

Proposed Plan

Lower Duwamish Waterway Superfund Site



United States

Environmental Protection Agency

Region 10

February 28, 2013

This page left blank for double sided printing

Opportunities to Comment on this Plan

This Proposed Plan includes a summary of the cleanup alternatives evaluated and a description of the U.S. Environmental Protection Agency's (EPA's) Preferred Alternative for cleanup of the Lower Duwamish Waterway Superfund Site. EPA is seeking comments on the Proposed Plan, including the Preferred Alternative, other alternative remedies considered, and the supporting analysis and information in the Administrative Record. Because of the high level of public interest in this Site, and because EPA has already received a request for a 45-day extension to the 60-day comment period initially considered, EPA has provided for a 105-day public comment period instead of the usual 30 days. EPA will accept comments from February 28 until June 13, 2013.

This Plan summarizes information that can be found in greater detail in the Remedial Investigation and Feasibility Study reports, other key documents identified in this Proposed Plan, and other documents maintained at the Information Repositories for the Site (see below for locations).

Where to Review the Proposed Plan and Administrative Record

The Administrative Record, which contains the Proposed Plan and other documents that form the basis for the proposed Preferred Alternative, is available for public review at these Information Repositories:

EPA Region 10 Superfund Records Center
1200 Sixth Avenue, Suite 900, MS ECL-076
Seattle, WA 98101
206-553-4494

South Park Public Library
8604 Eighth Avenue South
Seattle, WA 98108
206-615-1688

Opportunities to Review and Comment on this Plan

Written comments on this Proposed Plan and other documents listed below can be submitted at any time during the public comment period in any of the following ways:

- **Post to the comments website:** www.resolve.org/site-ldpc
- E-mail: ldpc@resolve.org
- Fax: 206-450-5999
- Mail: Allison Hiltner, EPA Region 10, 1200 Sixth Avenue, Suite 900, MS ECL-111, Seattle WA 98101

Public meetings will be offered during the public comment period. EPA will take oral as well as written comments at those meetings. Meeting information will be published in the Seattle Times and other publications and locations, as well as on EPA's website: www.epa.gov/region10/duwamish.html

EPA will respond to comments received during the public comment period in a Responsiveness Summary which will be part of EPA's Record of Decision (ROD) that selects the final remedy.

Other Documents Available for Review and Comment

Two important documents are appended to the Proposed Plan for the convenience of reviewers. Although these documents are not part of the Proposed Plan, they will be carefully considered in the development of the ROD as well as its implementation. The two appendices are: A) Ecology's *Lower Duwamish Waterway Source Control Strategy*, and B) EPA's *Environmental Justice Analysis for the Lower Duwamish Waterway Cleanup*. Ecology is concurrently seeking comments on its Source Control Strategy, and EPA is concurrently seeking comments on its Environmental Justice Analysis. Comment responses for those two documents will be separate from comment responses for this Proposed Plan.

This page left blank for double sided printing

Executive Summary

Over 100 years of industrial and urban use has polluted the sediments, water, and marine life in the Lower Duwamish Waterway (LDW). This Proposed Plan presents the U. S. Environmental Protection Agency's (EPA's) Preferred Alternative to clean up contamination in the in-waterway portion of the LDW Superfund Site. There are three components to the strategy proposed by EPA and the Washington Department of Ecology (Ecology) for cleaning up the LDW: 1) early identification and cleanup of the most contaminated areas in the waterway, referred to as Early Action Areas (EAAs); 2) controlling sources of contamination to the waterway; and 3) cleanup of the remaining contamination in the waterway—addressed in this Proposed Plan—including long-term monitoring to measure the success of the remedy in achieving cleanup goals.

Cleanups have been completed at three EAAs, and are underway at two more EAAs. Ecology is the lead agency for the second component of the strategy, source control. Ecology and other agencies have made substantial progress towards finding, investigating, and controlling historical and ongoing sources to the LDW, though more work remains. Appendix A provides Ecology's strategy for its continuing efforts to identify and address sources of contamination to the waterway.

The proposed cleanup in this plan addresses the third component of this strategy, cleanup of the in-waterway portion of the Site. It is based on four goals, which EPA calls Remedial Action Objectives (RAOs):

RAO 1: Reduce to protective levels the human health risks associated with consumption of contaminated Lower Duwamish Waterway resident fish and shellfish by adults and children with the highest potential exposure.

RAO 2: Reduce to protective levels the human health risks from direct contact (skin contact and incidental ingestion) to contaminated sediments during netfishing, clamming, and beach play.

RAO 3: Reduce to protective levels the risks to benthic invertebrates from exposure to contaminated sediments.

RAO 4: Reduce to protective levels the risks to crabs, fish, birds, and mammals from exposure to contaminated sediment, surface water, and prey.

The cleanup alternatives in the Proposed Plan list actions that must be taken if specific numerical criteria are exceeded. The two primary criteria used to determine if cleanup is needed are:

- 1) Long-term goals, which EPA calls Preliminary Remediation Goals (PRGs); and
- 2) Remedial Action Levels, (RALs), which trigger cleanup action in certain areas, and allow for Monitored Natural Recovery in other areas where contamination levels are low.

Active cleanup will include a combination of the following:

- Dredging contaminated sediments;
- Capping contaminated sediments with clean material; or
- Enhanced Natural Recovery, which means adding about six to nine inches of clean material (such as sand) to areas with moderate amounts of contamination, with possible amendment with activated carbon or other substances that make contaminants less harmful.

The method of active cleanup will depend on several different things, such as:

- The type and amount of contamination;
- The depth of the contamination;
- The likelihood that people will come into contact with the contamination through activities like clamming or playing on the beach;
- The likelihood of fish, shellfish, or other marine creatures coming into contact with the contamination;
- The likelihood that “vessel scour” (a ship or other marine vessel churning up the sediments) or other activities such as building docks or piers will bring contamination up to the surface or suspend it in the water;
- The need to maintain water depths and habitat so that people and marine creatures can continue to use the waterway; and
- The likelihood of natural processes depositing cleaner sediments from upriver in a particular area.

Areas with low levels of contamination that are not specified for active cleanup will still be watched. They are called Monitored Natural Recovery areas. To make sure the waterway recovers in these areas, EPA will sample throughout the natural recovery period to make sure that clean material from upstream builds a clean layer above the current waterway bottom. If sampling results show the waterway isn’t clean enough considering the criteria established in this plan, EPA will determine whether additional cleanup is necessary.

EPA considered many alternatives and is proposing the Preferred Alternative described in this Proposed Plan because we believe it provides the best balance between minimizing the time it takes to reduce contaminant concentrations in the waterway, and providing for a thorough and protective cleanup that minimizes the risk of future releases of buried contamination. The cleanup proposed in this plan, in addition to cleaning up the EAAs and controlling sources of contamination to the waterway, is estimated to reduce risks from people eating contaminated fish and shellfish by 90% or more.

EPA estimates that the proposed cleanup will take about 7 years to implement, with an additional 10 years to reduce contaminant concentrations to their lowest predicted concentrations through natural recovery. The proposed cleanup plan addresses 156 acres of contaminated sediments through dredging, capping, or Enhanced Natural Recovery, removing an estimated 790,000 cubic yards of contaminated sediments from the waterway. Contaminant concentrations in the rest of the waterway will be reduced through cleanups at the EAAs (29 acres) or Monitored Natural Recovery areas (256 acres). The estimated cost of the proposed cleanup is \$305 million.

Contents

Opportunities to Comment on this Plan.....	i
Executive Summary.....	iii
Acronyms and Abbreviations.....	viii
1 Introduction.....	1
2 Site Background	5
2.1 Cleanup Activities Planned and Completed to Date	7
2.2 Source Control Investigations and Actions Completed to Date	8
2.3 Public Involvement	11
2.4 Involvement by Federally Recognized Tribes	11
2.5 Environmental Justice Analysis	11
3 Lower Duwamish Waterway Setting.....	13
3.1 Land Use	13
3.2 Waterway Use	14
3.3 Ecological Communities in the LDW	14
3.4 Sediment Transport and Deposition	16
3.5 Extent of Contamination	19
3.6 Background and Upstream COC Concentrations	25
4 Summary of Site Risks	29
4.1 Human Health Risks.....	29
4.2 Ecological Risks	37
4.3 Basis for Action.....	38
5 Scope and Role of the Response Action.....	41
5.1 Component 1: Early Identification and Cleanup of EAAs.....	41
5.2 Component 2: Controlling Sources of Contamination	41
5.3 Component 3: In-Waterway Cleanup	42
6 Remedial Action Objectives.....	43
7 Preliminary Remediation Goals.....	45
7.1 Sediment PRGs.....	45
7.2 Fish and Shellfish Tissue PRGs.....	48
7.3 Surface Water PRGs	49
8 Development of Remedial Alternatives.....	51
8.1 Framework for Developing Remedial Alternatives	51
8.2 Summary of Remedial Alternatives	53

9	Evaluation of Alternatives.....	73
9.1	Threshold Criteria	74
9.2	Balancing Criteria	82
9.3	Modifying Criteria.....	86
9.4	Summary of CERCLA Evaluation.....	87
10	EPA's Preferred Alternative	89
10.1	Description of the Preferred Alternative	89
10.2	Implementation of the Preferred Alternative	93
10.3	Rationale for Identification of 5C Plus as the Preferred Alternative	94
10.4	Preferred Alternative Summary	96
11	Key Terms	105
12	Key Documents	109

List of Tables

Table 1.	Statistical Summaries for Human Health COCs in Sediment	20
Table 2.	Summary of Selected Human Health COCs in Fish and Shellfish Tissue ^a	24
Table 3.	Summary of PCB, Arsenic, cPAH, and Dioxin/Furan Data for Natural Background Concentrations in Sediment.....	26
Table 4.	Estimates of Sediment and Suspended Sediment COC Concentrations of PCBs, Arsenic, cPAHs, and Dioxins/Furans from Upstream of the LDW Study Area.....	27
Table 5.	Summary of PCB, Arsenic, cPAH, and Dioxin/Furan Data for Natural Background Concentrations in Fish and Shellfish Tissue.....	28
Table 6.	Cancer and Non-Cancer Risk Estimates for Human Health Scenarios.....	32
Table 7.	Surface Sediment Contaminant Concentrations and Comparison to SMS Numerical Standards.....	38
Table 8.	Sediment PRGs for PCBs, Arsenic, cPAHs, and Dioxins/Furans for Human Health and Ecological COCs.....	46
Table 9.	Sediment PRGs for Ecological (Benthic Invertebrate) COCs.....	47
Table 10.	LDW Resident Fish and Shellfish Tissue PRGs	49
Table 11.	Criteria for Assigning Recovery Categories.....	52
Table 12.	Remedial Alternatives and Associated Remedial Technologies, Remedial Action Levels, and Actively Remediated Acres	60
Table 13.	Remedial Alternative Areas, Volumes, and Costs	61
Table 14.	Alternative 5C Plus Ecological Risk Reduction (Benthic Protection) RALs	71
Table 15.	Key ARARs for the LDW	80

List of Figures

Figure 1. Lower Duwamish Waterway and Early Action Areas	4
Figure 2. LDW Parks, Beach Play, and Potential Clamming Areas	15
Figure 3. Potential Scour Areas and Estimated Net Sedimentation Rates.....	18
Figure 4. PCB Distribution in Surface Sediment.....	21
Figure 5. SMS Status in Surface Sediment	22
Figure 6. Conceptual Model for Baseline Human Health Risk Assessment.....	30
Figure 7. Baseline Excess Cancer Risk and Non-Cancer Hazard Quotients for Consumption of Various Seafood Species as a Function of the Number of Meals Consumed per Month	34
Figure 8. Baseline Non-cancer Hazard Quotients and Excess Cancer Risk for the Seafood Consumption RME Scenarios.....	35
Figure 9. Baseline Excess Cancer Risk for the Direct Sediment Contact RME Scenarios	36
Figure 10. Conceptual Site Model for LDW Fish and the Benthic Invertebrate Community.....	40
Figure 11. Conceptual Site Model for Wildlife.....	40
Figure 12. Recovery Categories	54
Figure 13. Areas Addressed by LDW Cleanup Alternatives	55
Figure 14. Summary of Alternatives.....	63
Figure 15. Time to Achieve Risk Benchmarks for All Alternatives.....	65
Figure 16. Excess Cancer Risks and Non-cancer HQs for Seafood Consumption Calculated Using Tissue PRGs.....	76
Figure 17. Comparison of Total PCB Excess Cancer Risks and Non-cancer HQs for Seafood Consumption Calculated using LDW Baseline, Model-predicted, and PRG Concentrations	77
Figure 18. Preferred Alternative	97
Figure 19. Intertidal Areas – Remedial Technology Applications	99
Figure 20. Subtidal Areas – Remedial Technology Application.....	101
Figure 21. Intertidal Areas – Remedial Action Levels Application	103
Figure 22. Subtidal Areas – Remedial Action Levels Application	104

Acronyms and Abbreviations

µg/kg	micrograms per kilogram
ARAR	applicable or relevant and appropriate requirement
AWQC	Ambient Water Quality Criteria
BEHP	bis(2-ethylhexyl)phthalate
bg	natural background
BCM	bed composition model
C	combined technology
CAD	contained aquatic disposal
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CSL	cleanup screening level
CSO	combined sewer overflow
cy	cubic yard
DMMP	Dredged Material Management Program
dw	dry weight
EAA	Early Action Area
Ecology	Washington Department of Ecology
EJ	environmental justice
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FS	feasibility study
HHRA	human health risk assessment
HPAH	high molecular weight polycyclic aromatic hydrocarbon
HWTR	Hazardous Waste Toxicity Reduction
FS	feasibility study

FEMA	Federal Emergency Management Act
KCC	King County Code
LDW	Lower Duwamish Waterway
LPAH	low molecular weight polycyclic aromatic hydrocarbon
mg/kg	milligrams per kilogram
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MLLW	mean lower low water
MHHW	mean higher high water
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
na; n/a	not applicable
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
nc	cannot be calculated
nd	not detected
NEPA	National Environmental Policy Act
ng/kg	nanograms per kilogram
ng/L	nanograms per liter
NOAA	National Oceanic and Atmospheric Administration
OC	organic carbon
OM&M	operation, maintenance, and monitoring
PCB	polychlorinated biphenyl
PRG	preliminary remediation goal
R	removal emphasis
RAL	remedial action level
RAO	remedial action objective
RBTC	risk-based threshold concentration
RCW	Revised Code of Washington
RI	remedial investigation
RME	reasonable maximum exposure

RM	river mile
ROD	Record of Decision
R-T	removal with physical treatment
SCWG	Source Control Work Group
SD	storm drain
SEPA	State Environmental Policy Act
SMS	Sediment Management Standards
SQS	sediment quality standard
STM	sediment transport model
SVOC	semivolatile organic compound
SWAC	spatially-weighted average concentration
TBD	to be determined
TEQ	toxic equivalent
TOC	total organic carbon
U.S.C.	United States Code
VOC	volatile organic compound
WAC	Washington Administrative Code
WDOH	Washington Department of Health
ww	wet weight

1 Introduction

This Proposed Plan (Plan) presents the U. S. Environmental Protection Agency's (EPA's) Preferred Alternative to clean up contamination in the in-waterway portion of the Lower Duwamish Waterway (LDW) Superfund Site (Site). This Plan describes contamination present in the LDW and the associated risks to human health and the environment, the cleanup alternatives considered, and EPA's Preferred Alternative to address these risks. This Plan is issued by EPA, as the lead agency for the in-waterway portion of the Site, in accordance with the public participation requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, 42 U.S.C. 9601 et seq. as amended) Section 117(a) and under 40 CFR Section 300.430(f)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The LDW Site, located south of downtown Seattle, Washington, extends over the northern five miles of the Duwamish River to the southern tip of Harbor Island (Figure 1), and includes the waterway as well as the upland sources of contamination. Industrial discharges, storm drains (SDs), and combined sewer overflows (CSOs) have polluted LDW surface water and sediments over the past 100 years. Numerous hazardous substances were found in sediments at concentrations that pose a risk to humans through consumption of seafood, and through direct exposure when playing on the beach, clamming, or netfishing. Sediment contamination also poses an ecological risk to bottom-dwelling organisms and to mammals such as river otters. Polychlorinated biphenyls (PCBs), arsenic, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), and dioxins/furans are the four contaminants of concern (COCs) that account for most of the human health risk. In addition, 41 COCs have been found to pose risks to bottom-dwelling organisms in the LDW.

The overall strategy for addressing contamination and the associated risks in the LDW and surrounding watershed includes three components: 1) early identification and cleanup of the most contaminated areas in the waterway, referred to as Early Action Areas (EAAs); 2) controlling sources of contamination to the waterway; and 3) cleanup of the remaining contamination in the waterway, including long-term monitoring to assess the success of the remedy in achieving cleanup goals.

Progress on component 1, cleanup of the EAAs, is described in Section 2. For component 2, source control, Ecology is the lead agency with EPA as a support agency. Ecology's source control activities are described in their *Lower Duwamish Waterway Source Control Strategy* (Source Control Strategy), which is attached as Appendix A. For component 3, cleanup of the in-waterway portion of the Site, EPA is the lead agency and Ecology is the support agency.

This Proposed Plan describes and invites comments on EPA's Preferred Alternative for cleanup of the in-waterway portion of the LDW. The Preferred Alternative is intended to be the final remedy for the in-waterway portion of the Site, to be implemented after cleanup in the EAAs has been completed, source control sufficient to minimize recontamination has been implemented, additional sampling and analysis has been conducted, and design of the remedy has been completed.

The Preferred Alternative, which addresses approximately 412 acres, includes the following elements:

- A total of 156 acres of active cleanup, consisting of:
 - 84 acres of dredging or partial dredging and capping (an anticipated total volume of 790,000 cubic yards would be dredged and disposed in an upland landfill);
 - 24 acres of capping, with possible amendment with activated carbon or other contaminant-sequestering agents; and
 - 48 acres of Enhanced Natural Recovery (ENR – placing 6 to 9 inches of clean material over contaminated sediments) with possible amendment with activated carbon or other contaminant-sequestering agents, if these amendments are shown to be effective in pilot tests.
- Further reduction of contaminant concentrations over time in the remaining 256 acres through Monitored Natural Recovery (MNR – relying on natural processes such as burial of contaminated sediments by cleaner sediments from upstream). Long-term monitoring data will determine whether additional cleanup actions will be necessary in MNR areas.
- Institutional controls (ICs) and LDW-wide monitoring to enhance and measure protectiveness, and to protect the integrity of remedial action elements such as capping and ENR, while minimizing reliance on seafood consumption-related ICs to the extent practicable.

The Preferred Alternative assumes completion of an additional 29 acres of cleanup in Early Action Areas (see Sections 2 and 5 for further discussion of the EAAs).

Implementation of the Preferred Alternative, or another cleanup alternative described in this Plan, is considered necessary to protect human health and the environment from actual or threatened releases of hazardous substances. EPA is seeking comments on this Proposed Plan, including the Preferred Alternative, other alternatives considered, and the supporting analysis and information located in the Information Repositories (see page i), including the Remedial Investigation and Feasibility Study reports (RI Report and FS Report) and other key documents listed on page i. Public comments will be used by EPA, in consultation with Ecology and the Muckleshoot and Suquamish Indian Tribes, to select the final remedy in its Record of Decision (ROD). EPA may modify the Preferred Alternative or select another cleanup alternative presented in this Plan based on new information or public comments. Therefore, the public is encouraged to review and comment on all the alternatives.

EPA anticipates issuing the ROD in 2014. The ROD will include a Responsiveness Summary summarizing and responding to public comments on the Proposed Plan. Once the ROD is issued, a detailed design of the cleanup, called remedial design, will follow, followed by implementation of the remedy, then long-term monitoring. Remedial design sampling will be conducted after the early actions are completed in 2015. Results from remedial design sampling will be used to determine the final areas and volumes to be remediated and the remediation technologies to be applied and may be used by Ecology to assist in their source control efforts. Decision criteria for modifying the cleanup footprint based on remedial design data are included in Section 10.2.

The Preferred Alternative is estimated to take 7 years to construct. The lowest contaminant concentrations in fish and shellfish tissue are predicted by modeling to be achieved in 17 years following the start of construction.

Total estimated net present value costs are \$305 million, of which capital costs are \$258 million, and operation, maintenance, and monitoring (OM&M) costs are approximately \$47 million.

In addition to Appendix A, Ecology's Source Control Strategy, this Proposed Plan presents EPA's *Environmental Justice Analysis for the Lower Duwamish Waterway Cleanup* (EJ Analysis) as Appendix B. These documents are not part of the Proposed Plan, but they will be carefully considered in the development of the ROD as well as its implementation.

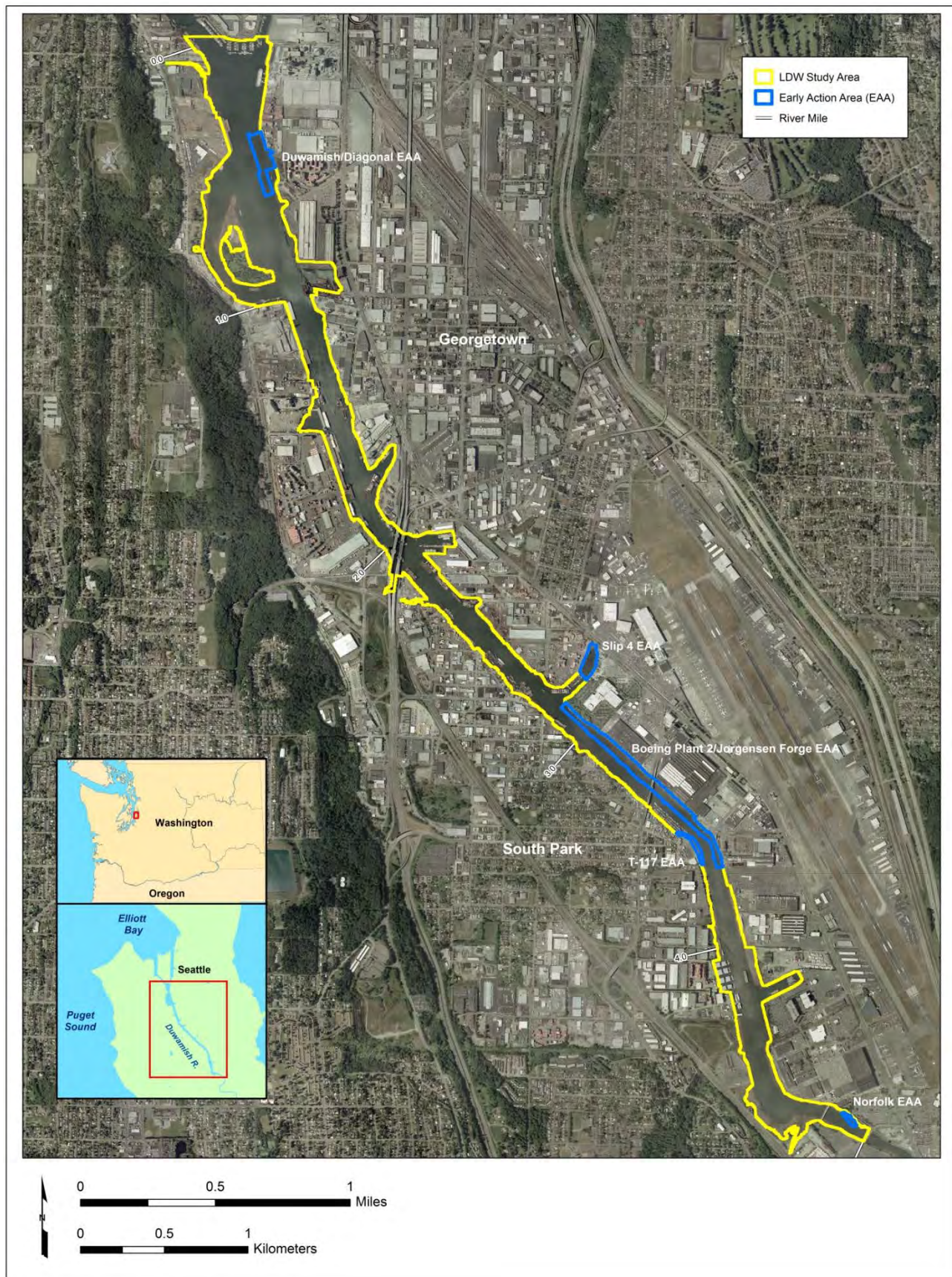


Figure 1. Lower Duwamish Waterway and Early Action Areas

2 Site Background

This section provides an overview of LDW topography and history, along with brief descriptions of contaminant sources, waterway use, and risks posed by contaminants.

LDW Topography and History

The Lower Duwamish Waterway (LDW) and adjacent upland areas have served as Seattle's major industrial corridor since the LDW was created by widening and straightening much of the Duwamish River in the early twentieth century. The Duwamish River flows north through Tukwila and Seattle, splitting at the southern end of Harbor Island to form the East and West Waterways, prior to discharging into Elliott Bay in Seattle, Washington. The in-waterway portion of the LDW Site evaluated for remedial action in this Proposed Plan extends for approximately 5 miles from the area around the Norfolk CSO (Norfolk EAA, at the southern end of the Site) at RM 5 to the southern tip of Harbor Island at river mile (RM) 0 (Figure 1). In total, the LDW includes approximately 441 acres of intertidal and subtidal habitats. The average width of the LDW is 440 feet.

Most of the upland areas adjacent to the LDW have been heavily industrialized since the early 1900s. Industrial uses include shipyard operations; manufacturing (airplane, cement, and chemical, e.g., paint, glue, resin, and wood preservatives); cargo storage and transport; metal manufacturing and recycling; petroleum storage; and the disposal of waste in landfills. Some of the wastes generated or disposed during these operations may have been discharged into or otherwise come to be located in the LDW, and may have contributed to the contamination of the LDW. Pathways for contaminants to enter the LDW can be direct (e.g., a stormwater discharge through a pipe into the LDW) or indirect (e.g., atmospheric deposition of contaminants within the watershed).

Contaminant Sources and Waterway Use

Within the LDW, sources of contaminants in LDW surface water and sediments include stormwater carrying the contaminants to the LDW via creeks, ditches, SDs, and CSOs; upland sites with contaminants reaching the LDW via groundwater, surface water, or erosion of contaminated soils; and atmospheric deposition to the LDW. Surface water and stormwater are major pathways for contaminants to enter the LDW. There are 208 pipes, creeks, and streams directly discharging into the LDW. Of these, 203 are public or private outfalls and five are creeks or streams. Twelve of the outfalls are CSOs, which discharge wastewater (residential, commercial, and industrial) and stormwater runoff. The potential source area discharging to the LDW encompasses a total area of 20,400 acres or approximately 32 square miles and includes: 1) the combined (sanitary and stormwater) sewer system, 2) the sanitary sewer service area, and 3) the separated stormwater drainage basins.

The CSO discharges typically occur during large storm events when the capacity of the combined sewer is exceeded and not all flow can be conveyed to a treatment plant. Non-CSO stormwater enters the waterway via storm drains and pipes, ditches, and creeks, or directly from properties adjacent to the waterway. Stormwater can carry contaminants when rain has come into contact with contaminants that have accumulated in or on soils and surfaces and subsequently drains into the stormwater system. The

contaminants that collect in storm drains/pipes, ditches or creeks are then carried to the waterway by stormwater. Groundwater is also a pathway for contaminants to reach the LDW.

In addition to industrial use, residential areas near and on the LDW include the neighborhoods of South Park and Georgetown and four marinas that permit live-aboard vessels. Though much habitat has been lost, many fish and wildlife species inhabit the LDW, particularly in the Kellogg Island area. Salmon runs passing through the LDW provide a valuable commercial and cultural resource for the Muckleshoot and Suquamish Tribes.

Risks Posed by Contaminants

Multiple hazardous substances have been and continue to be discharged into the LDW and remain in the water column and waterway sediments. Once in the water and sediment, the contaminants may be taken up by organisms, including bottom-dwelling organisms (also called benthic invertebrates), fish, and shellfish. The consumption of these organisms by larger fish, shellfish, and wildlife provides a mechanism for the contaminants to move from the sediment and water up through the food chain. This poses threats to human health and the environment when people and wildlife consume resident fish and shellfish from the LDW. People and wildlife may also face risks from direct contact with contaminated LDW sediments.

Hazardous substances that pose unacceptable risk to human health and the environment are called contaminants of concern or COCs in this Proposed Plan. The four COCs that pose the greatest risk to human health are polychlorinated biphenyls (PCBs), arsenic, carcinogenic polynuclear aromatic hydrocarbons (cPAHs)¹, and dioxins/furans. Forty-one hazardous substances are of concern because they are found at concentrations shown to be toxic to bottom-dwelling organisms; for example, phthalates. Of the COCs found in LDW sediments, PCBs are the most widespread.

Remedial Investigation/Feasibility Study

In December 2000, the City of Seattle, King County, the Port of Seattle, and The Boeing Company (Boeing), collectively known as the Lower Duwamish Waterway Group (LDWG), were issued an Administrative Order on Consent jointly by EPA and Ecology, requiring them to conduct a remedial investigation/feasibility study (RI/FS) pursuant to both CERCLA and Washington State's Model Toxics Control Act (MTCA). During the RI, LDWG compiled and analyzed available data from numerous investigations conducted prior to 2000, collected extensive additional data, conducted preliminary human health and ecological risk assessments, and identified areas of greater contamination to be considered for early cleanup. The Final Lower Duwamish Waterway Remedial Investigation Report (RI Report) was completed in 2010. The RI included an assessment of risks to human health and the environment posed by the contamination, and identified additional areas that require cleanup. In the Final Lower Duwamish Waterway Feasibility Study (FS Report), completed in 2012, LDWG developed alternatives for cleanup of the in-waterway portion of the Site. Also in 2012, LDWG developed two memoranda to supplement the FS, which consider refinements to the alternative being considered as the Preferred Alternative (see Key Documents on page 109). EPA and Ecology jointly provided oversight for the RI/FS.

1. cPAHs consist of a subset of seven PAHs which EPA has classified as probable human carcinogens: benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

2.1 Cleanup Activities Planned and Completed to Date

King County completed two cleanups of contaminated sediment in the LDW before and a few years after the start of the RI/FS under a 1991 CERCLA Natural Resource Damages Consent Decree, to address contamination from CSOs in Elliott Bay and the LDW:

- In 1999, 5,190 cubic yards (cy) of PCB-contaminated sediments outside the Norfolk CSO were dredged by King County. The area was then backfilled. (A small area of PCB-contaminated sediments inshore of this cleanup was excavated [60 cy] and capped by Boeing under Ecology's Voluntary Cleanup Program in 2003.)
- In 2003 and 2004, a 7-acre area around the Duwamish/Diagonal CSO/SD was dredged (68,000 cy) and capped. The COCs that triggered this action were PCBs, mercury, bis(2-ethylhexyl)phthalate (BEHP) and butyl benzyl phthalate. In 2005, a 6-inch layer of clean sand was placed over an additional area that had elevated PCB concentrations following cleanup.

The first phase of the RI identified additional areas with high levels of contamination that warranted early cleanup action, called Early Action Areas (EAAs). Five EAAs were identified, including the two King County cleanups described above. Three of the cleanups have been completed (the King County cleanups described above, and the Slip 4 cleanup described below), and two more will be completed (also described below) before the Preferred Alternative described in this Proposed Plan is implemented. Together, the cleanups at these five EAAs (Figure 1) cover 29 acres, and address some of the highest levels of contamination found in the LDW. Completion of the EAA cleanups will reduce the LDW-wide surface area-weighted average sediment PCB concentration by an estimated 50%.

- Slip 4: Approximately 10,000 cy of PCB-contaminated sediments were dredged and 3.4 acres were capped with clean sand, gravel, and granular activated carbon amended filter material, from October 2011 through January 2012, by the City of Seattle under an EPA Administrative Order and Settlement Agreement on Consent (Consent Order).
- Terminal 117: Soils on the upland portion of T-117 with elevated concentrations of PCBs were removed by the Port of Seattle with EPA oversight pursuant to separate Consent Orders issued by EPA in 1999 and 2006. Upland cleanup of associated yards, streets, and rights of way will be completed by the City of Seattle in 2013. Cleanup of T-117 EAA PCB-contaminated sediments are projected to be completed by the Port and City in 2014 under an EPA Consent Order issued in June 2011.
- Boeing Plant 2/Jorgensen Forge: Adjacent areas of sediment contamination off shore of the adjacent Boeing Plant 2 and Jorgensen Forge facilities will be cleaned up starting in 2013, now that sufficient source control actions have been completed at the upland facilities. During the LDW remedial investigation, EPA initially identified these areas as one EAA, but they are being addressed as separate actions pursuant to separate EPA decision documents and Consent Orders under different laws that require implementation coordination. Boeing Plant 2 contaminated sediments will be addressed under a Resource Recovery and Conservation Act (RCRA) Consent Order issued to Boeing in January 1994. Sediments contaminated with metals and other hazardous substances at Jorgensen Forge will be cleaned up under a 2012 CERCLA removal Consent Order. EPA anticipates completion of both these early actions by 2015.

The following timeline provides a summary of LDW activities to date.

Lower Duwamish Waterway Timeline

1999	Cleanup was completed at the Norfolk CSO
2000	A Consent Order was issued by EPA and Ecology requiring LDWG to conduct the RI/FS
2001	LDW was listed as a Superfund site
2002	LDW was listed by Ecology as a cleanup site under MTCA EPA and Ecology signed a Memorandum of Understanding (MOU) designating EPA as the lead for in-waterway sediment cleanup, and Ecology as the lead for source control. The MOU was revised in 2004. Ecology initiated the Source Control Work Group
2003	The LDW Phase 1 RI was completed, and additional cleanup was conducted at the Norfolk CSO
2004	Ecology issued its Source Control Strategy
2005	Cleanup was completed at the Duwamish/Diagonal CSO/SD
2010	The Final LDW RI was completed
2010	EPA issued an Action Memorandum (cleanup plan) for the T-117 EAA
2011	EPA issued a RCRA corrective action Final Decision (cleanup plan) for Boeing Plant 2 sediment EPA issued an Action Memorandum for Jorgensen sediments and shoreline bank soils
2012	Cleanup was completed at the Slip 4 EAA The Final LDW FS was completed
2013	Cleanup started at Boeing Plant 2

2.2 Source Control Investigations and Actions Completed to Date

Ecology is the lead agency for identifying direct and indirect sources of contaminants to the LDW Site. Ecology uses its regulatory authority and works with other governments that have regulatory authority (EPA, King County, City of Seattle, and Port of Seattle), also referred to as the Source Control Work Group (SCWG), to control ongoing sources to the extent possible. The SCWG began its work in 2002, with the goal of identifying, prioritizing, and controlling sources of contamination to the LDW before the cleanup discussed in this Proposed Plan is completed.

Members of the SCWG performed numerous investigations to identify ongoing sources of contaminants. These include:

- Compiling a water-wide summary of potential sources and investigating those potential sources.
- Developing Source Control Action Plans for each of the Source Control Action Areas that drain to the LDW. Each plan identifies the authorities, tools, and milestone accomplishments for controlling the sources and identifies criteria or other goals that determine effectiveness and completeness of source

control actions within each drainage basin. Ecology (with the SCWG) has identified 24 distinct drainage basins that drain to the LDW, and has completed Source Control Action Plans for 20 of them.

- Tracing sources by sampling solids within storm drains and catch basins for contaminants. This helps identify facilities where historical, unidentified, or illegal disposal of contaminants has occurred or is occurring, making the facility an active source of contaminants affecting the LDW.
- Investigating and addressing contamination at upland facilities, including those contributing contamination to the LDW via groundwater, stormwater, soil erosion, or air deposition.
- Developing and implementing other studies to identify ongoing sources, including: inputs to the Green/Duwamish River; inputs due to outfalls and other lateral sources; and inputs of PCBs in or from building materials in the source area.

Ecology, with the SCWG, has made substantial progress in finding, investigating and controlling both historical and ongoing sources to the LDW, though more work remains. The summary on the next page highlights numerous ongoing LDW source control actions. More detailed information about the source control studies and work to date can be found on Ecology's website at:

http://www.ecy.wa.gov/programs/tcp/sites_brochure/lower_duwamish/lower_duwamish_hp.html.

Summary of Source Control Actions To Date

All of the work conducted to date and summarized below involved one or more of the following elements: source control investigations, site assessment and cleanup, inspections, source tracing, sampling, and monitoring. For comprehensive accounts, and up to date information, check the most recent Source Control Status Reports on Ecology's website at http://www.ecy.wa.gov/programs/tcp/sites_brochure/lower_duwamish/lower_duwamish_hp.html.

One hundred ninety-six confirmed or suspected contaminated upland facilities have been identified within the LDW drainage basin, although only some of those are sources of contaminants to the LDW.

Thirteen facilities along or near the LDW are under agreed orders for investigation and cleanup administered by Ecology's Toxic Cleanup Program:

- | | |
|---|---|
| – Jorgensen Forge Corporation | – North Boeing Field/Georgetown Steam Plant |
| – 8801 East Marginal Way (former Paccar site) | – Fox Avenue/Great Western Chemical |
| – South Park Landfill | – Glacier NW/Reichhold |
| – Crowley Marine Services | – Duwamish Shipyard |
| – Industrial Containers/Trotsky/Northwest Cooperage | – Douglas Management Properties |
| – Boeing Isaacson-Thompson | – Port of Seattle Terminal 115 North |
| – Duwamish Marine Center | |

Five additional facilities in the LDW source area are under agreed orders for investigation and cleanup administered by Ecology's Hazardous Waste Treatment and Reduction (HWTR) program:

- | | |
|------------------------------|--|
| – Art Brass Plating | – Blaser Die Casting |
| – Capital Industries | – General Electric — Dawson Street Plant |
| – Philip Services Georgetown | |

Ecology has conducted site investigations at:

- | | |
|--|------------------------------|
| – South Park Marina (former A and B Barrel) | – Basin Oil |
| – Washington State Liquor Control Board Warehouse | – Douglas Management Company |
| – Industrial Container Services (formerly Northwest Cooperage) | |

Four voluntary cleanups under MTCA are occurring or have been completed at:

- | | |
|--|--|
| – Boeing Developmental Center | – Port of Seattle Terminal 106/108 |
| – General Services Administration — Federal Center South | – City of Seattle 7th Ave Pump Station |

(Approximately ten other voluntary cleanups have been completed or are occurring within the LDW Source Area at facilities not adjacent to the LDW)

Eight facilities along or near the LDW are under an EPA cleanup process:

- | | |
|--|--|
| – Boeing Plant 2 (RCRA) | – Jorgensen Forge shoreline (CERCLA) |
| – Rhône-Poulenc (RCRA) | – Port of Seattle Terminal 117 (CERCLA) |
| – Boeing Electronics Manufacturing Facility (CERCLA) | – Tully's/Rainier Commons (Toxic Substances Control Act) |
| – 24" stormwater outfall Boeing/Jorgensen property line (CERCLA) | |
| – North Boeing Field/King County International Airport Storm Drain Treatment System (CERCLA) | |

In addition:

- Since 2003, the City of Seattle and King County have completed more than 3,000 inspections at nearly 1,400 businesses in the LDW area. In addition, they have collected more than 800 sediment samples from storm drains and combined sewer systems to help identify and characterize sources discharging to the municipal storm and wastewater collection systems.
- In 2008, Ecology signed an interagency agreement with the City of Seattle to expand source tracing sampling. As part of this agreement, Seattle Public Utilities installed twenty additional sediment traps in the LDW study area, including areas on King County International Airport and unincorporated King County.
- From October 2009 through November 2012, Ecology's Lower Duwamish Urban Waters Initiative inspection team has completed 230 water quality inspections and 191 hazardous waste inspections.
- Approximately 100 facilities in the LDW drainage basin have wastewater discharge permits from Ecology; approximately 90 facilities are regulated under a general industrial stormwater permit; two active facilities have individual industrial wastewater discharge permits; two facilities operate under a general permit for boatyards; and four facilities operate under a general permit for sand and gravel facilities.
- Four local governments have municipal separate stormwater general discharge permits (Phase I for the city of Seattle and King County, and the Port of Seattle as a secondary permittee; and Phase II Western Washington for the city of Tukwila).
- Two local governments (the city of Seattle and King County) have individual discharge permits for their combined sanitary sewer and stormwater systems.

2.3 Public Involvement

Public involvement is a cornerstone of EPA's and Ecology's LDW work. In 2002, EPA and Ecology developed a community involvement plan to promote meaningful involvement of the public during the investigation and cleanup of the LDW. This plan was developed based on interviews with community members and identified stakeholders. Throughout the RI/FS process, EPA and Ecology have regularly held public meetings and have attended community and advisory group meetings. The Agencies hold quarterly stakeholder meetings to provide updates on the RI/FS, cleanup of the EAAs, and source control activities. EPA and Ecology have consistently sought input from the Tribes, community groups, and natural resource agencies when reviewing and commenting on sampling plans, the human health and ecological risk assessments, and other RI/FS documents. Other community involvement activities have included mailing fact sheets, providing opportunities for public comment on the RI and FS Reports, providing information about EPA's work at the Site at annual community festivals, and providing updates at neighborhood meetings. EPA and Ecology used input from a 2010 public review of the draft FS to finalize the FS and develop this Proposed Plan. EPA provides technical assistance grants to the community advisory group for the Site, the Duwamish River Cleanup Coalition/Technical Advisory Group. This organization reviews information about the Site and shares it with community members. EPA will continue to consult with Ecology and the Muckleshoot and Suquamish Tribes and engage with the community throughout design, construction, and long-term monitoring of the remedy.

2.4 Involvement by Federally Recognized Tribes

The LDW is actively used by the Muckleshoot Tribe as part of their usual and accustomed fishing area, and the Suquamish Tribe fishes the area north of the Spokane St. Bridge, immediately north of the LDW. Consideration of how Tribal members may be exposed to contaminants in the LDW while engaging in seafood harvest activities has been a primary factor shaping the assessment of human health risks. The Tribes, as sovereign nations, have engaged in government to government consultations with EPA on the cleanup process. The Tribes have also broadly and actively participated in meetings determining the course of the cleanup to date.

2.5 Environmental Justice Analysis

In conjunction with the FS, in response to comments on the 2010 draft FS, an Environmental Justice (EJ) Analysis for the LDW was conducted and a report was produced by EPA (Appendix B). EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." The purpose of the EJ Analysis was to 1) screen for EJ concerns, and 2) identify disproportionate adverse impacts from the cleanup alternatives and the Preferred Alternative and, if found, provide recommendations to mitigate such impacts. The information and recommendations from the EJ Analysis have been considered in the development of this Proposed Plan and will also be considered for the ROD. Recommendations from the EJ analysis that fall outside of the scope or authority of CERCLA may be referred to another agency for their consideration.

This page left blank for double sided printing

3 Lower Duwamish Waterway Setting

The LDW, originally the natural meandering estuary at the confluence of the Green/Duwamish River system and Elliot Bay, was modified in the early 1900s to become an engineered navigation channel for commercial use, termed a waterway, from RM 0 to RM 4.7. The in-waterway portion of the LDW Superfund Site extends from RM 0 to RM 5, encompassing approximately 441 acres. Much of the natural wetland habitat and mudflat areas associated with the original Duwamish River estuary are no longer present as a result of the waterway construction and subsequent upland development.

The LDW supports major shipping activities for containerized and bulk cargo. Approximately 40 berthing areas are located along the LDW. The central portion of the waterway is maintained as a federal navigation channel by the US Army Corps of Engineers (USACE). The navigation channel is maintained at authorized navigable depths of 30 ft below “mean lower low water” (-30’ MLLW)² from Harbor Island to the First Avenue South Bridge (RM 2), at -20 feet MLLW from the First Avenue South Bridge to Slip 4 (RM 2.8), and at -15 ft MLLW from Slip 4 to the Upper Turning Basin (RM 4.7). Depths outside the navigation channel immediately south of Harbor Island at the mouth of the waterway are as deep as -47 ft MLLW. To maintain navigation depths, the USACE dredges the upstream portion of the navigation channel every one to three years. The area typically dredged is the Upper Turning Basin and downstream to approximately RM 4. In addition, private parties periodically dredge berthing areas to maintain depths for their own purposes, typically shipping and marina uses.

Outside of the navigation channel, the LDW banks are comprised of sloped subtidal embankments, shallow subtidal and intertidal areas (including five slips along the eastern shoreline and three embayments along the western shoreline), and Kellogg Island near the downstream end. The shoreline consists primarily of hardened surfaces, including riprap, aprons for piers, and sheet pile walls, with some beaches and intertidal habitat remaining in isolated patches.

3.1 Land Use

The LDW and surrounding area is Seattle’s primary industrial corridor. Industries currently operating along the Duwamish include marine construction, boat manufacturing and repair, marinas, cement manufacturing, cargo handling and storage, paper and metals fabrication, food processing, airplane parts manufacturing and a municipal airport. However, the Duwamish estuary subwatershed (extending from RM 11 to Elliott Bay) of the Green/Duwamish watershed has more residential land use (36%) than industrial and commercial land use combined (29% combined; 18% and 11%, respectively). Eighteen percent of the subwatershed is used for right-of-way areas (including roads and highways); while 17% is open/undeveloped land and parks.

Two neighborhoods, South Park and Georgetown, are located to the west and east, respectively, of the LDW. EPA and Ecology have identified environmental justice concerns in the South Park and Georgetown neighborhoods in accordance with Executive Order 12898, *Federal Actions to Address*

2. The LDW has two high tides and two low tides each day. MLLW is the average lowest daily low-water height and mean higher high water (MHHW) is the average highest daily high-water height, averaged over many years.

Environmental Justice in Minority Populations and Low-Income Populations. As noted in EPA's *Environmental Justice Analysis for the Lower Duwamish Waterway Superfund Cleanup* (EJ Analysis), included as Appendix B to this Proposed Plan, incomes in South Seattle where these neighborhoods are located are approximately 50% lower and percentages of minority populations are significantly higher than in the City of Seattle (the population of the City of Seattle is approximately 30% minority, compared to the LDW corridor which is approximately 50% minority). This area also has higher rates of asthma hospitalizations and rates of other chronic diseases such as diabetes than other Seattle neighborhoods and King County as a whole. These neighborhoods support a mixture of residential, recreational, commercial, and industrial uses.

3.2 Waterway Use

The LDW supports considerable commercial navigation and is also used for various recreational activities such as boating, kayaking, fishing, and beach recreation. Several public parks and publicly accessible shoreline areas exist within the LDW, and there are plans to create additional recreational and habitat opportunities in the LDW corridor. To inform these waterway users about risks from eating fish and shellfish, the Washington Department of Health (WDOH) provides advisories (described in Seafood Advisories for the Lower Duwamish Waterway, below).

The LDW is one of the locations of the Muckleshoot Tribe's commercial, ceremonial, and subsistence fishery for salmon, as part of its usual and accustomed fishing area. The Suquamish Tribe actively manages aquatic resources north of the Spokane Street Bridge, just north of the LDW study area.

Four marinas and two public parks (Terminal 107/Herring's House and Duwamish Waterway Park) are located along the LDW, and several other access points allow the public to enter the LDW for recreational purposes. A third, non-Federally recognized Tribe, the Duwamish Tribe, uses parks along the LDW for cultural gatherings and canoe launching. A human access survey conducted along the LDW shoreline as part of the RI survey identified the following uses:

launching and hauling out hand-powered boats or motorboats, walking, fishing, swimming, and picnicking. Although recreational use may increase at some point in the future, the primary uses of the waterway and surrounding area are anticipated to remain commercial (navigation and fisheries), industrial, and residential (Figure 2).

Seafood Advisories for the Lower Duwamish Waterway

The Washington State Department of Health (WDOH) currently recommends no consumption of fish and shellfish (other than salmon) from the LDW. The WDOH maintains a web site and provides publications and other educational forums that cover healthy eating and seafood consumption. In addition, the seafood consumption advisories are posted on signs at public access locations within the LDW. More information can be found at <http://www.doh.wa.gov/fish>.

3.3 Ecological Communities in the LDW

The LDW is home to a diverse ecology, with abundant resident and non-resident fish and shellfish, bottom-dwelling organisms, marine mammals, and birds.

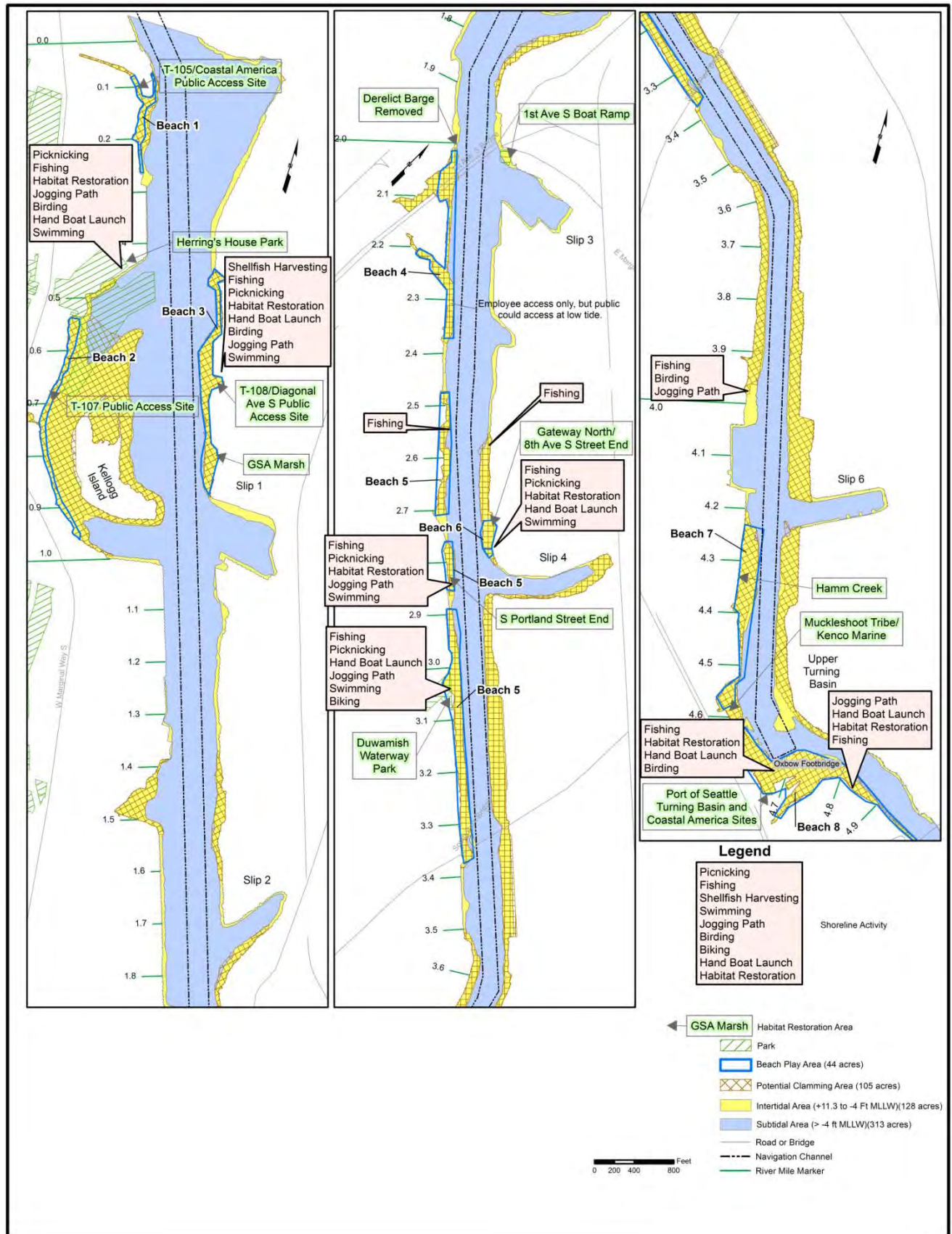


Figure 2. LDW Parks, Beach Play, and Potential Clamming Areas

Several bottomfish (sole, sculpin, flounder) and water column fish (perch and herring) are abundant in the LDW, as are salmon. The Green/Duwamish River system supports eight species of salmonids: coho, Chinook, chum, sockeye, and pink salmon, plus cutthroat trout, both winter- and summer-run steelhead, and bull trout. Juvenile Chinook and chum have a residence time in the LDW from several days to two months; coho are in the LDW for only a few days; and sockeye are rare in the LDW. Salmon found in the LDW spawn mainly in the middle reaches of the Green River and its tributaries. The juvenile outmigration generally starts between March and June. Outmigration usually lasts through mid-July to early August.

Puget Sound Chinook salmon are listed as threatened under the federal Endangered Species Act (ESA). Other relevant fish species listed as threatened under the ESA include the coastal Puget Sound bull trout and the Puget Sound steelhead. The LDW is designated as critical habitat for bull trout and Chinook salmon. The bald eagle was delisted in 2007 under the ESA but is protected under the Bald and Golden Eagle Protection Act, and under the Migratory Bird Treaty Act.

Typical of most estuaries, the benthic invertebrate community is dominated by annelids (worms), mollusks (clams and snails), and crustaceans (e.g., shrimp and crabs). Dungeness and other crabs are present in the LDW, although their distribution is generally limited to the portions of the LDW with higher salinity.

The common shorebirds and wading birds observed in the LDW are sandpipers, killdeer, and great blue herons. Bald eagles, ospreys, and great blue herons nest on or near the LDW and use the LDW for foraging. The LDW provides habitat for mammal species including harbor seals, sea lions, and river otters.

3.4 Sediment Transport and Deposition

Human activity has greatly influenced water and sediment movement in the LDW. Rivers that historically flowed into the upstream Green River were diverted in the early twentieth century, reducing the volume of water entering the LDW by approximately 70%. Water flows are now managed by the Howard Hanson Dam, constructed in 1961, approximately 65 miles upstream. In addition, the LDW has been widened and deepened to permit navigation. As a result, peak flows are much smaller with maximum flows rarely exceeding 12,000 cubic feet per second. The reduction in peak flows results in less erosion and more deposition of sediments.

The LDW is a two-layer salt wedge estuary, with outflow that is mostly freshwater originating from the Green/Duwamish River at the surface, and tidally-influenced salt water from Puget Sound entering the LDW at the mouth of the waterway beneath it. The saltwater “wedge,” or interface between fresh water at the surface and salt water at depth, is always present from RM 0 to RM 2.2, and is periodically present between RM 2.2 and RM 4, depending on tide height and river flow. Between RM 4 and RM 5 freshwater is usually predominant, although the saltwater wedge can extend through this area when the tide is high and river flow is low. LDW tidal fluctuations average about 11 feet. The presence of the salt water layer in some portions of the LDW helps reduce sediment scour during high river flows.

Sediment Transport Model

A three-dimensional sediment transport model (STM) was developed to simulate water and sediment movement over a wide range of flow and tidal conditions to inform the type of sediment cleanup technologies that would be appropriate for the area. The model estimated that, on average, more than

200,000 metric tons of sediment enters the LDW each year. About 50% of the incoming sediment deposits within the LDW. The rest is exported further downstream to Elliott Bay. Approximately 50% of the sediment that settles in the LDW is removed by periodic navigational maintenance dredging. The annual average amount dredged from the LDW by the US Army Corps of Engineers (USACE) is 51,000 metric tons, mostly in the Upper Turning Basin. Thus, approximately 25% of the incoming sediment remains in the LDW after dredging.

Based on the STM, approximately 99% of the sediment entering the waterway is from upstream. The other approximately 1% is directly discharged into the LDW via storm drains, CSO outfalls, and small streams. Although direct discharges to the LDW only account for approximately 1% of the sediment load to the LDW, the contaminant concentrations in these sediments are much higher than in the sediments coming in from upstream. This often causes elevated contaminant concentrations in localized areas around outfalls. These higher concentrations are being addressed as part of source control (see Section 2.2).

Deposition and erosion predicted by the model, along with estimated vessel scour areas (not predicted by the model), are illustrated in Figure 3. The STM results indicate that, overall, there is more deposition of sediment than erosion in the LDW. Some areas are more erosional and some are more depositional. Erosion of the sediment bed by river flow (high-flow scour) is limited, even during high-flow events. Most bed erosion due to high-flow scour is less than 10 centimeters (cm) in depth and maximum estimated net erosion depths are 22 cm. Vessels may cause localized scour to depths greater than 22 cm but likely less than 60 cm. The STM's predictions are corroborated by sediment contaminant concentration data collected in the same locations over time, which indicate that natural recovery (as described in Section 8.2.1) is occurring in some areas of LDW.

Bed Composition Model

A second model, the bed composition model (BCM), was used to estimate future COC concentrations in LDW sediments. The BCM used predictions of sediment movement from the STM, data on sediment contaminant concentrations in the LDW and in sediment entering the LDW from the Green/Duwamish River, and data on other sediment inputs to the LDW from ditches, streams, and municipal discharges in the LDW basin. The BCM provided predictions of approximate future sediment contaminant concentrations that would exist after implementation of each of the proposed cleanup alternatives.

Uncertainty and Sensitivity Analyses

Uncertainty and sensitivity analyses were performed for the STM and for the BCM. The primary sources of uncertainty in the physical and chemical model predictions are: 1) COC concentrations in incoming sediments from upstream and lateral sources, 2) the rate of net sedimentation/burial from incoming sediment loads, and 3) the potential for deep disturbances of subsurface contaminated sediments by mechanisms such as vessel (propeller wash) scour and earthquakes. While long-term projections of contaminant concentrations and the time to reach the lowest model-projected concentrations must be viewed in light of these uncertainties, the STM and BCM modeling, along with a subsurface-disturbance analysis provided in the FS, provide a sufficient basis for comparison of alternatives and selection of a Preferred Alternative.

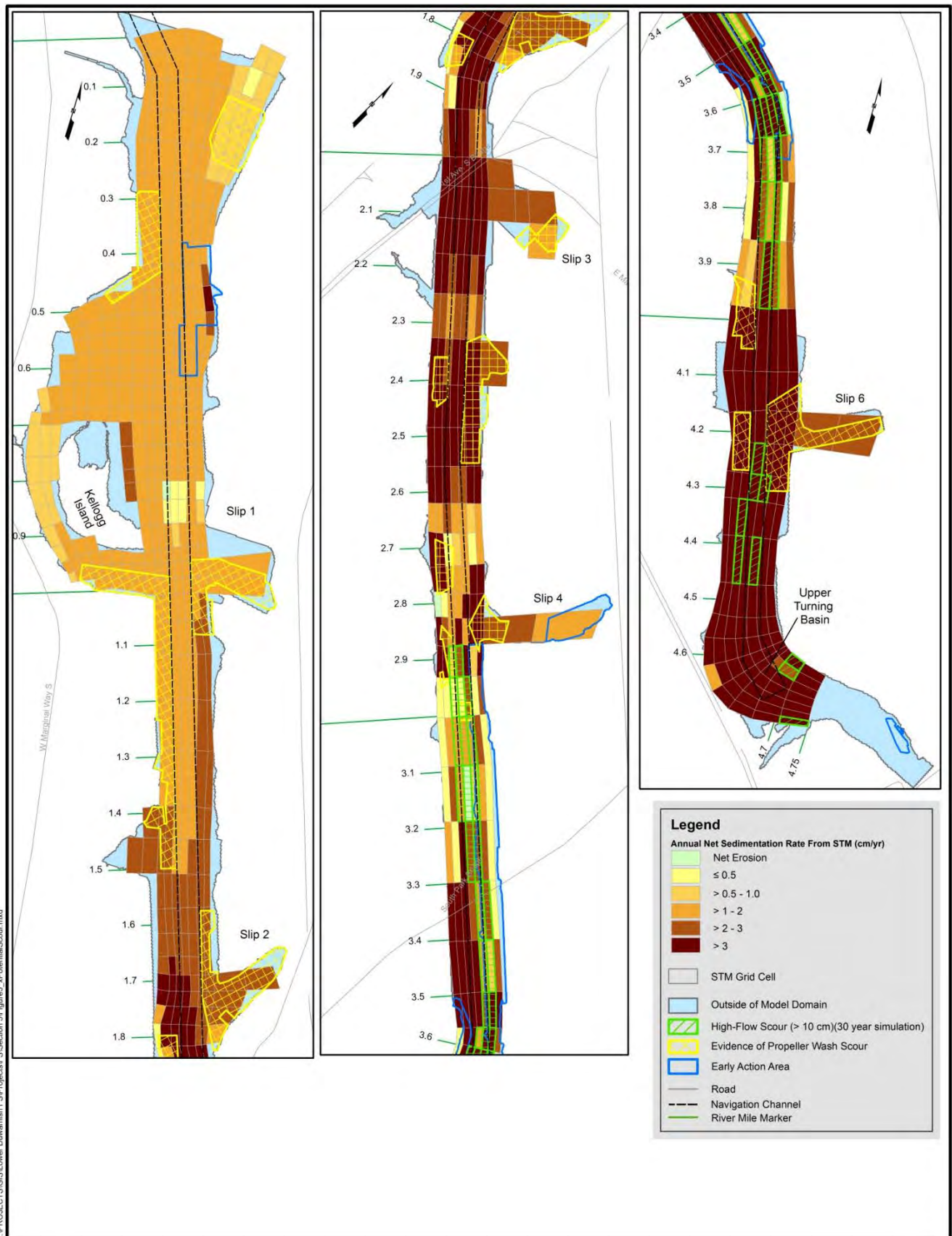


Figure 3. Potential Scour Areas and Estimated Net Sedimentation Rates

3.5 Extent of Contamination

Numerous investigations have been conducted to determine the nature and extent of contamination in the LDW. The National Oceanic and Atmospheric Administration (NOAA) and EPA conducted waterway-wide investigations of the LDW in 1997 and 1998, respectively. At least 25 smaller, location-specific investigations have been conducted by King County, the City of Seattle, Boeing, and other private entities.

LDWG completed Phase 1 of the RI in 2003. This study compiled and analyzed pre-existing data, identifying areas of higher contamination to be considered for early cleanup. LDWG collected extensive additional data during Phase 2 of the RI through 2009. These additional data, new data collected by other parties, and Phase 1 data were used to develop the RI Report, which was completed in 2010. The RI study area extended to RM 7, but the study area was reduced to the lower five miles in the FS because RI data showed very low levels of contamination upstream of RM 5.

The nature and extent of hazardous substance contamination was

evaluated in the RI based on the concentration of contaminants in approximately 1,500 surface sediment samples (top 10 cm of the river bed), 900 subsurface sediment samples, 420 fish and shellfish tissue samples, 480 surface water samples, 110 seep samples, and 90 porewater samples. Toxicity tests were performed on 76 surface sediment samples. Data collected in multiple investigations between 1990 and April 2010 were incorporated into the RI dataset. Of these, approximately 900 samples were collected as part of the RI in 2004 – 2006. An additional 47 samples were collected during the FS in 2009 – 2010. The results of these investigations for sediments, fish and shellfish tissue, and surface water are described below.

3.5.1 Surface and Subsurface Sediments

Table 1 summarizes minimum and maximum detected concentrations, average concentrations, and detection frequencies for PCBs, arsenic, cPAHs, and dioxins/furans in surface and subsurface sediments. These contaminants account for the majority of human health risks from contamination in the LDW.

What Are the Most Harmful Contaminants in the Lower Duwamish Waterway?

There are many hazardous substances found in LDW sediments, fish, and shellfish. Most of the human health risk comes from these four:

PCBs are manmade chemicals that were banned in the late 1970s. PCBs were widely used in coolants and oils, paints, caulking, and building material. PCBs stay in the environment for a long time and can build up in fish and shellfish. Children exposed to PCBs may develop learning and behavior problems later in life. PCBs are known to impact the immune system and may cause cancer in people who have been exposed to them over a long time.

Arsenic is associated with industrial uses like lumber treatment and watercraft repair. Industrial activities have spread additional arsenic over much of the Puget Sound Region. It is also naturally present at low levels in Puget Sound area rock and soil. Long-term exposure to toxic forms of arsenic may cause skin, bladder, and other cancers.

PAHs are formed during the burning of substances such as coal, oil, gas, wood, garbage and tobacco and during the charbroiling of meat. Historical industrial activities are a known source of PAHs, as well as creosote treated timber. Long periods of breathing, eating, or having skin contact with high levels of some of the PAHs may increase a person's risk of cancer.

Dioxins/furans are by-products of burning (either in natural or industrial settings), chemical manufacturing, and metal processing. Historically, dioxins/furans were byproducts of pentachlorophenol (used in wood treating), pesticide, and PCB production. Dioxins last a long time in the environment and, like PCBs, can build up in fish and fatty foods. Specific toxic effects related to dioxins include: reproductive problems, problems in fetal development or in early childhood, immune system damage, and cancer.

Table 1. Statistical Summaries for Human Health COCs in Sediment

Data Type/Contaminant	Summary Statistics for Sediment in the LDW (RM 0 to RM 5)				Total Number of Sediment Samples	
	Minimum Detected	Calculated Mean	Maximum Detected	Spatially-Weighted Average Concentration (SWAC)	Total	With Detected Values
Surface Sediment						
PCBs (µg/kg dw) ^a	2.2	1,100	220,000	350	1,392	1,309
Arsenic (mg/kg dw)	1.2	17	1,100	16	918	857
cPAHs (µg TEQ/kg dw) ^b	9.7	460	11,000	400	893	852
Dioxins/Furans (ng TEQ / kg dw) ^c	0.25	42	2,100	26	123	119
Subsurface Sediment						
PCBs (µg/kg dw)	0.52	2000	890,000	n/a	1,504	1,131
Arsenic (mg/kg dw)	1.2	30	2,000	n/a	531	453
cPAHs (µg TEQ/kg dw) ^b	1.2	370	7,000	n/a	542	449
Dioxins/Furans (ng TEQ / kg dw) ^c	0.15	17	190	n/a	64	64

NOTE: Based on FS baseline dataset, which includes sampling data from all EAAs except the Duwamish/Diagonal CSO/SD and Norfolk CSO EAAs (these cleanups were completed before the start of the FS).

- Two PCB samples, at the inlet at RM 2.2, were considered outliers and were not included in the data considered; their detected concentrations were 230,000 and 2,900,000 µg/kg. Mean and SWAC for PCBs were calculated without the two outliers; if the outliers were included, the mean would be 3,400 µg/kg dw and the SWAC would be 1,300 µg/kg dw.
- The cPAH TEQ was calculated using compound-specific potency equivalency factors.
- The dioxin/furan TEQ was calculated using World Health Organization's mammalian toxic equivalent factors.

Surface Sediments

Based on RI data, PCBs are the most widespread contaminant in LDW surface sediment; they were detected at 94% of the locations where samples were analyzed for PCBs. The distribution of PCBs in LDW surface sediment is shown in Figure 4.

To identify areas where COCs were present at concentrations toxic to benthic invertebrates, the RI/FS used the Washington State Sediment Management Standards (SMS), which are explained in What are the Sediment Management Standards? on page 37. In the SMS, the numerical sediment quality standards (SQS) are contaminant concentrations below which no adverse effects on benthic invertebrate organisms are expected. The SMS also establishes cleanup screening levels (CSLs), higher levels for the same contaminants at which minor effects are expected. The SMS regulations also allow use of site-specific biological effects criteria (based on toxicity testing or benthic abundance data) to determine whether a location passes or fails the SQS or CSLs.

Surface sediment samples from a subset of locations were tested for both contaminant concentrations and biological effects. Sample locations where SQS or CSL chemical numerical standards were exceeded but biological criteria were not exceeded were designated as not exceeding the SQS or CSL—that is, the determination of whether criteria are exceeded was based on biological criteria not chemical numerical standards. It is important to note that risks to human health or to animals coming into contact with sediment or eating fish and shellfish that live in the waterway are not addressed by either the SMS chemical numerical standards or biological criteria. Those risks are addressed separately as described in this Plan.

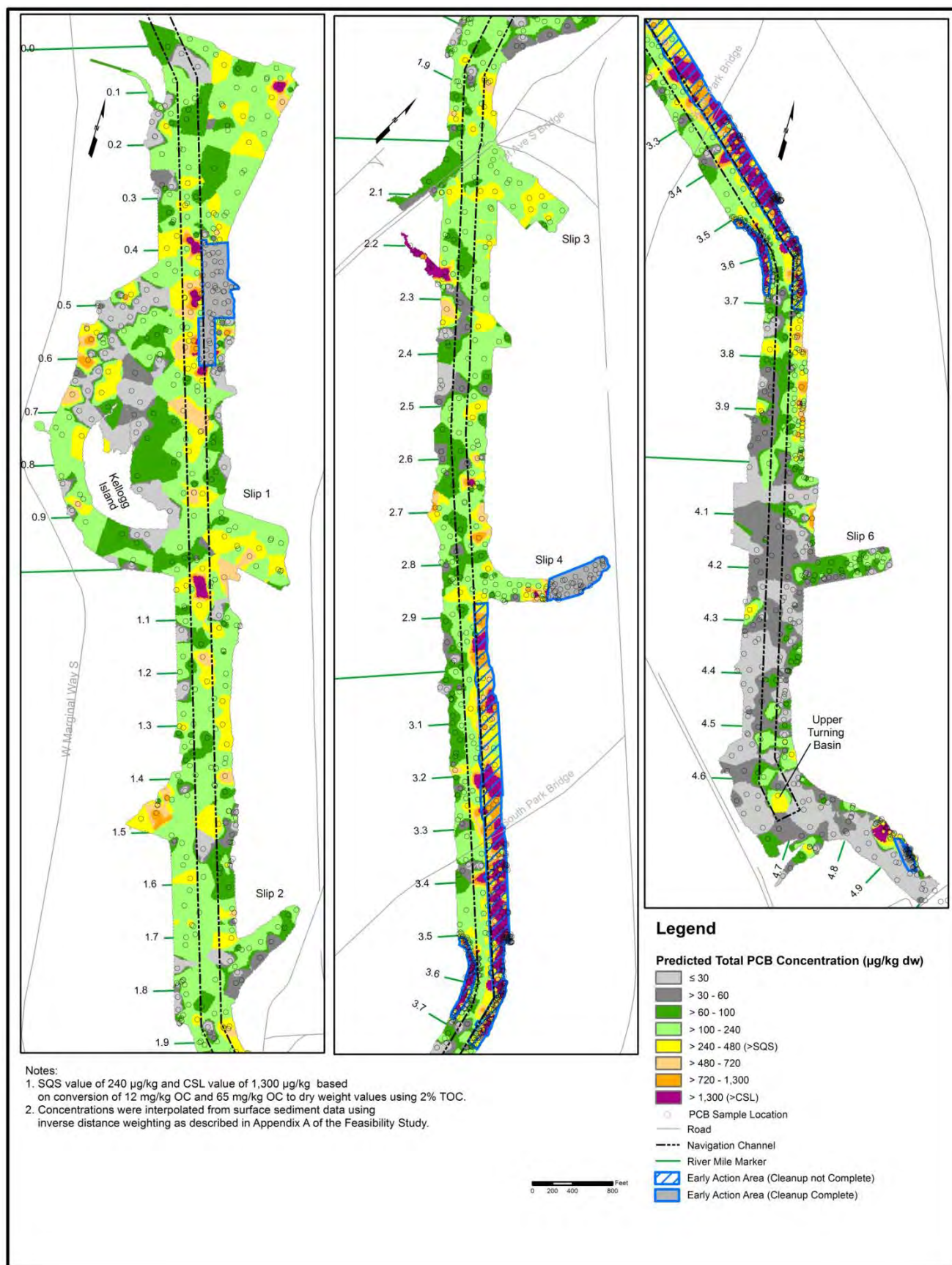


Figure 4. PCB Distribution in Surface Sediment

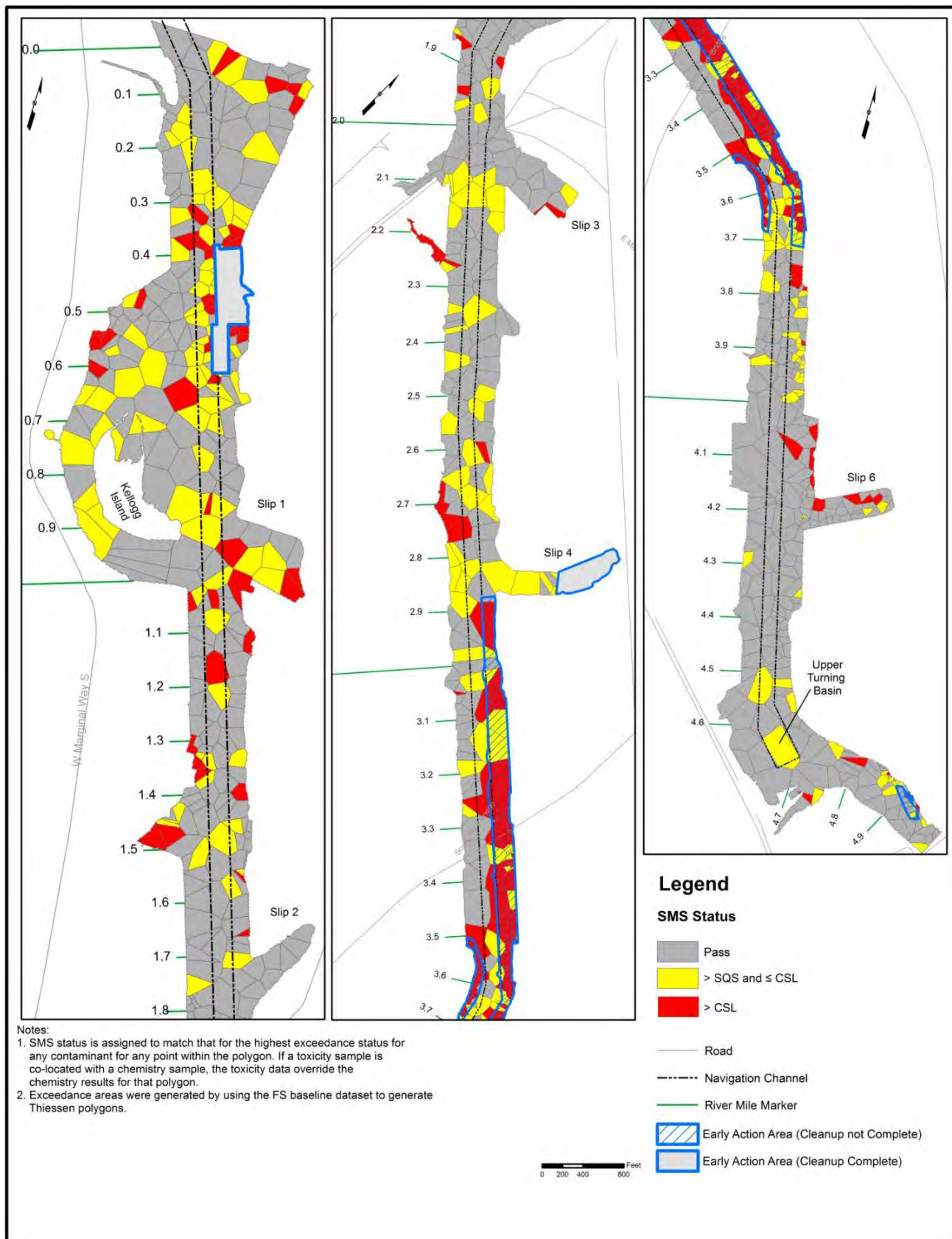


Figure 5. SMS Status in Surface Sediment

Figure 5 shows areas where neither SQS or CSLs were exceeded, areas where only SQS but not CSLs were exceeded, and areas where CSLs were exceeded (and therefore SQS were exceeded also).

Forty-one hazardous substances were detected in LDW sediment at concentrations that exceed the chemical SQS and were designated as COCs for benthic invertebrates. PCB concentrations in surface sediment exceeded the SQS more frequently than any other COC (Figure 4), followed by BEHP, then butyl benzyl phthalate. The locations where these exceedances occur and extent of these exceedances vary by COC.

Table 7 (on page 38, in the Ecological Risks section) provides summary information on surface sediment contamination for these 41 COCs, including minimum and maximum detected concentrations, average concentrations, and detection frequencies. In addition to contaminant concentrations, several other parameters were measured during the RI. The percent fines (sum of clay and silt fractions) in surface sediments ranged from 13 to 87% with an average of approximately 53%. The LDW-wide average total organic carbon (TOC) content is 2%. Sediment grain size and TOC influence the quality of habitat for benthic invertebrates and other organisms. Grain size is also important in determining whether sediments will erode from or be deposited in the LDW. TOC influences the bioavailability of some organic contaminants. Because of this, many organic contaminants are “normalized” to TOC in the SMS.

Subsurface Sediments

Detected contaminant concentrations were above the SQS for at least one of the SMS contaminants in 49% of the subsurface sediment samples. The average thickness of subsurface sediments with COC concentrations greater than the SQS is four feet. Of the COCs detected in subsurface sediments at concentrations above the SQS, PCBs were detected most frequently (48%), followed by BEHP (25%). Table 1 summarizes surface and subsurface sediment contaminant concentration data for the human health COCs: PCBs, arsenic, cPAHs, and dioxins/furans.

3.5.2 Fish, Shellfish, and Benthic Invertebrate Tissue

The ranges of contaminant concentrations for all types of organisms and tissue types sampled during the RI/FS (in some cases whole organisms and in other cases portions of the organisms were sampled), and the general trends in tissue concentrations observed are summarized as follows:

- **PCBs** – Detected in almost all samples, ranging from 6.9 micrograms per kilogram wet weight (µg/kg ww) to 18,400 µg/kg ww. Mean PCB concentrations were highest for Dungeness crab hepatopancreas (“crab butter”) and whole-body English sole, followed by whole-body shiner surfperch. Clam and crab edible meat had much lower mean PCB concentrations, with mean PCB concentrations being lowest for mussels.
- **Inorganic arsenic** – Detected in almost all samples, ranging from non-detect (< 0.003) to 11.3 milligrams per kilogram wet weight (mg/kg ww). Inorganic arsenic is the most toxic form for humans and wildlife. Total arsenic was measured in sediments and water and inorganic arsenic was measured in fish and shellfish tissue. Eastern softshell clams (the most abundant clam species found in the LDW) had the highest average concentrations of inorganic arsenic, approximately 3 mg/kg ww. Clam inorganic arsenic concentrations were 12- to 1500-fold greater than inorganic arsenic concentrations found in other organisms.

- **Other COCs** — Concentrations of cPAHs were highest in clam, mussel, and benthic invertebrate tissue. Phthalates were frequently detected in clams and benthic invertebrates. Most other organic hazardous substances were infrequently detected. Sampling for dioxin/furans in tissue was not included as part of the RI because data that were already available indicated that dioxin/furan concentrations in most Puget Sound fish and shellfish tissues would present unacceptable risk at the consumption rates used in the human health risk assessment. No further data were needed for the human health risk assessment, which assumed unacceptable risks due to dioxins/furans. Data were gathered from a small number of dioxin/furan samples of skin-off English sole fillets collected near Kellogg Island by Ecology in May 2007, after completion of the human health risk assessment.

Table 2 summarizes PCB, inorganic arsenic, cPAH, and dioxins/furan tissue concentrations in some of the LDW fish and shellfish collected and analyzed in the RI.

Table 2. Summary of Selected Human Health COCs in Fish and Shellfish Tissue^a

Contaminant and Tissue Type	Detection Frequency	Concentration		
		Minimum	Mean	Maximum
PCBs ($\mu\text{g/kg ww}$)				
English sole (fillet with skin)	26/26	170	860	2,010
Shiner surfperch (whole body)	78/78	20 ^b	1,300	18,400 ^b
Dungeness crab (edible meat)	14/17	15	130	300
Dungeness crab (whole body)	16/16	97	890	1,900
Clams (not depurated)	20/20	15 ^b	130	580 ^b
Inorganic Arsenic (mg/kg ww)				
English sole (fillet with skin)	6/7	0.003	0.004	0.006
Shiner surfperch (whole body)	8/8	0.020	0.070	0.160
Dungeness crab (edible meat)	2/2	0.010	0.010	0.010
Dungeness crab (whole body)	2/2	0.022 ^b	0.029	0.035
Clams	23/23	0.132	2.72	11.3
cPAHs ($\mu\text{g TEQ/kg dw}$)				
English sole (fillet with skin)	4/7	0.37 ^b	0.35	0.53
Shiner surfperch (whole body)	24/27	0.37 ^b	3.1	2.2
Dungeness crab (edible meat)	6/9	0.54 ^b	3.7 ^b	0.84 ^b
Dungeness crab (whole body)	7/9	0.60	2.6	2.4
Clams	14/14	6.8	15	44
Dioxins/Furans (ng TEQ/kg dw)^c				
English sole (fillet without skin)	6/6	0.26	0.30	0.35

- Section 5.1 describes the selection of human health COCs.
- These data points are analytically estimated values.
- The dioxin/furan data are from samples collected in a small portion of the LDW as part of a 2007 Ecology study, and were not used in the LDW risk assessments.

Relationships among concentrations in tissue and concentrations in sediments for PCBs, arsenic, and cPAHs were investigated in the RI. In species with small foraging ranges (clams, benthic invertebrates, shiner surfperch, and staghorn sculpin), tissue PCB concentrations were higher in areas with higher sediment PCB concentrations; in species with larger foraging ranges (English sole and crabs), tissue concentrations did not show a clear relationship to sediment concentrations. Clams had the highest inorganic arsenic and cPAH tissue concentrations, but no strong relationship was seen between sediment concentrations and clam tissue concentrations of arsenic and cPAHs.

3.5.3 Surface Water

The water column, along with the contaminated sediments, is an important pathway for COCs to reach benthic organisms, fish, and shellfish. LDW surface water was collected and analyzed by King County for metals, semi-volatile organic compounds, and PCBs in 1996 and 1997 and for PCBs in 2005. For the human health COCs, PCB concentrations in 2005 LDW surface water samples ranged from 0.13 to 3.2 nanograms per liter (ng/L). Arsenic concentrations ranged from 0.18 to 1.5 micrograms per liter (µg/L). Of the cPAHs, chrysene had the highest concentrations, at 0.17 to 0.4 µg/L. Dioxins/furans were not measured in surface water due to the difficulty in detecting these contaminants in whole water samples. EPA determined that more water quality sampling during the RI would not have affected the analysis of human health or ecological risks, or have influenced the development of alternatives for the in-waterway portion of the Site.

3.6 Background and Upstream COC Concentrations

Documenting background concentrations (concentrations at locations away from the Site and away from any urban or contamination source) is important in the process of identifying cleanup goals. This section describes how contaminant concentrations in sediments and in fish and shellfish in non-urban areas of Puget Sound were used to estimate background conditions, and how upstream contaminant concentrations were used in the BCM to estimate the concentrations of COCs in sediments that deposit in the LDW.

3.6.1 Sediment Background and Upstream Concentrations

When risk-based threshold concentrations (RBTCs, see Section 4) are below background, background concentrations are used as Preliminary Remediation Goals (PRGs are COC concentrations EPA proposes to select as cleanup levels in the ROD, see Section 7). In cases where applicable or relevant and appropriate requirements (ARARs) for a CERCLA action allow cleanup to be considered complete when background levels are reached, the response action generally should be carried out in accordance with the ARAR. For this reason, whenever PRGs and cleanup levels at CERCLA sites in the State of Washington are based on background levels, natural background levels as established in the MTCA are used³, consistent with WAC 173-340-700(6)(d).

3. Generally, under CERCLA, cleanup levels are not set at concentrations below natural background levels. Similarly, for concentrations of human-made (anthropogenic) contaminants, the CERCLA program normally does not set cleanup levels below anthropogenic (human-influenced) background concentrations. The reasons for this approach include cost-effectiveness, technical practicability, and the possibility that remediated areas could be recontaminated by surrounding areas with elevated background concentrations.

MTCA (at WAC 173-340-200) defines the “natural background” level of a hazardous substance as the concentration that is consistently present in an environment that has not been influenced by localized human activities. Thus, under MTCA, a “natural background” concentration can be defined for human-made compounds even though they may not occur naturally. For example, PCBs (human-made compounds) can be picked up and carried by the winds and then deposited into an alpine lake that has not been locally influenced by human activities, and the concentration of PCBs that is then consistently present in that lake is the “natural background” level.

Although COC concentrations in suspended sediments from upstream were not used as background concentrations in the RI/FS, they were used to estimate upstream COC concentrations to use as inputs to the BCM.

Sediment Background COC Concentrations

Data from a 2008 EPA study of sediment contaminant concentrations in non-urban areas in Puget Sound were used to characterize sediment natural background COC concentrations. Sediment samples were collected at locations that are away from populated and industrial areas and known contaminated sites. Summary statistics were then calculated for each of the four human health COCs. Table 3 summarizes these data.

Table 3. Summary of PCB, Arsenic, cPAH, and Dioxin/Furan Data for Natural Background Concentrations in Sediment

Human Health COC	Detection Frequency	Concentration					
		Minimum	Maximum	Mean	Median	90th Percentile	95th Percentile Upper Confidence Limit on the Mean (UCL95) ^b
PCBs (µg/kg dw) ^a	70/70	0.01	11	1.2	0.6	2.7	2
Arsenic (mg/kg dw)	70/70	1.1	21	6.5	5.9	11	7
cPAHs (µg TEQ/kg dw)	61/70	1.3	58	7.1	4.5	15	9
Dioxins/Furans (ng TEQ/kg dw)	70/70	0.2	12	1.4	1.0	2.2	2

a. Only congener data were used, as there were few detected values in the Aroclor data

b. These values are rounded to one significant figure

Sediment COC Concentrations from Upstream of the LDW Study Area

Several datasets with sediment COC concentrations from upstream locations were evaluated for use in estimating COC concentrations in suspended sediments entering the LDW from the Green/Duwamish River. Because of the large volume of suspended sediments entering the LDW from the Green/Duwamish River, these data were important input parameters for BCM-predicted estimates (see Section 3.4) of future COC concentrations in the LDW after implementation of the cleanup alternatives evaluated in the FS.

Datasets included:

- COC concentrations in Green/Duwamish River surface sediments and suspended sediments immediately upstream of the Site from two 2008 Ecology studies. Surface sediments in the Green/Duwamish River are generally much coarser than those found in the LDW. In order to match the grain size of sediments that deposit in the LDW, only surface sediments with greater than 30% fines were included.
- Sediment core data collected from the LDW Upper Turning Basin from 1991 to 2009 by the US Army Corps of Engineers for maintenance dredging. The LDW Upper Turning Basin is a sink for sediments entering the LDW from upstream. These data provide an indicator of suspended sediments settling in the upper reach of the LDW.

Table 4 shows the mid-range estimates of upstream suspended sediment COC concentrations selected for use in the BCM, for the four human health COCs. Each sampling technique may over- or underestimate the COC concentrations in sediments entering the LDW. Best professional judgment was used to select mid-range values used as upstream input values for the BCM, and also to select high and low values used for sensitivity analysis.

Table 4. Estimates of Sediment and Suspended Sediment COC Concentrations of PCBs, Arsenic, cPAHs, and Dioxins/Furans from Upstream of the LDW Study Area

Human Health COCs	Selected ^a Upstream Value	Dataset and Statistic Used to Calculate BCM Upstream Input Value
PCBs (µg/kg dw)	36	Upper Turning Basin subsurface sediment data, mean
Arsenic (mg/kg dw)	9	Upstream Green/Duwamish River surface sediment data, mean
Carcinogenic PAH (µg TEQ/kg dw)	73	Upper Turning Basin subsurface sediment data, mean
Dioxins/Furans (ng TEQ/kg dw)	4	Midpoint between the means of Green/Duwamish River surface sediment and suspended sediment data ^b

a. These values were selected for use as inputs to the BCM.

b. No dioxin/furan data were collected in the Upper Turning Basin during the FS, so data from upstream samples were used.

3.6.2 Fish and Shellfish Tissue Background COC Concentrations

A dataset of COC concentrations in fish and shellfish tissue samples collected between 1991 and 2009 from non-urban areas in Puget Sound, away from populated and industrial areas and known contaminated sites, was compiled for each of the four human health COCs (PCBs, inorganic arsenic, cPAHs, and dioxins/furans) to define background COC concentrations. These non-urban Puget Sound fish and shellfish tissue data, shown in Table 5, were used to set tissue PRGs (Section 7) when RBTCs were below background.

Non-urban Puget Sound fish and shellfish tissue background COC concentrations are more uncertain than sediment background concentrations. The dataset is comprised of data from various studies representing different sampling and analysis methods. It also contains widely differing numbers of samples for the

various COCs and tissue types, depending on data availability and data quality considerations. No tissue data were collected upstream of the Site because the river conditions transition from marine and estuarine to a freshwater environment, with different fish and shellfish species.

Table 5. Summary of PCB, Arsenic, cPAH, and Dioxin/Furan Data for Natural Background Concentrations in Fish and Shellfish Tissue

Species	Natural Background Fish and Shellfish Tissue Data			
	Detected Samples / Total Samples	Range of Detected Concentrations	Mean	95 th Percentile Upper Confidence Limit on the Mean (UCL95)
PCBs ($\mu\text{g/kg ww}$)				
English sole, rock sole, fillet	158 / 238	1.3 – 75	11	13
Dungeness crab (edible meat)	17 / 17	0.43 – 1.9	0.87	1.1
Dungeness crab (whole body)	15 / 15	3.0 – 16	7.1	9.1
Butter clam, geoduck, horse clam, littleneck clam (whole body)	24 / 70	0.09 – 1.4	0.3	0.42
Inorganic arsenic (mg/kg ww)				
English sole, fillet	3 / 12	0.002 – 0.004 ^a	0.002	0.0029
Shiner surfperch (whole body)	8 / 9	0.009 ^a – 0.03	0.017	0.021
Dungeness crab, slender crab (edible meat)	12 / 12	0.01 – 0.04	0.021	0.026
Dungeness crab, slender crab (whole body)	12 / 12	0.032 – 0.13	0.075 ^c	0.13
Eastern softshell clams (whole body) ^b	6 / 0	0.047 / 0.112	0.064	0.087
cPAH TEQ ($\mu\text{g/kg ww}$)				
Starry flounder, fillet	0 / 1	< 0.11 ^c	<0.11 ^c	NC
Dungeness crab (edible meat)	0 / 8	< 1.6 ^c	<0.41 ^c	NC
Dungeness crab (whole body)	0 / 7	< 0.92 ^c	<0.23 ^c	NC
Butter clam, geoduck, littleneck clam (whole body)	3 / 11	0.069 – 0.17	0.088	0.12
Dioxin/furan TEQ (ng/kg ww)				
Starry flounder, rock sole, fillet	4 / 4	0.17 – 0.92	0.42	NC
Dungeness crab (edible meat)	27 / 27	0.027 – 1.4	0.24	0.53
Dungeness crab (whole body)	25 / 25	0.089 – 5.1	0.81	2.0
Butter clam, geoduck, horse clam, littleneck clam (whole body)	43 / 43	0.011 – 1.6	0.34 ^d	0.71

NC – cannot be calculated

a. This value is an analytical estimate.

b. Only clams collected from Dungeness Spit were selected by EPA for this category, as these were the only ones in the dataset likely unaffected by the atmospheric deposition of arsenic from the former Tacoma ASARCO smelter.

c. There were no detected values in this category.

d. This is a nonparametric mean, as there was no discernible distribution according to ProUCL v. 4.1

4 Summary of Site Risks

As a standard part of the RI/FS, human health and ecological risk assessments (HHRA and ERA) were conducted to determine potential pathways by which people (human receptors) or animals (ecological receptors) could be exposed to contamination in seafood, sediments, or water, the amount of contamination receptors of concern may be exposed to, and the toxicity of those contaminants. Multiple exposure pathways by which humans or animals could be exposed to contaminants in the in-waterway portion of the Site (referred to as the "waterway" or LDW) were evaluated.

4.1 Human Health Risks

As part of the RI, a baseline HHRA was conducted to estimate the risks and hazards to human health associated with current and potential future exposures to contamination in the waterway. A four-step process was used as described in "What is Human Health Risk and How is it Calculated?" on the next page. First, EPA identified contaminants of potential concern that were detected in sediments, fish, and shellfish in the LDW at concentrations that exceeded risk-based screening criteria. EPA then identified exposure scenarios for evaluation in the HHRA, as shown in Figure 6 and described below:

Consumption of resident seafood from the LDW – Risks were evaluated for Tribal members (adults and children), Asian and Pacific Islanders (adults), and other consumers (adults).

Direct contact with sediment – Risks were evaluated for exposure to contaminated sediment through both dermal (skin) contact and incidental ingestion during commercial netfishing (adults), clamming (adult Tribal members and recreational users), and beach play (children).

The LDW HHRA relied on an analysis of LDW and Elliott Bay swimming risks evaluated by King County in 1999 for risks due to exposure to contaminants in surface water while swimming. The excess lifetime cancer risks (excess cancer risks) for swimming were determined to be less than 1 in 1,000,000, lower than any other risk evaluated for the waterway. Because of these low risks, the swimming pathway was not evaluated further in the HHRA.

What is Human Health Risk, and How is it Calculated?

A Superfund human health risk assessment estimates the "baseline risk." This is an estimate of the likelihood of health problems occurring if no cleanup action were taken at a site. To estimate the baseline risk at a Superfund site, EPA undertakes a four-step process:

- **Step 1:** Analyze Contamination Data
- **Step 2:** Estimate Exposure
- **Step 3:** Assess Potential Health Dangers
- **Step 4:** Characterize Site Risk

In **Step 1**, EPA gathers and analyzes data on the concentrations of contaminants found at a site to identify the contaminants that will be the focus of the risk assessment.

In **Step 2**, EPA considers the different ways that people might be exposed to the contaminants identified in Step 1, the concentrations that people might be exposed to, and other information needed to determine the amount of a contaminant that could enter a person's body, such as how frequently they might be exposed to the contamination. Using this information, EPA calculates a "reasonable maximum exposure" (RME) scenario, which portrays the highest level of human exposure that could reasonably be expected to occur.

In **Step 3**, EPA collects information on cancer risk and non-cancer toxicity of each contaminant of potential concern using past scientific studies on the effects of these contaminants on people or animals.

In **Step 4**, EPA uses the information from the three previous steps to determine whether site cancer or non-cancer risks are great enough to potentially cause health problems for people at or near the Superfund site. EPA risk estimates are designed to err on the side of protecting the public. The likelihood of any kind of cancer resulting from exposure to contaminants at a Superfund site is generally expressed as a probability; for example, a "1 in 10,000 chance" of developing cancer over the course of a lifetime. In other words, for every 10,000 people that could be exposed, one extra cancer may occur as a result of exposure to site contaminants. An extra cancer case means that one more person could get cancer than would normally be expected to from all other causes.

For non-cancer health effects, EPA calculates a "hazard quotient" (HQ). The hazard quotient is the dose of a contaminant a person might be exposed to divided by a risk-based threshold level. If the ratio is 1 or less, no non-cancer effects are expected for individual chemicals. A "hazard index" (HI) considers the non-cancer effects of multiple contaminants using the same approach.

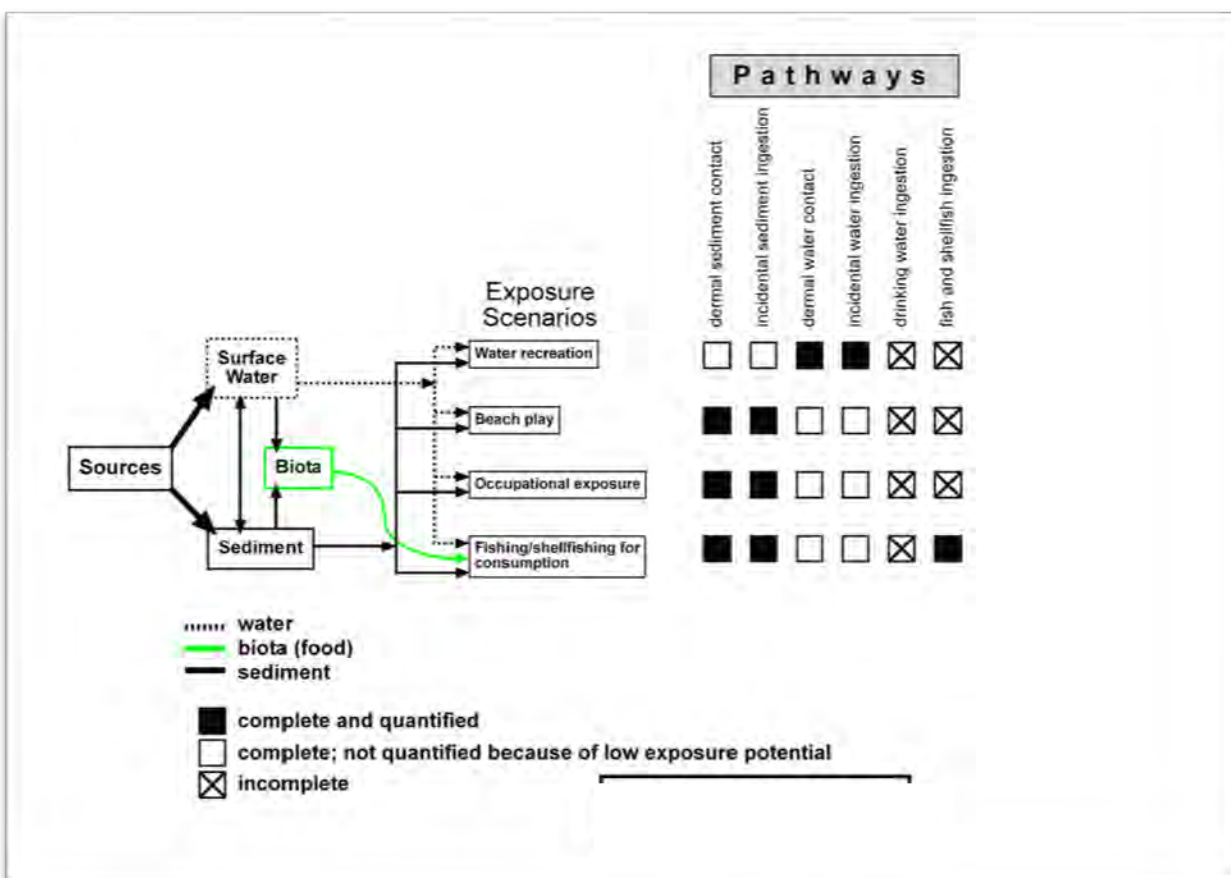


Figure 6. Conceptual Model for Baseline Human Health Risk Assessment

Reasonable maximum exposure (RME) scenarios represent the highest exposures that are reasonably expected to occur at a site. Consistent with EPA's Human Health Risk Assessment policy and the findings of the EJ Analysis (Appendix B), the HHRA evaluated RME excess cancer risk and non-cancer hazards for children, low income, minority, and Tribal communities. People in the following groups eat more fish and shellfish on average than the general population: Tribal adults, Tribal children, and Asian/Pacific Islander adults. The consumption rates used for RME scenarios ranged from 2 to 13 eight-ounce meals per month. Meals consisted of a combination of fish (English sole or other flatfish and perch) and shellfish (crabs, clams, and mussels) based on information from regional seafood consumption surveys of Native Americans and Asian/Pacific Islanders. Although salmon are a highly preferred and consumed fish from the LDW, human health risks were not calculated for the consumption of salmon because most of the contaminants in their bodies are accumulated while they are feeding in the open ocean, where they spend most of their lives. Central tendency or average risks were also estimated for these groups. Additionally, an upper bound Tribal risk estimate was derived using estimated Tribal consumption rates based on Suquamish Tribe seafood consumption data. Finally, the risk assessment provided information that individuals could use to assess the risks that would result from consuming one meal per month of different species found in the LDW.

For evaluation of risk related to direct contact exposure to contaminated sediment, each exposure scenario evaluated dermal (skin) contact and incidental ingestion pathways. Commercial netfishers may come into contact with sediments anywhere in the LDW. The risk assessment focused on clam habitat areas accessible by boat or shore to evaluate clamming risks, while children's beach play activities were evaluated over several discrete areas of intertidal sediment accessible from the shoreline, assuming that small children would not access all intertidal sediments. Figure 2 shows the areas used for the clamming and beach play scenarios.

PCBs, arsenic, cPAHs and dioxins/furans were identified as human health COCs based on an excess cancer risk greater than 1 in 1,000,000 for carcinogenic chemicals, or a hazard quotient (HQ) greater than 1 for non carcinogens. For any given contaminant, the HQ is the ratio of the exposure concentration or dose to the lowest observed adverse effect level; the hazard index (HI) is the same but for multiple contaminants. Although BEHP, pentachlorophenol, vanadium, tributyltin, and several pesticides were found in the waterway at concentrations that exceeded risk thresholds, they were not selected as COCs due to low detection frequency, low contribution to overall risk, or quality assurance concerns with analytical data.

Table 6 provides a summary of the risk levels associated with each COC and exposure scenario.

Table 6. Cancer and Non-Cancer Risk Estimates for Human Health Scenarios

RME Scenario ^a	Medium	Contaminant of Concern	Excess Cancer Risk	Hazard Quotient
Adult Tribal Seafood Consumption - Tulalip Survey	Fish and Shellfish	PCBs	2 in 1,000	40
		Inorganic arsenic	2 in 1,000	4
		cPAHs	8 in 100,000	< 1
		Other	4 in 1,000	3.6
		Total	4 in 1,000	--
Child Tribal Seafood Consumption - Tulalip Survey	Fish and Shellfish	PCBs	3 in 10,000	87
		Inorganic arsenic	3 in 10,000	8
		cPAHs	8 in 100,000	< 1
		Other	8 in 100,000	6.4
		Total	8 in 10,000	--
Adult Asian Pacific Islander Seafood Consumption	Fish and Shellfish	PCBs	5 in 10,000	29
		Inorganic arsenic	7 in 10,000	3
		cPAHs	3 in 100,000	< 1
		Other	1 in 10,000	2.3
		Total	1 in 1,000	--
Netfishing (Direct Sediment Contact)	Subtidal and Intertidal Sediment	PCBs	2 in 1,000,000	< 1
		Arsenic	6 in 1,000,000	< 1
		cPAHs	1 in 1,000,000	< 1
		Dioxins/Furans	2 in 100,000	< 1
		Other	2 in 1,000,000	< 1
		Total	3 in 100,000	--
Clamming (Direct Sediment Contact)	Intertidal Sediment	PCBs	8 in 1,000,000	< 1
		Arsenic	2 in 100,000	< 1
		cPAHs	5 in 1,000,000	< 1
		Dioxins/Furans	1 in 10,000	< 1
		Other	6 in 1,000,000	< 1
		Total	1 in 10,000	--
Beach Play (Direct Sediment Contact - Ranges for 8 beaches)	Intertidal Sediment	PCBs	3 in 100,000,000 to 6 in 100,000	< 1 ^b
		Arsenic	3 in 1,000,000 to 3 in 100,000	< 1
		cPAHs	1 in 1,000,000 to 8 in 1,000,000	< 1
		Dioxins/Furans	1 in 10,000,000 to 1 in 100,000	< 1
		Total	4 in 1,000,000 to 6 in 10,000	--

a. For the netfishing and clamming RME scenarios, the total excess cancer risks are based data from the Remedial Investigation. For the beach play RME scenarios, the total excess cancer risks include additional data collected during the Feasibility Study.

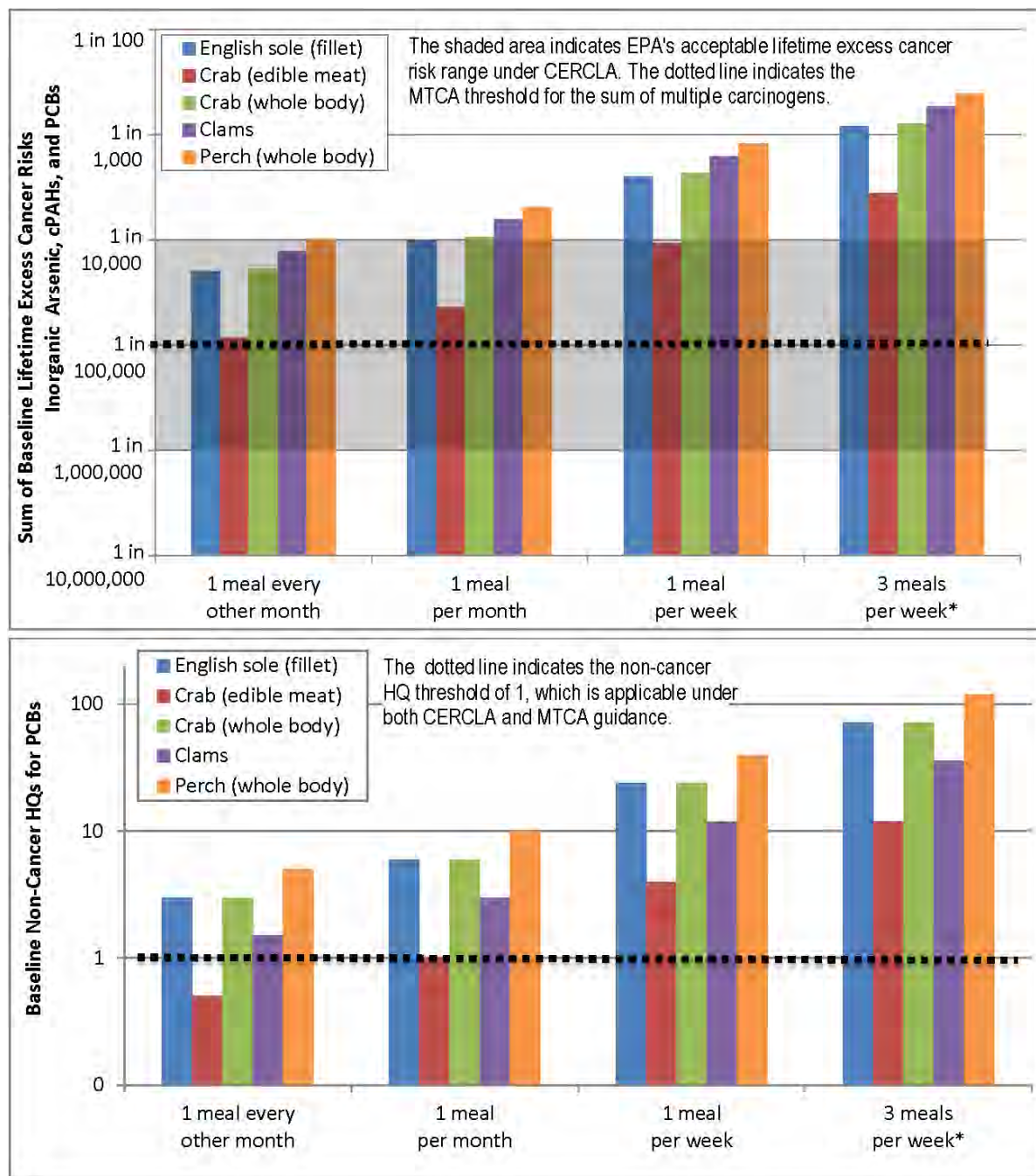
b. All beaches but Beach Play Area 4 at RM 2.2 have HQ <1. The Beach Play Area 4 HQ of 2 excludes two very high PCB concentrations (see footnote b to Table 1); If the two high PCB concentrations were included, the HQ would be 187. Beach Play Areas are shown in Figure 2.

Dioxins and furans are not included in the total excess cancer risk calculation for the RME seafood consumption scenarios because dioxin/furan seafood tissue data were not collected during the RI. These data were not gathered during the RI because data already available indicated that dioxin/furan concentrations in most Puget Sound fish and shellfish would present unacceptable risk at the RME consumption rates; therefore additional data were not needed and the HHRA assumed unacceptable risks due to dioxins/furans in the LDW without further investigation. However, in May 2007, after the HHRA was finalized, Ecology sampled and analyzed a few skin-off English sole fillets collected near Kellogg Island. The excess cancer risks associated with dioxins/furans were calculated to be 6 in 100,000 for the Adult Tribal RME scenario. However, this risk estimate is uncertain because it is based on a smaller number of samples than in datasets typically used for an HHRA and is from a very limited portion of the LDW. It also does not include dioxin concentrations for all seafood species used in the HHRA. Nevertheless, it provides some information on dioxin/furan risks relative to other COCs.

Figure 7 summarizes the baseline (before cleanup) excess cancer risk and the non-cancer risk related to the number and type of seafood meals consumed per month. Figure 8 and Figure 9 summarize the excess cancer risk and the non-cancer risk associated with the RME scenarios for seafood consumption and direct sediment contact, respectively. Site seafood consumption RME risks exceed direct contact risks. seafood consumption risks RME and direct contact HQs exceed risk thresholds established by CERCLA, which are excess cancer risks of 1 in 10,000, and the non-cancer HQ (or HI) of 1. MTCA thresholds are also exceeded, which are excess cancer risks of 1 in 1,000,000 for individual contaminants or 1 in 100,000 for multiple contaminants, and the non-cancer HQ or HI of 1. Direct contact HQs were less than 1, with the exception of beach play at Beach Area 4 (Table 6).

The COCs associated with the highest risks varied for direct contact and seafood consumption exposures. The majority of risks for seafood consumption were from PCBs and inorganic arsenic. While risks from PCBs were associated with all types of fish and shellfish evaluated, the vast majority of risks due to inorganic arsenic and cPAHs (96-98%) were attributable to consumption of clams. The majority of risks for adult direct sediment exposure pathways were from dioxins and furans. In contrast, the majority of risks for children through direct sediment exposure pathways (i.e., beach play) were from cPAHs, because cPAHs are more toxic to young children than to adults.

PCBs, arsenic, cPAHs, and dioxins/furans, along with the COCs identified by the Ecological Risk Assessment, were used to identify areas requiring cleanup in the FS. Other contaminants that exceeded risk thresholds but were not designated as COCs were still evaluated in the FS to ensure that a cleanup based on the COCs would also address risk due to these other contaminants.

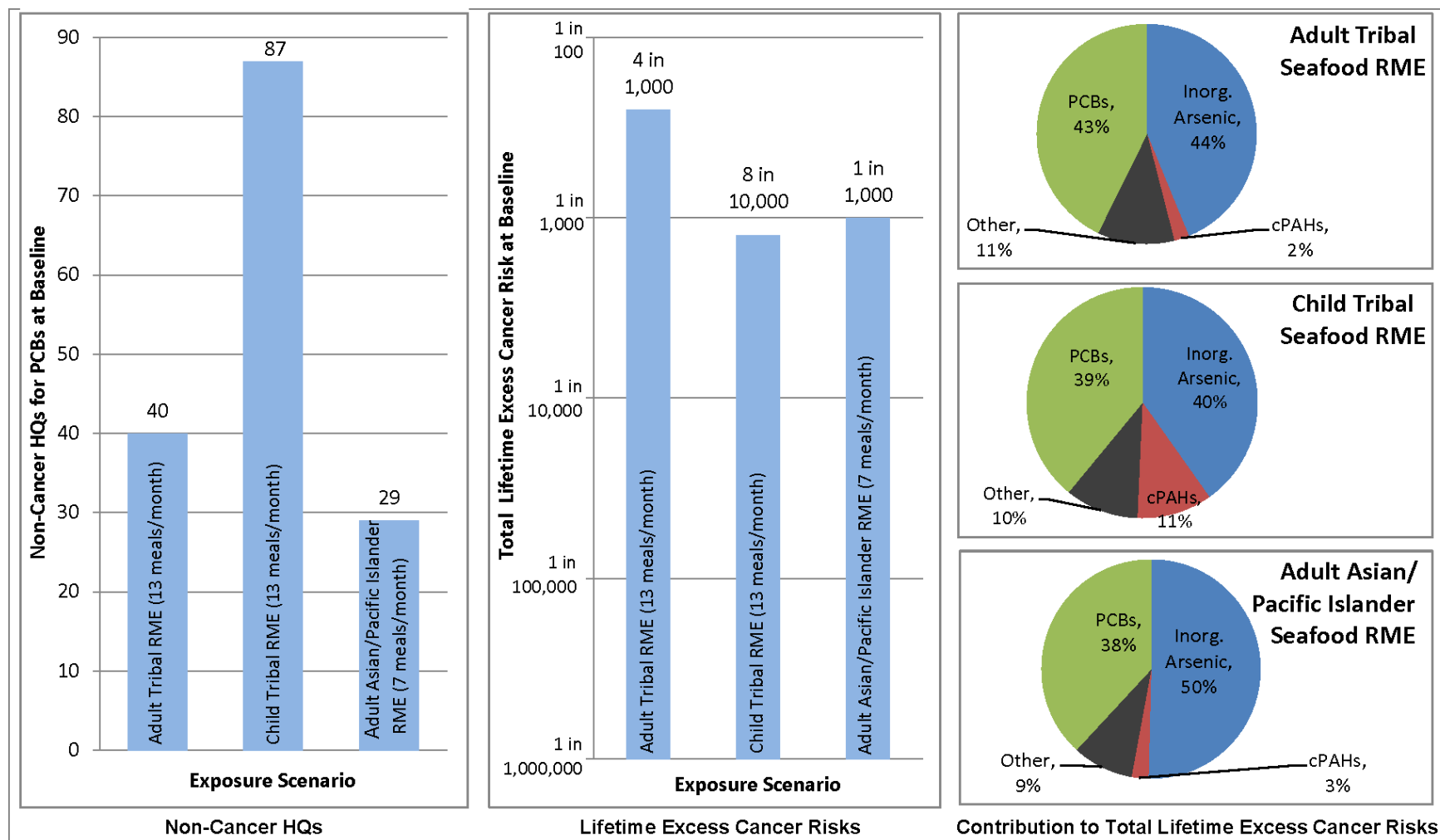


* 3 meals per week is approximately equal to the rate used for the adult tribal RME seafood consumption rate. One meal is equal to 8 ounces.

Baseline lifetime excess cancer risks are calculated as the sum of the risk estimates for inorganic arsenic, cPAHs, and PCBs. These estimates do not include risk estimates from dioxins and furans, as discussed in Section 4.1.

Baseline HQs: HQs are presented for PCBs only because non-cancer HQs were by far the highest for PCBs.

Figure 7. Baseline Excess Cancer Risk and Non-Cancer Hazard Quotients for Consumption of Various Seafood Species as a Function of the Number of Meals Consumed per Month



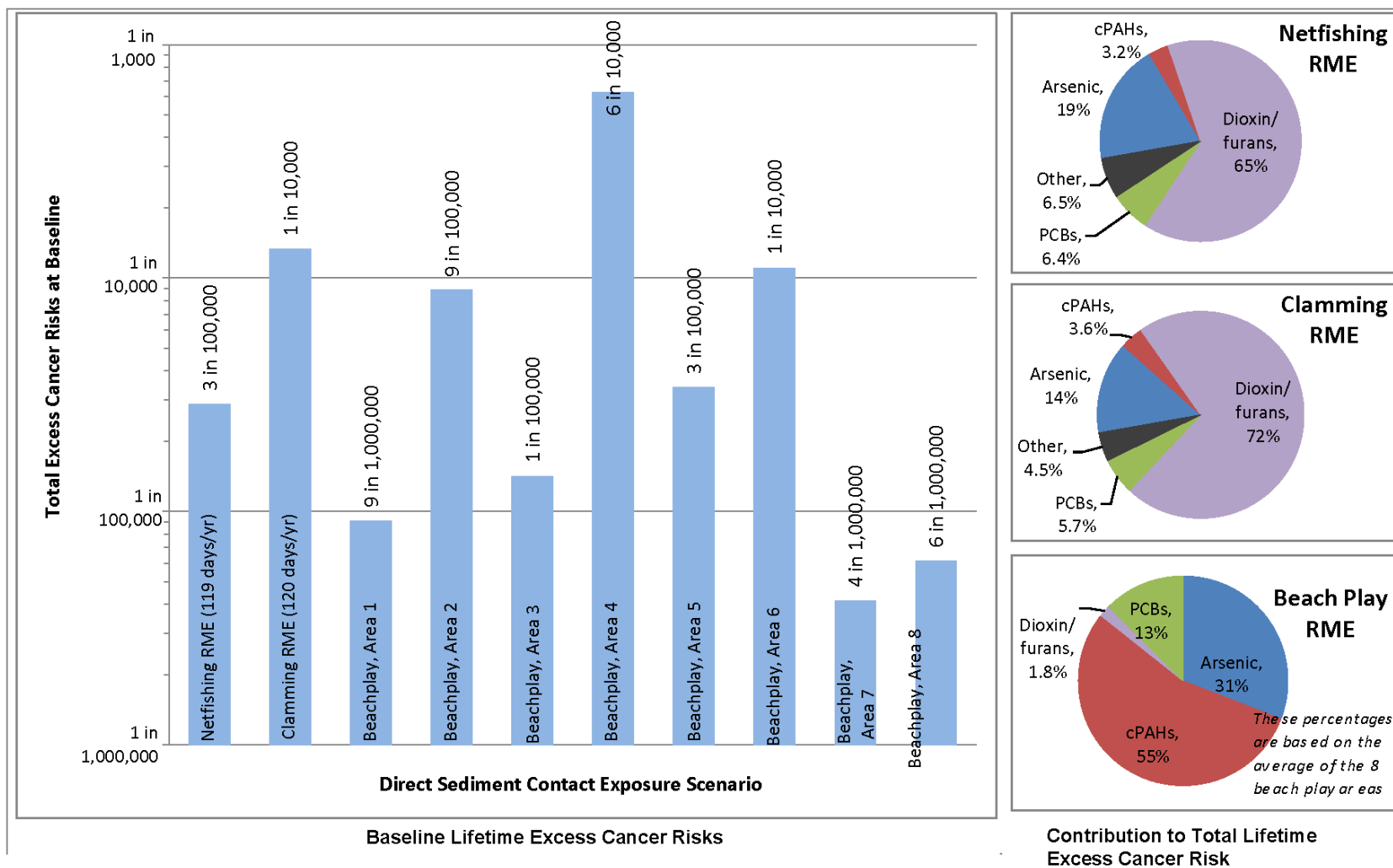
One meal is equal to 8 ounces.

Baseline lifetime excess cancer risks: calculated as the sum of the risk estimates for inorganic arsenic, cPAHs, and PCBs. They do not include risk estimates from dioxins and furans, as discussed in Section 4.1.

Baseline HQs: HQs for PCBs are presented because non-cancer HQs were the highest for PCBs.

Other contaminants: The "other" category includes those contaminants evaluated in the HHRA with concentrations greater than conservative screening levels (includes both those that exceed risk thresholds and those that do not).

Figure 8. Baseline Non-cancer Hazard Quotients and Excess Cancer Risk for the Seafood Consumption RME Scenarios



Non-cancer hazard quotients (HQs): HQs are not shown here because they were less than 1 in all cases except for one beach play area in which two samples (located at the head of the inlet at river mile 2.2, west) with high PCB concentrations resulted in an HQ of 187. If these two samples were removed, the resulting HQ would be equal to 2.

Other contaminants: The "other" category includes those contaminants evaluated in the HHRA with concentrations greater than conservative screening levels (includes both those that exceed risk thresholds and those that do not).

Figure 9. Baseline Excess Cancer Risk for the Direct Sediment Contact RME Scenarios

4.2 Ecological Risks

The baseline Ecological Risk Assessment (ERA) evaluated risks to four types of ecological receptors exposed to the contaminants in the LDW sediment, either directly or via ingestion of prey: bottom-dwelling organisms (benthic invertebrates), crabs, fish (juvenile Chinook salmon, Pacific staghorn sculpin, English sole), and wildlife species (spotted sandpiper, great blue heron, osprey, river otter, and harbor seal). These species were selected to represent organisms with a range of characteristics that affect exposure, such as habitat, dietary preferences, level in the food chain, sensitivity to contaminants, and status as a threatened or endangered species. Generally, if these particular species are protected then the many species they represent are also protected. Like the HHRA, this was a baseline risk assessment, an estimate of the likelihood of ecological problems occurring if no cleanup action is taken. Summaries of exposure pathways determined to be complete for ecological receptors are provided in Figure 10 and Figure 11.

The baseline ERA concluded the following:

Risks to bottom-dwelling organisms (benthic invertebrates) – Effects on the benthic invertebrate community were assessed by comparing the contaminant concentrations in LDW surface sediment and results of site-specific toxicity tests to the SMS standards (see What are the Sediment Management Standards? on this page). Forty-one contaminants were determined to present risks to benthic invertebrates because their concentrations in surface sediments exceeded the SQS. For any sample that exceeded the SQS (or CSL) but did not exceed the biological criteria, the sample was designated as not exceeding the SQS (or CSL). Based on data from the FS, one or more of the SQS (SQS or CSL) were exceeded in approximately 18%, or 80 acres, of the LDW. In 16 of those 80 acres (4% of the LDW) the CSL was exceeded, indicating a higher likelihood of adverse effects. The three COCs with the most frequent exceedances were PCBs, bis(2-ethylhexyl)phthalate (BEHP), and butyl benzyl phthalate. For all other COCs, exceedances occurred in 5% or less of the sediment samples (Table 7).

What are the Sediment Management Standards (SMS)?

The SMS are State standards designed to reduce and ultimately eliminate adverse effects on biological resources and significant health threats to humans from surface sediment contamination.

The SMS include two tiers of numerical standards, both based on relationships between sediment contaminant concentrations and adverse effects on benthic invertebrates (reduced population size or laboratory toxicity tests showing mortality, reduced growth, or impaired reproduction) using several hundred samples from the Puget Sound area. They are: tier 1) sediment quality standards (SQS), lower numerical chemical concentrations below which contaminants are designated as having no adverse effects on benthic invertebrates; and tier 2) cleanup screening levels (CSLs), higher chemical concentrations at which there is a potential for more pronounced adverse effects on benthic invertebrates. The sediment cleanup standards are set as close as practicable to the SQS.

The SMS also provides SQS and CSL biological-effects criteria that allow the use of site-specific toxicity tests and benthic community abundance data to determine compliance with the SMS instead of basing the determination on the numerical standards.

The SMS numerical standards do not address risks to people, mammals, birds, and other organisms due to bioaccumulation of contaminants in the food chain; those risks are addressed through narrative standards.

Risk to crabs, fish, birds and mammals – A hazard quotient (HQ) approach was used to assess risk for these organisms. The HQ was calculated for fish and crabs by dividing the contaminant concentration in the organism itself by the respective concentration from the scientific literature that indicated a potential for adverse effects. For birds and mammals, the HQ was calculated by dividing the contaminant concentration in items ingested (prey, water and sediments) by the respective concentration from the scientific literature that indicated a potential for adverse effects. Calculated risk to these organisms was low, with the exception of river otters. River otters have a higher risk of adverse effects such as reduced reproductive success from the ingestion of seafood contaminated with PCBs.

Selection of COCs – A subset of COCs were identified as ecological COCs to focus the evaluation of remedial alternatives for the LDW. Forty-one contaminants (including PCBs) were identified as COCs for benthic invertebrates, and PCBs were also identified as a COC for river otters (Table 7).

4.3 Basis for Action

It is EPA's judgment that the Preferred Alternative identified in this Proposed Plan, or one of the other active measures considered in this Proposed Plan, is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

Table 7. Surface Sediment Contaminant Concentrations and Comparison to SMS Numerical Standards

Contaminant	Summary Statistics for Surface Sediments			Total Number of Surface Sediment Samples that Exceed the SQS or CSL ^b				
	Minimum Detected Concentration	Maximum Detected Concentration	Mean	Total Samples	Detection Frequency	> SQS, ≤ CSL, detected	> CSL, detected	> SQS or CSL, detected
Metals (mg/kg dw)								
Arsenic	1.2	1,100	17	918	94%	5	9	14
Cadmium	0.03	120	1.0	895	71%	2	12	14
Chromium	4.8	1,700	41	907	100%	1	10	11
Copper	5	12,000	110	909	100%	0	13	13
Lead	2	23,000	140	909	100%	2	23	25
Mercury	0.015	250	0.53	928	88%	20	30	50
Silver	0.018	270	1.0	876	61%	0	10	10
Zinc	16	9,700	190	906	100%	26	19	45
PAHs (µg/kg dw)								
2-Methylnaphthalene	0.38	3,300	42	884	19%	1	4	5
Acenaphthene	1	5,200	65	893	39%	16	4	20
Anthracene	0.58	10,000	130	893	73%	2	0	2
Benzo(a)anthracene	4.3	8,400	320	893	92%	10	6	16
Benzo(a)pyrene	6.5	7,900	310	888	92%	7	5	12
Benzo(g,h,i)perylene	2.4	3,800	160	893	86%	10	12	22

Contaminant	Summary Statistics for Surface Sediments			Total Number of Surface Sediment Samples that Exceed the SQS or CSL ^b				
	Minimum Detected Concentration	Maximum Detected Concentration	Mean	Total Samples	Detection Frequency	> SQS, ≤ CSL, detected	> CSL, detected	> SQS or CSL, detected
Total benzo(a)fluoranthenes	6.6	17,000	730	887	94%	6	6	12
Chrysene	5	7,700	470	893	95%	29	3	32
Dibenzo(a,h)anthracene	1.6	1,500	62	893	56%	18	6	24
Dibenzofuran	1	4,200	54	890	31%	7	3	10
Fluoranthene	11	24,000	890	893	97%	35	12	47
Fluorene	0.68	6,800	78	893	48%	11	3	14
Indeno(1,2,3-cd)pyrene	5.2	4,300	180	893	90%	16	13	29
Naphthalene	3	5,300	49	884	21%	0	2	2
Phenanthrene	4.1	28,000	430	893	93%	27	3	30
Pyrene	8.3	16,000	720	893	96%	2	6	8
Total HPAH	20	85,000	3,800	893	98%	25	6	31
Total LPAH	4.7	44,000	700	893	94%	4	3	7
Phthalates (µg/kg dw)								
Bis(2-ethylhexyl) phthalate	5.4	17,000	590	887	79%	46	58	104
Butyl benzyl phthalate	2	7,100	87	879	54%	80	10	90
Dimethyl phthalate	2	440	25	879	21%	0	2	2
Chlorobenzenes (µg/kg dw)								
1,2,4-Trichlorobenzene	1.6	940	19	872	1%	0	2	2
1,2-Dichlorobenzene	1.3	670	19	872	2%	0	4	4
1,4-Dichlorobenzene	1.5	1,600	23	872	6%	0	4	4
Hexachlorobenzene	0.4	95	17	875	5%	4	2	6
Other SVOCs and COCs (µg/kg dw)								
2,4-Dimethylphenol	6.1	290	44	870	3%	0	25	25
4-Methylphenol	4.8	4,600	43	887	13%	0	4	4
Benzoic acid	54	4,500	240	877	13%	0	9	9
Benzyl alcohol	8.2	670	49	868	4%	9	7	16
n-Nitrosodiphenylamine	6.5	230	27	872	3%	0	2	2
Pentachlorophenol	7	14,000	120	841	4%	1	1	2
Phenol	10	2,800	91	887	32%	19	6	25
PCBs (µg/kg dw)								
PCBs	1.9	220,000 ^a	1,100	1393	94%	336	179	515

NOTE: Based on FS baseline dataset.

a Two PCB samples, at the Inlet at RM 2.2, were considered outliers and were not included in the data considered; their detected concentrations were 230,000 and 2,900,000 µg/kg.

b. As required by the SMS and described in the RI/FS Reports, for some organic compounds, dry weight values shown in this table were normalized to organic carbon (OC) for comparison to SQS and CSL (see Table 9).

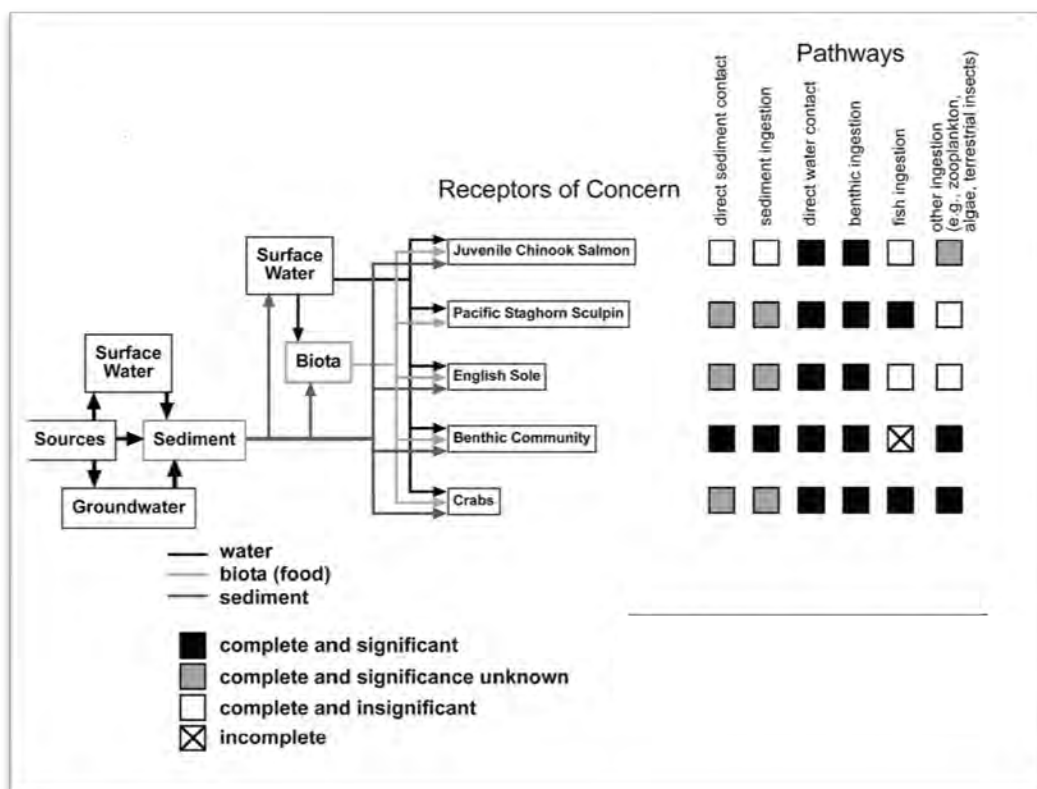


Figure 10. Conceptual Site Model for LDW Fish and the Benthic Invertebrate Community

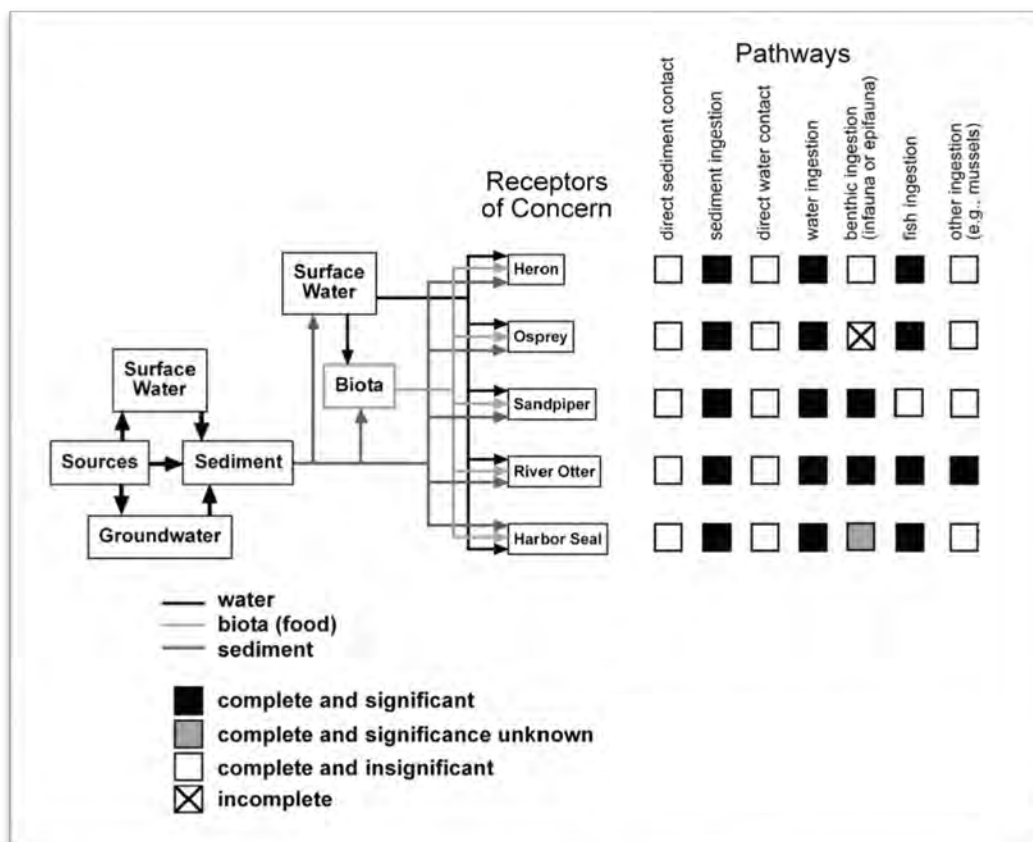


Figure 11. Conceptual Site Model for Wildlife

5 Scope and Role of the Response Action

Given the need for CERCLA action, EPA is proposing to select an LDW in-waterway remedy as the third and final part of an overall strategy for addressing contamination in the waterway and surrounding watershed that includes: 1) early identification and cleanup of EAAs to address the most contaminated areas in the waterway; 2) controlling sources of contamination to the waterway; and 3) cleanup of the remaining contamination in the waterway, including long-term monitoring to assess the success of the remedy in achieving cleanup goals. These three components together are designed to address the areal extent of contamination at the Site, including resident seafood tissue concentrations and water quality within the waterway, to the fullest practicable extent. As described below, the Preferred Alternative (this proposed action) is intended to be the final remedy for the in-waterway portion of the Site, to be implemented after completion of additional sampling during the design phase of remedy implementation (remedial design), and after implementation of the EAA cleanups and sufficient source control to minimize recontamination.

5.1 Component 1: Early Identification and Cleanup of EAAs

The first phase of the LDW RI included identification of the most contaminated areas of the waterway for consideration as EAAs. Section 2.1 describes progress to date on cleaning up the EAAs. Cleanup alternatives, costs, and outcomes in this Proposed Plan assume completion of the EAA cleanups, all of which are scheduled for implementation by the end of 2015.

EPA has reviewed the EAA cleanup actions being performed under EPA Consent Orders and has determined that the completed Slip 4 EAA is consistent with the Preferred Alternative and requires no further active remediation, and other planned EAAs are similarly expected to require no further active remediation if they achieve their stated objectives. Nevertheless, as with the rest of the LDW, all the EAAs will be subject to performance review to assure that human health and the environment are being protected. EPA will review the Institutional Controls Plans and long-term monitoring plans for all EAAs and will require that the EAAs be incorporated into plans for the rest of the LDW as necessary to make them consistent with the selected remedy in the ROD. For the cleanups conducted under the 1991 Natural Resource Damages Consent Decree (Duwamish/Diagonal CSO/SD and Norfolk CSO), EPA will conduct a review during the remedial design phase to determine whether any additional work is needed to make these cleanup actions consistent with the selected remedy in the ROD.

5.2 Component 2: Controlling Sources of Contamination

As a general principle, EPA seeks to control sources of contamination early when managing contaminated sediment risks at hazardous waste sites. Sources of contaminants in LDW surface water and sediments include combined sewer overflows, stormwater carrying the contaminants of concern via stormwater drains and other discharges; upland facilities or source areas with contaminants discharging to the LDW via groundwater, surface water, or erosion of contaminated soils; and atmospheric deposition of COCs. Section 2.2 and Appendix A provide more information on how Ecology as the lead agency for source control is leading this important component of the Site remediation.

An objective of source control is to find and sufficiently control sources prior to sediment remediation and thereby prevent or minimize recontamination after the cleanup is completed. EPA and Ecology will coordinate to sufficiently control ongoing sources to the extent possible before initiating sediment cleanup

in a specific area. The coordination of the source control and sediment cleanup activities will be established in a Memorandum of Understanding (MOU) to be developed by EPA and Ecology prior to issuance of the ROD. The MOU will detail how EPA and Ecology will coordinate sequencing of source control and sediment remedial actions. The process for determining when source control is sufficient to begin sediment cleanup activities for a particular area without significant risk of recontamination is described in Ecology's Source Control Strategy in Appendix A.

To date, Ecology and the Source Control Workgroup have performed extensive investigations and initiated multiple actions to address known sources of contaminants. For a summary of these actions, see Section 2.2 and for more detailed information, see Ecology's website at

http://www.ecy.wa.gov/programs/tcp/sites_brochure/lower_duwamish/lower_duwamish_hp.html.

Appendix A to this Proposed Plan is Ecology's 2012 draft final revision of its 2004 Source Control Strategy. It provides a broad framework for organizing the work of the federal, state, and local agencies under various legal authorities. Ecology is separately seeking public comments on this proposed revision, and will provide responses after EPA's public comment period for this Proposed Plan.

The 2012 Source Control Strategy anticipates a "Source Control Implementation Plan" from each of the Federal, State, and local source control agencies. The Implementation Plans will describe how each agency will conduct its various programs to address source control work for the LDW source area. Ecology is currently requesting implementation plans from EPA, King County and the City of Seattle, and may request implementation plans from other entities in the future. Ecology will also develop its own Source Control Implementation Plan. Once completed, these plans will be appended to the Strategy and available on Ecology's web site. In the unlikely event that timely and effective source control is not implemented, EPA may implement actions pursuant to CERCLA or other Federal authority to ensure the protectiveness of the remedy selected in the ROD following public comment on this Proposed Plan.

5.3 Component 3: In-Waterway Cleanup

The third element of the overall cleanup strategy for the Site, and the focus of this Proposed Plan, is the in-waterway cleanup. The alternatives considered in this Proposed Plan, including the Preferred Alternative, address contaminated sediments and surface water below the mean higher high water (MHHW) level (11.3 feet above the mean lower low water level [MLLW]) that are expected to remain after completion of the EAA cleanup work (component 1). Although no alternatives directly address surface water, COC concentrations in surface water will be reduced through implementation of source control and sediment cleanup. The proposed cleanup will be implemented after completion of additional sampling and remedial design, and implementation of the EAA cleanups (component 1) and sufficient source control (component 2) to minimize recontamination in any particular area within the waterway.

The Preferred Alternative described in this Proposed Plan is a final action which will be protective of public health and the environment, as described in detail in Section 10. It is EPA's expectation that once all anticipated action for the Site has been implemented, COC concentrations in the sediment, surface water, and fish and shellfish tissue will be protective of all anticipated uses. These actions include source control and institutional controls, as necessary, to limit fish and shellfish consumption.

6 Remedial Action Objectives

In accordance with the NCP, EPA developed Remedial Action Objectives (RAOs) to describe what the proposed cleanup is expected to accomplish to protect human health and the environment. The RAOs for the LDW are based on results of the human health and ecological risk assessments described in Section 4. RAOs help focus the development and evaluation of remedial alternatives and form the basis for establishing Preliminary Remediation Goals (PRGs) and the cleanup levels to be established in the ROD. The following four RAOs were established for LDW:

RAO 1: Reduce to protective levels human health risks associated with the consumption of contaminated resident LDW fish and shellfish by adults and children with the highest potential exposure. Risk will be reduced by reducing sediment and surface water concentrations or bioavailability of PCBs, arsenic, cPAHs and dioxins/furans, the primary COCs that contribute to the estimated cancer and non-cancer risks from consumption of resident seafood, with additional reduction in exposure through the use of seafood consumption advisories and education and outreach programs as may be needed.

RAO 2: Reduce to protective levels human health risks from direct contact (skin contact and incidental ingestion) to contaminated sediments during netfishing, clamming, and beach play. Risks will be reduced by reducing sediment concentrations or bioavailability of PCBs, arsenic, cPAHs, and dioxins/furans, the primary COCs that contribute to the estimated excess cancer and non-cancer risks.

RAO 3: Reduce to protective levels risks to benthic invertebrates from exposure to contaminated sediments. Risks will be reduced by reducing sediment concentrations of the 41 contaminants listed in Table 9 to the chemical or biological SQS.

RAO 4: Reduce to protective levels risks to crabs, fish, birds, and mammals from exposure to contaminated sediment, surface water, and prey. Risks will be reduced by reducing sediment and surface water PCB concentrations or bioavailability. Addressing risks to river otters due to consumption of PCB-contaminated seafood, along with addressing risks associated with RAOs 1 – 3, will also protect other ecological receptors.

This page left blank for double sided printing

7 Preliminary Remediation Goals

This section describes Preliminary Remediation Goals (PRGs) for the in-waterway cleanup. PRGs are contaminant concentrations used in the FS to measure the success of the cleanup alternatives in meeting the RAOs. They are based on applicable or relevant and appropriate requirements (ARARs), which provide minimum legal standards, and other information such as toxicity information from the HHRA and ERA to address risks that the ARARs do not adequately address. PRGs are refined into final contaminant-specific cleanup levels in the ROD. EPA proposes to select the PRGs for sediment, surface water, and fish and shellfish described below as cleanup levels in the ROD, subject to consideration of public comment.

The most significant ARARs for the in-waterway portion of the Site are in MTCA, which includes the SMS and its numerical standards for the protection of benthic invertebrates, and the requirements for protection of human health discussed below. PRGs associated with RAO 3 (protection of benthic invertebrates) are based on the SQS of the SMS. Consistent with the NCP and as required by MTCA for final cleanups (WAC 173-340-700(5)(b), (6)(d); 705(2), (4)-(6)), sediment PRGs for RAOs 1 and 2 (protection of human health) were set at a risk-based threshold concentration (RBTC) of 1 in 1,000,000 excess cancer risk, and a non-cancer HQ of 1. Consistent with EPA policy and as required by the MTCA, where this concentration is more stringent than the background levels, the PRG was set at the MTCA natural background level (see Section 3.6).

Sediment, fish and shellfish tissue, and surface water PRGs are discussed below. Although fish and shellfish tissue and surface water are not being directly remediated, they are key exposure pathways that are being addressed by the Preferred Alternative as part of the areal extent of contamination in the waterway. For this reason, EPA has determined that it is important to establish PRGs (and cleanup levels) for them to ensure protectiveness and measure progress towards achieving RAOs. Controlling sources of contamination to the LDW along with remediation of contaminated sediments will reduce COC concentrations in surface water and fish and shellfish tissue in addition to reducing COC concentrations in sediment.

7.1 Sediment PRGs

Table 8 lists sediment PRGs for RAOs 1, 2, and 4, and Table 9 lists sediment PRGs for RAO 3. Sediment PRGs are either applied to all locations (i.e., point-based; applicable to any sample location) or are applied over a specific area. Of the four human health COCs, PCBs are the most widespread, and largely define the cleanup footprint. The exposure areas identified in the risk assessments determine whether a PRG is applied to the entire LDW, or to a specific exposure area such as a beach. Benthic PRGs (the SQS numerical standards) can be overridden by biological criteria (see What are the SMS? on page 37) unless they are collocated with exceedances of human health PRGs. In that case, the human health PRGs are used to measure compliance.

EPA will determine if PRGs have been met in specific areas of compliance after the cleanup is completed, including natural recovery. For RAO 3, PRGs must be met at every sampling location. For

RAOs 1, 2 and 4, the 95% upper confidence limit on the mean (UCL95) measured over the following areas of compliance will be used to measure success in attaining PRGs.

- For RAO 1, PRGs must be met LDW-wide.
- For RAO 2, PRGs are applied as follows:
 - For beach play areas, PRGs must be met at individual beaches identified in Figure 2.
 - For clamming areas, PRGs must be met across all clamming areas (Figure 2).
 - For net-fishing, PRGs must be met LDW-wide.
- For RAO 4, PRGs must be met LDW-wide.

The PRGs must be met, on average, at varying depths, as described below:

- In intertidal areas including beaches used for recreation and clamming, human-health direct contact PRGs (for PCBs, arsenic, cPAHs, and dioxins/furans) must be met in the top 45 cm because exposure to sediments at depth is more likely through digging or other disturbances. Human health PRGs for RAO 1 (seafood consumption) and ecological PRGs must be met in surface sediments (top 10 cm).
- In subtidal areas, PRGs for all COCs must be met in surface sediments (top 10 cm).

Table 8. Sediment PRGs for PCBs, Arsenic, cPAHs, and Dioxins/Furans for Human Health and Ecological COCs

COC	Preliminary Remediation Goals				
	RAO 1: Human Seafood Consumption	RAO 2: Human Direct Contact	RAO 4: Ecological (River Otter)	Basis	Spatial Scale of PRG Application
PCBs (µg/kg dw)	2	1,300	128 - 159	background (RAO 1) RBTC (RAO 2) RBTC (RAO 4)	LDW-wide
	n/a	500	n/a	RBTC	Clamming Areas
	n/a	1,700	n/a	RBTC	Individual Beaches
Arsenic (mg/kg dw)	n/a	7	n/a	background	LDW-wide
	n/a	7	n/a	background	Clamming Areas
	n/a	7	n/a	background	Individual Beaches
cPAH (µg TEQ/kg dw)	n/a	380	n/a	RBTC	LDW-wide
	n/a	150	n/a	RBTC	Clamming Areas
	n/a	90	n/a	RBTC	Individual Beaches
Dioxins/Furans (ng TEQ/kg dw)	2	37	n/a	background (RAO 1) RBTC (RAO 2)	LDW-wide
	n/a	13	n/a	RBTC	Clamming Areas
	n/a	28	n/a	RBTC	Individual Beaches

RBTC - Risk-based threshold concentration (based on 1 in 1,000,000 excess cancer risk or HQ of 1)

Background - see Table 3 in Section 3.6.1

No sediment PRGs were identified for arsenic or cPAHs for the human health seafood consumption pathway (RAO 1). Seafood consumption excess cancer risks for these two COCs were largely attributable to eating clams. However, data collected during the RI/FS showed little relationship between arsenic or cPAH concentrations in sediment and concentrations in clam tissue. EPA will define the sediment cleanup footprint based on other PRGs, then use the clam tissue PRGs (Section 7.2) to measure reduction in cPAH and arsenic concentrations in clams. EPA is conducting research to study the relationships between clam tissue and sediment concentrations for arsenic and cPAHs and methods to reduce concentrations of these contaminants in clams. This research will continue into the remedial design phase.

Table 9. Sediment PRGs for Ecological (Benthic Invertebrate) COCs

Benthic COC	Preliminary Remediation Goals for RAO 3		Benthic COC	Preliminary Remediation Goals for RAO 3	
	Value	Basis		Value	Basis
SMS metals , (mg/kg dw)			OC-normalized SMS Organic Compounds (continued) (mg/kg OC)		
Arsenic	57	SQS	Benzo(g,h,i)perylene	31	SQS
Cadmium	5.1	SQS	Chrysene	110	SQS
Chromium	260	SQS	Dibenz(a,h)anthracene	12	SQS
Copper	390	SQS	Indeno(1,2,3-cd)pyrene	34	SQS
Lead	450	SQS	Fluoranthene	160	SQS
Mercury	0.41	SQS	Fluorene	23	SQS
Silver	6.1	SQS	Naphthalene	99	SQS
Zinc	410	SQS	Phenanthrene	100	SQS
Dry Weight Basis SMS Organic Compounds, (µg/kg dw)			Pyrene	1,000	SQS
4-methylphenol	670	SQS	HPAH	960	SQS
2,4-dimethylphenol	29	SQS	LPAH	370	SQS
Benzoic acid	650	SQS	Bis(2-ethylhexyl)phthalate	47	SQS
Benzyl alcohol	57	SQS	Butyl benzyl phthalate	4.9	SQS
Pentachlorophenol	360	SQS	Dimethyl phthalate	53	SQS
Phenol	420	SQS	1,2-dichlorobenzene	2.3	SQS
OC-normalized SMS Organic Compounds, (mg/kg OC)			1,4-dichlorobenzene	3.1	SQS
PCBs	12	SQS	1,2,4-trichlorobenzene	0.81	SQS
Acenaphthene	16	SQS	2-methylnaphthalene	38	SQS
Anthracene	220	SQS	Dibenzofuran	15	SQS
Benzo(a)pyrene	99	SQS	Hexachlorobenzene	0.38	SQS
Benz(a)anthracene	110	SQS	n-Nitrosodiphenylamine	11	SQS
Total benzofluoranthenes	230	SQS			

As discussed above, the sediment PRGs for PCBs and dioxins/furans (RAO 1) and for arsenic (RAO 2) are set at natural background for final cleanups. Modeling conducted during the RI/FS (see Sections 3.4 and 3.6.1) projected that long term LDW COC concentrations would be higher than natural background regardless which of the cleanup alternatives is selected. This is because the concentrations of these contaminants in incoming sediments (suspended solids) from the Green/Duwamish River are currently higher than natural background and because of practical limitations on control of sources within the LDW and Green/Duwamish River drainage basins.⁴ The term cleanup objective was used in the FS to mean the PRG or as close as practicable to the PRG. For the purposes of comparing alternative remedies, the lowest model-predicted concentration was used as a surrogate for “as close as practicable to the PRG” when the PRG was not predicted to be achieved within a 45-year period. These long-term model-predicted COC concentrations are highly uncertain, because future concentrations in upstream and lateral-source sediments are uncertain. Ecology and King County are currently conducting studies to refine estimates of contaminant inputs from the Green/Duwamish River, and to better understand upstream sources of contamination. Ecology in consultation with EPA will use this information to further assess upstream source control. All predictions of future outcomes in the FS and in this Proposed Plan are based on RI/FS data, which necessarily do not reflect anticipated refinements in estimates of contaminant loading to the LDW from upstream, and potential reductions due to future source control in the Green/Duwamish watershed. EPA is therefore retaining natural background, along with the risk-based values (RBTCs), as PRGs for LDW sediments.

7.2 Fish and Shellfish Tissue PRGs

EPA has determined that fish and shellfish tissue PRGs (and ultimately cleanup levels) are necessary and appropriate for this Site because they are the most direct and reliable measure of risk to people consuming seafood. Fish and shellfish PRGs are not based on ARARs, because MTCA defines a cleanup level as a “concentration of a hazardous substance in soil, water, air, or sediment” (WAC 173-340-200 and 700(2)). However, tissue PRGs have been developed consistent with the criteria for developing the sediment PRGs (which are based on MTCA ARARs) to ensure protectiveness for humans, including sensitive subpopulations.

Table 10 lists PRGs for resident fish and shellfish (crab and clam) tissue for RAO 1. Tissue PRGs are based on the higher of: the RBTC at 1 in 1,000,000 excess cancer risk or HQ of 1 for the adult Tribal RME scenario; or the current concentrations in non-urban Puget Sound data. Fish and crab tissue PRGs must be met as a 95% UCL LDW-wide. Clam tissue PRGs must be met as a 95% UCL across all clamming areas.

4. For example, the PCB sediment PRG for seafood consumption is 2 µg/kg, while the BCM predicts that post-cleanup PCB concentrations will reach a steady state at approximately 40 µg/kg over 45 years, with a sensitivity range using low and high input values of approximately 9 – 100 µg/kg.

Table 10. LDW Resident Fish and Shellfish Tissue PRGs

Species/Group and Tissue Type	Species ^{a,b}	PRG	Source of PRG
PCBs ($\mu\text{g/kg ww}$)			
Benthic fish, fillet	English sole	12	background
Pelagic fish, whole body	Perch	1.8	RBTC
Crab, edible meat	Dungeness crab	1.1	background
Crab, whole body	Dungeness crab	9.1	background
Clams	Eastern softshell clam	0.42	background
Inorganic arsenic (mg/kg ww)			
Clams	Eastern softshell clam	0.09	background
cPAH TEQ ($\mu\text{g/kg ww}$)			
Clams	Eastern softshell clam	0.24	RBTC
Dioxin/furan TEQ (ng/kg ww)			
Benthic fish, whole body	English sole	0.35	background
Crab, edible meat	Dungeness crab	0.53	background
Crab, whole body	Dungeness crab	2.0	background
Clams	Eastern softshell clam	0.71	background

a Substitutions of similar species may be made if sufficient numbers of the species listed here are not available.

b Background - see Table 5 in Section 3.6.2

As discussed in Section 3.6.2, fish and shellfish tissue PRGs based on background data are uncertain because they were developed with a limited dataset. Additional fish and shellfish background data will be collected during the remedial design phase to increase understanding of non-urban tissue concentrations of the human health COCs. Similar to sediment PRGs, post-cleanup tissue concentrations (for PCBs only) were predicted in the FS using the BCM and food-web model. These models predict that background-based fish and shellfish tissue PRGs for PCBs will not be met in the long term because of the influence of incoming water and suspended sediments from the Green/Duwamish River, as well as incoming surface water from Elliott Bay. If true, this is likely to be the case for tissue PRGs for other COCs as well. As discussed in Section 7.1, these model-predicted values are highly uncertain, and EPA is retaining the background-based values as PRGs. If appropriate, EPA may adjust these PRGs based on new data, which would be documented in a ROD Amendment or ESD.

7.3 Surface Water PRGs

As discussed above, surface water will not be directly remediated, but it is a key exposure pathway to aquatic organisms and those that consume them. Therefore, it is important to establish surface water PRGs (and cleanup levels) and monitor surface water quality to measure progress towards achieving RAOs 1 and 4. The PRG for PCBs in surface water is 0.064 ng/L, based on the recommended Ambient Water Quality Criteria (AWQC) for the protection of human health for consumption of organisms only. EPA is establishing this PRG for the Preferred Alternative (Section 10) as a proposed cleanup level for the ROD based on the water column data that was collected prior to or during the RI/FS. During remedial design sampling, EPA intends to further evaluate surface water COC concentrations. If other COC surface water concentrations exceed the recommended Federal AWQC (Clean Water Act Section 304(a) guidance values) or State Water Quality Standards, the more stringent of the two will be used to monitor progress towards achieving RAOs.

This page was left blank for double sided printing.

8 Development of Remedial Alternatives

Remedial alternatives for the LDW were developed to meet the requirements of CERCLA and its regulations, the NCP, and MTCA and its regulations (including the SMS). The NCP and MTCA require that a range of remedial alternatives be evaluated to provide protection of human health and the environment primarily by preventing or controlling exposure to hazardous substances, pollutants, or contaminants within a site. The development and analysis of the remedial alternatives form the basis for EPA's selection of the Preferred Alternative and are discussed below.

8.1 Framework for Developing Remedial Alternatives

EPA considered several factors in developing remedial alternatives, including: the levels of COCs in surface and subsurface sediments, the likelihood of contact with contaminated sediments, the likelihood that sediment disturbances, many of which can result from ordinary use of the waterway, might expose contamination in the future, and the potential for contaminated sediments to be covered by incoming cleaner sediments and therefore pose less risk. EPA also considered use of the waterway by people and aquatic organisms, as discussed in Section 8.2. To support the evaluation of alternatives, EPA used three criteria: 1) Remedial Action Levels (RALs); 2) PRGs (described in Section 7); and 3) Recovery Categories.

Remedial Action Levels (RALs) are contaminant-specific sediment concentrations that will be used to identify specific areas of sediments that require active remediation (dredging, capping, enhanced natural recovery [ENR], or a combination thereof), taking into consideration the human health and ecological risk reduction that could be achieved by the different remedial technologies. These RALs are set by EPA so that, in each area, PRGs will be met either immediately after construction or in the long term after natural recovery, to the extent practicable given the uncertainties discussed in Section 7. The sediment RALs in this Proposed Plan are equal to or higher than the sediment PRGs for each COC and are used only to delineate the Site into areas where different remedial technologies would be used. The use and application of RALs does not affect or alter the requirement to achieve cleanup levels established in the ROD.

A number of alternative cleanup options (alternative remedies) are presented in this Proposed Plan. Each alternative has its own set of sediment RALs. Sediment RALs reflect a range in risk reduction to be achieved over time, in the projected rate of natural recovery, and in which remedial technologies are used. Different RALs were established for surface and subsurface sediments, intertidal and subtidal sediments, and Recovery Category areas, as discussed below.

Contaminant-specific RALs for surface sediments are compared to contaminant concentrations in the top 10 cm (4 in) of sediments. Consistent with the SMS, the top 10 cm represents the biologically active zone where most of the benthic invertebrates reside. For subsurface sediments in intertidal areas (shallower than -4 ft MLLW), certain RALs (identified as intertidal RALs in Table 12, page 60) are also compared to the contaminant concentration averaged over the top 45 cm (1.5 ft). For subsurface sediments in intertidal and subtidal areas with a higher potential for erosion or scour (see Recovery Category 1 description below), RALs are also compared to the contaminant concentration averaged over the top 60 cm (2 ft). Where concentrations exceed the RALs, active remediation technologies are selected based on

technology assignment criteria described in Section 8.2. Although RALs are applied as an average over the depth intervals described above, they are applied at each sampling location, not as averaged values over an area. While RALs were used in the FS to identify areas of active remediation for each alternative, those areas will be further defined through sampling conducted during remedial design to determine the areal and vertical extent of sediments to be remediated following cleanup of the EAAs.

PRGs are described in Section 7. In the FS, the projected short-term and long-term sediment and seafood tissue concentrations after implementation of each alternative (developed using the RALs and Recovery Categories) were compared to PRGs to measure its protectiveness and compliance with ARARs.

Recovery Categories were used to assign remedial technologies to specific areas based on information about the potential for sediment contaminant concentrations to be reduced through natural recovery or for subsurface contamination to be exposed at the surface due to erosion or scour. Based on data collected and modeling performed in the RI/FS, three Recovery Categories were developed as shown in Table 11.

Table 11. Criteria for Assigning Recovery Categories

Criteria		Recovery Categories		
		Category 1 Recovery Presumed to be Limited	Category 2 Recovery Less Certain	Category 3 Predicted to Recover
Physical Criteria				
Physical Conditions	Vessel scour	Observed vessel scour	No observed vessel scour	
	Berthing areas	Berthing areas with vessel scour	Berthing areas without vessel scour	Not in a berthing area
Sediment Transport Model	STM-predicted 100-year high-flow scour (depth in cm)	> 10 cm	< 10 cm	
	STM-derived net sedimentation rate (cm/yr) using average flow conditions	Net scour	Net sedimentation	
Rules for applying criteria		If an area is in Category 1 for any one criterion, that area is designated Category 1	If conditions in an area meet a mixture of Category 2 and 3 criteria, that area is designated Category 2	An area is designated Category 3 only if all conditions meet the Category 3 criteria
Empirical Contaminant Trend Criteria – used on a case-by-case basis to adjust recovery categories from the criteria above				
Empirical Contaminant Trend Criteria	Resampled surface sediment locations	Increasing PCBs or increasing concentrations of other detected COCs exceeding the SQS (> 50% increase)	Equilibrium and mixed (increases and decreases) results (for COCs exceeding the SQS)	Decreasing concentrations (> 50% decrease) or mixed results (decreases and equilibrium)
	Sediment cores (top 2 sample intervals in upper 2 ft)			

a Observed vessel scour areas, berthing areas, high-flow scour areas, and modeled net sedimentation rates are shown on Figure 3.

The spatial extent of the areas assigned to each of these three categories in the FS is shown in Figure 12. The use of Recovery Categories allows for more aggressive remedial technologies (such as capping and dredging) in areas with less potential for natural recovery and a higher likelihood of scour or other disturbance, and less aggressive remedial technologies (such as ENR and MNR) in areas where recovery is predicted to occur more readily and disturbance is less likely.

Section 8.2 describes how Recovery Categories are used in assigning cleanup technologies. Recovery Category areas will be further refined using data collected in the remedial design phase and the criteria set forth in Table 11.

8.2 Summary of Remedial Alternatives

Using the framework described above, along with other criteria such as maintaining sufficient water depths for human use and habitat areas, twelve remedial action alternatives were developed in the FS using varying combinations of technologies as described below. The FS alternatives include one no further action alternative (Alternative 1), seven removal-emphasis alternatives (“R” Alternatives 2R, 2R-Contained Aquatic Disposal (CAD), 3R, 4R, 5R, 5R-Treatment, and 6R) and four combined technology alternatives (“C” Alternatives 3C, 4C, 5C, and 6C). FS Alternative 5C was further modified to include additional remedial elements as described in a 2012 technical memorandum⁵ (the FS Supplement), as discussed in Section 8.2.2; this modified alternative is called 5C Plus in this Plan. A general approximation of the areas of sediments addressed by the FS cleanup alternatives is shown in Figure 13.

5. *Technical Memorandum: Supplement to the Feasibility Study for the LDW Superfund Site, Approaches for Addressing Additional Concerns in Alternative 5C and Development of Alternative 5C Plus Scenarios for the Lower Duwamish Waterway (FS Supplement)*; see Key Documents.

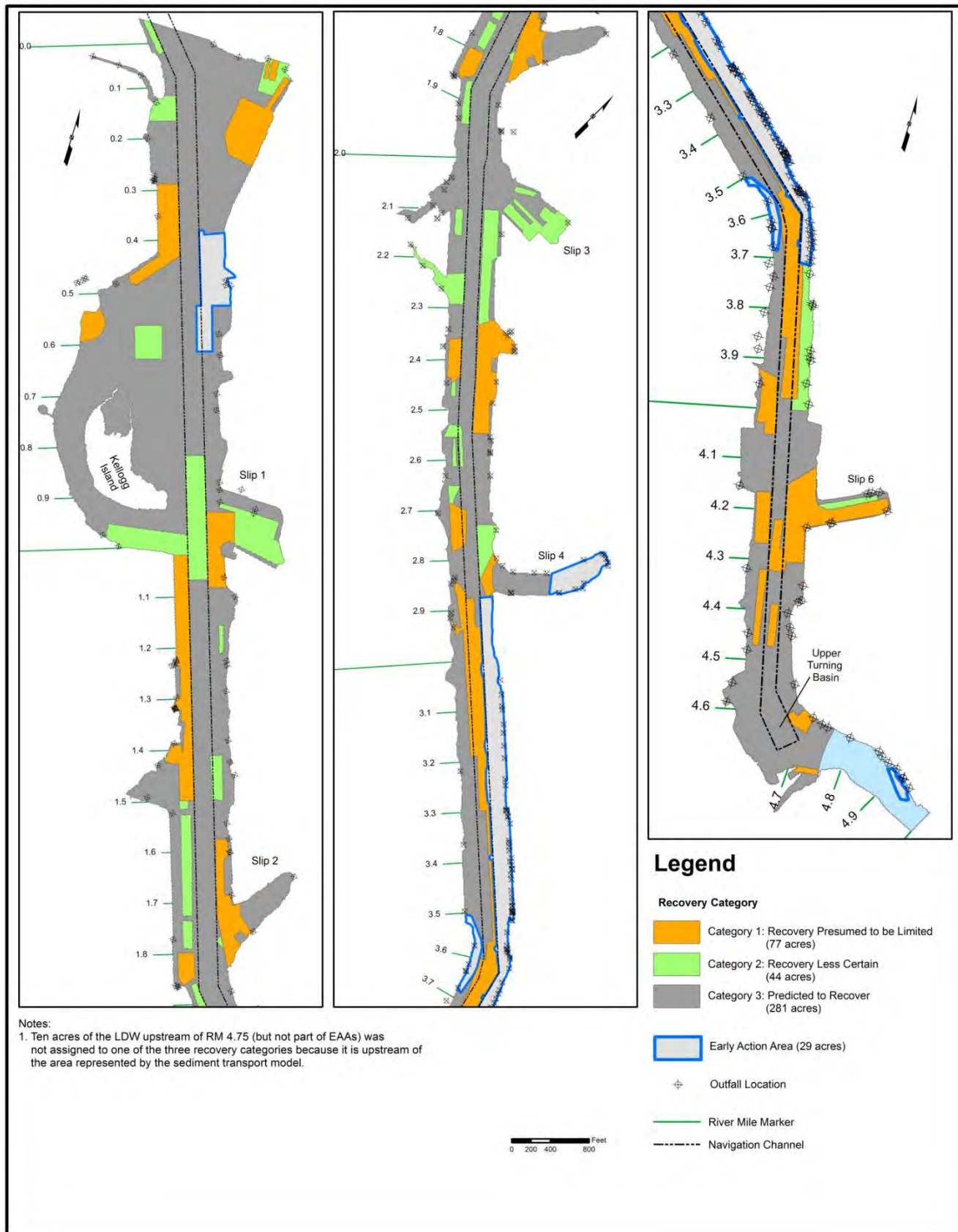


Figure 12. Recovery Categories



Figure 13. Areas Addressed by LDW Cleanup Alternatives

8.2.1 Technologies Common to all Remedial Alternatives

The remedial cleanup technologies described below were used to develop remedial action alternatives to address contamination in the LDW, including dredging and excavation, capping, treatment, enhanced natural recovery (ENR), and monitored natural recovery (MNR). The “no action” alternative would use no remedial technologies (although it does include long-term monitoring). All alternatives would be implemented after cleanup is completed in the Early Action Areas (29 acres) along with sufficient source control to minimize recontamination. The engineered remedial technologies are as follows:

- **Dredging and Excavation** – Removal of sediments through dredging or excavation in areas where it is necessary to maintain water depth for human use or to maintain habitat; dredging and excavation is incorporated into all remedial alternatives.
- **Sediment disposal** – All alternatives include disposal of dredged or excavated materials at an off-site upland permitted facility. Alternative 2R-CAD also includes disposal of contaminated sediments in a contained aquatic disposal (CAD) site within the LDW. Alternative 5R-Treatment includes treatment of dredged sediments prior to disposal.
- **Capping** – Many alternatives include capping of contaminated sediments in areas where there is sufficient water depth to build a cap. Engineered sediment caps are constructed by placing clean sand, gravel, and rock on contaminated sediments to provide physical and chemical isolation of contaminants. Caps will be a minimum of 4 feet thick in intertidal clamming areas, and cap thickness in other areas will be determined during remedial design. In habitat areas, the uppermost layers of caps will be designed using suitable habitat materials. Other materials, such as activated carbon or other contaminant-sequestering agents, may be used to reduce the potential for contaminants to migrate through the cap. The effectiveness and potential impacts of these amendment technologies will be evaluated in pilot studies performed during remedial design.
- **Enhanced Natural Recovery (ENR)** – Many alternatives include Enhanced Natural Recovery of contaminated sediments. ENR refers to the placement of a thin layer (approximately 6 to 9 inches) of clean sand or other suitable habitat materials on sediments, which immediately provides a new surface substrate of clean sediments. This cleaner material mixes with the underlying contaminated material, through mechanisms such as bioturbation. ENR reduces contaminant concentrations in surface sediments more quickly than would happen by natural sedimentation processes alone. ENR is proposed for areas with less sediment contamination and only in Recovery Category 2 and 3 areas. In some areas, ENR may be combined with in situ treatment; in other words, the sand layer may be amended with activated carbon or other sequestering agents to reduce the bioavailability of organic contaminants such as PCBs. The effectiveness and potential impacts of using in situ treatment or amendment technologies, as well as the areas best suited for these technologies, will be evaluated in pilot studies performed during remedial design.

Other, non-engineered, technologies common to all alternatives include: monitored natural recovery, monitoring, and institutional controls, as described below:

- **Monitored Natural Recovery (MNR)** – Monitored natural recovery relies on natural processes to reduce ecological and human health risks to acceptable levels, while monitoring recovery of

sediments over time to determine remedy success. Within the LDW, natural burial of contaminants through sedimentation from upstream is the primary natural recovery mechanism. The sediment transport model (STM) and bed composition model (BCM), supported by RI/FS data, were used to estimate reduction of sediment COC concentrations over time through natural recovery.

- **Two categories of MNR for the Preferred Alternative Only: MNR To SQS and MNR Below SQS** – Terminology used to describe MNR in this Proposed Plan for the Preferred Alternative differs from that used in the FS, as follows.
 - In the FS the term "MNR" referred only to reduction of COC concentrations through natural processes until the SQS are reached (i.e., only areas where concentrations are above the SQS; once SQS are reached, MNR would no longer apply and the area would be designated "long-term monitoring"). As used in the FS, MNR included more intensive monitoring and additional actions in any areas where the SQS is not achieved within 10 years after remedial action. Areas where COC concentrations are below the SQS were designated in the FS as "long-term monitoring" areas with a lower sampling density, although the FS acknowledged that reduction of COC concentrations through natural recovery would continue in those areas also.
 - In this Proposed Plan (and in the 2012 FS Supplement; see Key Documents), the term "MNR" is used to describe all areas where reduction of COC concentrations through natural recovery is predicted to continue after cleanup is complete (i.e., areas where concentrations are above the SQS and areas where they are below the SQS). For the Preferred Alternative only, the Proposed Plan further refines MNR, dividing it into two different categories: 1) MNR To SQS, for areas where MNR would be used to achieve the SQS (PRGs for RAO 3); and 2) MNR Below SQS for areas where MNR is used to further reduce COC concentrations to the remaining PRGs for RAOs 1, 2, and 4. Use of this terminology is more fully described in Section 10.
- **Monitoring** – Monitoring includes sampling sediments, surface water, fish and shellfish tissue, and other media to assess site conditions before, during and after cleanup. All alternatives include baseline monitoring during the remedial design phase. Monitoring will continue through construction to assess compliance with construction performance standards, and will continue over the long term to determine whether technologies are operating as intended and to assess progress toward achieving the cleanup levels.
- **Institutional controls** – Because none of the alternatives evaluated in the FS would provide sufficient risk reductions to allow for unrestricted use of the LDW, all alternatives include use of Institutional Controls (ICs). It is important to recognize that even if all natural background-based PRGs were met (keeping in mind that calculated risk-based concentrations are more stringent than background levels), this would not safely allow for unrestricted use of the LDW (human consumption of unlimited quantities of resident fish and shellfish). The ICs considered for the LDW include:
 - **Informational devices**, such as seafood consumption advisories, public outreach, and education to reduce human exposure from consuming contaminated fish and shellfish within the LDW, and monitoring and notification of waterway users, including use of the state's Environmental Covenants Registry; and

- **Proprietary controls**, such as environmental covenants to protect the integrity of the engineered features such as sediment caps. They would typically require EPA or Ecology approval prior to activity that may disturb or encounter contamination that remains in the LDW after cleanup.

Institutional controls will only be relied upon to the minimum extent practicable, consistent with MTCA institutional control regulations (WAC 173-340-440(6)).

8.2.2 Remedial Alternatives

The alternatives use varying combinations of the technologies listed above. Elements that vary among alternatives include 1) the extent of the active remediation, 2) the technologies assigned, and 3) the COC concentrations (RALs) where a technology may be applied.

Each of the twelve remedial alternatives are briefly described below. Higher numbered alternatives must achieve progressively lower RALs and they have increasingly larger cleanup footprints (e.g., the cleanup footprint for Alternative 3 is larger than that of Alternative 2).

For the alternatives that emphasize removal (the "R" alternatives), dredging/excavation and disposal would be the primary technologies used for active remediation. The combined technology ("C") alternatives emphasize the use of capping, enhanced natural recovery (ENR), and in situ treatment. They would use dredging and excavation only where capping and ENR/in situ treatment are not feasible due to requirements to maintain water depths in habitat areas, the navigation channel, or berthing areas. In the "C" alternatives, ENR is used only in areas with low scour potential and moderate sediment contaminant concentrations because underlying sediment contamination is not isolated by this technology. For the FS and this Proposed Plan, moderate contamination is defined as 1 to 1.5 times the intertidal RAL (applied in the top 45 cm) and 1 to 3 times the LDW-wide RAL (applied in the top 10 cm). More aggressive technologies such as isolation caps would be used in highly contaminated areas (where concentrations are greater than 1.5 times the intertidal RAL or 3 times the LDW-wide RAL) and in areas with scour potential. Dredging, and partial dredging and capping, would be used where elevation constraints preclude capping alone.

Figure 13 shows the areas that would be addressed by the cleanup alternatives. The areas addressed by the cleanup alternatives depicted in the FS and this Proposed Plan are preliminary. The sediment contaminant concentrations used to delineate the areas addressed in FS remedial alternatives were collected over a 20-year period, from 1991 to 2010, with the bulk of the data collected prior to 2005. For the final remedy, different sediment contaminant concentrations may be established based on results from sampling conducted during remedial design; for example, some areas may have already recovered naturally while others may have become more contaminated due to ongoing input from contaminant sources. The specific areas to be addressed by remedial technologies and MNR will be refined based on results from additional sampling during remedial design.

Because all alternatives use similar technologies, the primary ARARs are the same for all alternatives, and are described in Section 9. All Alternatives (except Alternative 1, No Action) include off-site disposal of dredged material. Data from the RI/FS indicate that sediment removed from the LDW can be disposed of in a solid waste (RCRA Subtitle D) landfill. If wastes that require disposal in a landfill permitted to

receive RCRA hazardous wastes or Toxic Substances Control Act (TSCA) regulated wastes are encountered during remedial design or remedial action, they will be disposed in a RCRA Subtitle C or TSCA-compliant landfill. Alternative 2 uses a different disposal technology, contained aquatic disposal, which would make Section 404 of the Clean Water Act a more important ARAR for that alternative. Only Alternative 5R-Treatment uses soil washing; however, ARARs for disposal or beneficial reuse of treated material would be the same as for disposal of untreated sediments.

Table 12 summarizes the RALs for each alternative. Table 13 summarizes the areas and volumes and associated with each remedial technology for each of the alternatives as well as costs and construction durations. The cost of implementing cleanups at the EAAs is estimated at \$95 million; this cost is not included in the cost estimates for the alternatives.

Figure 14 shows a summary of technologies used, cleanup timeframes, and cost for each alternative. Figure 15 shows the construction period and time for each alternative to achieve a range of risk reduction benchmarks.

Table 12. Remedial Alternatives and Associated Remedial Technologies, Remedial Action Levels, and Actively Remediated Acres

Remedial Alternatives and Technologies ^a	Remedial Action Levels ^a					Actively Remediated Area (Acres)
	PCBs (mg/kg OC) ^b	Arsenic (mg/kg dw)	Dioxins/Furans (ng TEQ/kg dw)	cPAHs (µg TEQ/kg dw)	Benthic SMS (41 Contaminants) ^d	
Alternative 1 No Further Action after removal or capping of Early Action Areas	n/a	n/a	n/a	n/a	n/a	29 acres
Alternative 2 (2R) – dredge emphasis with upland disposal/MNR	65 to 110 (LDW-wide); 10-yr post-construction target: 65 ^c	93	50	5,500	CSL to 3 × CSL 10-yr post-const. target: CSL	32 acres
Alternative 2 with CAD (2R-CAD) – dredge emphasis with contained aquatic disposal/MNR						
Alternative 3 removal (3R) – dredge emphasis with upland disposal/MNR	65 (LDW-wide)	93 (LDW-wide)	35 (LDW-wide)	3,800 (LDW-wide)	CSL toxicity or chemistry	58 acres
Alternative 3 combined technologies (3C) – ENR/in situ /cap/MNR where appropriate, otherwise dredge with upland disposal		28 (intertidal)	28 (intertidal)	900 (intertidal)		
Alternative 4 removal (4R) – dredge emphasis with upland disposal/MNR	12 to 35 (LDW-wide) 10-yr post-const. target: 12 ^c	57 (LDW-wide)	25 (site-wide)	1,000 (LDW-wide)	SQS to CSL	107 acres
Alternative 4 combined technologies (4C) – ENR/in situ /cap/MNR where appropriate, otherwise dredge with upland disposal		28 (intertidal)	28 (intertidal)	900 (intertidal)	10-yr post-const. target: SQS	
Alternative 5 removal (5R) – dredge emphasis with upland disposal	12 (LDW-wide)	57 (LDW-wide)	25 (LDW-wide)	1,000 (LDW-wide)	SQS toxicity or chemistry	157 acres
Alternative 5 removal with treatment (5R-T) – dredge with soil washing treatment and disposal/re-use		28 (intertidal)	28 (intertidal)	900 (intertidal)		
Alternative 5 combined technologies (5C) – ENR/in situ /cap where appropriate, otherwise dredge with upland disposal						
Alternative 6 removal (6R) – dredge emphasis with upland disposal	5 (LDW-wide)	15 (LDW-wide)	15 (LDW-wide)	1,000 (LDW-wide)	SQS toxicity or chemistry	302 acres
Alternative 6 combined technologies (6C) – ENR/in situ /cap where appropriate, otherwise dredge with upland disposal		28 (intertidal)	28 (intertidal)	900 (intertidal)		
Preferred Alternative (5C Plus) - ENR/in situ /cap where appropriate, otherwise dredge with upland disposal.	12 (LDW-wide) 65 (intertidal) 195 (subtidal subsurface)	57 (LDW-wide) 28 (intertidal)	25 (LDW-wide) 28 (intertidal)	1,000 (LDW-wide) 900 (intertidal)	2 X SQS chemistry (not to exceed CSL)^c or SQS toxicity 10-year post-const. target: SQS	156 acres

- a. LDW-wide remedial action levels are applied in the upper 10 cm of sediment throughout the LDW and in the upper 60 cm in potential scour areas (i.e., Recovery Category 1 areas). Intertidal remedial action levels are applied in the upper 45 cm of sediment in intertidal areas (above -4 ft MLLW). An intertidal PCB RAL of 65 mg/kg OC was added in Alternative 5C Plus in the top 45 cm in intertidal areas. Alternative 5C Plus added a subtidal PCB RAL of 195 mg/kg OC for top 60 cm in Recovery Category 2 and 3 areas in areas of potential vessel scour. These potential scour areas comprise: north of the 1st Avenue South bridge (located at approximately RM 2) in water depths from -4 to -24 ft MLLW, and south of the 1st Avenue S bridge, in water depths from -4 to -18 ft MLLW.
- b. PCB RALs are normalized to organic carbon (OC) for consistency with the SMS, and because the organic content of sediments affects the bioavailability and toxicity of PCBs.
- c. The RALs for SMS contaminants (except arsenic) are a range for Alternatives 2 and 4. The upper RALs are used where conditions for recovery are predicted to be more favorable (Recovery Category 3); the lower RALs are used where conditions for recovery are predicted to be limited or less certain (Recovery Categories 1 or 2), or where the BCM does not predict recovery to the 10-yr post-construction target concentration.
- d. See Table 14 for these values.

Table 13. Remedial Alternative Areas, Volumes, and Costs

Site -wide Remedial Alternative	Remedial Alternative Technology and Areas								Total Dredge Volume (cy)	Construction Time Frame (years)	Net Present Value Cost ^c (\$MM)
	EAA's (acres) ^a	Dredge (acres)	Partial Dredge and Cap (acres)	Cap (acres)	ENR/ in situ (acres)	MNR To SQS ^b (acres)	MNR (MNR Below SQS in Alt 5C Plus) (acres)	Total Active Remedy (acres)			
1 No Further Action	29	0	0	0	0	0	412	0	n/a	n/a	\$9
2 Removal	29	29	3	0	0	148	232	32	580,000	4	\$210
2 Removal with CAD	29	29	3	0	0	148	232	32	580,000	4	\$200
3 Removal	29	50	8	0	0	122	232	58	760,000	6	\$270
3 Combined Technology	29	29	8	11	10	122	232	58	490,000	3	\$200
4 Removal	29	93	14	0	0	73	232	107	1,200,000	11	\$360
4 Combined Technology	29	50	18	23	16	73	232	107	690,000	6	\$260
5 Removal	29	143	14	0	0	23	232	157	1,600,000	17	\$470
5 Removal with Treatment	29	143	14	0	0	23	232	157	1,600,000	17	\$510
5 Combined Technology	29	57	23	24	53	23	232	157	750,000	7	\$290
Preferred Alternative (5 Combined Technology Plus)	29	64	20	24	48	33	223	156	790,000	7	\$305
6 Removal	29	274	28	0	0	0	110	302	3,900,000	42	\$810
6 Combined Technology	29	108	42	51	101	0	110	302	1,600,000	16	\$530

a. The 29 acres addressed by the EAAs are not included in area estimates for other alternatives.

b. Includes areas that the FS predicted will have naturally recovered enough that concentration levels are below the SQS by the time sampling is conducted for remedial design (called "verification monitoring" in the FS).

c. Net Present Value calculated using a 2.3% annual discount rate

This page left blank for double sided printing.

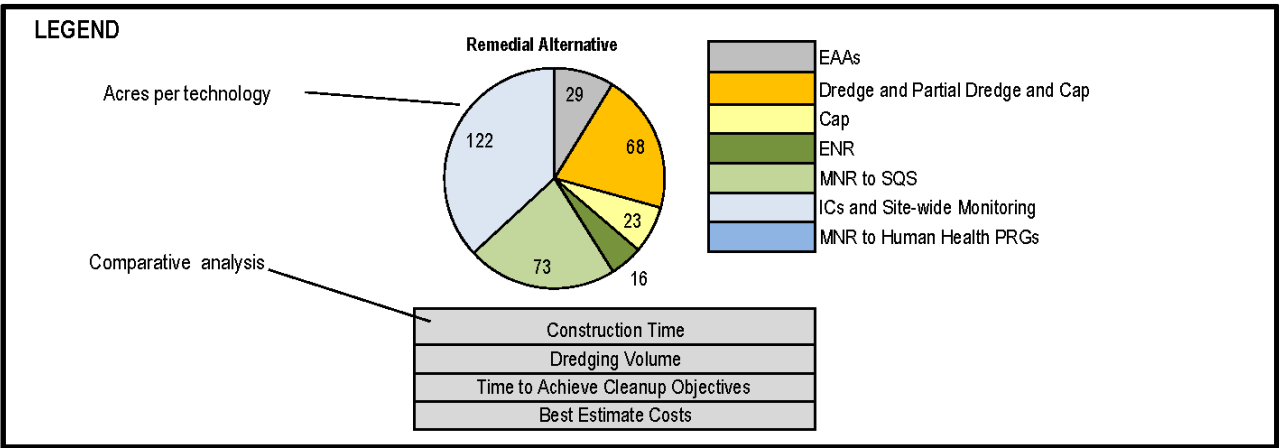
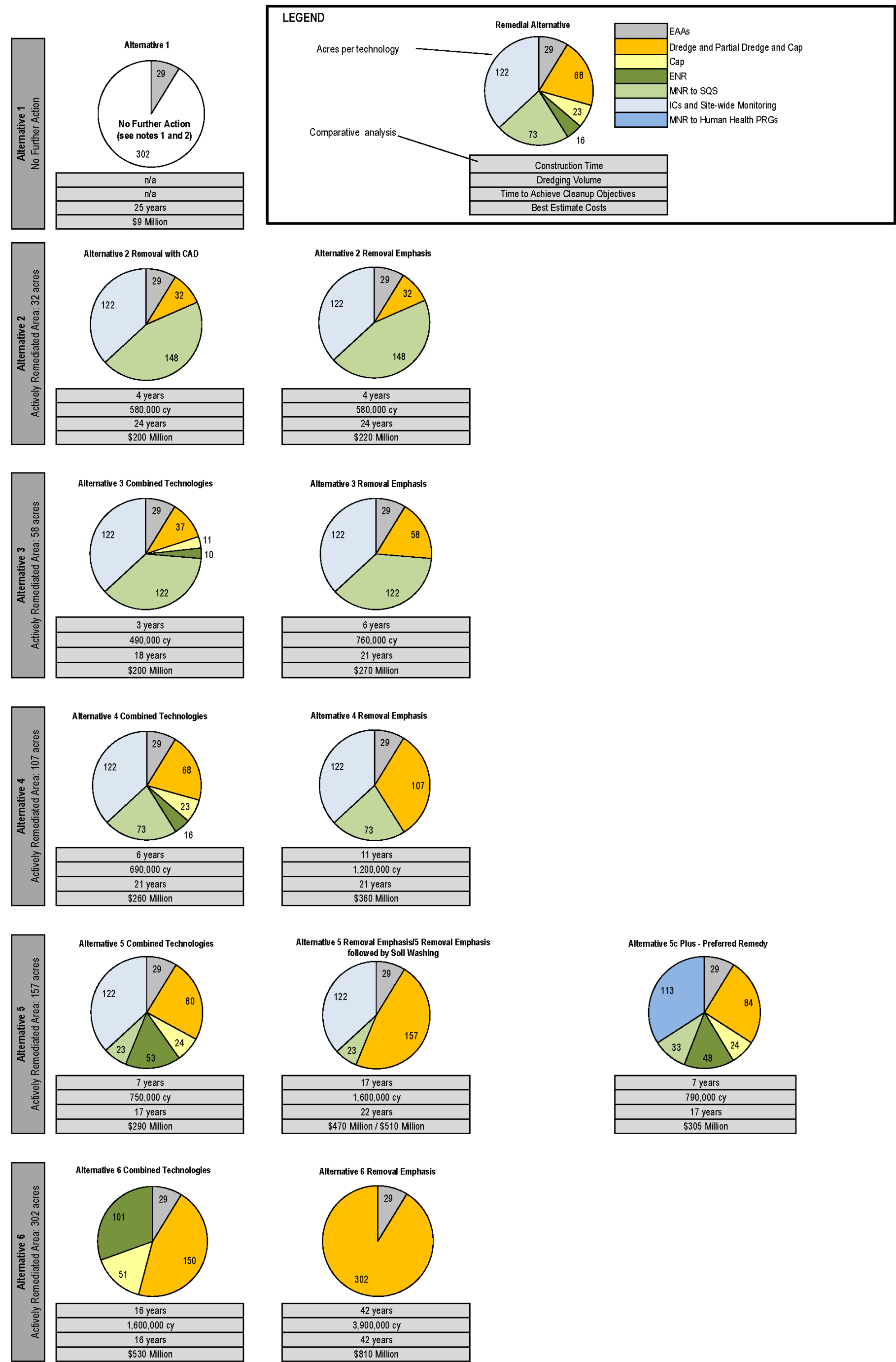


Figure 14. Summary of Alternatives

This page left blank for double sided printing.

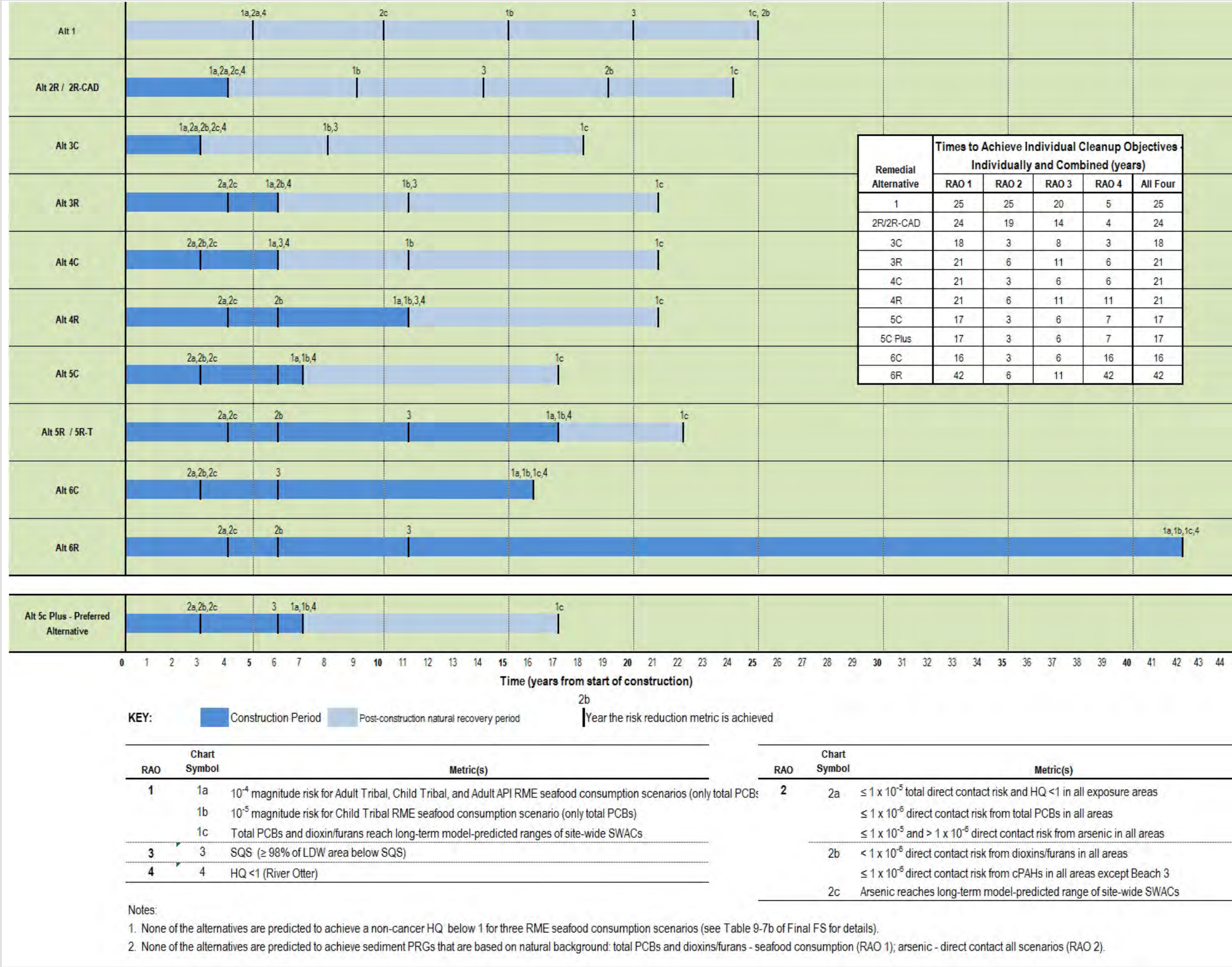


Figure 15. Time to Achieve Risk Benchmarks for All Alternatives

This page left blank for double sided printing.

Alternative 1 – No Further Action – This alternative would not implement any further action following removal or capping implemented through Early Actions, with the exception of continued LDW-wide monitoring. It includes no ICs other than the existing seafood consumption advisories and those implemented for the Early Actions. This alternative provides a baseline to compare the other remedial alternatives against; its inclusion is required by CERCLA. LDW-wide monitoring costs, at present value (PV), for Alternative 1 are estimated to be \$9 million.

Alternatives 2R and 2R-CAD – These alternatives would actively remediate 32 acres with contaminant concentrations above the Alternative 2 RALs (Table 12). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 13. Alternatives 2 and 2R include:

- For areas with COC concentrations exceeding the RALs, Alternative 2R includes dredging with upland landfill disposal, while Alternative 2R-CAD adds contained aquatic disposal (CAD) to address disposal of some of the dredged material.
- In areas with COC concentrations below the RALs, MNR would be used to reduce COC concentrations to the SQS (RAO 3) within 20 years following construction as well as to achieve cleanup objectives⁶ for RAOs 2 and 4. As noted above, the FS makes no distinction between MNR To SQS and MNR Below SQS, so these terms are not used for any alternative except the Preferred Alternative (5C Plus). As discussed in Section 8.2.1, the FS used the term "MNR" to include enhanced monitoring and additional actions only for any area where COC concentrations are not reduced to the SQS levels. For simplicity, this Proposed Plan uses the term MNR to refer to all areas where COC concentration reduction is predicted, to levels both above and below the SQS.
- Seafood consumption advisories, outreach, and education programs would be used to further reduce exposure to contamination in fish and shellfish, and proprietary controls such as environmental covenants would be used to reduce the likelihood of exposure where contamination remains above cleanup levels.

These alternatives are designed to achieve the following at a minimum, relative to the RAOs for the in-waterway portion of the Site:

- For RAO 1 (human health seafood consumption): Incremental risk reduction through active remediation and further risk reduction through MNR.

Remedial Action Objectives

RAO 1: Reduce to protective levels human health risks associated with the consumption of contaminated resident LDW fish and shellfish by adults and children with the highest potential exposure.

RAO 2: Reduce to protective levels human health risks from direct contact (skin contact and incidental ingestion) of contaminated sediments during netfishing, clamming, and beach play.

RAO 3: Reduce to protective levels risks to benthic invertebrates from exposure to contaminated sediments.

RAO 4: Reduce to protective levels risks to crabs, fish, birds, and mammals from exposure to contaminated sediment, surface water, and prey.

6. The term "cleanup objectives" is used in the FS to mean the PRG or as close as practicable to the PRG where the PRG is not predicted to be achievable. The FS uses long-term model-predicted concentrations as estimates of "as close as practicable" to PRGs.

- For RAO 2 (human health direct contact): Meet cleanup objectives within 10 years following construction.
- For RAO 3 (protection of benthic community): Reduce contaminants in sediment to meet the CSL within 10 years following construction, and the SQS within 20 years following construction. (See Section 4.2 for additional information on CSL and SQS).
- For RAO 4 (protection of river otter): Meet PRG within 10 years following construction.

Alternatives 3R and 3C – These Alternatives actively remediate 58 acres with contaminant concentrations above the Alternative 3 RALs (Table 12). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 13. A greater amount of surface and subsurface contamination is removed by these alternatives than Alternative 2, and they rely more on active remediation to reduce risks to human health from consuming contaminated seafood than the previous alternatives. Alternatives 3R and 3C include:

- For areas exceeding the RALs, Alternative 3R has a removal emphasis (i.e., dredging) with upland disposal/MNR, and Alternative 3C uses a combined technology approach (i.e., capping and ENR/MNR/in situ treatment) in addition to dredging with upland disposal.
- MNR is used in areas with concentrations below RALs to achieve the SQS within 20 years following construction, with additional COC concentration reduction over time to the cleanup objectives.
- ICs would be used as described in Alternative 2.

These alternatives are designed to achieve, at a minimum, the outcomes of Alternative 2, plus:

- For RAO 1: Achieve greater reduction of risk because there is a larger area of active remediation.
- For RAOs 2 and 4: Achieve cleanup objectives immediately following construction, rather than 10 years following construction.
- For RAO 3: Achieve the CSL immediately following construction, rather than 10 years following construction. The SQS would still not be projected to be reached for 20 years.

Alternatives 4R and 4C – These alternatives actively remediate 107 acres with contaminant concentrations above the Alternative 4 RALs (Table 12). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 13. MNR is used in areas with concentrations below the RALs to achieve the SQS within 10 years following construction, with additional COC concentration reduction over time to the cleanup objectives. ICs would be used as described in Alternative 2. Alternatives 4C and 4R rely more on active remediation than previous alternatives to reduce COC concentrations. These alternatives are designed to achieve, at a minimum, the outcomes of Alternative 3, plus:

- For RAO 1: Achieve greater risk reduction because there is a larger area of active remediation.
- For RAOs 2 and 4: Same as Alternative 3.
- For RAO 3: Achieve the SQS for within 10 years following construction as opposed to 20 years following construction.

Alternatives 5R, 5R-Treatment, and 5C –These alternatives actively remediate 157 acres with contaminant concentrations above the Alternative 5 RALs (Table 12). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 13. These three alternatives do not use MNR to reach the SQS⁷, however, MNR is relied upon to further reduce risks to the cleanup objectives. Alternative 5R-Treatment utilizes removal with ex situ treatment (soil washing) and disposal/re-use. These three alternatives rely more on active remediation than previous alternatives to reduce COC concentrations. These alternatives are designed to achieve, at a minimum, the outcomes of Alternative 4, plus:

- For RAO 1: Achieve greater risk reduction because there is a larger area of active remediation.
- For RAOs 2 and 4: Same as Alternative 3.
- For RAO 3: Achieve the SQS immediately following construction as opposed to 10 years following construction.

Alternatives 6R and 6C – These alternatives actively remediate 302 acres with contaminant concentrations above the Alternative 6 RALs (Table 12). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 13. Alternative 6R has a dredging emphasis with upland disposal, while Alternative 6C emphasizes combined technologies including ENR/capping where appropriate, in addition to dredging with upland disposal. These alternatives are designed to achieve, at a minimum:

- For RAO 1: Achieve the lowest model-projected COC concentrations immediately after construction, rather than relying on MNR.
- For RAOs 2 and 4: Same as Alternative 3.
- For RAO 3: Achieve the SQS immediately following construction as opposed to 10 years following construction.

Alternatives 6C and 6R rely the most on active remediation to reduce COC concentrations relative to all other alternatives.

Preferred Alternative (5C Plus) – Alternative 5C Plus was developed by modifying FS Alternative 5C to include additional remedial elements as described in the FS Supplement (see Key Documents). The FS Supplement evaluated these additions to address several concerns, including the need for:

- Additional RALs for subsurface sediments in areas outside of Recovery Category 1 areas to address the potential that subsurface contamination could be disturbed and exposed at the surface through activities such as emergency or high-power vessel operations, vessel groundings, maintenance activities, or earthquakes;
- Additional dredging in shoaled areas of the navigation channel where COC concentrations exceed RALs to address the potential that subsurface contamination could be disturbed through maintenance dredging;
- Increased cap thickness in intertidal clamming areas to provide adequate habitat for clams; and

7. Although Table 12 shows 23 acres of MNR, the FS predicts that COC concentrations in these areas will be reduced to the SQS prior to the start of construction.

- Increased sediment monitoring to evaluate natural recovery progress in areas where COC concentrations are below the SQS but above PRGs (designated as MNR Below SQS in this Proposed Plan).

In addition, the FS Supplement evaluated greater use of MNR to reduce concentrations of non-human health COCs in surface sediments, while continuing to use active remediation when RALs for human health COCs are exceeded.

Six scenarios were developed in the FS Supplement. EPA, in consultation with Ecology, selected FS Supplement Scenario 5a (referred to as Alternative 5C Plus or the Preferred Alternative in this Proposed Plan). Estimates of cleanup areas and volumes for Alternative 5C Plus were then further refined in a February 2013 memorandum⁸: Alternative 5C Plus actively remediates 156 acres with contaminant concentrations above the Alternative 5C Plus RALs (Table 12 and Table 14). These RALs are the same as for Alternative 5, except:

- To address the concern that high concentrations of PCBs, the most prevalent COC in the LDW, could become exposed through human activities such as digging in the beach in intertidal areas or emergency ship maneuvering in intertidal or subtidal areas, new subsurface PCB RALs were added in Recovery Category 2 and 3 areas. For subsurface sediments in intertidal areas, the PCB RAL is 65 mg/kg OC, and for subtidal areas it is 195 mg/kg OC. No other alternatives have subsurface RALs for PCBs in Recovery Category 2 and 3 areas.
- The RALs for non-human health COCs in surface sediments were increased to 2 times the SQS, not to exceed the CSL, in Recovery Category 2 and 3 areas. The SQS must be met within 10 years of completing remedial action.

The area and volume of contaminated sediments remediated by each remedial technology and the estimated costs are provided in Table 13. Alternative 5C Plus includes 33 acres of MNR To SQS, and 223 acres of MNR Below SQS (with more monitoring than in the FS Alternatives) for RAO 1. Alternative 5C Plus would rely more on active remediation than 5C (but less than 6C) to reduce COC concentrations in surface sediments. Alternative 5C Plus is designed to achieve, at a minimum, the following outcomes:

- For RAOs 1, 2 and 4: Achieve greater risk reduction than 5C because there would be a larger volume of sediments actively remediated, and an increased emphasis on reducing high concentrations of PCBs in subsurface sediments.
- For RAO 3: Achieve the CSL immediately following construction, and the SQS within 10 years following construction.

8. *Development of Final Technology Assignments and Modifications to Alternative 5C Plus Scenario 5a in Support of EPA's Preferred Alternative*; see Key Documents.

Table 14. Alternative 5C Plus Ecological Risk Reduction (Benthic Protection) RALs

SMS Contaminant of Concern	RAL for Recovery Category 1 Areas ^a (SQS)	RAL for Recovery Category 2 & 3 Areas (2 x SQS or CSL, whichever is lower)
Metals (mg/kg dw)		
Cadmium	5.1	6.7 ^b
Chromium	260	270 ^b
Copper	390	390 ^b
Lead	450	530 ^b
Mercury	0.41	0.59 ^b
Silver	6.1	6.1 ^b
Zinc	410	820 ^c
PAHs (mg/kg OC)		
2-Methylnaphthalene	38	64 ^b
Acenaphthene	16	32 ^c
Anthracene	220	440 ^c
Benzo(a)anthracene	110	220 ^c
Benzo(a)pyrene	99	198 ^c
Benzo(g,h,i)perylene	31	62 ^c
Total benzofluoranthenes	230	450 ^b
Chrysene	110	220 ^c
Dibenzo(a,h)anthracene	12	24 ^c
Dibenzofuran	15	30 ^c
Fluoranthene	160	320 ^c
Fluorene	23	46 ^c
Indeno(1,2,3-cd)pyrene	34	68 ^c
Naphthalene	99	198 ^b
Phenanthrene	100	200 ^c
Pyrene	1,000	1,400 ^b
Total HPAHs	960	1,920 ^c
Total LPAHs	370	740 ^c
Phthalates (mg/kg OC)		
Bis(2-ethylhexyl)phthalate	47	78 ^b
Butyl benzyl phthalate	4.9	9.8 ^c
Dimethyl phthalate	53	53 ^b
Chlorobenzenes (mg/kg OC)		
1,2,4-Trichlorobenzene	0.81	1.62 ^c
1,2-Dichlorobenzene	2.3	2.3 ^b
1,4-Dichlorobenzene	3.1	6.2 ^c
Hexachlorobenzene	0.38	0.76 ^c

SMS Contaminant of Concern	RAL for Recovery Category 1 Areas ^a (SQS)	RAL for Recovery Category 2 & 3 Areas (2 x SQS or CSL, whichever is lower)
<i>Other SVOCs and COCs, (µg/kg dw except as shown)</i>		
2,4-Dimethylphenol	29	29 ^b
4-Methylphenol	670	670 ^b
Benzoic acid	650	650 ^b
Benzyl alcohol	57	73 ^b
n-Nitrosodiphenylamine, mg/kg OC	11	11 ^b
Pentachlorophenol	360	690 ^b
Phenol	420	840 ^c

PCBs and arsenic are not shown because they are also human health COCs. The site-wide surface sediment RALs for these contaminants are the SQS.

- As noted in Table 12, for Recovery Category 1 areas, the SQS is the RAL to 10 cm and 45 cm for intertidal zones and to 10 cm and 60 cm for subtidal areas.
- Based upon CSL, which is less than 2 x SQS
- Based upon 2 x SQS

9 Evaluation of Alternatives

EPA used the nine criteria required by CERCLA and the NCP to evaluate and select a preferred alternative for the in-waterway portion of the LDW Superfund Site. This section describes the relative performance of each alternative against the nine criteria, noting how the Preferred Alternative, 5C Plus, compares to the other alternatives. The findings and recommendations in EPA's EJ Analysis (Appendix B) were also considered as part of the CERCLA nine criteria analysis.

The nine criteria are in three categories: threshold criteria, primary balancing criteria, and modifying criteria.

Nine Criteria for CERCLA Remedy Selection

Threshold criteria. Each alternative must meet threshold criteria to be eligible for selection.

Overall Protection of Human Health and the Environment — addresses whether each alternative provides adequate protection of human health and the environment and describes how risks posed through each exposure pathway are eliminated, reduced, or controlled through treatment, engineering controls, and/or institutional controls.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) — Section 121(d) of CERCLA and NCP §300.430(f)(1)(ii)(B) requires that remedial actions at CERCLA sites at least attain legally applicable or relevant and appropriate Federal and State requirements, standards, criteria, and limitations which are collectively referred to as ARARs, unless such ARARs are waived under CERCLA Section 121(d)(4).

Primary balancing criteria. Balancing criteria are used to evaluate the major technical, cost, and other trade-offs among the various remedial alternatives.

Long-Term Effectiveness and Permanence — refers to expected residual risk and the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup levels have been met. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of controls.

Reduction of Toxicity, Mobility, or Volume Through Treatment — refers to the anticipated performance of the treatment technologies that may be included as part of a remedy.

Short-Term Effectiveness — addresses the period of time needed to implement the remedy and any adverse impacts to workers, the community, and the environment during construction and operation of the remedy until cleanup levels are achieved (and how they may be mitigated).

Implementability — addresses the technical and administrative feasibility of a remedy from design through construction and operation. Factors such as availability of services and materials, administrative feasibility, and coordination with other governmental entities are also considered.

Cost — addresses the cost of construction and any long term costs to operate and maintain the alternative, in terms of estimated capital, annual operation and maintenance, and total net present worth costs.

Modifying criteria. Modifying Criteria are considered to the extent that information is available during the FS, but will be fully considered only after public comments are received on the Proposed Plan.

State /Tribal acceptance — Assessment of state concerns including (1) The State's position and key concerns related to the Preferred Alternative and other alternatives; and (2) State comments on ARARs or the proposed use of ARAR waivers. Concerns of affected Tribes are also considered.

Community acceptance — This assessment includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose.

9.1 Threshold Criteria

An alternative must meet the two threshold criteria to be eligible for selection as a remedial action.

9.1.1 Overall Protection of Human Health and the Environment

All of the alternatives except Alternative 1 provide a substantial reduction in risk when compared to baseline conditions. They meet the threshold criterion of overall protection of human health and the environment over varying timeframes, providing an adequate level of protection with varying degrees of reliance on natural recovery and institutional controls. The objective of all alternatives is to reach PRGs in the long term; however, alternatives that rely more on natural recovery have greater uncertainty in their projected outcomes, and are predicted to take longer to reach steady state in the waterway; see Figure 15.

Risk at PRGs. Estimated cancer and non-cancer risks for the adult Tribal RME seafood consumption rate after cleanup to the fish and shellfish tissue PRGs for all COCs (which, for some COCs, are based on natural background levels that are higher than calculated protective risk-based levels [RBTCs], see Table 10) are estimated to be 3 in 10,000, above the excess cancer risk thresholds in CERCLA and MTCA (Figure 16), mainly due to the contribution of arsenic and dioxins/furans. At PRG levels, none of the 4 human health COCs meet the MTCA individual carcinogen risk threshold of 1 in 1,000,000, nor do they together meet the MTCA excess cancer risk threshold of 1 in 100,000 for multiple contaminants. Thus, even if all PRGs are achieved, seafood consumption advisories will be needed to provide adequate protectiveness. At PRG levels, the HQ for non-cancer risks is less than the CERCLA and MTCA threshold of 1 (based on PCBs, the COC with the highest HQ).

Risk at model-predicted steady state concentrations. As discussed in Section 7, RI/FS models (the STM, the BCM, and the food-web model) predicted that for all alternatives, LDW sediment and tissue COC concentrations would reach a long-term steady state at concentrations higher than the risk- and non-urban background-based sediment and tissue PRGs. The magnitudes and types of risks to humans, wildlife, and the benthic community from PCBs that would remain in surface sediments after implementation of the cleanup alternatives were estimated through the use of natural recovery modeling (which predicts future sediment contaminant concentrations) and a food-web model (which predicts the movement of contaminants from sediments and water to organisms). Only PCBs could be addressed in the RI/FS food-web model, because RI data did not provide sufficient information to develop predictable relationships between sediment concentrations and tissue concentrations for arsenic and cPAHs, and because of insufficient tissue data for dioxins/furans⁹. The FS estimated an adult Tribal RME excess cancer risk of 2 in 10,000 and non-cancer risk of HQ of 4 for PCBs only at the model-predicted steady state (Figure 17). An important distinction between this and the risks estimated at the PRG levels discussed above is that these FS seafood consumption residual risk estimates have been calculated for PCBs only, whereas the risks estimates at the PRGs discussed above have been calculated for all COCs. Risks for PCBs only at the tissue PRG are estimated to be 5 in 1,000,000 and HQ of less than 1. These estimates of post-cleanup risks represent a reduction in PCB risks of approximately 90% at the model-predicted steady state and 99% at the PRG for the adult Tribal RME seafood consumption rate when compared to baseline risks presented in Section 4.1.

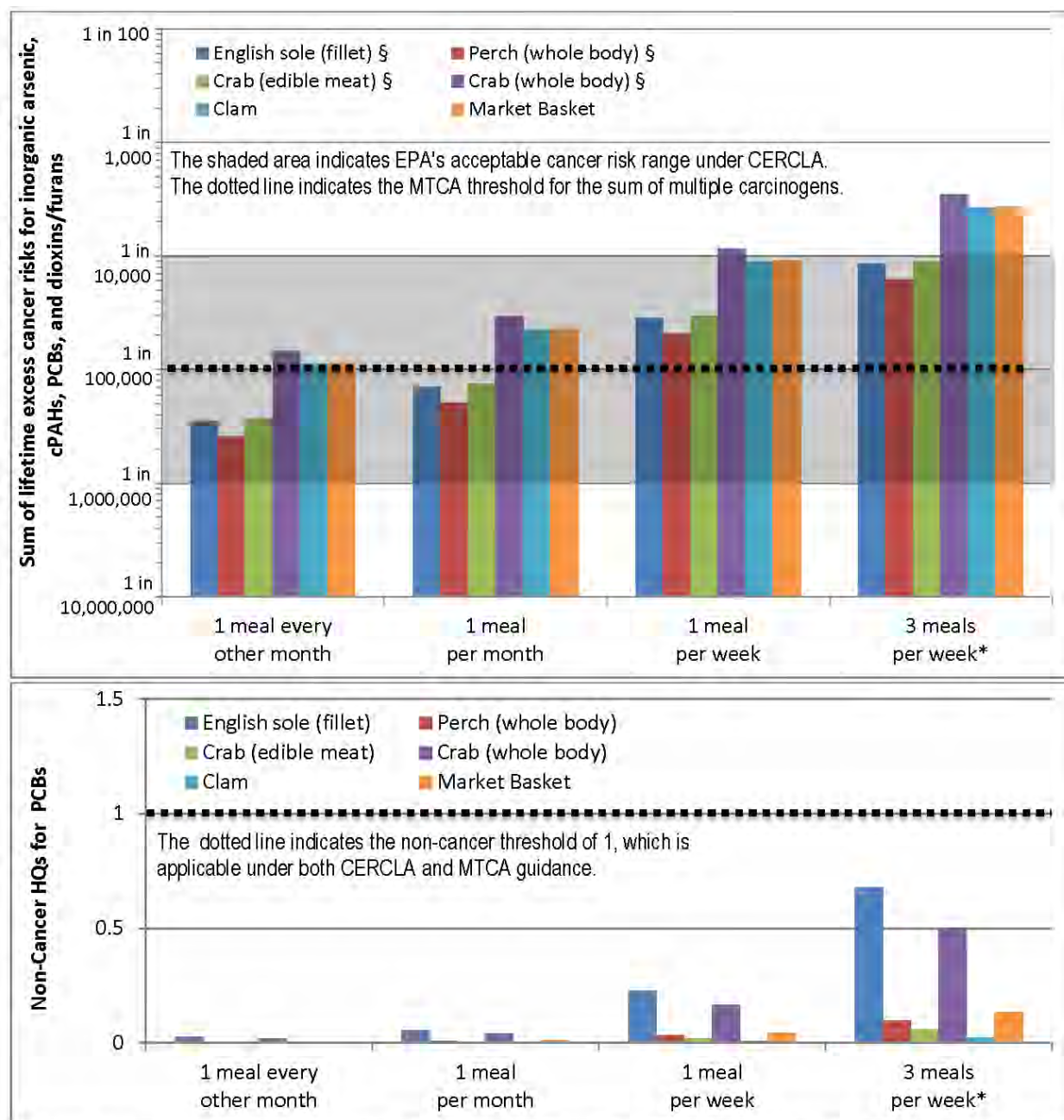
9. Additional studies will be performed during the design phase to collect more data on baseline fish and shellfish COC concentrations and consider whether and by what means arsenic and cPAH tissue concentrations in clams (the only species showing high risks for these COCs) can be reduced.

Risks at a range of seafood consumption rates. Calculating health risks from eating fish or shellfish is critically dependent on how much seafood a person may eat. None of the alternatives would allow for consumption of resident fish and shellfish at the high consumption rates reported for Tribal or Asian Pacific Islander populations, even if they were to meet the PRGs. However, at the proposed PRGs or even some model-projected steady state COC concentrations, people who consume moderate or small amounts of fish and shellfish from the LDW would be protected. Figure 16 shows estimated cancer and noncancer risks at the PRGs at a range of consumption rates for different seafood types. At a consumption rate of one meal every other month, seafood consumption risks for all seafood types except crab whole body are at or below the MTCA excess cancer risk threshold for multiple contaminants of 1 in 100,000. Figure 17 compares PCB risks for the current condition (baseline), at the model-predicted steady state concentrations, and at tissue PRG concentrations.

All alternatives achieve protectiveness for seafood consumption at the RME seafood consumption rates through varying combinations of: 1) reduction of contaminant concentrations through active remediation, 2) MNR, and 3) institutional controls designed to reduce exposure, especially from consumption of resident LDW seafood. EPA's intent is for the selected remedy to achieve risk reduction and protectiveness while minimizing reliance on seafood consumption-related Institutional Controls to the extent practicable. Alternative 1 would not protect human health and the environment. It does not include any active cleanup or institutional controls beyond the current Washington Department of Health (WDOH) health advisory, and those controls implemented at EAAs. It is therefore not discussed further.

The time to achieve a range of risk benchmarks for each alternative is summarized in Figure 15. The RI/FS models predicted that Alternatives 2-6 would reach the lowest model-predicted concentrations and associated risks described above in 16 to 42 years. The amount of time to reach the estimated risk reduction at the PRGs could not be predicted by the model because it predicted that LDW COC concentrations would reach steady state at concentrations higher than the PRGs. However, model predictions are uncertain and necessarily limited to technologies available at the time of the modeling. Long-term model-predicted COC concentrations in the LDW are highly dependent on COC concentrations in incoming Green/Duwamish River water and suspended sediments (in addition to the extent of sediment remediation and the extent to which ongoing contaminant sources within the LDW drainage basin are addressed). As noted previously, all projections used in the Proposed Plan also use current conditions in the Green/Duwamish and do not consider additional sampling currently being conducted by Ecology and King County to better understand Green/Duwamish River inputs to the LDW and potential reductions due to source control in the Green/Duwamish watershed. These projections may be refined during the remedial design phase.

For direct contact with sediments in netfishing, clamming, and beach play areas (RAO 2), all alternatives are predicted to result in risks within the CERCLA risk range and meet the minimum MTCA requirements for risk reduction: 1) a total excess cancer risk of less than 1 in 100,000 cumulatively for all COCs; 2) excess cancer risks for individual COCs less than or equal to 1 in 1,000,000 (except for arsenic), and 3) non-cancer HI less than or equal to 1. The natural recovery model predicts arsenic will reach an excess cancer risk range below 1 in 100,000 but above 1 in 1,000,000. Alternative 2 requires a period of natural recovery to meet these objectives which means higher uncertainty in the modeling projections for these outcomes, whereas Alternatives 3 – 6 meet them after construction.



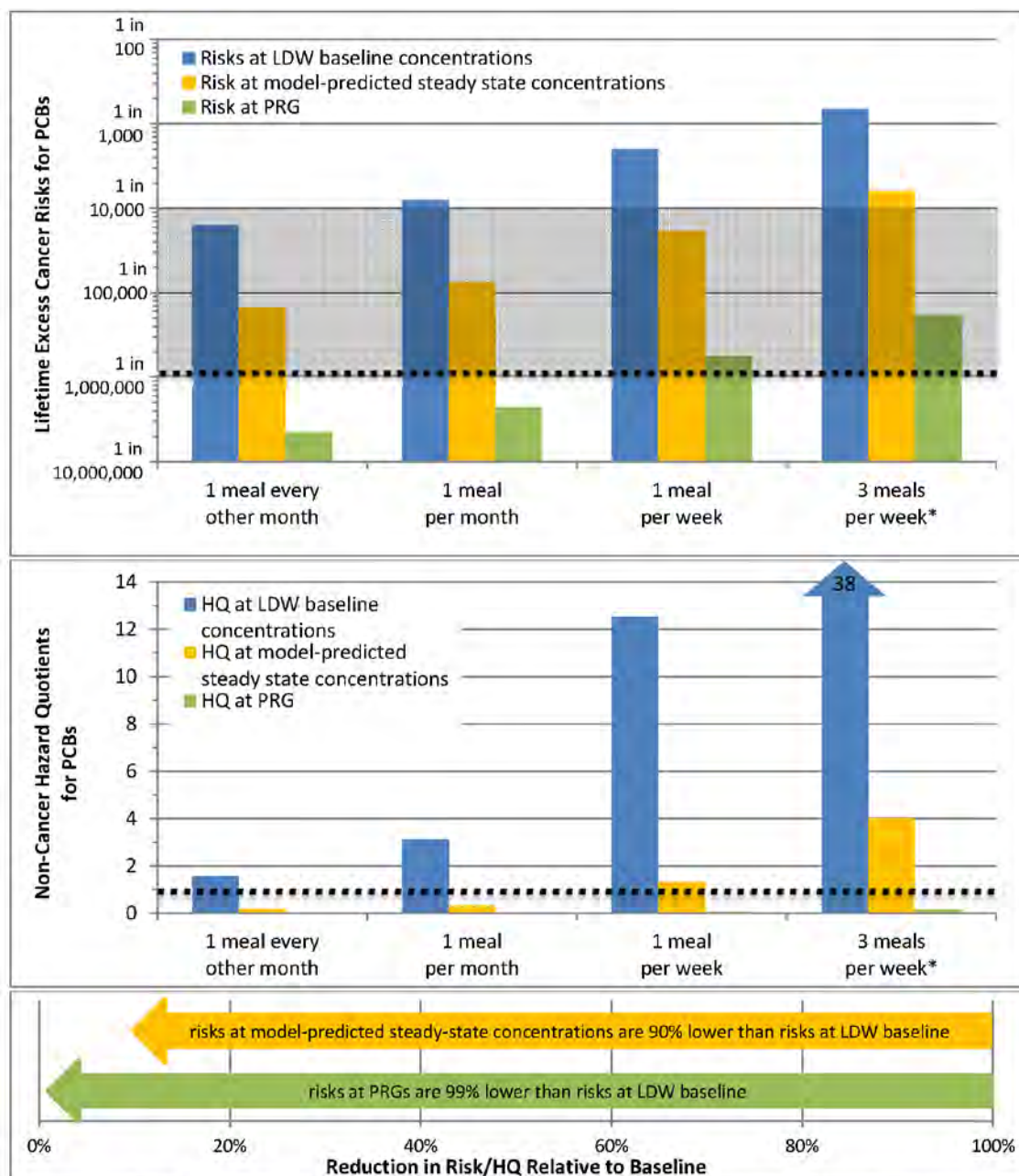
* 3 meals per week is approximately equal to the rate used for the adult tribal RME scenario in the HHRA. One meal is equal to 8 ounces.

Tissue PRGs are presented in Table 10.

Excess cancer risks: Risks were calculated as the sum of excess cancer risks for inorganic arsenic, cPAHs, PCBs, and dioxins/furans, depending on whether target concentrations were available for a given contaminant-species combination. For English sole, perch, and crabs, only PCB and dioxin/furan data were available, as noted by the § in the legend. For calculating market basket consumption, the risks for cPAHs and inorganic arsenic are based only on the consumption of clams because clams account for over 95% of the risk. It should also be noted that a target concentration was not available for dioxins/furans for benthic fish fillet and pelagic fish. Thus, the whole body benthic fish target for dioxins/furans was used as a surrogate for risk calculations.

Non-cancer HQs: HQs for PCBs only are presented because HQs for PCBs were by far the highest.

Figure 16. Excess Cancer Risks and Non-cancer HQs for Seafood Consumption Calculated Using Tissue PRGs



Exposure assumptions: Excess cancer risks and non-cancer hazard quotients (HQs) were calculated assuming market basket consumption using the exposure assumptions for the adult tribal RME seafood consumption scenario. Three meals per week is approximately equal to the consumption rate used for the adult Tribal RME Scenario in the HHRA. A meal is equal to 8 ounces.

Lifetime excess cancer risks and non-cancer HQs shown in this figure are only for total PCBs; the calculation of total risks for the site would include all contaminants. Excess cancer risks and non-cancer HQs were calculated using a) LDW baseline tissue concentrations from the LDW HHRA; b) model-predicted steady-state tissue concentrations, based on predictions of tissue concentrations using the calibrated LDW food web model at a sediment concentration of 40 µg/kg dw and a water concentration of 0.6 ng/L; and c) PRG concentrations, based upon either the higher of either non-urban Puget Sound tissue concentrations or the species-specific tissue RBTCs.

Risk thresholds: In the top portion of the figure showing the excess cancer risks, the shaded area indicates EPA's acceptable excess cancer risk range under CERCLA. The dotted line indicates the MTCA threshold for individual carcinogens. In the lower portion of the figure showing non-cancer HQs, the dotted line indicates the CERCLA and MTCA non-cancer threshold.

Figure 17. Comparison of Total PCB Excess Cancer Risks and Non-cancer HQs for Seafood Consumption Calculated using LDW Baseline, Model-predicted, and PRG Concentrations

All alternatives are predicted to achieve the SQS, the PRGs for protection of benthic invertebrates (RAO 3), in 6 to 20 years. Alternatives 2 to 4 and 5C Plus rely on MNR To SQS to reduce COC concentrations to the SQS, with more reliance (and greater uncertainty) in lower-numbered alternatives. Alternative 5C Plus differs from Alternatives 2 – 4 in that it relies on MNR To SQS to reduce COC concentrations only for non-human health COCs.

All alternatives are predicted to achieve the RAO 4 PRG for protection of wildlife (river otters) shortly following construction. Alternatives 2 and 3 are predicted to require a short period of natural recovery to achieve the PRG.

It is EPA's expectation that after implementation of the actions anticipated in Alternatives 2 – 6, along with source control activities for which Ecology has the lead, levels in the sediment, surface water, and fish and shellfish tissue will be protective of all anticipated uses, with the addition of fish and shellfish consumption advisories.

9.1.2 Compliance with ARARs

Key ARARs for the cleanup alternatives are shown in Table 15. The most important ARARs are MTCA and Federal and State water quality standards and criteria (both of which include the SMS). MTCA requires final cleanup levels to be set at natural background concentrations when MTCA RBTCs¹⁰ are below natural background. The objective of each of the alternatives is to meet ARARs throughout the in-waterway portion of the LDW. However, as discussed above, the RI/FS models indicate that the long-term COC sediment concentrations achievable in the in-waterway portion of the LDW will be limited by the extent to which all ongoing sources, including COCs entering the waterway from the upstream Green/Duwamish River system and remaining lateral sources, can be controlled in this urban environment. Specifically, the RI/FS models indicate that while remediation is predicted to result in significant improvements in sediment and tissue COC concentrations, it is not predicted to achieve sediment PRGs based on MTCA ARARs for PCBs, dioxins/furans (for RAO 1), and arsenic (for RAO 2); and fish and shellfish tissue PRGs for PCBs, arsenic, cPAHs and dioxins/furans. In addition, current concentrations of PCBs in the upstream Green/Duwamish River are higher than Federal Ambient Water Quality Criteria (AWQC) and the RI/FS model projections assumed no future decrease in the current upstream concentration.

Based on the uncertainties in model projections, and particularly in estimates of COC concentrations in incoming sediments from the Green/Duwamish River, each of the alternatives can potentially meet ARARs in spite of RI/FS model projections suggesting otherwise. As discussed under Long-Term Effectiveness and Permanence, uncertainty in achieving some ARARs increases with increasing reliance on natural recovery because natural recovery outcomes are generally more uncertain than active remediation. The objective of the Preferred Alternative and Ecology's source control program is to reduce COC concentrations to natural background or risk-based PRGs. EPA expects to monitor progress of these actions, including measuring long-term COC concentrations in sediment, fish and shellfish tissue, and

10. MTCA requires a total excess cancer risk of less than or equal to 1 in 100,000 and excess cancer risks for individual COCs less than or equal to 1 in 1,000,000 and a non-cancer HQ or HI of less than 1.

surface water. EPA will evaluate the results the actions have achieved over time in terms of ARAR compliance as well as protectiveness.

PRGs for the protection of benthic invertebrates (RAO 3) are based on the SMS. Over time, all of the alternatives are predicted to reduce contaminant concentrations to the SQS. However, Alternative 2 may not do so within 10 years following active remediation (based on model prediction uncertainty), as required by the SMS to the extent practicable.

To protect threatened species under the ESA, including Puget Sound Chinook salmon, environmental windows (also known as “fish windows”) have been established for the LDW. These are designated periods (generally from October through February), when effects of in-water construction on spawning, rearing, and habitat are minimized, largely because juvenile salmon are not migrating through the waterway during that period. EPA will consult with the National Marine Fisheries Service to ensure protection of threatened salmon species.

If long-term monitoring data and trends indicate that some ARARs-based cleanup levels selected in the ROD after public comment on this Proposed Plan are not met, a waiver of these ARARs could be considered by EPA in a future decision document (ROD Amendment or Explanation of Significant Differences [ESD]). For example, if monitoring shows such levels have reached the SQS but have not reached the surface water PRGs or human health and natural background-based sediment PRGs, and EPA were to conclude that no further action would practicably improve these levels, the ARARs that are not met would be eligible for a technical impracticability (TI) waiver. Because EPA cannot know whether and to what extent ARARs for these various levels for different COCs will be achieved, consideration of the potential for such a waiver prior to the collection of monitoring data sufficient to inform any TI waiver decision(s) is neither warranted nor justifiable.

The ARARs discussed in this Proposed Plan apply only to EPA's in-waterway cleanup and should not be construed to govern actions under other laws.

Table 15. Key ARARs for the LDW

Topic	Standard or Requirement	Regulatory Citation		Comment
		Federal	State	
Hazardous Substances	Requirements for all affected media		Model Toxics Control Act (Chapter 70.105D RCW, WAC 173-340)	All substantive MTCA requirements are ARARs to the extent they are more stringent than CERCLA requirements. Key more stringent requirements include acceptable excess cancer risk standards, the default to natural background for final remedies where risk-based cleanup levels are below background, an institutional control (IC) mandate and limits on IC usage.
Sediment Quality	Sediment quality standards; cleanup screening levels		Sediment Management Standards (WAC 173-204)	The SMS are MTCA rules and Water Quality Standards under CWA and are an ARAR under CERCLA. Numerical standards for the protection of benthic marine invertebrates.
Surface Water Quality	Surface Water Quality Standards	Ambient Water Quality Criteria established under Section 304(a) of the Clean Water Act (33 U.S.C. 1251 et seq) http://www.epa.gov/ost/criteria/wqctable/ and National Toxics Rule (40 CFR 131.36)	Surface Water Quality Standards (RCW 90-48; WAC 173-201A)	State surface water quality standards apply where the State has adopted, and EPA has approved, Water Quality Standards that are more stringent than Federal recommended Water Quality Criteria established under Section 304(a) of the Clean Water Act. The National Toxics Rule applies for human health criteria in the State of Washington. Both chronic and acute standards, and marine and freshwater are used as appropriate.
Land Disposal of Waste	Disposal of materials containing PCBs	Toxic Substances Control Act (15 U.S.C. 2605; 40 CFR Part 761)		
	Hazardous waste	Resource Conservation and Recovery Act Land Disposal Restrictions (42 U.S.C. 7401-7642; 40 CFR 268)	Dangerous Waste Regulations Land Disposal Restrictions (RCW 70.105; WAC 173-303, -140, -141)	

Topic	Standard or Requirement	Regulatory Citation		Comment
		Federal	State	
Dredge/Fill and Other In-water Construction Work	Discharge of dredged/fill material into navigable waters or wetlands	Clean Water Act (33 U.S.C. 401 et seq; 33 U.S.C. 141; 33 U.S.C. 1251-1316; 40 CFR 230, 231, 404; 33 CFR 320-330) Rivers and Harbors Act (33 U.S.C. 401 et seq.	Hydraulic Code Rules (RCW 75.20; WAC 220-110)	For in-water dredging, filling or other construction.
	Open-water disposal of dredged sediments	Marine Protection, Research and Sanctuaries Act (33 U.S.C. 1401-1445) 40 CFR 227	Open Water Disposal Sites (RCW 79.90; WAC 332-30-166)	
Solid Waste Disposal	Requirements for solid waste handling management and disposal	Solid Waste Disposal Act (42 U.S.C. 215103259-6901-6991; 40 CFR 257, -258)	Solid Waste Handling Standards (RCW 70.95; WAC 173-350)	
Discharge to Surface Water	Point source standards for new discharges to surface water	National Pollutant Discharge Elimination System (40 CFR 122, 125)	Discharge Permit Program (RCW 90.48; WAC 173-216, -222)	
Habitat for Fish, Plants, or Birds	Evaluate and mitigate habitat impacts	Clean Water Act (Section 404 (b)(1)); U.S. Fish and Wildlife Mitigation Policy (44 FR 7644); U.S. Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq); Migratory Bird Treaty Act (16 U.S.C. 703-712)		
Critical Habitat for Endangered Species	Conserve endangered or threatened species, consult with species listing agencies	Endangered Species Act of 1973 (16 U.S.C. 1531 et seq; 50 CFR 200, -402); Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1801-1884)	Endangered, threatened, and sensitive wildlife species classification (WAC 232-12-297)	Consult and obtain Biological Opinions.

9.2 Balancing Criteria

The balancing criteria evaluate the major trade-offs among alternatives.

9.2.1 *Long-Term Effectiveness and Permanence*

Although all alternatives are predicted by RI/FS models to result in the same long-term risks after cleanup, as discussed in Section 9.1.1, alternatives that rely less on natural recovery have less uncertainty in long-term model projections, though this uncertainty can be reduced to some extent through monitoring and adaptive management, as is required for MNR To SQS. The higher-numbered alternatives have increasingly larger cleanup footprints, and rely progressively less on natural recovery to achieve cleanup objectives.

Alternatives that remove more surface and subsurface contamination through dredging provide the most permanence, followed by those that effectively isolate it through engineered caps. Dredged contaminated sediment is permanently removed from the LDW, and capped sediment is securely segregated from contact with receptors. Caps typically maintain their effectiveness as long as they are monitored and maintained. Contamination remaining in subsurface sediments and not isolated by a cap would contribute to future risks if they are brought to the surface of the waterway through natural or man-made events such as earthquakes, vessel scour, or construction activities. ENR and MNR are not designed to isolate contamination, so alternatives that use these in areas with lower contaminant concentrations provide better long-term effectiveness than those that use them in areas with higher concentrations. The potential for increased surface COC concentrations through disturbance of subsurface sediments is not accounted for in the BCM; thus the BCM may underestimate the long-term COC concentrations.

All alternatives require that RALs be met in the top 60 cm in Recovery Category 1 areas to address the potential for exposure of subsurface contamination in the areas where disturbance is most likely. All alternatives also require that direct contact (RAO 2) RALs for arsenic, cPAHs, and dioxins/furans be met in the top 45 cm to protect people clamming or digging on the beach. However, it is not possible to anticipate every location where disturbance might occur. Alternative 5C Plus adds PCB RALs of 65 mg/kg OC in the top 45 cm in intertidal sediments to reduce the potential for exposure of subsurface contamination through digging on the beach, and 195 mg/kg OC in the top 60 cm of subtidal sediments to reduce the influence of activities such as vessel scour¹¹. Only alternatives 5R, 6C, and 6R would remove more subsurface contamination in all potentially erosive areas than 5C Plus.

Monitoring of sediment, fish and shellfish tissue, and surface water will be required under all remedial alternatives. Areas that are dredged require the least long-term sediment monitoring. Capping and ENR require more sediment monitoring to ensure surface concentrations remain low. MNR requires the most

11. The FS Supplement evaluated several options for subsurface RALs. EPA selected the 5C Plus RALs listed here because other options removed less subsurface contamination with an associated increased risk of exposure, or removed more subsurface contamination at a higher cost that was disproportional to the increase in long-term effectiveness and permanence. The 60 cm PCB RAL of 195 mg/kg OC applies to potential vessel scour depths in Recovery Categories 2 and 3; see Section 10.2. In the intertidal zone for Alternative 5C Plus, all intertidal RALs must be met to 45 cm depth in Recovery Category 1 areas instead of the top 60 cm for FS alternatives. This is because 45 cm was deemed by EPA to be sufficiently protective.

monitoring to determine if surface sediment COC concentrations are reducing over time as projected by the natural recovery model. Alternatives with a larger area of ENR and MNR require more long-term monitoring and maintenance to ensure their effectiveness.

All alternatives rely on institutional controls (ICs) to reduce exposure to contamination remaining after remediation. Alternatives that rely more on removal of contamination from the waterway through dredging rely less on institutional controls. Resident seafood consumption advisories are included for all alternatives; these are informational devices that have historically had limited effectiveness according to published studies and in EPA's experience. As noted in EPA's EJ Analysis, the community and affected Tribes have identified several concerns about the use of institutional controls, including the burden placed on Tribes exercising their treaty rights and on other people who fish in the LDW. To address this concern to the extent practicable, the EJ Analysis recommends that the affected community and Tribes with treaty rights be directly involved in advising EPA on institutional controls development, and that enhanced outreach and education programs be developed for all alternatives. These outreach efforts would include periodic seafood consumption surveys to identify what species are being eaten by whom, which may serve as a basis for a more targeted education and outreach program.

Other ICs such as environmental covenants or restricted navigation areas would be employed to protect caps. Institutional controls in either of these forms regarding ship/vessel use and/or anchoring restrictions would be used under all alternatives to reduce the possibility of releases of COCs in underlying sediments. However, these restrictions may be unreliable in much of this heavily used waterway.

Alternative 2R-CAD has the least long-term effectiveness and permanence because it leaves the largest amount of contamination in place and requires long-term maintenance of a CAD site in the LDW. Alternatives that leave less subsurface contamination in the waterway are progressively more effective for this criterion. Alternatives 5C Plus, 5R, 6C, and 6R were the most effective, while other alternatives are comparatively less effective based on the amount of subsurface contamination left behind.

9.2.2 *Reduction of Toxicity, Mobility, or Volume through Treatment*

Alternative 5R-Treatment utilizes ex situ soil washing to reduce volumes which would be disposed in a landfill. The FS assumes that 50% of the ENR area will include in situ treatment (e.g., use of activated carbon or other amendments) to reduce toxicity and bioavailability. Thus, the reliance on in situ treatment is proportionate to the amount of ENR. Alternative 6C (with 101 total ENR acres) has the greatest reliance on ENR (with potential in situ treatment); while 4C (with 16 total ENR acres), and 3C (with 10 total ENR acres) would utilize this technology significantly less. Alternative 5C Plus is in the mid-range, with 48 total ENR acres. Both in situ and ex situ treatments will require verification and bench or pilot scale testing during the remedial design phase.

The NCP directs that this criterion also discuss the presence of principal threat waste (PTW) and any treatment considered for it. PTW is defined in EPA guidance as source material that is highly toxic or highly mobile, such as pools of non-aqueous phase liquids, and that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. No direct evidence of any significant amounts of non-aqueous phase liquids has been found in LDW

sediment. EPA has determined that contaminated sediment to be addressed in the LDW by this Proposed Plan generally is low-level threat waste; however, treatment was included for some alternatives.

Based on these considerations, Alternative 5R-T would provide the most treatment of contaminated sediment. The “C” alternatives, including 5C Plus, also provide treatment, the degree of which is based on the amount of area proposed for ENR/in situ treatment.

Alternatives with more dredging and capping provide greater reduction in toxicity and volume of contaminants in the LDW, although they do not do so by treatment. Dredging, while not considered treatment under CERCLA, does substantially reduce the toxicity and mobility of contaminants in the waterway by removing contaminants and placing them in a landfill where they cannot be taken up by fish and shellfish and be consumed by humans and wildlife. Capping physically and chemically contains contaminants beneath the cap, thereby reducing mobility and exposure potential.

9.2.3 *Short-Term Effectiveness*

Short-term impacts associated with the cleanup alternatives may include traffic, noise, air emissions, habitat disturbance, and elevated fish tissue concentrations during implementation of the cleanup. Local transportation impacts (traffic, noise, air pollution) from implementation of these alternatives are proportional to the amount of dredging or the amount of capping, fill, and ENR materials that have to be transported. Among the technologies evaluated, dredging has the highest potential for short-term impacts because it takes longer to implement than other technologies, requires transportation of sediments to a landfill, and creates more disturbance of contaminated subsurface sediments. Short-term impacts identified in the RI/FS will be evaluated further during remedial design and efforts will be made to mitigate them and otherwise enhance the environmental benefits of the remedy consistent with CERCLA, the NCP, and EPA Region 10's Green Remediation policy. For example, impacts due to construction will be reduced to the extent possible using best management practices and performing in-waterway work when threatened juvenile salmon are not migrating through the waterway. Dredging often leaves residual contamination behind; this will be managed by placing a thin layer of clean sand in areas where RALs are not met after dredging.

EPA's EJ Analysis (Section 9.3.3 and Appendix B) emphasizes the need to reduce risks as quickly as possible to minimize impacts to the community and Tribes during construction. As recommended by the EJ Analysis, EPA plans to work with the community and consult with Tribal representatives to reduce impacts on community and Tribal resources during implementation of the remedy.

Figure 15 describes the construction time and predicted time for each alternative to achieve modeled risk reduction benchmarks associated with each RAO. These estimates are derived from the time to complete construction and the natural recovery estimates predicted by the BCM. As discussed in Section 9.1.1, it was not possible to predict the time to achieve all PRGs. Generally, the potential for short-term impacts increases as the construction timeframe (based on the area and volume to be actively remediated) increases. Lower-numbered alternatives, with higher RALs, can be implemented faster than higher-numbered alternatives with lower RALs. However, lower-numbered alternatives also rely more on natural recovery and therefore have more uncertainty in their long-term effectiveness.

Alternatives 5C and 5C Plus provide the best short-term effectiveness by providing the best balance of a relatively short construction time (7 years) along with a relatively short projected time to reach all cleanup objectives (17 years). While Alternatives 2R, 3C, 3R, and 4C have shorter construction times, (3 – 6 years), they are projected to take longer to reach all cleanup objectives (18 – 24 years) because of the extended time needed for natural recovery. Alternative 6C is projected to take 16 years to reach all cleanup objectives, but has a much longer construction time of 16 years. Alternative 6R has a long construction time and time to reach cleanup objectives of 42 years.

9.2.4 Implementability

Technologies used in these cleanup alternatives have been implemented successfully at other projects in the Puget Sound region. Alternatives with longer construction times and lower RALs have the potential for more delays or difficulties. The use of in situ treatment technologies in association with ENR is a relatively new technology in the Puget Sound region and will require pilot testing before full implementation. The soil washing component of Alternative 5R-Treatment has potential technical and administrative challenges associated with locating and permitting an upland soil washing facility, and potentially with reuse or disposal of treated material. Treatability studies would be required to verify the suitability of soil washing as a viable treatment technology.

Alternatives with higher RALs and larger MNR footprints have a higher potential for requiring additional actions if MNR To SQS does not reduce contaminant concentrations as expected. This may cause an additional administrative burden to determine specific additional actions, and to provide oversight during implementation of such actions. Alternative 2R-CAD has a potentially significant administrative challenge related to locating, using, and maintaining one or more CAD facilities.

Institutional controls are an expected requirement of all remedial alternatives to manage human health risks from resident seafood consumption. The primary control mechanisms are seafood consumption advisories, public education and outreach, and environmental covenants pursuant to the Washington Uniform Environmental Covenants Act. This Act extends statutory enforcement rights to both EPA and Ecology. However, these controls can be difficult to monitor. Seafood consumption advisories are not enforceable, and have limited effectiveness. For these reasons, alternatives that rely less on institutional controls are more readily implementable.

Alternatives 5R, 5R-T, 6R, and 2R-CAD have the greatest potential implementability challenges due to the long construction timeframes for 5R and 6R and the difficulties associated with building and operating a soil washing technology (5R-T) or a CAD site (2R-CAD). Alternatives 4C, 4R, 5C, and 5C Plus are all similarly highly implementable because they rely on technologies that have been proven effective at other cleanups and are administratively feasible, and their large actively remediated areas equate to a low probability for triggering additional actions in the future.

9.2.5 Cost

Thirty-year net-present value costs for each alternative, calculated with a 2.3% discount rate, are provided in Table 12. The estimated cost of \$305 million for Alternative 5C Plus falls within the low end of the cost range for the FS alternatives (\$200 million – \$810 million).

9.3 Modifying Criteria

Modifying Criteria are considered to the extent that information is available during the FS, but will be fully considered only after public comment is received on the Proposed Plan. The findings and recommendations in EPA's EJ Analysis (Appendix B) were also considered as part of the two modifying criteria.

9.3.1 *Community Acceptance*

Community acceptance of the preferred remedy will be assessed in the ROD based on public comments received on this Proposed Plan. However, EPA and Ecology have provided opportunities for comment throughout the RI/FS process, including informal public comment periods on the RI and FS Reports. More than 300 letters were received from individuals, businesses, interest groups, Tribes, and government agencies during a 2010 informal public comment period on the FS. Concerns raised during the FS comment period included:

- The importance of reducing pollution entering the LDW to avoid new contamination and to help keep cleaned-up areas from becoming contaminated again (i.e., source control).
- Concern about the cost of the cleanup and who will pay for it.
- Concern that cleanup of the LDW is not anticipated to achieve contaminant concentrations that would allow people to eat an unrestricted amount of resident fish and shellfish.
- A desire for flexibility in cleanup decision-making.
- A request for an environmental justice analysis to identify vulnerable communities affected by the cleanup, and how these communities will be affected by each of the alternatives.

9.3.2 *State/Tribal Acceptance*

EPA and Ecology co-issued the RI/FS Consent Order for the LDW, and oversaw its implementation together. Ecology supports the Preferred Alternative, and EPA supports Ecology's Source Control Strategy (Appendix A). Tribal acceptance will be determined following government-to-government consultation with The Muckleshoot and Suquamish Tribes, consistent with EPA policy.

Community and Tribal concerns were also considered during the development of EPA's EJ analysis, discussed below. EPA will evaluate State, Tribal, and community acceptance of the Preferred Alternative following the public comment period on this Proposed Plan.

9.3.3 *Environmental Justice Analysis*

EPA's EJ Analysis examined the impacts of the Preferred Alternative and other FS alternatives on those who subsist on, work in, and play in the LDW. The EJ analysis considered the potential for disproportionate adverse impacts from the FS alternatives and the Preferred Alternative on the community and affected Tribes, particularly those who consume resident fish and shellfish or have contact with LDW sediments. In the EJ analysis, the cleanup alternatives were compared qualitatively for their long-term and

short-term residual cancer and non-cancer risks; the time to achieve human health targets; the certainty of the methods used to conduct the cleanup; and the dependence upon institutional controls which have implications for environmental justice concerns on behalf of the affected community. EPA's EJ Analysis determined that the Preferred Alternative balances the need to reduce human health risks quickly while providing certainty that the methods used in cleanup will be effective and will remain effective in the future. It also recommended additional measures to mitigate adverse disproportionate impacts. The EJ Analysis lists the following recommendations:

1. Emphasize reduction of greatest human health risks as soon as possible while ensuring that cleanup methods used will be effective and last over the long-term;
2. Form and fund an advisory group with support for local community outreach experts to meaningfully involve the community in developing the most appropriate mitigations for exposure from eating resident seafood at the Site;
3. Continue support for Tribal consultation, participation, and early involvement;
4. Support a local fisher consumption survey specific to the LDW (to find out where, when, and what they are fishing for to provide critical information in the development of institutional controls, offsets, and enhanced education)¹²;
5. Establish a mechanism to provide offsets in the event of higher short-term concentrations in fish tissue in the LDW: fish trading may be the most straightforward, but there would be cost savings potentially through a sustainable aquaculture or alternative transportation method; offsets for Tribes to be developed in consultation;
6. Use green remediation techniques, such as technologies that reduce air impacts, with any cleanup alternative chosen.

9.4 Summary of CERCLA Evaluation

Alternative 1 is not protective and cannot achieve ARARs; it is eliminated from further consideration. Alternatives 2 to 6 rely on MNR to varying degrees. They are protective and are projected by RI/FS models to provide substantial risk reduction. All Alternatives also rely on seafood consumption advisories as institutional controls to limit seafood consumption to protect human health. These Alternatives can also meet ARARs, although whether the Preferred Alternative, in conjunction with source control, can achieve all human health PRGs is uncertain.

Alternative 2R-CAD provides the least long-term effectiveness and permanence because it requires long-term maintenance of a CAD site within the waterway and leaves the most subsurface contamination in place. The removal-emphasis alternatives, 2R through 6R, leave progressively less subsurface contamination in place that could be exposed by vessel scour or earthquakes, and require fewer use restrictions and less maintenance. They also have comparatively longer construction times and are more

12. EPA has already started to implement this recommendation as part of the RI/FS.

expensive than combined (“C”) alternatives with similar RALs. The combined alternatives, 3C through 6C, and especially the lower-numbered combined alternatives, have more area managed by ENR and MNR (and thus more subsurface contamination left in place), and have greater monitoring and maintenance requirements. Alternative 5C Plus adds to Alternative 5C an increased emphasis on removal of high levels of PCBs in shallow subsurface sediments, providing greater permanence. Under 5C Plus, MNR is allowed in areas with moderate to low concentrations of non-human health COCs to allow for a moderate construction time and to shorten the overall time to achieve cleanup objectives. While Alternatives 5R, 6C and 6R remove more subsurface contamination, they disrupt the waterway over a much longer construction period, and at a considerably higher cost than 5C Plus (Table 13).

10 EPA's Preferred Alternative

After consideration of the remedial alternatives presented in the 2012 Feasibility Study, the 2012 FS Supplement, and in consultation with the State of Washington and Muckleshoot and Suquamish Tribes, EPA proposes Alternative 5C Plus (Scenario 5a in the FS Supplement), as the Preferred Alternative for the in-waterway portion of the Site.

The Preferred Alternative may change in response to public comments or if new information becomes available that would influence remedy selection. Any changes (below the threshold requiring another public comment period) will be identified in the ROD and discussed further in the Responsiveness Summary.

Section 10.1 provides a brief description of the Preferred Alternative, and Section 10.2 provides details about how RALs, PRGs, and Recovery Categories were used to identify the areas in which specific technologies were applied, and how they will be used to refine these areas during remedial design. Section 10.3 provides EPA's rationale for selecting the Preferred Alternative.

10.1 Description of the Preferred Alternative

Figure 18 shows the areas of contaminated sediments that would be remediated under Alternative 5C Plus. Figure 19 and Figure 20 describe how remedial technologies were applied to the RI/FS sediment data to develop the map in Figure 18. The PRGs EPA is proposing to select as cleanup levels in the ROD are described in Section 7. The RALs for the Preferred Alternative are shown in Table 12 and Table 14.

The Preferred Alternative addresses all areas where contaminant concentrations exceed the PRGs through a combination of active cleanup technologies, monitored natural recovery, and institutional controls. It consists of the following elements:

Apply active cleanup technologies in a total of 156 acres:

- Dredge or partial-dredge and cap approximately 84 acres of more highly contaminated sediments (see Section 10.2) where it is necessary to maintain water depth for human use or to maintain habitat. Approximately 790,000 cubic yards of dredged materials will be transported via truck or rail for disposal at a permitted upland off-site landfill facility.¹³ If sediment contamination is 4 feet thick¹⁴ or less in an area selected for dredging, all contaminated sediments will be dredged. If contamination is greater than 4 feet thick, sediments will be partially dredged and capped.
- Place engineered sediment caps on approximately 24 acres of more highly contaminated sediments where there is sufficient water depth for a cap.

13. Some clean materials may be dredged as part of the cleanup; for example, in order to maintain appropriate sideslopes at the edge of a dredge cut. Clean sediments that pass the Dredged Materials Management Program's criteria may be disposed at an open-water disposal site.

14. The 4-ft thickness for dredging is based on an FS evaluation that it is cost-effective to dredge all contaminated sediments when the contamination thickness is 4 ft or less, but at a thickness of greater than 4 ft, it is more cost-effective to partially dredge the contaminated sediments then construct a cap to isolate the remaining contamination.

- Place a thin layer (6 to 9 inches) of clean material (referred to as enhanced natural recovery [ENR]) in approximately 49 acres of sediments in areas that meet the criteria for ENR (Figure 19 and Figure 20). Suitable habitat materials will be used in habitat areas. ENR may include in situ treatment using activated carbon or other amendments, and engineered designs for sediment stability. The effectiveness and potential impacts of using in situ treatment or amendment technologies, as well as the areas best suited for these technologies, will be evaluated in pilot studies performed during remedial design.
- Maintain sufficient water depth for human use and habitat function through application of the following criteria:
 - All areas above -10 ft MLLW are considered habitat areas, and will be maintained at their current elevation and backfilled or capped with suitable habitat materials.
 - The Federal navigation channel and berthing areas will be maintained at or below their current operating depths. In order to avoid damage to a cap or ENR layer during maintenance dredging, the top of any ENR layer will be at least 2 ft and the top of any cap will be at least 3 ft below the authorized Federal navigation channel depth (2 ft below the operating depth for berthing areas).
 - Shoaled areas in the navigation channel (where the bottom elevation is currently shallower than the navigation depth) will be dredged if COCs in the top 2 ft of sediments exceed the RALs.
- Remove debris and pilings throughout the LDW as necessary or as required by EPA to implement the remedy, and dispose of materials at a permitted off-site facility.

Implement monitored natural recovery (MNR) in approximately 256 acres of sediments where surface sediment contaminant concentrations are predicted to be reduced over time through deposition of cleaner sediments from upstream. MNR will apply to those areas that are not subject to active remediation, using either MNR To SQS or MNR Below SQS, as described below. The STM and BCM, supported by data collected during the RI/FS, were used to estimate the amount of time required to reduce COC concentrations in sediments through natural recovery. For all areas where MNR is applied, long-term monitoring of surface sediments (top 10 cm) will be implemented to evaluate whether the PRGs for protection of benthic invertebrates (the SQS) are being achieved in a reasonable timeframe or are not met within 10 years after remediation.

- In MNR areas, more intensive long-term monitoring will be conducted in areas with sediment COC concentrations that are less than sediment RALs but greater than the SQS (referred to as MNR To SQS).
- Should MNR not achieve SQS or progress sufficiently toward achieving it in 10 years, additional cleanup (e.g., dredging, capping, or ENR, following the decision criteria in Figure 19 and Figure 20) will be required.
- Less intensive monitoring will be conducted in areas with sediment COC concentrations that are below the SQS but above the sediment PRGs for protection of human health (referred to as MNR

Below SQS). If these PRGs are not achieved, additional cleanup actions will be considered in a future decision document.

- **Sample the entire LDW (441 acres) as part of baseline, construction, post-construction, and long-term monitoring** – Conduct sampling and analysis to establish post-EAA cleanup baseline conditions during remedial design, including surface and subsurface sediments, surface water, and fish and shellfish tissue.
 - Remedial design sampling data will be used to modify the cleanup footprint shown in Figure 18. Sampling data will be compared to sediment RALs for intertidal and subtidal areas in Figure 21 and Figure 22, and as described in Section 10.2.
 - Remedial design data will also be analyzed to evaluate the effectiveness of EAA cleanups and natural recovery that have occurred since the RI/FS sampling and to serve as a baseline for comparison to post-cleanup data.
 - If any sediment COC concentration at any location exceeds its contaminant-specific RAL for a specified interval, then active remediation (dredging, capping, or ENR, or a combination thereof) will be required.
 - The type of remedial technology to be applied will be consistent with remedial technology applications shown in Figure 19 and Figure 20. Area-specific technologies will be selected for areas with structural or access limitations (e.g., under piers).
- Conduct research during remedial design to further assess the relationship between arsenic and cPAH concentrations in sediment and clam tissue, and to assess whether remedial action can reduce clam tissue concentrations to the PRGs. EPA anticipates that source control and the proposed remedial actions in the Preferred Alternative will lower clam inorganic arsenic and cPAH concentrations; however, the amount of reduction is unknown. If EPA determines, based on these studies, that additional remedial action is needed to achieve clam tissue cleanup levels, this decision will be addressed in a future decision document.
- Conduct environmental compliance monitoring during construction, as well as monitoring during and after construction, to ensure compliance with construction standards and project design documents.
- Conduct post-construction and long-term monitoring for sediments, surface water, fish and shellfish tissue, and other media as determined during remedial design to ensure protectiveness of human health and the environment and to protect the integrity of the remedial actions and aid in the evaluation of source control effectiveness. A subset of baseline and long-term monitoring samples will be analyzed for other contaminants not selected as COCs but identified in the HHRA as posing an excess cancer risk of greater than 1 in 1,000,000 or non cancer HQ of 1 at the adult Tribal RME, to assess their reduction over time.

Provide institutional controls (ICs) for the entire waterway to reduce exposure to contaminants, ensure remedy protectiveness, and protect the integrity of the remedy, while minimizing reliance on ICs, particularly seafood consumption-related ICs, to the extent practicable. ICs will include proprietary

controls in the form of environmental covenants pursuant to the Washington Uniform Environmental Covenants Act (UECA), and informational devices including fish and shellfish consumption advisories to reduce human exposure from ingestion of contaminated resident seafood. EPA will rely on the existing WDOH fish and shellfish consumption advisories (see Seafood Advisories for the Lower Duwamish Waterway, page 14) and may implement additional advisories or other measure to provide additional protectiveness. Outreach and education programs will also be used to enhance seafood consumption advisories.

Cost of the Preferred Alternative – The total estimated capital costs (net present value) to construct the Preferred Alternative are \$258 million, and the total estimated operation, maintenance, and monitoring costs (net present value) are approximately \$47 million for a total of \$305 million (excluding the cost of source control, which is not part of the in-waterway portion of the Site, and the cost of the Early Actions). The Preferred Alternative is estimated to take 7 years to construct.

Role of EAAs in the Preferred Alternative – The remedial technologies described above for the Preferred Alternative apply to 412 acres of the LDW. An additional 29 acres of the most contaminated sediments in the LDW have been or will be addressed by cleanups in Early Action Areas (described in Sections 2.1 and 5.1). EPA has reviewed the EAA cleanup actions subject to implementation under EPA Consent Orders (Slip 4, Terminal 117, and Boeing Plant 2/Jorgensen Forge), and has determined that the completed Slip 4 EAA is consistent with the Preferred Alternative and requires no further active remediation, and other planned EAAs are similarly expected to require no further active remediation if they achieve their stated objectives. For the cleanups conducted under the 1991 Natural Resource Damages Consent Decree (Norfolk CSO and Duwamish/Diagonal CSO/SD), EPA will conduct a review during the remedial design phase to determine whether additional work is needed to make these cleanup actions consistent with the remedy selected in the ROD. EPA will review the ICs Plans and long-term monitoring plans for all of the EAAs and will require that the EAAs be incorporated into plans for the rest of the LDW as necessary to make them consistent with the remedy selected in the ROD.

Role of Source Control in the Preferred Alternative – The Selected Remedy will be implemented while a comprehensive source control program is managed by Ecology, as originally described in the 2004 Source Control Strategy and further defined in the 2012 Source Control Strategy (Appendix A). EPA and Ecology will coordinate to their respective work as lead agencies to maximize consistency and ensure that sources have been sufficiently controlled to minimize recontamination before initiating sediment cleanup in any portion of the waterway. The coordination process will be further developed in a new Memorandum of Understanding (MOU) (replacing a 2004 MOU), which the Agencies expect to execute prior to issuance of the ROD for the in-waterway portion of the Site.

This Proposed Plan addresses EPA's in-waterway cleanup only and does not limit the laws and regulations Ecology uses to implement source control as detailed in Appendix A. In addition, Ecology may require sampling and control of additional contaminants beyond those listed as COCs in this Proposed Plan to address the goals and objectives of the source control program.

10.2 Implementation of the Preferred Alternative

The estimates of areas, volumes, time to reach cleanup objectives, and cost described in Section 10.1 are based on RI/FS data. Remedial design sampling will be conducted after the early actions are completed in 2015. Results from design sampling will be used by EPA to refine areas to be remediated and the remediation technologies to be applied, and inform source control activities.

This section describes how future data will be used to refine the areas where each technology will be applied. RALs will be applied in intertidal and subtidal areas to identify areas for active remediation as described below and in Figure 21 and Figure 22. The type of remedial technology to be applied to sediments is described below and in Figure 19 and Figure 20.

In Recovery Category 1 areas, (approximately 11 intertidal acres and 66 subtidal acres), active remediation (dredging, capping, or a combination thereof) is required when:

- Any sediment COC concentration in the top 10 cm is greater than the ecological RALs (SQS) or greater than the four human health RALs (PCBs, arsenic, cPAHs, dioxins/furans) in intertidal and subtidal areas.
- Sediment COC concentrations averaged over the top 45 cm in intertidal areas are greater than any of the four human health RALs.
- Sediment COC concentrations averaged over the top 60 cm in subtidal areas are greater than any of the SQS RALs or greater than any of the four human health RALs.
- ENR will not be applied to Recovery Category 1 areas.

In Recovery Category 2 and 3 areas (approximately 102 intertidal and 233 subtidal acres), active remediation (dredging, capping, ENR, or a combination thereof) is required:

- In intertidal and subtidal areas, when any sediment COC concentration in the top 10 cm is greater than 2 times the SQS or the CSL, whichever is lower (Table 14) or is greater than any of the four human health RALs.
- In intertidal areas, when sediment COC concentrations averaged over the top 45 cm are greater than any of the human health RALs for arsenic, cPAHs, or dioxins/furans, or when PCB sediment concentrations are greater than the CSL.
- In subtidal areas at depths above potential vessel scour depths¹⁵ (approximately 128 acres), when sediment PCB concentrations averaged over the top 60 cm are greater than 3 times CSL (195 mg/kg OC) for PCBs. There are no RALs for the top 60 cm in Category 2 and 3 areas in deeper water depths (105 acres).

15. Subtidal areas in Recovery Categories 2 and 3 deemed to be potentially subject to vessel scour especially by tugboats are: north of the 1st Avenue South Bridge (located at approximately RM 2) in water depths from -4 to -24 ft MLLW, and south of the 1st Avenue South Bridge, in water depths from -4 to -18 ft MLLW. These depths are based on the size of tugboats that normally operate in these areas.

ENR with or without in situ treatment will be selected based on sediment COC concentrations and the potential for sediment scour at certain water depths, as discussed below:

- In intertidal areas in Recovery Categories 2 and 3, ENR will be applied when any sediment COC concentration in the top 10 cm is between 1 and 3 times the top 10 cm intertidal RALs, or when any sediment COC concentration averaged over the top 45 cm is between 1 and 1.5 times the intertidal RALs for the 45 cm interval (e.g., 65 – 97 mg/kg OC PCBs) (Figure 21 and Table 14).
- In Recovery Category 2 and 3 subtidal areas, ENR will be applied when any sediment COC concentration in the top 10 cm is between 1 and 3 times the top 10 cm subtidal RALs as noted in Figure 20 and Table 14. In potential vessel scour areas, PCB concentrations in the top 60 cm must also be less than 3 times the CSL.
- Pilot testing will be performed in the remedial design phase to develop criteria for determining whether ENR/in situ treatment is effective in reducing toxicity and bioavailability of COCs while avoiding unacceptable impacts to biota. The results of pilot testing will determine the locations where in situ treatment will be applied. If pilot testing is successful, EPA will consider, in coordination with the State, Tribes, and stakeholders, expanding the area to which ENR/in situ treatment may be applied.
- Areas not suitable for ENR will be remediated by dredging, capping, or partial dredging and capping, as described in Figure 19 and Figure 20.

In all other areas of the LDW, MNR will be applied as follows:

- In areas with concentrations of COCs at or below the Alternative 5C ecological risk reduction RALs (2 times the SQS or the CSL, whichever is lower [Table 14]), MNR To SQS will be used to reduce COC concentrations to the SQS so long as the human health RALs are not also exceeded. If the SQS is not reached in 10 years after remediation, additional remedial action will be required.
- In areas where COC concentrations are below the SQS, MNR Below SQS will further reduce COC concentrations in sediments after active remediation is complete.

10.3 Rationale for Identification of 5C Plus as the Preferred Alternative

The Preferred Alternative is recommended because it is protective of human health and the environment, and provides the best balance of tradeoffs among the balancing criteria. It reduces risks within a reasonable time frame, is practicable and cost-effective, provides for long-term reliability of the remedy, and minimizes reliance on institutional controls. It will achieve substantial risk reduction by dredging and capping the most contaminated sediments, reduce remaining risks to the extent practicable through ENR and MNR, and manage remaining risks through institutional controls. This combination provides the best balance of construction time, long term effectiveness and permanence, time to achieve risk reduction, and cost.

In selecting 5C Plus as the Preferred Alternative, EPA considered several options for surface and subsurface RALs. EPA selected the RALs listed in this Proposed Plan because other options removed

less subsurface contamination with an associated increased risk of exposure, or removed more subsurface contamination at a higher cost that was disproportional to the increase in long-term effectiveness and permanence. More than other alternatives, Alternative 5C Plus emphasizes removal of PCB contamination in shallow subsurface sediments while allowing MNR in areas with low concentrations of non-human health COCs, providing greater permanence in comparison to other alternatives of similar cost and construction duration. Less costly alternatives rely more on technologies such as ENR and MNR that have uncertainty as to their long-term effectiveness. In more costly alternatives, the additional costs are not proportional to the overall increase in protectiveness. Alternative 5C Plus provides the best balance of minimizing short-term risks due to construction in a 7-year construction period, while maximizing long-term effectiveness by dredging or capping the most contaminated sediments. The Preferred Alternative will utilize treatment to reduce the toxicity and bioavailability of contaminants in the form of ENR with in situ amendments if pilot testing is successful. It is consistent with current and reasonably anticipated future uses of the waterway.

Addressing Environmental Justice concerns – Environmental Justice concerns will be addressed before, during and after implementation of the remedy by:

1. Proposing a Preferred Alternative that reduces human health risks as quickly as possible, while also providing for long-term effectiveness and permanence.
2. Conducting surveys to learn more about the affected community (those who consume Duwamish resident seafood) in order to enhance outreach efforts. As noted in Section 9.3.3, EPA has already started implementing this recommendation as part of the RI/FS.
3. Continuing to engage the community throughout remedial design and implementation of the cleanup, including convening an advisory group as a means for the affected community and local agencies to work together on mitigating the impacts of the cleanup on the affected community.
4. Continuing consultation with affected Tribes on recommendations for the remedy.
5. Reducing the impacts of the cleanup on residents through green remediation techniques.

Attaining ARARs – The intent of the Preferred Alternative is, in conjunction with cleanup of the EAAs and source control activities described in the attached 2012 Source Control Strategy, to be protective of human health and the environment and to attain ARARs, although some ARARs may not be achieved for many years. It is intended to minimize reliance on seafood consumption-related Institutional Controls to the extent practicable.

The goal of this CERCLA cleanup action and Ecology's source control program is to reduce in-waterway contamination and sources to the waterway to levels needed to achieve all ARARs-based and risk-based cleanup levels in the ROD. EPA acknowledges that the RI/FS modeling results conclude that it may not be possible for any alternative to do so; however, as discussed in Sections 7 and 9, it is difficult to predict long-term Site conditions with any degree of accuracy. Model results are based on current Site conditions, and do not take into account potential future advances in technologies for addressing contamination in urban waterways.

EPA will review long-term monitoring data to assess the success of the remedy, including measuring contaminant concentrations in sediment, surface water, and fish and shellfish tissue. If long-term monitoring data show that any SQS (Table 9) are exceeded, additional actions will be taken to reduce COC concentrations to the SQS. If monitoring data reach a steady state at levels below the SQS but above the human health risk reduction or background-based cleanup levels in the ROD, EPA will review the data and consider whether additional sediment cleanup has the potential to further reduce COC concentrations in sediments, tissue, or surface water and associated human health risk and is technically practicable. If so, EPA, in consultation with Ecology and the Suquamish and Muckleshoot Tribes, will select additional remedial action in a future decision document (ROD Amendment or ESD). If EPA determines that no additional practicable actions can be implemented to meet ARARs, EPA may issue a Proposed Plan for a ROD Amendment or ESD providing the basis for a technical impracticability waiver for specified sediment and/or water quality-based ARARs under Section 121(d)(4)(C) of CERCLA and including an opportunity for public comment as appropriate.

Whether ARARs are attained or not, implementation of the Preferred Alternative, along with the EAAs and source control, will substantially improve the quality of LDW sediments and surface water, reduce COC concentrations in waterway organisms, and result in an estimated 90% or greater reduction in seafood consumption risk .

10.4 Preferred Alternative Summary

Based on the information currently available, the Preferred Alternative described in this Proposed Plan is a final action which meets the threshold criteria and provides the best balance of tradeoffs with respect to the balancing and modifying criteria. EPA expects the Preferred Alternative to satisfy the following statutory requirements of CERCLA §121(b): 1) be protective of public health and the environment; 2) attain ARARs; 3) be cost-effective; 4) utilize permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable; and 5) satisfy the preference for treatment as a principal element, or explain why the preference for treatment will not be met.

Ecology supports the Preferred Alternative , and EPA supports Ecology's Source Control Strategy (Appendix A).

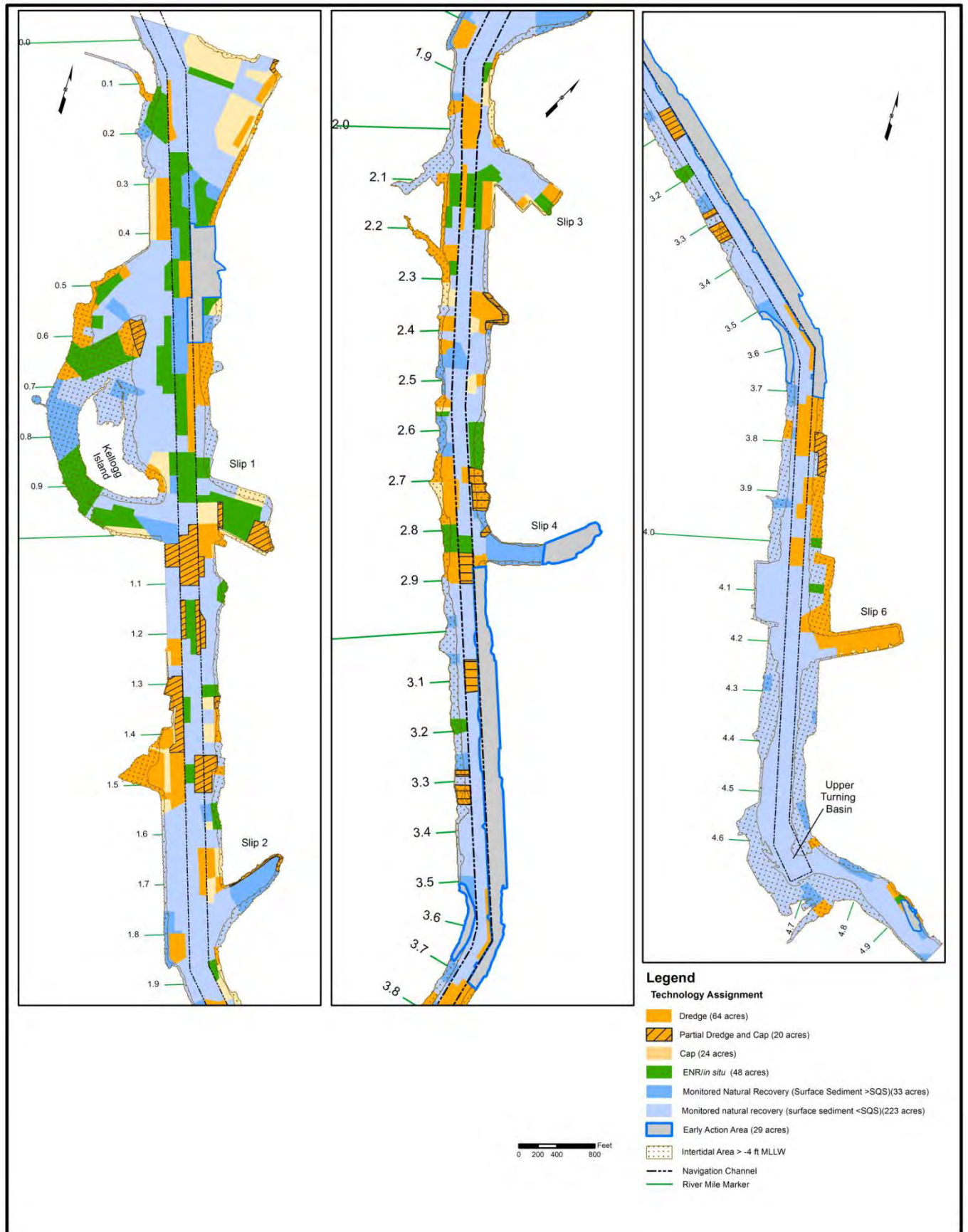
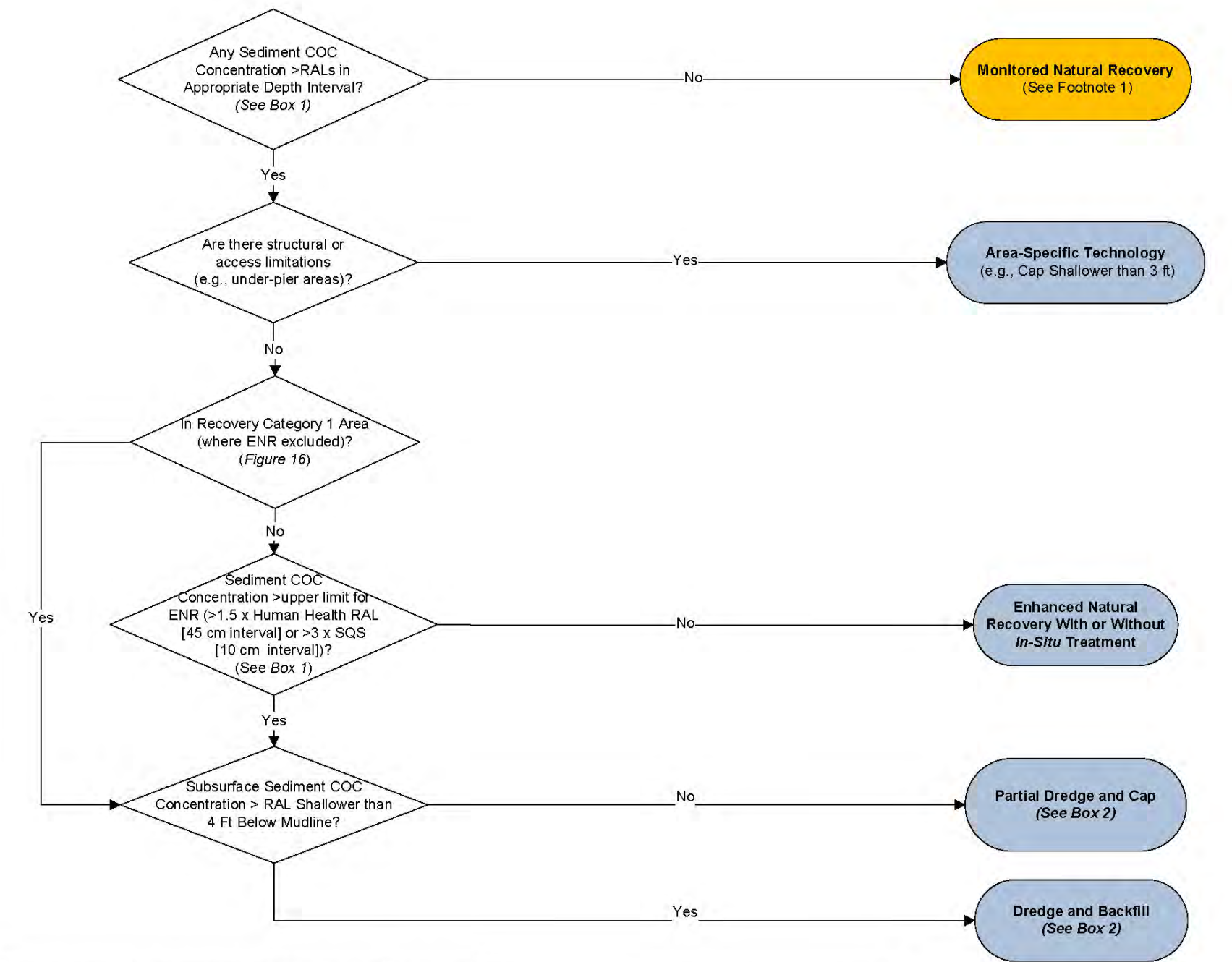


Figure 18. Preferred Alternative

This page left blank for double sided printing.



Box 1. Intertidal Sediments (+11.3 ft MLLW to -4 ft MLLW)						
Remedial Action Levels (RALs) and Vertical Point of Compliance ("Depth Interval")-Footnote 2						
Contaminant	Units	Recovery Category 1 Areas		Recovery Category 2 and 3 Areas		Risk Drivers
		4 in (10 cm) depth interval	1.5 ft (45 cm) depth interval	4 in (10 cm) depth interval	1.5 ft (45 cm) depth interval	
PCBs (Total) Footnote 3	mg/kg-OC	12	12	12	65	Human Health Risk Reduction ^{a,b,c}
cPAH	TEQ ug/kg-dw	1000	900	1000	900	
Dioxins/Furans	ng TEQ/kg-dw	25	28	25	28	
Arsenic (Total)	mg/kg-dw	57	28	57	28	
41 SMS Chemicals ^e		SQS ^e	--	2xSQS ^{a,f}	--	Ecological Risk Reduction ^d

Notes:
The average concentrations in depth interval (e.g., vertically composited samples) are compared to RALs.
RALs Must Be Met Immediately Following Construction.
^a RAO 1 - Human Health Seafood Consumption
^b RAO 2 - Human Health Direct Contact is Beach Play, Clamming, and Netfishing
^c RAO 4 - Ecological Protection for River Otter (Addressed by Meeting Human Health PCB RAL)
^d RAO 3 - Ecological Protection of Benthic Community
^e Washington State Sediment Management Standards (SMS) Sediment Quality Standards (SQS) for 41 contaminants are shown in Table 7; the SMS Also Lists Toxicity Test-out Criteria for Bioassays. Test-out is not allowed for the 4 human health risk driver COCs.
^f RAL is "2xSQS and not to exceed CSL." This RAL is for 39 SQS, which excludes the two SQS COCs that are human health COCs (PCBs and Arsenic)

Legend:

Monitored Natural Recovery

Active Remedial Technology Application

All Remedial Technologies Include Long-Term Monitoring and Institutional Controls

Box 2. Habitat Area Restoration
Elevations of Intertidal Habitat Areas are Assumed to be Unaffected by Addition of 6-9" Materials (i.e., ENR)
Dredge and Backfill or Partial Dredge and Cap to Pre-Construction Grade; Finish with Suitable Habitat Layer
In Clam Habitat areas (Proposed Plan Figure 4), Minimum of 4 ft of Suitable Clean Material Including a Surface Suitable for Clam Growth

Footnotes:

1) For concentrations less than SQS, should further remedial action be required, they will be the subject of a new decision document.

2) See Figure 23, which shows the application of RALs in intertidal areas.

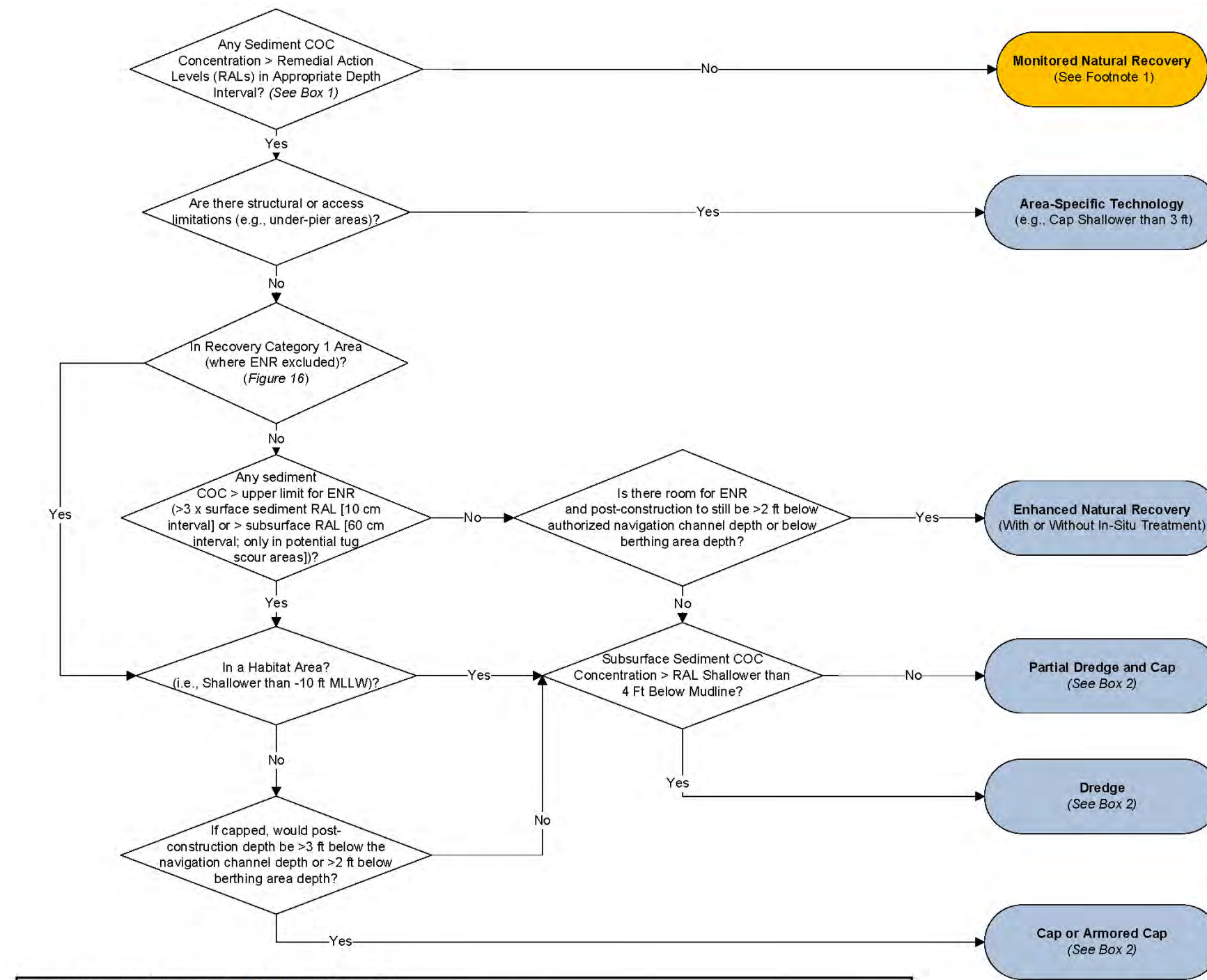
3) The FS used 240 ppb PCBs (dry weight equivalent of 12 ppm-OC PCB at 2% organic carbon content) for mapping purposes.

Definition: Remedial Action Levels (RALs) are contaminant-specific sediment concentrations designed to address human health and ecological risk and to trigger the need for active remediation.

Abbreviations: COC – risk driver contaminant of concern; cPAH - carcinogenic polynuclear aromatic hydrocarbons; ENR – Enhanced Natural Recovery; MLLW – mean lower low water; RAL – remedial action level; RAO – remedial action objective; PCB – polychlorinated biphenyls; SQS – Sediment Quality Standards, TEQ – toxicity equivalents: for dioxins/furans TEQ is expressed as 2,3,7,8-Tetrachloro-*p*-dibenzodioxin equivalents; for cPAHs, TEQ is expressed as benzo[a]pyrene equivalents

Figure 19. Intertidal Areas – Remedial Technology Applications

This page left blank for double sided printing.



Box 1. Subtidal Sediments (-4 ft MLLW and Deeper)						
Remedial Action Levels (RALs) and Vertical Point of Compliance ("Depth Interval")-Footnote 2						
Contaminant	Units	Recovery Category 1 Areas		Recovery Category 2 and 3 Areas		Risk Drivers
		4 in (10 cm) depth interval	2 ft (60 cm) depth interval	4 in (10 cm) depth interval	2 ft (60 cm) depth interval (applied only at potential tug scour areas) Footnote g	
PCBs (Total)	mg/kg-OC	12	12	12	195	Human Health Risk Reduction ^{a,b,c}
Footnote 3						
cPAH	TEQ ug/kg-dw	1000	1000	1000	--	
Dioxins/Furans	ng TEQ/kg-dw	25	25	25	--	
Arsenic (Total)	mg/kg-dw	57	57	57	--	Ecological Risk Reduction ^d
41 SMS Chemicals ^e		SQS ^e	SQS ^e	2xSQS ^{e,f}	--	
Notes						
The average concentrations in depth interval (e.g., vertically composited samples) are compared to RALs.						
Potential tug scour areas are subtidal elevations potentially susceptible to propellor wash (shallower than -24 ft MLLW north of 1st Ave Bridge and shallower than -18 ft MLLW north of 1st Ave Bridge at RM 2.0). Below these water depths, no RAL is employed in the 60 cm depth interval.						
RALs Must Be Met Immediately Following Construction.						
^a RAO 1 - Human Health Seafood Consumption						
^b RAO 2 - Human Health Direct Contact is Beach Play, Clamming, and Netfishing						
^c RAO 4 - Ecological Protection for River Otter (Addressed by Meeting Human Health PCB RAL)						
^d RAO 3 - Ecological Protection of Benthic Community						
^e Washington State Sediment Management Standards (SMS) Sediment Quality Standards (SQS) for 41 contaminants are shown in Table 7; the SMS Also Lists Toxicity Test-out Criteria for Bioassays. Test out is not allowed for the 4 human health risk driver COCs.						
^f RAL is "2xSQS and not to exceed CSL." This RAL is for 39 SQS, which excludes the two SQS COCs that are human health COCs (PCBs and Arsenic)						

Box 2. Habitat Areas (Shallower than -10 ft MLLW and Excluding Engineered Slopes, Riprap, or Berthing Areas)
Elevations of Intertidal Habitat Areas are Assumed to be Unaffected by Addition of 6-9" Materials (i.e., ENR)
Dredge and Backfill or Partial Dredge and Cap to pre-Construction Grade; Finish with Suitable Habitat Layer

Footnotes:

1) For concentrations less than SQS, should further remedial action be required, they will be the subject of a new decision document.

2) See Figure 24, which shows the application of RALs in subtidal areas.

3) The FS used 240 ppb PCBs (dry weight equivalent of 12 ppm-OC PCB at 2% organic carbon content) for mapping purposes.

Definition: Remedial Action Levels (RALs) are contaminant-specific sediment concentrations designed to address human health and ecological risk and to trigger the need for active remediation.

Abbreviations: COC – risk driver contaminant of concern; cPAH - carcinogenic polynuclear aromatic hydrocarbons; ENR – Enhanced Natural Recovery; MLLW – mean lower low water; OC – organic carbon, RAL – remedial action level; RAO – remedial action objective; PCB – polychlorinated biphenyls; SQS – Sediment Quality Standards; TEQ – toxicity equivalents: for dioxins/furans TEQ is expressed as 2,3,7,8-Tetrachloro-p-dibenzodioxin equivalents; for cPAHs, TEQ is expressed as benzo[a]pyrene equivalents

Figure 20. Subtidal Areas – Remedial Technology Application

This page left blank for double sided printing.

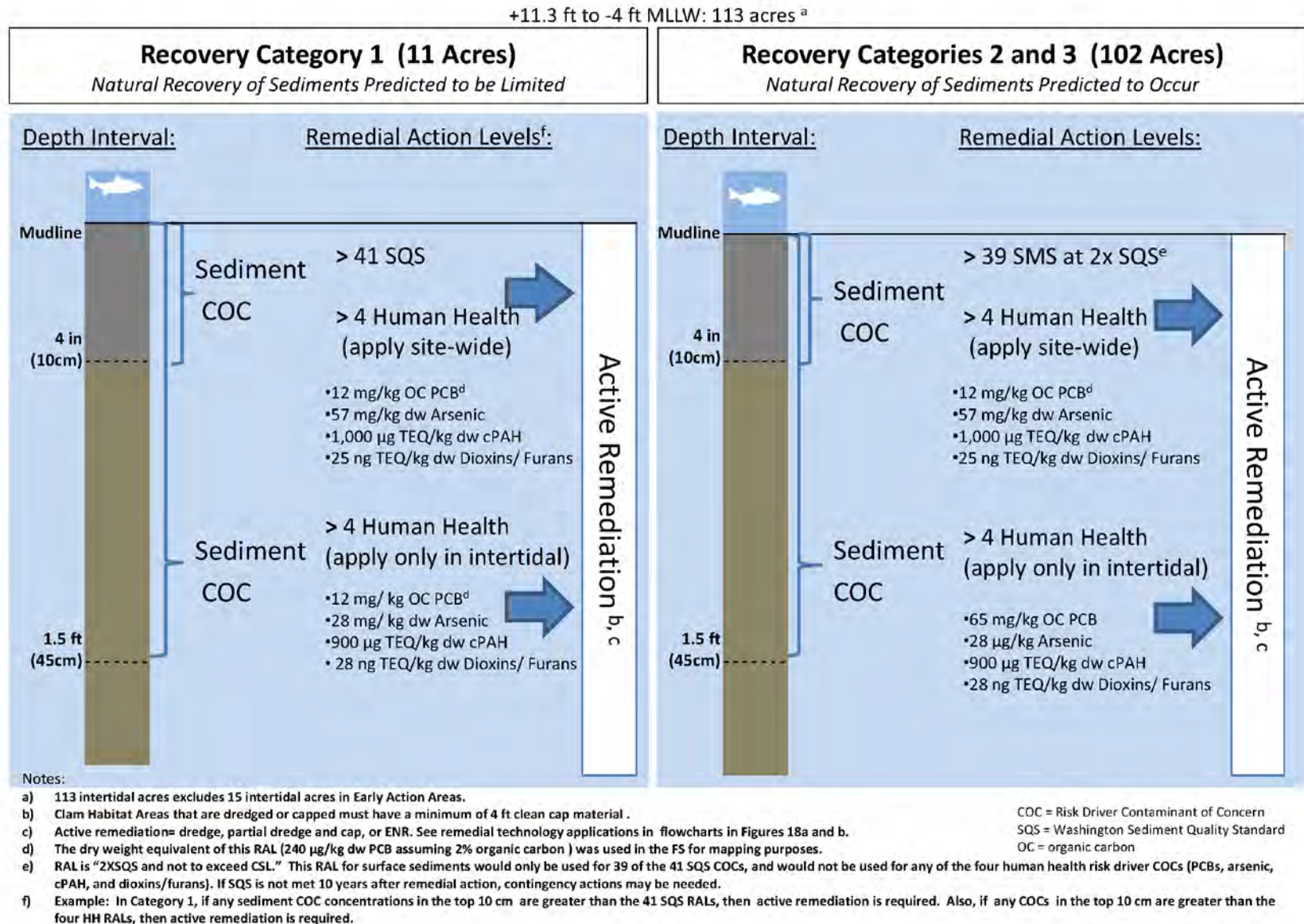


Figure 21. Intertidal Areas – Remedial Action Levels Application

-4 ft MLLW and Deeper: 299 acres^a

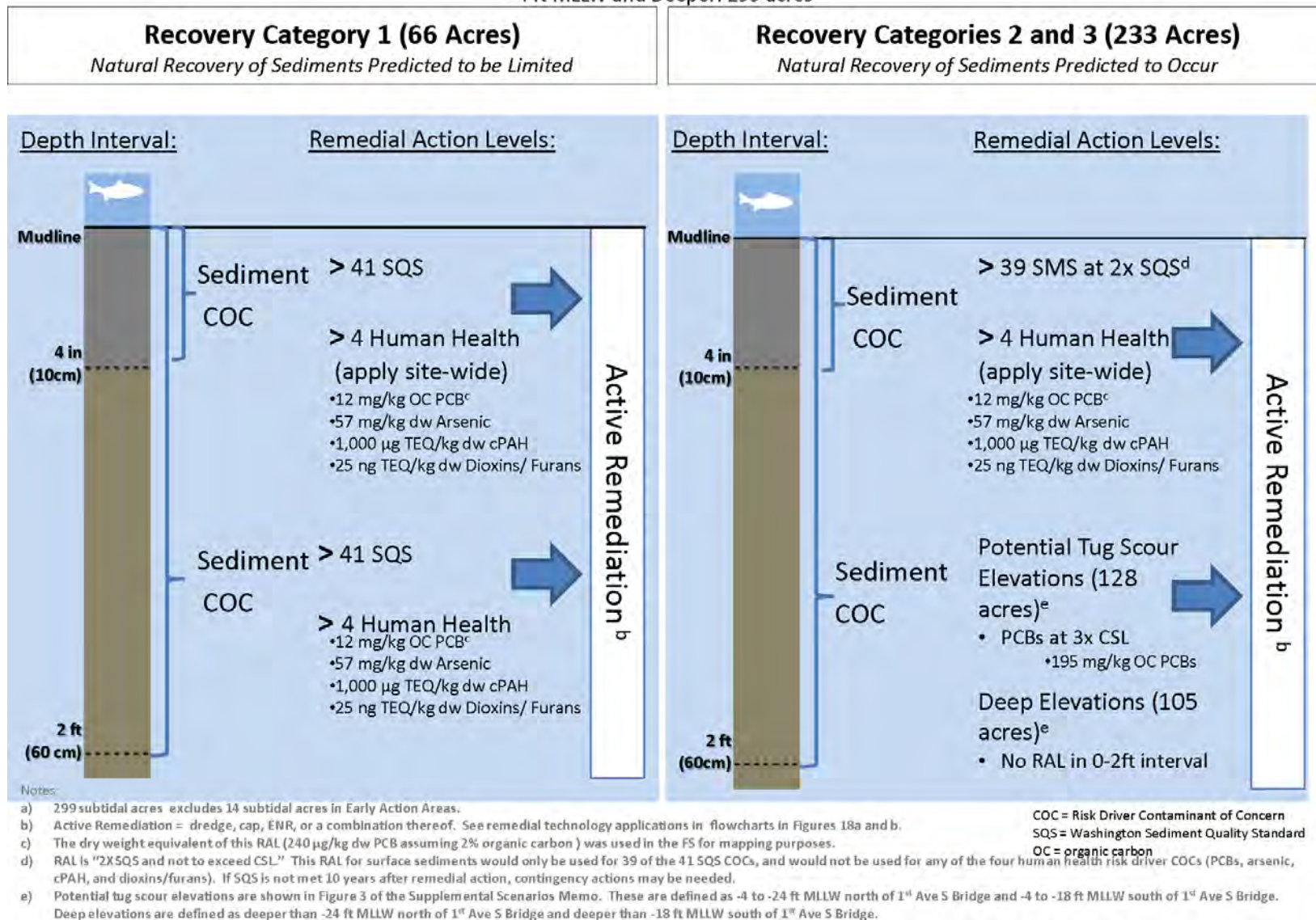


Figure 22. Subtidal Areas – Remedial Action Levels Application

11 Key Terms

Applicable or Relevant and Appropriate Requirements (ARARs) – under CERCLA Section 121, remedial actions must comply with or EPA must formally waive any standard, requirement, criteria or limitation under Federal environmental laws or more stringent State environmental or facility siting laws.

Bed Composition Model (BCM) – along with the Sediment Transport Model, this was a tool used in the Feasibility Study to predict future contaminant concentrations in LDW sediments during and following implementation of each of the proposed cleanup alternatives.

Benthic Invertebrates – sediment-dwelling organisms such as amphipods, clams, and oligochaete worms.

CERCLA – the Comprehensive Environmental Response, Compensation, and Liability Act—also known as Superfund—CERCLA is a Federal law which authorizes response actions to reduce the dangers associated with releases or threats of releases of hazardous substances that may endanger public health or the environment.

Contained Aquatic Disposal (CAD) – disposal of dredged sediment in a depression or bermed area at the bottom of a water body. The area is then capped with clean sediment.

Contaminant of Concern (COC) – a hazardous substance or group of substances that pose unacceptable risk to human health or the environment.

Enhanced Natural Recovery (ENR) – an active remedial technology which includes placement of a thin clean sand or sediment layer as a means to accelerate recovery.

Excess Lifetime Cancer Risk – the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogen.

Food-Web Model (FWM) – a model that estimates the relationship among sediment, water, and tissue contaminant concentrations.

Hazard Index (HI) – the sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, subchronic, and shorter-duration exposures. An HI may be used to evaluate the risk for multiple non-carcinogenic hazardous substances with similar modes of toxic action.

Hazard Quotient (HQ) – a method to summarize the relative level of risk for a single non-carcinogenic hazardous substance that is based on the ratio of an exposure over a specified time period to a reference dose.

Human Health Risk assessment (HHRA) – an assessment to determine potential pathways by which humans could be exposed to contamination at or from a site. The assessment determines the amount of exposure, and estimates the resulting level of toxicity.

In situ Treatment – an active remedial technology conducted in place (e.g., without removing sediment). It includes reactive caps and amendments that enhance breakdown of or bind contaminants.

Institutional controls (ICs) – non-engineered measures that may be selected as remedial or response actions either by themselves or in combination with engineered remedies, such as administrative and legal controls that minimize the potential for human exposure to contamination by limiting land or resource use.

Lowest Observed Adverse Effect Level (LOAEL) – the lowest contaminant concentration documented to have shown a related negative impact on the reference species either from observation or by experiment.

Mean Lower Low Water (MLLW) – the average height of the lowest tide recorded at a tide station each day over the period from 1983 to 2001.

Model Toxics Control Act (MTCA) – a Washington State hazardous substances law generally similar to CERCLA. MTCA establishes substantive requirements for cleanup actions (as State ARARs) when those requirements are more stringent than CERCLA requirements. MTCA includes the SMS and its numerical and biological standards for the protection of marine benthic invertebrates.

Monitored Natural Recovery (MNR) – MNR is a passive remedial technology that relies on natural processes to reduce ecological and human health risks to acceptable levels, while monitoring recovery over time to verify remedy success.

Natural Background – as defined in MTCA regulations, the concentrations of hazardous substances that are consistently present in an environment that have not been influenced by localized human activities. For some contaminants such as PCBs, background conditions may be influenced by global-distribution patterns.

Organic Carbon (OC) Normalized Values – the bioavailability and toxicity of some organic contaminants in sediments have been found to correlate with the organic carbon content of sediment. Therefore, some SMS criteria have been set on an OC-normalized basis. An OC-normalized sediment value is determined by dividing the dry weight value by the fraction of total OC present in the sample.

Preliminary Remediation Goals (PRGs) – contaminant concentrations that are developed during an RI/FS. They are based upon applicable or relevant and appropriate requirements (ARARs) and other information whenever ARARs are not adequately protective of all receptors at a site, such as concentrations associated with the 1 in 1,000,000 cancer risk or an HQ equal to 1 for non-carcinogens calculated from EPA toxicity information.

Principal Threat Waste (PTW) – a source of hazardous substances that is highly toxic or highly mobile, such as pools of non-aqueous phase liquids, and that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.

Reasonable Maximum Exposure (RME) – the risk assessment scenario which portrays the highest level of human exposure that could reasonably be expected to occur.

Recovery Categories – categories used to assign remedial technologies to specific areas based on information about the potential for sediment contaminant concentrations to be reduced through natural recovery or for subsurface contamination to be exposed at the surface due to erosion or scour (Category 1 – recovery presumed to be limited, Category 2 – recovery less certain, and Category 3 – recovery predicted to occur).

Remedial Action Levels (RALs) – contaminant-specific sediment concentrations designed to identify specific areas of sediments that require active remediation, taking into consideration the human health and ecological risk reduction achieved by the different remedial technologies.

Remedial Action Objectives (RAOs) – objectives that describe what the proposed cleanup is expected to accomplish in order to protect human health and the environment.

Risk-based Threshold Concentrations (RBTCs) – the calculated concentrations in any medium estimated to be protective of a particular receptor for a given exposure pathway and target risk level. RBTCs are based on the baseline risk assessments conducted during the RI. Consistent with the the NCP and as required by MTCA for final Washington cleanups (WAC 173-340-700(5)(b), (6)(d); 705(2), (4)-(6)), sediment PRGs were set at a RBTC of 1 in 1,000,000 lifetime excess cancer risk for individual hazardous substances, or 1 in 100,000 for multiple hazardous substances cumulatively, and a noncancer HQ of 1.

Sediment Transport Model (STM) – a three-dimensional model developed to simulate sediment movement over a wide range of flow and tidal conditions to inform the type of sediment cleanup technologies that would be appropriate for the LDW. See also Bed Composition Model.

Storm Drain (SD) – a collection, conveyance, and related discharge outfall location from public or private storm water systems. Unless designated as combined sewer overflows (CSOs) storm drains are not connected to sewer water systems.

Toxic Equivalent (TEQ) – a single value used to express the joint toxicity of a mixture of compounds with a similar toxic action.

95% Upper Confidence Limit (UCL95) on the Mean – the UCL95 is used to estimate exposure to human health, fish, and wildlife to concentrations of hazardous substances in the environment. It is intended to ensure that these concentrations are not underestimated when a number of values are averaged. Use of this statistic assures no more than a 5% chance that the average of point concentrations will be exceeded.

This page left blank for double sided printing.

12 Key Documents

RI Report – Windward Environmental LLC 2010. *Lower Duwamish Waterway Remedial Investigation, Remedial Investigation Report*. Final. Prepared for Lower Duwamish Waterway Group for submittal to U.S. Environmental Protection Agency, Seattle, WA and Washington State Department of Ecology, Bellevue, WA. July 2010.

FS Report – AECOM 2012a. *Final Feasibility Study Lower Duwamish Waterway, Seattle, Washington*. For submittal to: The U.S. Environmental Protection Agency Region 10 Seattle, WA and The Washington State Department of Ecology Northwest Regional Office, Bellevue, WA. October 2012.

FS Supplement – AECOM 2012b. *Technical Memorandum: Supplement to the Feasibility Study for the LDW Superfund Site, Approaches for Addressing Additional Concerns in Alternative 5C and Development of ALT 5C Plus Scenarios*. Prepared for Lower Duwamish Waterway Group for submittal to U.S. Environmental Protection Agency, Seattle, WA and Washington State Department of Ecology, Bellevue, WA. December 2012.

FS Supplement Technical Memorandum – AECOM 2013. *Development of Final Technology Assignments and Modifications to Alternative 5C Plus Scenario 5a in Support of EPA's Preferred Alternative*. . Prepared for Lower Duwamish Waterway Group for submittal to U.S. Environmental Protection Agency, Seattle, WA and Washington State Department of Ecology, Bellevue, WA. February 2013.