredged Material Disposal Areas—Test Procedures. Prepared for the U.S. Army Corps of Engineers, Waterways Experiment Station. EEDP-04-2. June.

Parsons Brinckerhoff, 2002. Marine Terminal Master Plan 2020, Volume 1, Section 3, Baseline Environmental Conditions. August.

Parsons Brinckerhoff, 2002. Marine Terminal Master Plan 2020, Volume 1, Section 1, Baseline Facility Conditions. June.

Plaxis, 2002. Version 8, Finite Element Computer Model for Geotechnical Applications.

Port of Portland, 1917. Photographs of Terminal 4 Construction, on file with Port of Portland.

Port of Portland, 1994. Sediment Quality Report, Sediment Test Results from Terminal 4 Slip 3, Berths 410, 411, and 412, April 1994.

Port of Portland, 2000. Preliminary Assessment, Port of Portland Terminal 4- Slip 1, 11040 N. Lombard, Portland, Oregon 97203, August 23, 2000.

Port of Portland, 2001. T/V Astypalea Oil Spill, Slip 1, Terminal 4, Port of Portland, April 7-8, 2001, July 10, 2001.

Port of Portland, 2002. Final Report – Sedimentation at the Port of Portland Terminals. February.

Port of Portland, 2003. Terminal 4 Hydrographic Conditions Survey (excluding Wheeler Bay), AutoCAD file format: T4 hydrosurvey June - 2003 condition.dwg, provided by the Port of Portland. June.

Roy F. Weston Inc., 1998. Portland Harbor Sediment Investigation Report, Multnomah County, Oregon.

Schenkenberger, Cindy, 1981. T-4 Gold Mine of Indian Artifacts. Portsmouth Biweekly, March 6:1 & 4.

Seed, R.B. and Harder L.F., 1990. "SPT-based analysis of cyclic pore pressure generation and undrained residual strength," J.M. Duncan ed., Proceedings from the H. Bolton Seed Memorial Symposium, University of California, Berkeley, Vol. 2., 351-376 pp.

Seed et al., 1985. Influence of SPT procedures in soil liquefaction resistance evaluations, Journal of Geotechnical Engineering, Vol. 111, No. 12, 1425-1445 pp.

Shannon and Wilson, 1962. Subsurface Investigation, Slip 1 Terminal 4, Portland Commission of Public Docks, Portland, Oregon. October.

Silverstein, Michael, 1990. Chinookans of the Lower Columbia. In *Northwest Coast*, edited by Wayne Suttles, pp. 533-546. Handbook of North American Indians, vol. 7, W.C. Sturtevant, general editor. Smithsonian Institution, Washington, D.C.

Singleterry, Lorraine, 1976. Early Days on the Peninsula. In *St. Johns History, Bicentennial Issue*, vol. 2, compiled by the St. Johns Historical Association. No pagination. St. Johns Historical Association, Portland, Oregon.

Smith, S.L., D.D. MacDonald, K.A. Keenleyside, C.G. Ingersoll, and J. Field, 1996. A Preliminary Evaluation of Sediment Quality Assessment Values for Freshwater Ecosystems. *Journal of Great Lakes Research* 22: 624-638.

Stark, Timothy D., 1996. Primary-Secondary Consolidation and Desiccation of Dredged Fill. Computer Model Prepared for U.S. Army Corps of Engineers, Washington, DC., University of Illinois at Urbana-Champaign, Department of Civil Engineering. November.

Striplin Environmental Associates, Inc., 2003. Draft – Lower Willamette River, May 2003, Multibeam Bathymetric Survey Report, prepared for Lower Willamette Group (LWG) (hard copy and CD). October 8, 2003.

Uhrich, M.A., and Wentz, D.A., 1999. Environmental Setting of the Willamette Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 97-4082-A, 20p.

U.S. Army Corps of Engineers (USACE), 1987. Confined Disposal of Dredged Material. EM 1110-2-5027. September 30.

U.S. Army Corps of Engineers (USACE), 1987b. Proposal for PCB/Metals Tests in Columbia/Willamette Sediments.

U.S. Army Corps of Engineers (USACE), 1988. Willamette River Raw Data, 1986-1988.

U.S. Army Corps of Engineers (USACE), 1999. Willamette River Sediment Data—1997 CRCD Project.

U.S. Army Corps of Engineers (USACE), 2002. Engineering and Design Hydrographic Surveying Manual. EM 1110-2-1003. Department of the Army, US Army Corps of Engineers, Washington, DC.

U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency Region 10, Washington Department of Ecology, Oregon Department of Environmental Quality, and Washington Department of Natural Resources, 1998. Dredged Material Evaluation Framework, Lower Columbia River Management Area, November 1998.

U.S. Coast and Geodetic Survey, 1895. Columbia River: Rales Landing to Portland, Oregon and Washington. Sheet 6, Navigation chart in map collection, Oregon Historical Society Regional Research Library, Portland.

U.S. Environmental Protection Agency (USEPA), 1987. Data Quality Objectives for Remedial Response Activities, Development Process. EPA/540/G-87/003. March.

U.S. Environmental Protection Agency (USEPA), 1993a. Federal Consent Decree, Case Number CV 930267 RE, May 7, 1993.

U.S. Environmental Protection Agency (USEPA), 1993b. Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA. EPA540-R-93-057. August.

U.S. Environmental Protection Agency (USEPA), 1994. Test Methods for Evaluating Solid Waste. SW-846, 3rd Edition, Update 11 Final. September.

U.S. Environmental Protection Agency (USEPA), 1994b. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates. EPA/600/R-94/024.

U.S. Environmental Protection Agency (USEPA), 1999. USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review. EPA 540/R-99/008. October.

U.S. Environmental Protection Agency (USEPA), 2000. Data Quality Objectives for Hazardous Waste Site Characterization, EPA QA/G-4W, Final. EPA/600/R-00/007. January.

U.S. Environmental Protection Agency (USEPA), 2001a. Administrative Order on Consent for Remedial Investigation/Feasibility Study, U.S. EPA Docket Number CERCLA-10-2001-0240.

U.S. Environmental Protection Agency (USEPA), 2001b. Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicologial Analyses: Technical Manual. EPA /823/B-01-002. October.

U.S. Environmental Protection Agency (USEPA), 2002. USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review. EPA 540-R-01-008. July.

U.S. Environmental Protection Agency (USEPA), 2003. Administrative Order on Consent for Removal Action in the matter of Portland Harbor Superfund Site, Terminal 4 Removal Action Area, Portland, Oregon, Port of Portland. October.

Ward, D.L. and A.A. Nigro, 1992. Differences in fish assemblages among habitats found in the lower Willamette River, Oregon: application of and problems with multivariate analysis. Fisheries Research: 13:119-132.

Washington State Department of Ecology, 1989. Draft Final Report, Puget Sound Dredged Disposal Analysis, Abbreviated Data Quality Evaluation for Dredged Material Disposal Projects. March.

9.2 List of Reference Drawings

City of Portland, Oregon, 1957. Commission of Public Docks, Pier 4 Main Dock – Typical Cross Section at Traveling Unloader Rails (Sheets 11 and 11A of 87) and Pier No. 4 General Plan, Traveling Bulk Unloader and Dock (Sheet 2 of 87) (full size).

Meyers, J.D., Rickert, D.A., Hines, W.G., and Vickers, S.D., 1979. Erosional Problems related to Land-Use Activities in the Willamette River Basin, Oregon: U.S. Geological Survey Miscellaneous Investigations Series (map I-921B).

Port of Portland, date unknown. CD of historical aerial photographs.

Port of Portland, October 23, 2003. CD ROM containing the following CAD and Image Files: aerial images, boundary surveys, contour surveys, hydro surveys, soil borings and utility surveys (provided by David Dittmer).

Port of Portland, 2002. Berths 410 and 411 Maintenance Dredging plans (reduced).

Sanborn Fire Insurance Map, 1924.

U.S. Department of the Interior, U.S. Geological Survey, 1990. Linnton Quadrangle, Oregon, 7.5-minute series (topographic map).