Record of Decision

Lower Duwamish Waterway Superfund Site

United States
Environmental Protection Agency
Region 10

November 2014

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Part 1 Declaration

Site Name and Location

Site Name: Lower Duwamish Waterway

Location: Seattle and Tukwila, King County, Washington

U.S. Environmental Protection Agency (EPA) identification number: WA00002329803

Statement of Basis and Purpose

This decision document presents the Selected Remedy for the In-waterway Portion of the Lower Duwamish Waterway Superfund Site, in King County, Washington. The Selected Remedy was chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and to the extent practicable, the National Contingency Plan (NCP). This decision is based on the Administrative Record file for this site. The State of Washington, through the Washington Department of Ecology, concurs with the Selected Remedy.

Assessment of the Site

The response action selected in this Record of Decision (ROD) is necessary to protect the public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment. Such a release or threat of release may present an imminent and substantial endangerment to public health, welfare, or the environment.

Description of the Selected Remedy

The Selected Remedy is a final action for the In-waterway Portion of the Lower Duwamish Waterway (LDW) Site. It addresses unacceptable human health risks associated with consumption of resident fish and shellfish, and with direct contact (skin contact and incidental ingestion) from net fishing, clamming, and beach play. It also addresses ecological risks to bottom-dwelling organisms (benthic invertebrates), fish, and wildlife.

The Selected Remedy is the third component of an overall strategy for addressing contamination and the associated risks in the LDW Site that includes:

1. early identification and cleanup of the most contaminated areas in the waterway, referred to as Early Action Areas (EAAs) — an estimated 29 acres will be cleaned up in the EAAs;
2. controlling sources of contamination to the waterway (Washington State Department of Ecology [Ecology] is the lead agency for this component); 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 (the Selected Remedy).

The Selected Remedy will be implemented after cleanup in the EAAs has been completed, source control sufficient to minimize recontamination (see Section 4.2) has been implemented, additional sampling and analysis has been conducted, and design of the remedy has been completed.

The Selected Remedy addresses approximately 412 acres, and includes the following elements:

- A total of 177 acres of active cleanup, consisting of:
  - 105 acres of dredging or partial dredging and capping (an anticipated total volume of 960,000 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 235 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.
  - In MNR areas, more intensive long-term monitoring will be conducted in an estimated 33 acres where contaminant of concern (COC) concentrations in sediment are less than the sediment remedial action levels (RALs – contaminant concentrations above which remedial action is required) but greater than the sediment cleanup objectives for protection of benthic invertebrates (benthic SCO); this is referred to as MNR To Benthic SCO. If MNR does not achieve the benthic SCO or progress sufficiently toward achieving it in 10 years, additional cleanup will be required as a part of this remedy.
  - Less intensive monitoring will be conducted in areas where sediment COC concentrations are below the benthic SCO but above the sediment cleanup levels[1] for protection of human health; this is referred to as MNR Below Benthic SCO. This includes 202 acres where COC concentrations were below the benthic SCO in remedial investigation sampling, and will also include the 33 acres described in the previous bullet after COC concentrations are reduced to below the benthic SCO in those areas. If the cleanup levels for protection of human health are not achieved, additional cleanup actions will be considered in a future decision document.
- Institutional controls (ICs) and LDW-wide monitoring, including:
  - Proprietary controls, e.g., under the Washington Uniform Environmental Covenants Act (UECA), to prohibit activity that could result in a release or exposure of COCs remaining in the subsurface absent EPA approval; and
  - Seafood consumption advisories.

The purpose of ICs is to protect the integrity of other remedial action elements such as capping, and to provide information about how much and what types of fish and shellfish are safe to consume in the form of fish advisories, education and outreach programs. A study is currently underway to gather information from people who harvest or consume seafood and who may assist in understanding aspects of seafood

[1] Cleanup levels are contaminant concentrations that must be achieved at the end of the 10-year natural recovery period. They include human health-based levels (which must be met on an area-wide basis) and benthic SCO criteria (which must be met on a point-by-point basis. See Section 8).

consumption from the LDW as a first step in developing effective and appropriate ICs intended to reduce exposure of the LDW seafood consuming community to risks from consuming resident fish and shellfish.

The Selected Remedy assumes completion of an additional 29 acres of cleanup in EAAs (see Section 4.1 for further discussion of the EAAs), not included in the 412 acres addressed by the remedy.

The Selected Remedy 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 (discounted at 2.3%) for the Selected Remedy are $342 million, of which capital costs are $295 million, and operation, maintenance, and monitoring (OM&M) costs are approximately $48 million.

Statutory Determinations

The Selected Remedy is protective of human health and the environment, complies with federal and state requirements that are applicable or relevant and appropriate to the remedial action, is cost effective, and utilizes permanent solutions and alternative treatment technologies to the maximum extent practicable for this Site.

This remedy does not satisfy the statutory preference for treatment as a principal element of the remedy. The NCP emphasizes the expectation that treatment will be used to address the principal threats posed by a site whenever practicable. Principal threat waste is defined in EPA guidance as source material that is highly toxic or highly mobile, and that generally cannot be contained in a reliable manner. EPA has determined that the contaminated sediments in the LDW outside of the EAAs are not highly mobile or highly toxic. The remedy does include potential treatment of some contaminated sediments through provisions for amendment of caps and ENR with activated carbon or other contaminant-sequestering agents.

Because this remedial action will result in hazardous substances, pollutants, or contaminants remaining on-site at levels above those that would allow for unlimited use and unrestricted exposure, statutory five-year reviews will be conducted every five years after initiation of remedial action to ensure that the remedy continues to be protective of human health and the environment.

ROD Data Certification Checklist

The following information is included in the Decision Summary (Part 2) of this ROD. Additional information can be found in the Administrative Record for the site.

- Contaminants of concern and their respective concentrations (Section 5.3)
- Baseline risks represented by the contaminants of concern (Section 7).
- Cleanup levels established for contaminants of concern and the basis for these levels (Section 8.2.1).
- How source materials constituting principal threats are addressed (Sections 11 and 14.5).
- Current and reasonably anticipated future land use assumptions and current and potential future beneficial uses of surface water used in the baseline risk assessment and the ROD (Section 6).
- Potential land and surface water use that will be available at the site as a result of the selected remedy (Section 13.4).

- Estimated capital, annual OM&M, and total present worth costs; discount rate; and the number of years over which the remedy cost estimates are projected (Section 13.3).
- Key factors that led to the selection of the remedy (Section 13.1).

Authorizing Signature

11/21/14

Lori Cohen, Associate Director
Office of Environmental Cleanup

Date

Contents

List of Tables

List of Figures

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Acronyms and Abbreviations

µg/kg	micrograms per kilogram
ARAR	applicable or relevant and appropriate requirement
ASTDR	Agency for Toxic Substance and Disease Registry
AWQC	Ambient Water Quality Criteria
BA	biological assessment
BCM	bed composition model
BiOp	biological opinion
BEHP	bis(2-ethylhexyl)phthalate
C	combined technology
CAD	contained aquatic disposal
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
COPC	contaminants of potential concern
CSL	cleanup screening level (SMS)
CSO	combined sewer overflow
CT	central tendency
CWA	Clean Water Act
cy	cubic yard
DMMP	Dredged Material Management Program
DRCC/TAG	Duwamish River Cleanup Coalition/Technical Advisory Group
dw	dry weight
EAA	Early Action Area
Ecology	Washington Department of Ecology
EFDC	Environmental Fluid Dynamics Code
EJ	environmental justice
ELCR	excess lifetime cancer risk
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ESA	Endangered Species Act
ESD	explanation of significant differences
FS	feasibility study
FWM	food web model
HEAST	Health Effects Assessment Summary Tables
HH	human health
HHRA	human health risk assessment

HI	hazard index
HPAH	high molecular weight polycyclic aromatic hydrocarbon
HQ	hazard quotient
HTLS	higher trophic level species
HWTR	Hazardous Waste Toxicity Reduction
I	informational
IC	institutional control
IRIS	Integrated Risk Information System
LAET	Lowest Apparent Effects Threshold
LDW	Lower Duwamish Waterway
LDWG	Lower Duwamish Waterway Group
LOAEL	lowest observed adverse effects level
LPAH	low molecular weight polycyclic aromatic hydrocarbon
mg/kg	milligrams/kilogram (parts per million)
MLLW	mean lower low water
MHHW	mean higher high water
MNR	monitored natural recovery
MOA	memorandum of agreement
MOU	memorandum of understanding
MTCA	Model Toxics Control Act
MVUE	minimum variance unbiased estimate
na, n/a, NA	not applicable
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
nc	not calculable or cannot be calculated
nd	not detected
NEJAC	National Environmental Justice Advisory Council
NEPA	National Environmental Policy Act
ng/kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effects level
NPDES	National Pollutant Discharge Elimination System
NTR	National Toxics Rule
OC	organic carbon
OM&M	operation, maintenance, and monitoring
PCB	polychlorinated biphenyl
PQL	practical quantitation limit
PRG	preliminary remediation goal
PRP	potentially responsible party
PTW	principal threat waste
R	removal emphasis
RAL	remedial action level

RAO	remedial action objective
RBTC	risk-based threshold concentration
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RfD	reference dose
RI	remedial investigation
RL	reporting limit
RME	reasonable maximum exposure
RM	river mile
ROC	receptor of concern
ROD	Record of Decision
SCO	sediment cleanup objective (SMS)
SCWG	Source Control Work Group
SD	storm drain
SF	slope factor
SMS	Sediment Management Standards
SQS	Sediment Quality Standard
STM	sediment transport model
SVOC	semivolatile organic compound
SWAC	spatially-weighted average concentration
TBT	tributyltin
TEQ	toxic equivalent
TI	technical impracticability
TMDL	total maximum daily load
TOC	total organic carbon
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UB	upper bound
UCL95	upper confidence limit on the mean with 95% confidence
UECA	Uniform Environmental Covenants Act
UL	upper limit
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
VOC	volatile organic compound
WAC	Washington Administrative Code
WDOH	Washington Department of Health
WPCA	Water Pollution Control Act
WQS	Water Quality Standards
ww	wet weight

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Part 2 Decision Summary

The Decision Summary provides an overview of the contamination present in the Lower Duwamish Waterway (LDW) and the associated risks to human health and the environment, the cleanup alternatives considered, and the U.S. Environmental Protection Agency's (EPA's) Selected Remedy to address these risks. It also explains how the Selected Remedy fulfills statutory and regulatory requirements.

1 Site Name, Location, and Brief Description

The LDW Site, located south of downtown Seattle, Washington, extends over the northern 5 miles of the Duwamish River to the southern tip of Harbor Island (Figure 1), and includes upland sources of contamination as well as the waterway. The southernmost portion of the site is located in Tukwila, Washington. The Site was listed on the National Priorities List on September 13, 2001. The EPA identification number for the Site is WA00002329803. Although the Site is not divided into operable units, EPA and Washington State Department of Ecology (Ecology) have divided lead-agency responsibility for addressing it. EPA has the lead for the In-waterway Portion to which this Record of Decision (ROD) is addressed, and Ecology has the lead for upland source control.

The 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 1900s. The Duwamish River flows north through Tukwila and Seattle, splitting at the southern end of Harbor Island to form the East and West Waterways, which discharge into Elliott Bay in Seattle, Washington. The In-waterway Portion of the LDW Site addressed in this ROD extends for approximately 5 miles from the area around the Norfolk Combined Sewer Overflow/Storm Drain (CSO/SD)[2] at the southern end of the Site at river mile (RM) 5 to the southern tip of Harbor Island at 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. Because this ROD does not address control of upland sources, and because the remedial investigation/feasibility study (RI/FS) did not investigate the nature or extent of upland contamination, this ROD does not define or bound the upland portion of the Site. To control contamination sources to the In-waterway Portion of the Site, Ecology, in coordination with EPA, has identified the immediate Source Area (see Section 2.4) which encompasses a total area of approximately 32 square miles, and within which Source Control Strategy activities will take place (see Section 4.2).

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. This ROD presents EPA's Selected Remedy for component 3, cleanup of the In-waterway Portion of the Site. EPA is the lead agency and Ecology is the support agency for component 3. Progress on component 1, cleanup of the EAAs, is described in Section 2. For component 2, source control, Ecology's proposed source control activities are described in their draft *Lower Duwamish Waterway Source Control Strategy* (Source Control Strategy) (Ecology 2012). EPA is the support agency for component 2.

[2] The Norfolk CSO/ SD also serves as an emergency overflow for City pump station number 17. For brevity, it is called CSO/SD in this document.

The Selected Remedy 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 (see Section 4.2) has been implemented, additional sampling and analysis has been conducted, and design of the remedy has been completed.

2 Site History and Enforcement Activities

This section provides background information on past activities that have led to the current contamination at the Site, and federal and state investigations and cleanup actions conducted to date under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and other authorities.

2.1 Site History and Sources of Contamination

Most of the upland areas adjacent to the LDW have been industrialized since the early 1900s. This section provides a brief history of industrial activities in the Duwamish valley and sources of contamination to the Duwamish.

1900 – 1935: The start of industrial and commercial activity along the Duwamish coincided with the dredging and straightening of the waterway in the early 1900s. Prior land use in the Duwamish valley was primarily agricultural. Early activities included operation of sawmills, lumber yards, wood treatment facilities, cement and brick companies, steel mills and foundries, and marine construction. Early facilities include the Georgetown Steam Plant (built in 1906), The Boeing Company (Boeing) Plant 1 airplane manufacturing (1917), and King County Airport/Boeing Field (1928).

1935 – 1955: Industrial use of the Duwamish accelerated with the onset of World War II. Many of the existing industries (e.g., airplane and steel manufacturing) grew to support the war effort, and new enterprises such as drum recycling and chemical production appeared. Boeing Plant 2 was constructed from 1937 to 1940. Waste disposal practices in the 1950s and earlier included local landfills for solid waste, soil infiltration for liquid waste, and direct disposal of liquid and solid waste into the waterway. A primary treatment sanitary sewage facility on Diagonal Way was opened in 1938.

1955 – present: By 1955, sawmills, lumberyards and brick manufacturing facilities had virtually disappeared. Current 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; and petroleum storage. A sanitary sewer system was constructed in the 1970s to serve both sides of the waterway. The landfills near the Duwamish are now inactive.

Historically, hazardous substances from upland industrial activities entered the environment through spills, leaks, dumping, and other inappropriate management practices. Contamination entered the LDW through a variety of pathways, including discharge through pipes, surface water or groundwater; dumping materials directly into the waterway; or soil erosion.

Although waste disposal practices have improved considerably, legacy contamination continues to threaten human health and the environment. At the same time, ongoing sources of contaminants are present in this urban watershed, and pathways for both old and new contaminant sources continue to transport contaminants to and from the LDW.

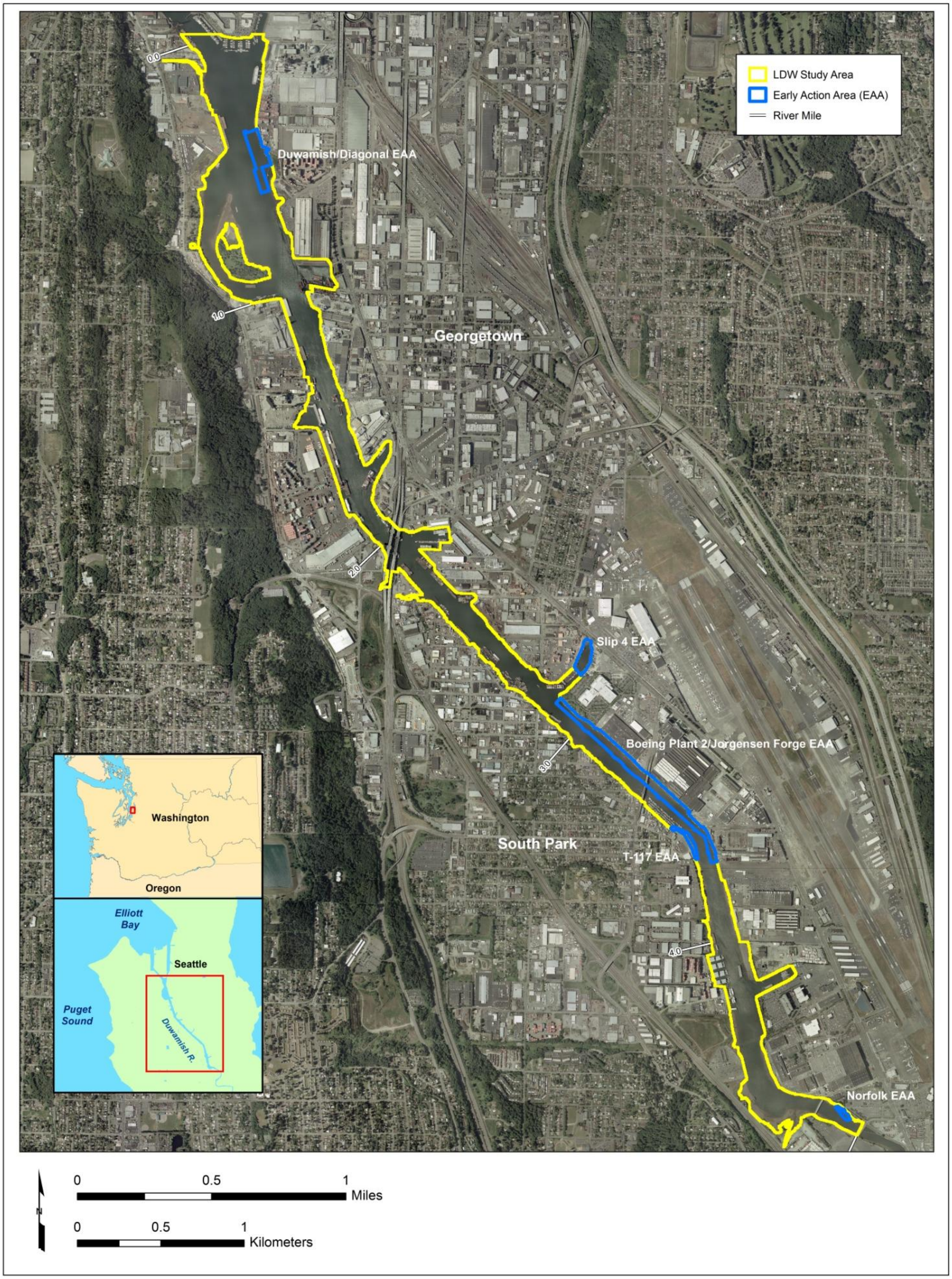


Figure 1. Lower Duwamish Waterway and Early Action Areas

Currently, contaminants enter the LDW through: direct discharges (stormwater, combined sewer overflows, industrial wastewater); surface runoff sheet flow; groundwater discharges; erosion/leaching of contaminated soils; in-water spills, dumping, leaks and inappropriate management practices; waterway operations and traffic; atmospheric deposition; and transport of contaminated sediments (within the LDW and from the upstream Green/Duwamish River watershed). Ecology’s draft Source Control Strategy (2012) provides detailed information about pollution sources and pathways to the LDW.

Ecology’s investigations indicate that addressing the direct discharge and stormwater pathways for contaminants is a higher priority than addressing the groundwater pathway. However, the groundwater pathway is being evaluated and addressed as it is encountered during source control activities. For example, EPA and Ecology have currently identified four groundwater plumes of primarily volatile organic compounds (VOCs). Ecology has identified four facilities with polychlorinated biphenyls (PCBs) in the groundwater. Three additional facilities have significant arsenic concentrations attributed to past industrial activities that occurred on those facilities. Several of these and other facilities have groundwater contaminated with carcinogenic polycyclic aromatic hydrocarbons (cPAHs) and metals. EPA and Ecology are currently investigating and remediating all of these facilities. Ecology will continue to investigate and address sources of contamination to the LDW, including groundwater, as part of its source control efforts.

2.2 Previous Investigations

Numerous investigations have been conducted to determine the nature and extent of contamination in the LDW. Early studies included waterway-wide investigations of the LDW by the National Oceanic and Atmospheric Administration (NOAA) and EPA 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.

In December 2000, the City of Seattle, King County, the Port of Seattle, and Boeing, collectively known as the Lower Duwamish Waterway Group (LDWG), voluntarily entered into an Administrative Order on Consent with EPA and Ecology that requiried LDWG to conduct a remedial investigation/feasibility study (RI/FS) pursuant to both CERCLA and the Model Toxics Control Act (MTCA) to investigate the nature and extent of contamination and develop remedial alternatives for the In-waterway Portion of the Site. During the RI, LDWG analyzed available data from numerous investigations conducted prior to 2000, collected extensive additional data, conducted 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; LDWG 2010) was completed in 2010. The RI included an assessment of risks to human health and the environment posed by the contamination. In the Final Lower Duwamish Waterway Feasibility Study (FS Report; LDWG 2012a), completed in 2012, LDWG developed alternatives for cleanup of the In-waterway Portion of the Site. After completion of the FS, LDWG developed two supplemental memoranda (LDWG 2012b, 2013) which consider refinements to the alternative under consideration for EPA’s preferred alternative in its 2013 Proposed Plan. EPA and Ecology jointly provided oversight for the RI/FS.

2.3 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 to partially implement the requirements of a 1991 CERCLA Natural Resource Damages Consent Decree to address contamination from CSOs in Elliott Bay and the LDW:

- In 1999, King County dredged 5,190 cubic yards (cy) of sediments contaminated with PCBs outside the Norfolk CSO/SD. 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, King County dredged (68,000 cy) and capped a 7-acre area around the Duwamish/Diagonal CSO/SD. The contaminants of concern (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 where PCBs remained elevated after the 2003-2004 cleanup was completed.

The first phase of the RI identified areas with high levels of contamination for consideration for early cleanup. Five EAAs were selected for action by EPA and Ecology, 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 Selected Remedy described in this ROD 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 spatially area-weighted average surface sediment PCB concentration by an estimated 50%.

EPA is conducting or has completed cleanups in the following areas.

Completed cleanups:

- 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 (with participation by King County) under an Administrative Settlement Agreement and Order on Consent (consent order) for a CERCLA removal. The first Long-Term Monitoring Data Report (for Year 1, 2013) was approved in January 2014.

Ongoing cleanups:

- Terminal 117: Soils on the upland portion of T-117 industrial property (referred to as "Upland") with elevated concentrations of PCBs and other contaminants were removed by the Port of Seattle with EPA oversight pursuant to separate 1999 and 2006 CERCLA consent orders. Cleanup of eight residential yards and an alleyway within the Study Area was completed in 2013, and cleanup of streets and rights of way, and installation of a permanent stormwater system, should be completed by the City of Seattle in 2015. Cleanup of the Upland soils and off-shore contaminated sediments was mostly completed in 2013-2014 by the Port of Seattle, with a small portion of the bank work remaining and scheduled for completion in winter 2014. All of the removal work conducted in the Study Area is being done by the Port and City under a June 2011 CERCLA consent order.
- Boeing Plant 2/Jorgensen Forge: Following completion of sufficient source control actions within the upland portion of the Jorgensen Forge facility and concurrent implemenation of interim

corrective measures and development of a Corrective Measures Study for the upland Boeing Plant 2 facility, cleanup in areas of sediment contamination in the banks and offshore of the adjacent Boeing Plant 2 and Jorgensen Forge facilities started in 2013. Although these areas are identified as one EAA, 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 are being addressed by Boeing under a 1994 Resource Conservation and Recovery Act (RCRA) Consent Order. Sediments contaminated with metals and other hazardous substances at Jorgensen Forge are being cleaned up under a 2012 CERCLA removal consent order by Earle M. Jorgensen, a former owner of the facility. EPA anticipates completion of both of these early actions in 2015.

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

Lower Duwamish Waterway Timeline

1999	Sediment cleanup was completed at the Norfolk CSO/SD
2000	A CERCLA and MTCA Consent Order was issued by EPA and Ecology requiring LDWG to conduct the RI/FS
2001	LDW was listed as a Superfund site on the National Priorities List
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 cleanup, and Ecology as the lead for source control. The MOU was revised in 2004, and was revised again in 2014 when the title was changed to Memorandum of Agreement (MOA).
	Ecology initiated the Source Control Work Group
2003	The LDW Phase 1 RI was completed, and additional cleanup was conducted at the Norfolk CSO/SD
2004	Ecology issued its Source Control Strategy
2005	Sediment cleanup was completed at the Duwamish/Diagonal CSO/SD
2006	EPA issued an Action Memorandum (cleanup plan) for the Slip 4 EAA
2010	The Final LDW RI was completed
2010	EPA issued an Action Memorandum for the Terminal 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 Forge sediments and shoreline bank soils
2012	Sediment cleanup was completed at the Slip 4 EAA
	The Final LDW FS was completed
2013	Cleanup started at Boeing Plant 2 and Terminal 117
2014	Cleanup started at Jorgensen Forge

2.4 Source Control Investigations and Actions Completed to Date

Ecology is the lead agency for identifying direct and indirect sources of contaminants to the In-waterway Portion of the Site. Ecology uses its regulatory authority and works with other governments that have regulatory authority (EPA, King County, and City 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 to support remedy selection in this ROD.

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

- Compiling a waterway-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. Ecology (with the SCWG) has identified 24 distinct Source Control Areas, and has completed Source Control Action Plans for all of them. 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.
- Tracing sources by sampling for contaminants in solids within storm drains and catch basins. 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.

Additionally, Ecology administers the Clean Water Act's National Pollutant Discharge Elimination System (NPDES) permitting program in Washington State. Ecology, with the other members of 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*.

2.5 Enforcement Activities

In addition to the CERCLA and MTCA RI/FS and removal orders and RCRA corrective action orders discussed above, EPA conducted activities to identify additional potentially responsible parties (PRPs) who may have contributed to contamination in the LDW. Information request letters were sent to 276 parties from 2006 to 2013. General notice letters were sent to 113 parties in November 2012. The general notice letters provided notification of the recipients' opportunity to comment on the Proposed Plan.

Summary of Source Control Actions To Date

All the source control work conducted to date and summarized below involved one or more of the following: source control investigations, site assessment and cleanup, inspections, source tracing, sampling, and monitoring. 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
- 8801 East Marginal Way (former Paccar site)
- South Park Landfill
- Crowley Marine Services
- Industrial Containers/Trotsky/Northwest Cooperage
- Boeing Isaacson-Thompson
- Duwamish Marine Center
- North Boeing Field/Georgetown Steam Plant
- Fox Avenue/Great Western Chemical
- Glacier NW/Reichhold
- Duwamish Shipyard
- Douglas Management Properties
- Port of Seattle Terminal 115 North

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
- Capital Industries
- Philip Services Georgetown
- Blaser Die Casting
- General Electric — Dawson Street Plant

Ecology has conducted site investigations at:

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

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

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

(Approximately ten other voluntary cleanups are ongoing or completed 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)
- Rhône-Poulenc (RCRA)
- Boeing Electronics Manufacturing Facility (CERCLA)
- Jorgensen Forge shoreline (CERCLA)
- Port of Seattle Terminal 117 (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:

- Between 2003 and December 2013, the City of Seattle and King County have completed more than 3,400 inspections at nearly 1,500 businesses in the LDW area. In addition, they have collected more than 1,025 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 December 2013, Ecology's Lower Duwamish Urban Waters Initiative inspection team completed 260 water quality inspections and 321 hazardous waste inspections.
- Approximately 104 facilities in the LDW drainage basin have NPDES permits from Ecology; approximately 94 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 six 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. Both entities have prioritized CSO control projects to address discharges to the LDW.

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*.

3 Community and Tribal Participation

This section summarizes the community involvement and Tribal consultation activities performed by EPA and Ecology during the RI/FS and the remedy selection process. 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, EPA and Ecology have:

- regularly held public meetings and have attended community and advisory group meetings;
- held quarterly stakeholder meetings to provide updates on the RI/FS, cleanup of the EAAs, and source control activities;
- 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;
- sent fact sheets to inform the community about Site progress;
- provided opportunities for public comment on the RI and FS Reports;
- provided information about EPA's work at the Site at annual community festivals; and
- provided updates at neighborhood meetings.

EPA and Ecology used input from a 2010 public review of the draft FS to finalize the FS and develop the Proposed Plan. EPA provides technical assistance grants to the community advisory group for the Site, the Duwamish River Cleanup Coalition/Technical Advisory Group (DRCC/TAG). This organization reviews information about the Site and shares it with community members. EPA plans to continue to coordinate with Ecology and engage with the community throughout design, construction, and long-term monitoring of the remedy, including any potential modifications to the remedy.

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. 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 and decisions. The Tribes have also broadly and actively participated in meetings determining the course of the cleanup to date. EPA plans to continue to consult with the Muckleshoot and Suquamish Tribes throughout design, construction, and long-term monitoring of the remedy, including any potential modifications to the remedy.

In conjunction with the FS, in response to comments on the 2010 draft FS, an environmental justice analysis (EJ Analysis) for the LDW was conducted and a draft was appended to the Proposed Plan (EPA 2013a) as Appendix B and made available for public comment concurrently with the Proposed Plan. 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 purposes of the EJ Analysis were 1) to screen for EJ concerns, and 2) to identify disproportionate adverse impacts from the cleanup alternatives and the Preferred Alternative in the Proposed Plan 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 ROD.

4 Scope and Role of the Response Action

The Selected Remedy is the third and final part of an overall strategy for addressing contamination in the LDW Site 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 sediment contamination, resident seafood tissue (edible portions of fish and shellfish) concentrations, and water quality within the waterway, to the extent practicable. As described below, the Selected Remedy 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.

4.1 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 2.3 describes progress to date on cleaning up the selected EAAs. Cleanup alternatives, costs, and outcomes identified in this ROD assume completion of the EAA cleanups, all of which are scheduled for completion 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 Selected Remedy and requires no further active remediation. The other selected 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. In conducting performance reviews, 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 this ROD.

4.2 Component 2: Controlling Sources of Contamination

As a general principle, EPA seeks to control sources of contamination early when managing risks at hazardous waste sites. Sources of contaminants in LDW surface water and sediments include stormwater carrying the contaminants of concern via CSOs, stormwater drains, and other point and non-point source 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. Ecology and the SCWG have performed extensive investigations and initiated multiple actions to address known sources of contaminants. Section 2.4 and Ecology's Source Control Strategy (Ecology 2012) provide more information on how Ecology as the lead agency for source control is leading this important component of the overall LDW remediation.

An objective of source control is to find and sufficiently control sources before conducting in-waterway remediation and thereby prevent or minimize recontamination after the cleanup is completed. EPA and Ecology will coordinate to find and sufficiently control sources of sediment contamination. Based on communications with Ecology, EPA anticipates that the process for determining whether source control is sufficient to begin in-water work will be fully described in Ecology's final Source Control Strategy, to be released in 2015. The focus of this work is to control sources sufficiently such that recontamination above the benthic SCO criteria and human health remedial action levels (RALs) (see Section 13.2 for an explanation of SCOs and RALs) is unlikely. Ecology plans to divide the waterway into three sections for the purposes of prioritizing source control activities, sequencing activities from the upstream to downstream sections of the LDW. Baseline and/or remedial design data will be necessary prior to conducting a sufficiency evaluation. After an evaluation, Ecology will provide EPA a recommendation whether or not to proceed with in-water remedial actions based on the status of source control in the immediate vicinity of the planned action. Upon EPA’s concurrence that source control is sufficient, active in-waterway sediment remediation can begin. This will prevent or minimize the likelihood that sediments will be recontaminated at levels that trigger additional active in-waterway sediment remediation (see Section 13). The coordination of the source control and in-waterway cleanup activities has been established in a Memorandum of Agreement (MOA). The MOA provides a broad framework for organizing the work of the federal, state, and local agencies under various legal authorities and describes how EPA and Ecology will coordinate sequencing of source control and sediment remedial actions. As stated earlier, Ecology’s draft Source Control Strategy (Ecology 2012) provides a broad framework for organizing the work of the federal, state, and local agencies under various legal authorities.

Overall, source control activities are expected to occur on two scales: 1) the immediate source area to the LDW where source control activities are focused on controlling sources and pathways of contamination to LDW sediments to prevent or minimize the likelihood that sediments will be recontaminated at levels that trigger additional active in-waterway sediment remediation; and 2) the larger watershed where source control activities are focused on regional efforts to address toxics that are present at ubiquitous concentrations in sediments, surface water, and stormwater, and via air deposition.

The final Source Control Strategy is expected to reference a Pollutant Loading Assessment (PLA; EPA and Ecology 2014) for the watershed to address the activities in the larger watershed (described in item 2 above). The PLA is needed to understand the relationship of water, sediment, and fish tissue quality to the overall health of the Green/Duwamish watershed. The goal of this assessment is to determine ways to reduce ongoing sources of pollution in the watershed. The PLA will help evaluate the relative importance of various sources of pollution to the watershed and inform targets and strategies for reducing those sources of pollution. The PLA tool will assess relative contribution of pollutants from various sources and pathways and will provide information to help prioritize source control activities in the watershed. The PLA will support and enhance Ecology and EPA’s current efforts to clean up the LDW. The LDW in-waterway cleanup is expected to significantly improve sediment quality in the LDW, but the success of the cleanup relies in part on cleaner sediments from upstream depositing on the LDW over time. By identifying strategies to reduce sources of pollution throughout the watershed, the PLA will help improve the effectiveness of the in-waterway cleanup.

Ecology sought public comment on its 2012 draft final revision of its 2004 Source Control Strategy concurrently with EPA’s public comment period for the Proposed Plan and is currently in the process of revising the Source Control Strategy to address public comments. Ecology is currently working with the federal, state and local source control agencies to develop Source Control Implementation Plans (Implementation Plans) as part of the final Source Control Strategy. 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. EPA submitted its draft Implementation Plan, which details its internal coordination process for source control projects within the LDW, to Ecology in 2013. Ecology will develop its own Source Control Implementation Plan. Ecology is expected to finalize its Source Control Strategy upon completion of the Implementation Plans, which it anticipates completing in 2015. Once completed, these plans will be available on Ecology's web site. In the unlikely event that timely and effective source control is not implemented, EPA may take actions pursuant to CERCLA or other federal authority to ensure the implementation and protectiveness of the Selected Remedy.

4.3 Component 3: In-Waterway Cleanup

The third element of the overall cleanup strategy for the Site, and the focus of this ROD, is the in-waterway cleanup. The Selected Remedy addresses, to the extent practicable, contaminated sediments and surface water below the mean higher high water (MHHW) level (in the LDW, MHHW is 11.3 feet above the mean lower low water [MLLW] level)[3] that are expected to remain after the EAA cleanup work (component 1) is completed. Although the Selected Remedy does not directly address surface water, COC concentrations in surface water will be reduced through implementation of source control and the Selected Remedy. The active response actions selected in this ROD 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 Selected Remedy described in this ROD is a final action that will be protective of public health and the environment, as described in detail in Section 13.4. It is EPA’s expectation that COC concentrations in sediment and in fish and shellfish tissue will have been reduced by 90% or more once the EAA cleanups are complete, adequate source control has been implemented, the active cleanup portions of the Selected Remedy have been implemented, and 10 years of monitored natural recovery have occurred after completion of the active cleanup portions of the remedy.

Although one goal of the combined actions is to attain applicable or relevant and appropriate requirements (ARARs), it may not be possible to attain all ARARs. Institutional controls (ICs) that limit seafood consumption in quantitites that present unacceptable health risks will be needed for the foreseeable future. The intent of the Selected Remedy is to reduce contaminant concentrations in sediments, surface water, and fish and shellfish tissue to the extent practicable, and to minimize reliance on fish and shellfish consumption advisories to reduce human exposure from ingestion of contaminated resident fish and shellfish. If EPA determines, after implementation of the remedy and long-term monitoring, that is it not technically practical to attain ARARs through the Selected Remedy or additional

[3] 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.

actions, EPA will consider waiving the ARAR in a future ROD Amendment or Explanation of Significant Differences (ESD) (see Sections 8.2.1 and 13.4).

It is important to note that meeting the requirements of CERCLA supports, but is not the same as attaining Washington's designated or existing uses under the Clean Water Act (CWA), as identified in WAC 173-201A. This ROD addresses the In-waterway Portion of the Site. Ecology is implementing other complementary actions, including actions under the CWA, to protect seafood consumers and aquatic life within the LDW. The CWA addresses pollutants in the water column through various mechanisms, including the NPDES permitting program under Section 402 of the CWA, which requires that point sources not cause or contribute to water quality standards violations, and the water quality standards and implementation plan program under Section 303 of the CWA. EPA delegated CWA permitting authority in Washington State to Ecology, and Ecology issues NPDES permits in compliance with CWA and state Water Pollution Control Act (WPCA) that authorize discharges to the LDW. Washington State's water quality assessment report prepared under section 303(d) and 305(b) of the CWA identifies numerous impairments in the LDW, including failure to meet water quality standards for approximately 40 different pollutants in sediment and fish tissue. The CWA requires that these impairments be addressed through development of a total maximum daily load (TMDL) or through the implementation of other pollution controls that will ensure that water quality standards are attained. EPA acknowledges that in order to address wide-spread contamination in the water column, Ecology may need to apply existing or revised water quality standards implementation tools. Changes to existing water quality standards implementation tools would be subject to EPA review and approval under the CWA. Over time, the integrated approach of CERCLA and longer-term clean water actions is expected to result in attainment of applicable surface water quality criteria and uses designated under the CWA.

5 Site Characteristics

This section summarizes information obtained through the RI/FS and other investigations conducted before or during the RI/FS. It includes a description of the physical characteristics of the LDW, including the results of the sediment transport model (STM) and the bed composition model (BCM), which are described in Sections 5.1.2 and 5.1.3, respectively, and the overall conceptual site model (CSM), described in Section 5.2. The CSM is supported in part by the food web model (FWM) used in the RI/FS and described in Section 5.2.1. Section 5.3 provides information on the nature and extent of contamination in the LDW, including concentrations of contaminants of concern (COCs) in the LDW as well as background levels and levels that enter the LDW from upstream.

5.1 Physical Characteristics

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 Site extends from RM 0 to RM 5, encompassing approximately 441 acres. Most 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 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 ft MLLW) from Harbor Island to the First Avenue South Bridge (RM 0 to 2), at -20 ft MLLW from the First Avenue South Bridge to Slip 4 (RM 2 to 2.8), and at -15 ft MLLW from Slip 4 to the Upper Turning Basin (RM 2.8 to 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, USACE dredges the upstream portion of the navigation channel every one to three years. USACE typically dredges 2 ft below the authorized depths (“advanced dredging”) in order to assure navigable depths are maintained until the next dredging event. 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 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.

5.1.1 Surface Water Hydrology

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 1900s, reducing the volume of water entering the LDW by approximately 70%. Water flows are now managed approximately 65 miles upstream by the Howard Hanson Dam, constructed in 1961. As a result, peak flows are much smaller with maximum flows rarely exceeding 12,000 cubic feet per second (cfs). Average river flows are estimated to be 1,340 cfs. In addition, the LDW has been widened and deepened to allow for navigation, resulting in reduced velocities. The reductions in peak flows and velocities result 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 denser salt water layer throughout much of the waterway forces the bulk of the freshwater to discharge upward toward the surface of the waterway, thus reducing sediment erosion during high river flows.

5.1.2 Sediment Transport Model

A three-dimensional sediment transport model (STM; LDWG 2008) was developed to simulate water flow and sediment erosion and deposition 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 STM linked a sediment transport model and a hydrodynamic model called Environmental Fluid Dynamics Code (EFDC) (see Section 5.2.1). The STM 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. Thus, approximately 25% of the incoming sediment remains in the LDW after dredging. The annual average amount dredged from the LDW by USACE is 51,000 metric tons, mostly in the Upper Turning Basin.

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. Sources that may be contributing to these higher concentrations are being investigated and addressed as part of source control (see Section 2.4).

Erosion and deposition[4] rates predicted by the STM are illustrated in Figure 2[5]. The STM results indicate that, overall, there is more deposition than erosion of sediment in the LDW. The highest net sedimentation rates in the LDW (up to 151.5 cm/year) occur in the area of the Upper Turning Basin from RM 4 to RM 4.8. The Upper Turning Basin serves as a trap for much of the coarser fraction of the bed load entering the LDW from upstream, and is dredged by USACE every few years. Throughout the LDW, net sedimentation rates were generally greater than 1 cm/year in the subtidal areas and less than 1 cm/year in the intertidal areas. Due to channel morphology, some areas are more erosional and some are more depositional. Erosion of the sediment bed by river flow (termed high-flow scour in Figure 2) is limited, even during high-flow events. Most bed erosion due to high-flow scour is less than 10 centimeters (cm) in depth and the maximum estimated net erosion depth is 22 cm. Routine vessel operations in shallow areas and berthing areas may cause localized propeller-wash scour (also known as vessel scour or tug scour) to depths greater than 22 cm, but likely less than 60 cm; routine vessel

[4] The combined or net effect of erosion and deposition is termed net sedimentation.

[5] In addition, Figure 2 shows areas that have evidence of propeller-wash scour which could redistribute sediments but were not included in the STM. See Section 9.2 and Table 22 for further discussion.

operations in the navigation channel are predicted to mix sediments to depths of 1-2 cm. Note that routine operations do not include emergency operations or shoreline and shallow water maintenance events, which occur sporadically in the waterway. 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 9.3) is occurring in some areas of LDW.

5.1.3 Bed Composition Model

A different 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.

As discussed in Section 10.1, the STM, the BCM, and empirical evidence were used in configuring and evaluating the long-term effectiveness of remedial alternatives. They were used to evaluate whether the sediment bed is stable (i.e., not subject to significant scour, erosion, and transport) and whether the net sedimentation rate is sufficient for natural recovery (burial of contaminated sediments) to occur. If these conditions are met in a given location, then monitored natural recovery (MNR) may be an applicable response action to evaluate in one or more remedial alternatives. Conversely, if natural processes do not appear to be effectively reducing contaminant concentrations in surface sediments, then only active remedial measures have been considered.

Key inputs to the BCM were upstream, lateral (e.g., from stormwater and CSOs), and bed-load contributions. Sensitivity testing of the BCM was performed as part of the FS to understand how model inputs affect the results. Low-end, mid-range, and high-end values were established for each type of input. The mid-range values were used as model inputs for developing and analyzing alternatives, and the low-end and high-end values were used for analyzing model sensitivity. Also, smaller scale areas were analyzed to evaluate local recovery potential and to assess whether empirical data and predictive models agree. Several lines of evidence[6] were combined to assess whether contaminated subsurface sediments are stable and are unaffected by surface-sediment movements, and whether surface sediment contaminant concentrations are expected to decrease over time.

[6] Lines of evidence considered for these purposes included isotopic analysis in core samples, sediment transport analysis, contaminant trend analyses, and evaluation of erosion potential.

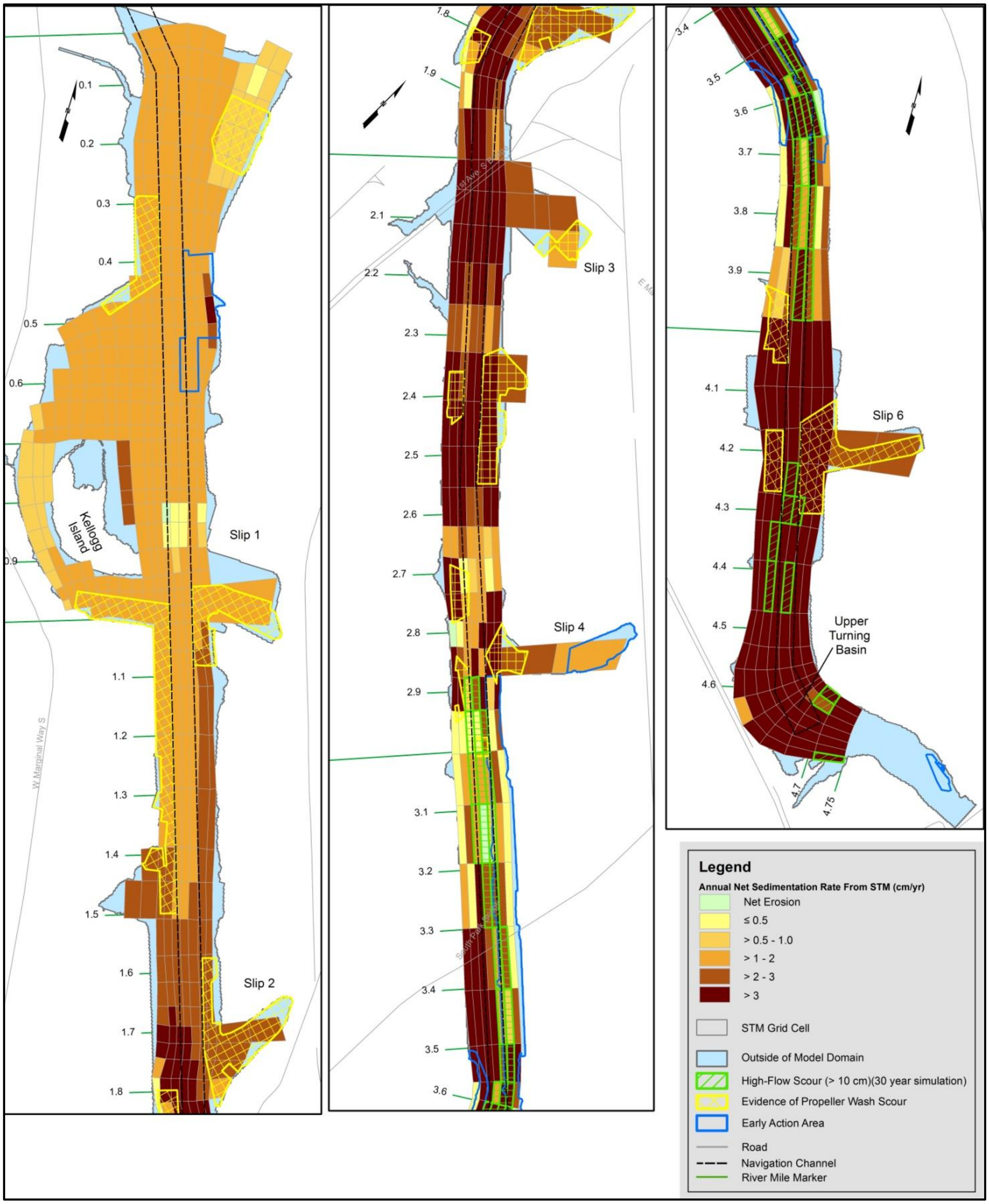


Figure 2. Potential Scour Areas and Estimated Net Sedimentation Rates

5.1.4 STM and BCM Uncertainty and Sensitivity Analyses

As noted above, analyses of uncertainty in the STM and BCM and of their sensitivity were performed during the RI and FS. The primary sources of uncertainty in the STM and BCM predictions are: 1) COC concentrations in incoming sediments from upstream and lateral sources; 2) the rate of net sedimentation (sediment burial) from incoming sediment loads (or net erosion); and 3) the potential for deep disturbances of subsurface contaminated sediments by mechanisms not accounted for in the model, such as vessel scour (propeller-wash or tug 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 the uncertain inputs, the STM, BCM, and food-web modeling, along with a subsurface-disturbance analysis in the FS, provide sufficient basis for comparison of alternatives and selection of the remedy. STM and BCM predictions for future waterway levels of contamination did not directly incorporate disturbances to bed sediments from propeller-wash scour; therefore, imaging of the waterway bed, interviews with waterway users, and sediment trend data were used to further refine understanding of these areas. Areas identified as potential "propeller-wash scour areas" are shown in Figure 2; however, they do not account for the possibility that an infrequent vessel scour event can occur virtually anywhere in the waterway. An additional uncertainty analysis evaluated the potential increase in contaminant concentrations due to infrequent scour events for each of the FS alternatives using PCBs as an indicator for all other contaminants.

5.2 Contaminant Transfer Conceptual Site Model

Figure 3 summarizes the pathways of contaminant transfer within the LDW. Multiple hazardous substances have been and continue to be discharged into the LDW and remain in the water column and waterway sediments. The sources of contamination and release/migration pathways are more fully described in Ecology's 2012 draft Source Control Strategy. Once contamination enters the waterway via the migration pathways shown in Figure 3, the contaminants may be taken up by organisms, including fish and shellfish, and bottom-dwelling organisms (also called benthic invertebrates). The consumption of these organisms by larger fish, shellfish, and wildlife provides a mechanism for the contaminants to move from the sediment and water 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. Fish such as salmon that only migrate through the LDW, instead of being resident, do not take up enough contaminants while in the LDW to be a concern. People and wildlife may also face risks from direct contact with contaminated LDW sediments. Section 7 describes exposure pathways for humans and wildlife and the associated risks.

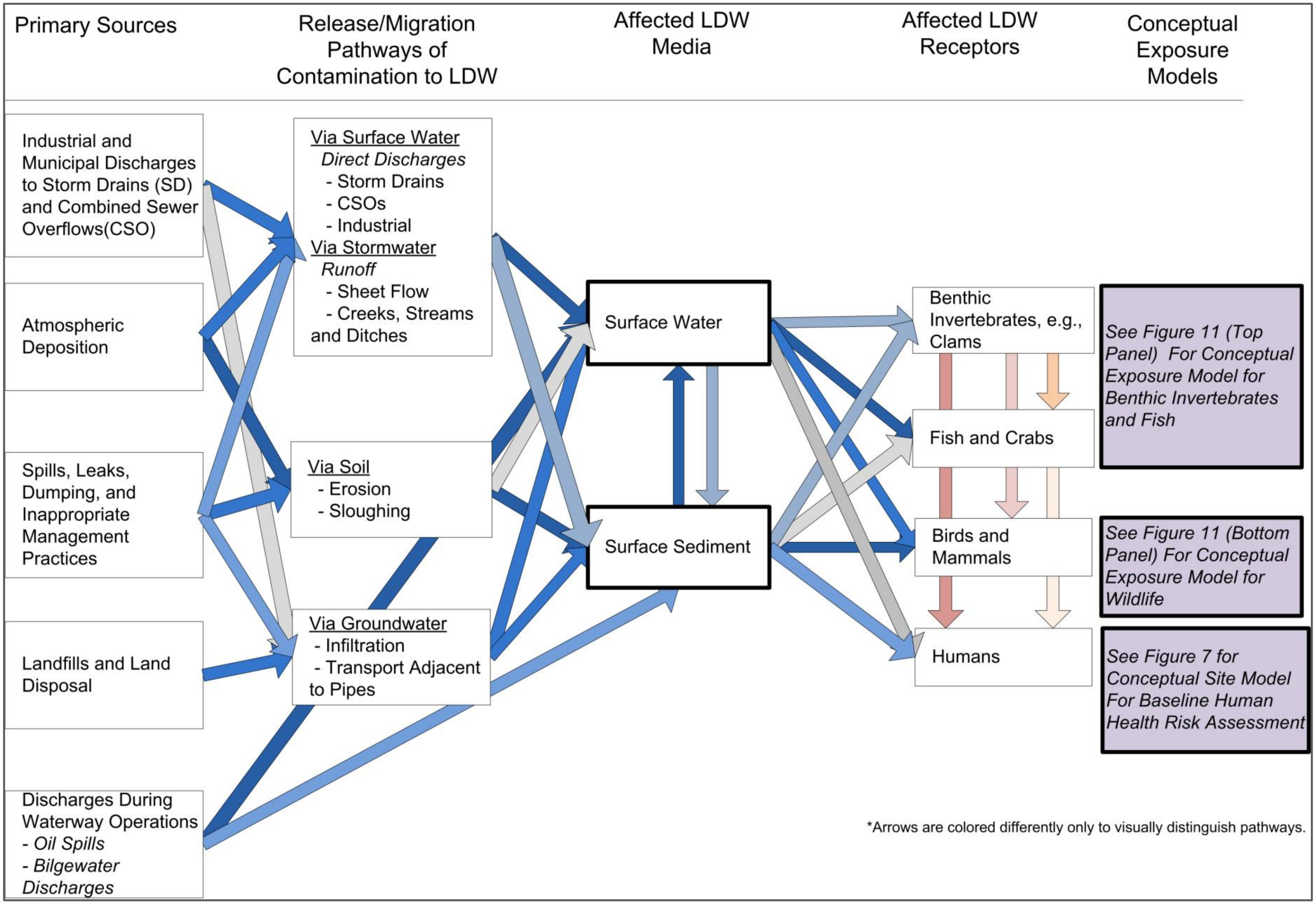


Figure 3. Conceptual Site Model.

5.2.1 Food Web Model

A food web model (FWM; LDWG 2010) based on a model initially developed by Arnot and Gobas (2004) was developed for the RI/FS to estimate relationships among PCB concentrations in surface sediment, in the water column, and in fish and shellfish tissue. The model has three environmental compartments: sediment, porewater, and surface water; and five biological compartments: phytoplankton/algae; zooplankton; predatory and filter-feeding benthic invertebrates; detritus-consuming benthic invertebrates; and fish.

Data for PCB concentrations in sediment, water, and tissue were combined with King County's EFDC hydrodynamic and contaminant fate and transport model to provide input parameters for the FWM (King County 2010). The EFDC model used for the FWM was a predecessor to the more refined EFDC model used in the STM (Section 5.1.2). The FWM was used to estimate PCB concentrations in water for the entire LDW over different spatial scales and over various temporal scales that include all four seasons.

The FWM results were used to: 1) estimate risk-based threshold concentrations (RBTCs) for PCBs in sediment for seafood consumption, and 2) estimate residual risks from PCBs that would remain after remediation under the FS alternatives for use in the comparative analysis of alternatives (Sections 10.1.1 and 10.2.1).

The FWM was used only for PCBs. The relationship between concentrations in sediment and concentrations in tissue for other seafood-consumption COCs was considered in the following ways:

- For arsenic and cPAHs[7], seafood consumption risks to humans were largely attributable to eating clams. However, analyses performed during the RI showed relationships between concentrations in clam tissue and in sediment were not statistically significant for either arsenic or cPAHs.
- For dioxins/furans, available data indicated that dioxin/furan concentrations in most Puget Sound fish and shellfish tissues would likely present unacceptable risk at the consumption rates used in the human health risk assessment. Therefore, no more modeling or study was needed to support a conclusion that the most appropriate dioxin/furan cleanup goals for LDW sediments would be background concentrations.

5.2.2 Food Web Model Uncertainty

Input parameters and distributions for the FWM were based on literature-derived and site-specific environmental data. Several analyses were performed to assess the sensitivity of the FWM to individual input parameters in combination with the uncertainty in estimates of those parameters. These analyses are summarized in the RI Report (LDWG 2010).

Key sources of uncertainty associated with use of the FWM for projecting post-cleanup residual risks are:

- Only PCBs were modeled; thus, any estimates of present or future risks using the FWM underestimate total risk by not including the other human-health seafood-consumption COCs.
- The FWM was calibrated using data collected in the late 1990s through 2005. The FWM has not been used with a different set of sediment and water concentrations to assess how accurately it can estimate tissue concentrations outside the range to which the FWM was calibrated. It is unknown how

[7] 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.

predictive the model will be under lower sediment concentrations such as are projected after remedial actions are completed.

- There is uncertainty in the projected post-remedy sediment PCB concentrations that are a key input parameter to the FWM. These post-remedy sediment PCB concentrations are based on the BCM, which is subject to its own set of uncertainties, as described in Section 5.1.4.
- EFDC model projections and best professional judgment were used to estimate a key input parameter to the FWM: post-remedy water PCB concentrations. A sensitivity analysis showed that the water PCB concentration becomes the most important factor for modeling tissue concentrations at the very low projected post-cleanup sediment PCB concentrations.

5.3 Nature and Extent of Contamination

See Section 2.2 for a summary of LDW investigations prior to the RI/FS. 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 initially extended to RM 7, but was later reduced to the lower 5 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/FS based on the concentration of contaminants in approximately 1,500 surface sediment samples (from within the 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. Approximately 900 of these samples were collected as part of Phase 2 of the RI in 2004 – 2006, and an additional 47 samples were collected during the FS in 2009 – 2010. The rest of the dataset consisted of data from samples collected during other investigations in the waterway (e.g., investigations conducted prior to the start of the RI discussed in Section 2.2, and investigations conducted as part of the EAA cleanups) between 1990 and April 2010, which were incorporated into the RI and FS datasets. Because the RI report was completed before the FS, the RI used a slightly different dataset than the FS. The RI baseline dataset included data collected between 1990 and October 2006. The FS baseline dataset included additional data collected after October 2006 and until April 2010. The expanded FS dataset filled data gaps but did not result in significant changes to the CSM or assessment of human health or ecological risks. The results of these investigations for sediments, fish and shellfish tissue, and surface water are described in the RI (LDWG 2010) and FS (LDWG 2012a) reports and summarized below. Data shown in Table 1 are from the FS dataset.

5.3.1 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. Sediment samples were analyzed for numerous contaminants during the RI/FS; these contaminants account for the majority of human health risks from contamination in the LDW, as discussed in Section 7.1.

5.3.1.1 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.

Table 1. Statistical Summaries for Baseline Human Health COC Concentrations in Sediment

Data Type/Contaminant	Summary Statistics for Sediment in the LDW (RM 0 to 5.0)				Total Number of Sediment Samples in FS Baseline Dataset	
	Minimum Detect	Calculated Mean	Maximum Detect	Spatially-Weighted Average Concentration (SWAC)	Total	With Detected Values
Surface Sediment						
PCBs (µg/kg dw)	2.2	1,136	220,000[a]	346	1,392 (1,390)[a]	1,309
Arsenic (mg/kg dw)	1.2	17	1,100	15.6	918	857
cPAHs (µg TEQ/kg dw)[b]	9.7	459	11,000	388	893	852
Dioxins/Furans (ng TEQ / kg dw)[c]	0.25	42	2,100	25.6	123	119
Subsurface Sediment						
PCBs (µg/kg dw)	0.52	1,953	890,000	n/a	1,504	1131
Arsenic (mg/kg dw)	1.2	29	2,000	n/a	531	453
cPAHs (µg TEQ/kg dw)[b]	1.2	373	7,000	n/a	542	449
Dioxins/Furans (ng TEQ / kg dw)[c]	0.15	17	194	n/a	64	64

Source: FS baseline surface and subsurface sediment dataset dated April 28, 2010 (surface) and May 14, 2010 (subsurface). This summary is based on data used for the Feasibility Study (see Section 5.3); however, for the human health and ecological risk assessments the RI dataset was used..

a. This table excludes two PCB samples, both collected at the inlet at RM 2.2. They were considered anomalous samples and statistical outliers and were not included in calculated mean and SWAC; their detected concentrations were 230,000 and 2,900,000 µg/kg. If the outliers were included, the mean would be 3,400 µg/kg dw and the SWAC would be 1,300 µg/kg dw.

b. The cPAH TEQs were calculated using compound-specific potency equivalency factors.

c. The dioxin/furan TEQs were calculated using World Health Organization's mammalian toxic equivalent factors.

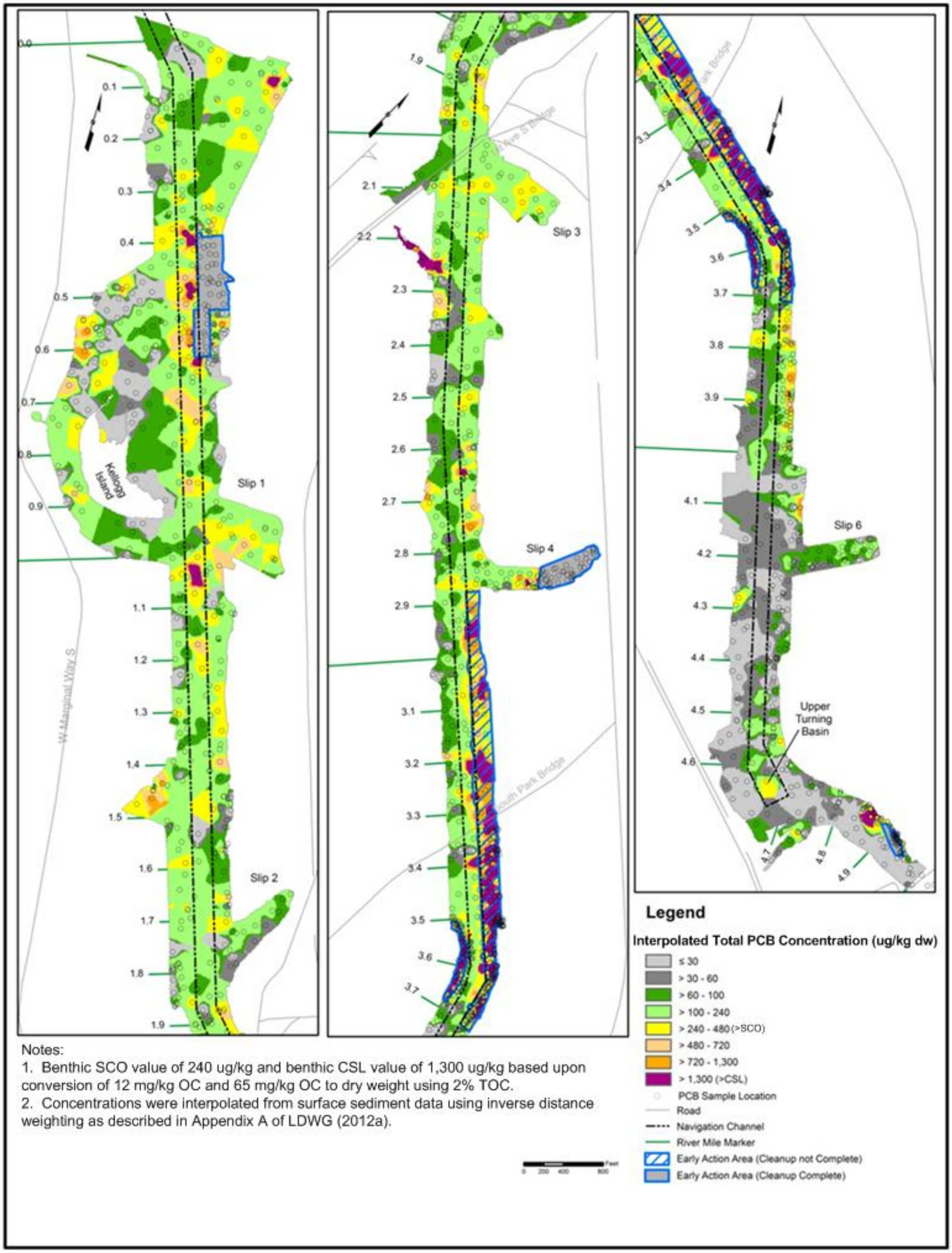


Figure 4. PCB Distribution in Surface Sediment

Areas where COCs were present at concentrations toxic to benthic invertebrates were identified in the RI/FS based on the Washington State Sediment Management Standards (SMS).

The SMS were revised on September 1, 2013, after issuance of the Proposed Plan; therefore some terminology used in the Proposed Plan has been changed for this ROD. Among other changes the revised SMS changes the term for the criteria for protection of marine benthic invertebrates to “sediment cleanup objectives" or SCO, formerly called “sediment quality standards” (SQS). This is a terminology change only; the benthic protection criteria themselves are unchanged. See "What are the Sediment Management Standards?" on page 26 for a summary of the revised SMS.

This ROD uses the terms "benthic SCO" and "benthic CSL" to refer to the criteria to protect benthic invertebrates. The more general terms “SCO” and “CSL” refer to the overall standards which include standards for the protection of human health (HH) and for the protection of higher trophic level species (HTLS) that have been referred to more simply as wildlife in this ROD. On occasion, the terms HH SCO and HTLS SCO are used.

In the SMS, the numerical sediment cleanup objectives (benthic SCOs) are contaminant concentrations below which no adverse effects on benthic invertebrate organisms are expected. The SMS also establishes cleanup screening levels (benthic CSLs), higher levels for the same contaminants at which minor effects are expected. These benthic SCOs and benthic CSLs, together, are called chemical criteria. The SMS regulations also allow use of alternate criteria — site-specific biological-effects criteria that are based on toxicity testing or benthic abundance data — to determine whether a location does or does not meet (i.e., passes or fails) the benthic SCO or benthic CSL; these are called biological criteria.

Surface sediment samples from 76 locations were tested for both contaminant concentrations and biological effects.[8] Figure 5 shows areas where neither benthic SCOs nor CSLs were exceeded (areas identified as “pass”), areas where only SCOs but not CSLs were exceeded, and areas where CSLs were exceeded.

Forty-one hazardous substances were designated as COCs for benthic invertebrates because they were detected in LDW sediment at concentrations that exceed the benthic chemical SCOs and. In surface sediment, PCB concentrations exceeded the benthic SCO more frequently than those of any other COC, followed by BEHP, then butyl benzyl phthalate. The locations where these exceedances occurred and extent of these exceedances varied by COC. Section 7.2.5 provides summary information on surface sediment contamination for these 41 COCs, including minimum and maximum detected concentrations, average concentrations, detection frequencies, and exceedances of benthic SCOs and benthic CSLs.

In addition to contaminant concentrations, several other parameters were measured during the RI. The percent fines (sum of clay and silt fractions) in LDW surface sediments ranged from 13 to 87% with an average of approximately 53%, and the LDW-wide average total organic carbon (TOC) content is 2%. Sediment grain size and TOC content 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.

[8] Sample locations where benthic SCO or benthic CSL chemical criteria were exceeded but benthic SCO or CSL biological criteria were not exceeded were designated as not exceeding the benthic SCO or CSL—that is, the determination of whether criteria are exceeded was based on biological criteria not chemical criteria. It is important to note that risks to human health or to fish and wildlife coming into contact with sediment or eating fish and shellfish that live in the waterway are not addressed by either the SMS numerical chemical criteria or the SMS biological criteria. Those risks are addressed separately as described in this ROD.

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 uses two tiers to establish a sediment cleanup level. The sediment cleanup level starts at the lower tier and may be adjusted no higher than the upper tier (provided certain factors are met).

- Tier 1) sediment cleanup objectives (SCOs), the level that is the environmental goal for establishing sediment cleanup levels; and
- Tier 2) cleanup screening levels (CSLs), the level used to identify cleanup sites and the maximum level for establishing sediment cleanup levels.

The sediment cleanup level for each COC is initially set at the SCO and is allowed to be adjusted upward (but cannot exceed the CSL) if it is not technically possible to achieve the SCO or if achieving the SCO will result in a net adverse environmental impact.

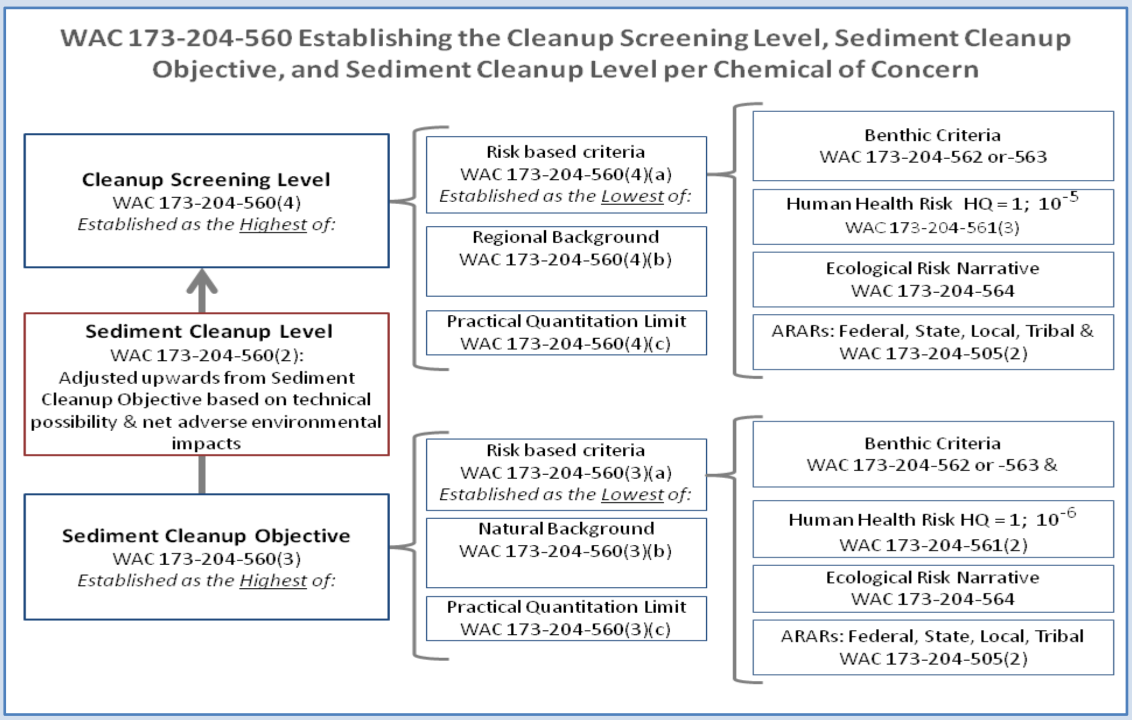
Each tier consists of:numerical chemical concentration criteria (chemical criteria) and biological effects criteria for protection of benthic invertebrates, risk-based standards for protection of human health, narrative standards for protection of other ecological receptors, and provisions for use of background concentrations. The chemical criteria for protection of marine benthic invertebrates are based on relationships between sediment contaminant concentrations and toxicity to 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. The biological-effects criteria allow for site-specific testing for toxicity or for abundance.

The SCO for each COC is established as the highest (least stringent) of risk-based concentrations, natural background concentrations, and practical quantitation limits (PQL). The risk-based criteria are the lowest (most stringent) of:

- concentrations protective of human health (based on an excess cancer risk of 1 x 10^{-6} for individual carcinogens, 1 x 10^{-5} for carcinogens culmulatively, or a noncancer Hazard Quotient [HQ] or Hazard Index [HI] of 1.0) (HH SCO)
- concentrations showing no adverse effects to the benthic community (benthic SCO), specified as chemical criteria and biological criteria in the SMS, and
- concentrations resulting in no adverse impacts to higher trophic level species (HTLS SCO).

The CSL for each COC is established as the highest (least stringent) of risk -based concentrations, regional background, and PQL. The risk-based criteria are the lowest (most stringent) of:

- concentrations protective of human health (based on 1 x 10^{-5} excess cancer risk for individual carcinogens and carcinogens cumulatively, or a noncancer HQ or HI of 1.0) (HH CSL),
- concentrations showing minor adverse effects to the benthic community (benthic CSL), specified as numerical chemical and biological criteria in the SMS, and
- concentrations resulting in no adverse impacts to HTLS (HTLS CSL).



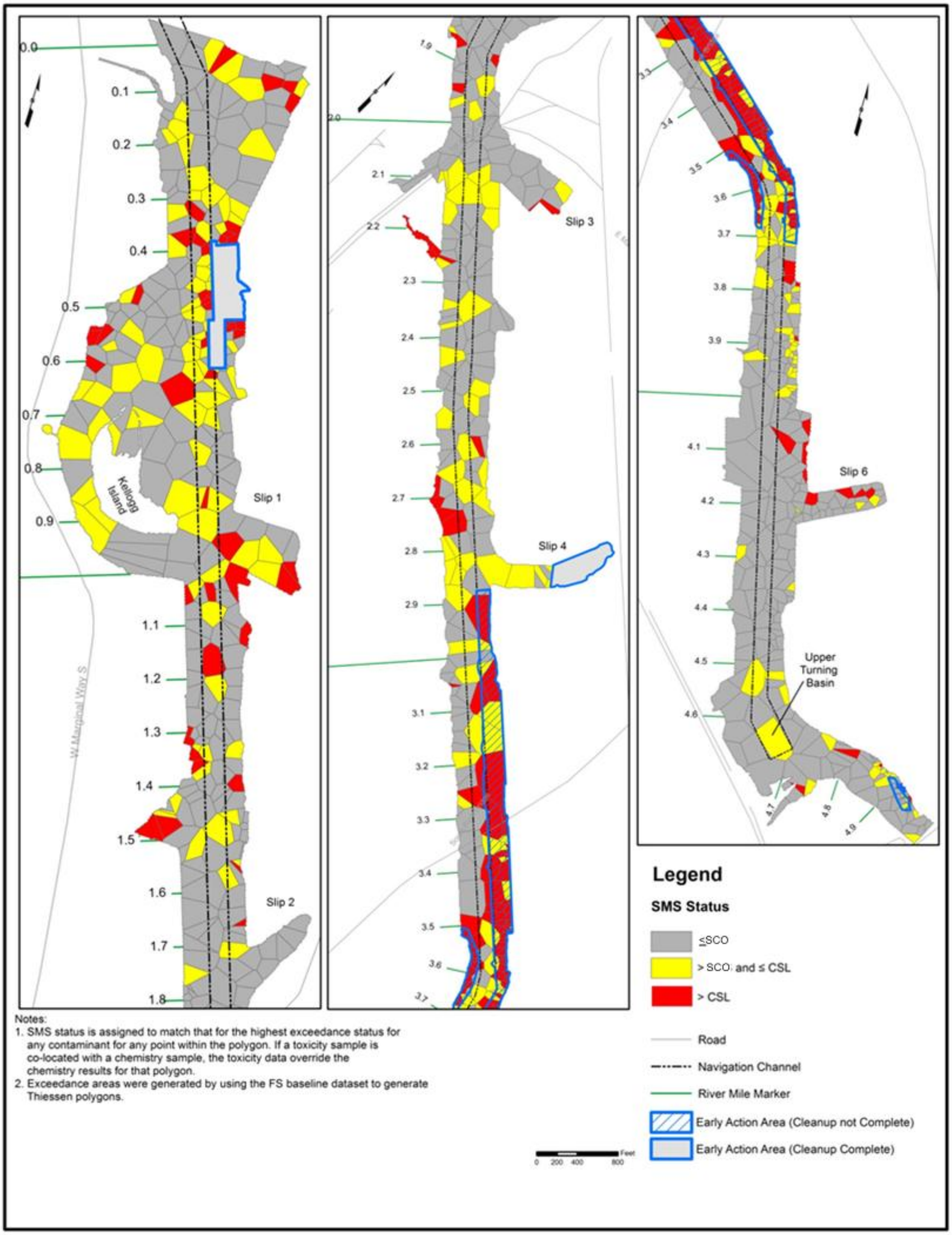


Figure 5. SMS Status in Surface Sediment

5.3.1.2 Subsurface Sediments

Detected contaminant concentrations were above the benthic SCO for one or more of the SMS contaminants in 49% of the subsurface sediment samples. The average thickness of subsurface sediments with COC concentrations greater than the benthic SCO is 4 ft. Of the COCs detected in subsurface sediments at concentrations above the benthic SCO, PCBs were detected most frequently (48% of the samples), followed by BEHP (25% of the samples). Table 1 summarizes sediment contaminant concentration data (both surface and subsurface) for the human health COCs: PCBs, arsenic, cPAHs, and dioxins/furans. (Selection of human health COCs is discussed in Section 7.1.1).

5.3.2 Fish, Shellfish, and Benthic Invertebrate Tissue

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

- **PCBs** – Detected in almost all samples, ranging from 6.9 to 18,400 micrograms per kilogram wet weight (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 0.003 milligrams per kilogram wet weight (mg/kg ww) to 11.3 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. Inorganic arsenic concentrations in clams in the LDW were one to three orders of magnitude 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 dioxins/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. Separate from the RI, 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; however, this was after completion of the human health risk assessment. See Section 7.1 for further discussion.

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

Tissue PCB concentrations in benthic invertebrates were often higher in areas with higher sediment PCB concentrations. A similar pattern was observed for some species of fish (shiner surfperch, and staghorn sculpin) indicating that they may have smaller foraging ranges; in others (English sole and crabs), tissue concentrations did not show a clear relationship to sediment concentrations, indicating they may have larger foraging ranges. 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.

Table 2. Summary of Selected Baseline Human Health COC Concentrations in Fish and Shellfish Tissue[a]

Contaminant and Tissue Type	Detection Frequency	Concentration		
		Minimum	Mean	Maximum
PCBs (µg/kg ww)				
English sole (fillet with skin)	26/26	170	860	2,010
Shiner surfperch (whole body)	78/78	200[b]	1,300	18,400[b]
Dungeness crab (edible meat)	14/17	15	130	300
Dungeness crab (whole body[c])	16/16	97	890	1,900
Clams	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[b]	0.010	0.010
Dungeness crab (whole body[c])	2/2	0.022[b]	0.029	0.035
Clams	23/23	0.132	2.72	11.3
cPAHs (µg TEQ/kg ww)				
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[c])	7/9	0.60[b]	2.6	2.4[b]
Clams	14/14	6.8	15	44
Dioxins/Furans (ng TEQ/kg ww)[d]				
English sole (fillet without skin)	6/6	0.26	0.30	0.35

Note: Additional fish and shellfish species were collected during the RI. All fish and shellfish COC data are presented in the RI.
a. Section 7.1.1 describes the selection of human health COCs.
b. These data points are analytically estimated values.
c. Whole body Dungeness crab concentrations were estimated based on results from edible meat and hepatopancreas samples.
d. 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.

5.3.3 *Surface Water*

The water column, along with 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 unfiltered surface water samples ranged from 0.13 to 3.2 nanograms per liter (ng/L), with the lowest concentrations detected during periods when flows were highest. Dissolved arsenic concentrations ranged from 0.18 to 1.5 micrograms per liter (µg/L). Detected surface-water PAH concentrations (collected using semipermeable membrane devices) ranged from 0.0027 ng/L for dibenzo(a,h)anthracene to 0.35 ng/L for benzo(a)anthracene. 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.

5.3.4 Background COC Concentrations

Documenting background concentrations (concentrations at locations away from the Site and away from other sources of contamination) 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.

5.3.4.1 Sediment Background Concentrations

Under CERCLA and MTCA/SMS, when risk-based threshold concentrations (RBTCs, see Section 8) are below background, background concentrations are used as cleanup levels. The State of Washington adopted its revised SMS in September 2013. The 2013 SMS sets two background levels. The first is the Sediment Cleanup Objective (SCO), which sets the background concentration at the natural background level. Natural background under MTCA is defined for sediments in WAC 173-204-505 (and for all other media in WAC 173-340-200) as “the concentrations of a hazardous substance consistently present in the 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. A second, new, background level is defined under the 2013 SMS rule at the Cleanup Screening Level (CSL), where the background concentration may be set at "regional background." Regional background concentrations for this Site have not been established. See Section 8.2.2.1 for further discussion of the 2013 SMS rule and the possible future use of regional background. The MTCA/SMS approach is consistent with EPA guidance (EPA 2002a), which calls for the use of natural or anthropogenic background as appropriate for the circumstances at a particular site.

To characterize sediment natural background COC concentrations, data from a 2008 study (USACE et al. 2009) of sediment contaminant concentrations in non-urban areas in Puget Sound were used. 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)[a]
PCBs (µg/kg dw)[b]	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. These values are rounded to one significant figure.
b. Only PCB congener data from the EPA (2009a) study were used, as there were few detected values in the Aroclor data.

5.3.4.2 Fish and Shellfish Tissue Background COC Concentrations

To define natural 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). These non-urban Puget Sound fish and shellfish tissue data, shown in Table 4, were used to set target tissue concentrations (Section 8.2.3, Table 21) when RBTCs were below background.

Table 4. 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 Concentra-tions	Mean	95th Percentile Upper Confidence Limit on the Mean (UCL95)
PCBs (µg/kg ww)				
English sole, rock sole (fillet)	158 / 238	1.3 – 75.4	11	12
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)				
Eastern softshell clams (whole body)[a,b]	6 / 0	0.047 / 0.112	0.064	0.09
cPAH TEQ (µg/kg ww)				
Butter clam, geoduck, littleneck clam (whole body)[a]	3 / 11	0.069 – 0.17	0.088	0.12
Dioxin/furan TEQ (ng/kg ww)				
Starry flounder, rock sole (whole body)[c]	7 / 7	0.17 – 0.92	0.28	0.35
Dungeness crab (edible meat)	27 / 27	0.027 – 1.4	0.57	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

a. Only clams are shown for inorganic arsenic and cPAH TEQ because most of the risk associated with these COCs was due to consumption of clams.

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 insufficient data to derive a background value for pelagic fish (e.g., perch) for total PCBs, cPAHs, and dioxins/furans; there were insufficient data for benthic fish (e.g., English sole) fillets for dioxins/furans.

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

Background COC concentrations for non-urban Puget Sound fish and shellfish tissue are much more uncertain than background concentrations for sediment. 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.

5.3.5 Sediment COC Concentrations from Upstream of the LDW Study Area

This section describes the information used in the BCM to estimate the concentrations of COCs in upstream sediments that deposit in the LDW.

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 of future COC concentrations in the LDW after implementation of the cleanup alternatives evaluated in the FS (see Section 9.4).

Datasets that were 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 USACE 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.

For the four human health COCs, Table 5 shows the low, high, and mid-range estimates of upstream suspended sediment COC concentrations selected for use in the BCM. Each sampling technique may over- or underestimate the COC concentrations in sediments entering the LDW. In addition, all of the datasets used in this evaluation were small (e.g., datasets used for the upstream input parameters ranged from 6 to 31 samples). All these factors make the estimates of incoming sediment COC concentrations more uncertain than background sediment concentrations. 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 5. Estimates of Upstream Suspended Sediment Concentrations of PCBs, Arsenic, cPAHs, and Dioxins/Furans Used in the LDW Bed Composition Model

Human Health COCs	BCM Parameters			Basis for BCM Upstream Input Values and Sensitivity Analysis Values[a]
	Input	Low	High	
PCBs (µg/kg dw)	35	5	80	Input: Upper Turning Basin subsurface sediment data, mean (36 rounded to 35). Low: Ecology upstream Green/Duwamish River surface sediment samples containing fines > 30%, mean. High: TSS-normalized King County (whole-water), UCL 95 (82 rounded to 80).
Arsenic (mg/kg dw)	9	7	10	Input: Ecology upstream Green/Duwamish River surface sediment samples containing fines >30%, mean. Low: Upper Turning Basin subsurface sediment data, mean. High: UCL 95, Ecology upstream Green/Duwamish River surface sediment samples containing fines >30%.
Carcinogenic PAH (µg TEQ/kg dw)	70	40	270	Input: Upper Turning Basin subsurface sediment data, mean (73 rounded to 70). Low: Ecology upstream Green/Duwamish River surface sediment samples containing fines >30%, mean (37 rounded to 40). High: TSS-normalized King County (whole-water), UCL 95 (269 rounded to 270).

Human Health COCs	BCM Parameters			Basis for BCM Upstream Input Values and Sensitivity Analysis Values[a]
	Input	Low	High	
Dioxins/Furans (ng TEQ/kg dw)	4	2	8	Input: Ecology upstream Green/Duwamish River surface sediment and upstream suspended sediment data, midpoint between means. Low: Ecology upstream Green/Duwamish River surface sediment samples containing fines > 30%, mean. High: Ecology upstream suspended sediment data, midpoint between mean and UCL 95.

a. Upstream BCM parameter values were revised using updated datasets and statistics reflective of current conditions (i.e., material entering the LDW from the Green/Duwamish River). The four primary datasets used for BCM parameterization are:

- Ecology's 2008 upstream bed sediment chemistry data: This dataset was screened to exclude samples with ≤30% fines in consideration of the systematic differences in grain size distributions between upstream (e.g., mid-channel) data and average conditions in the LDW.
- Total Suspended Solids (TSS)-normalized King County data: King County surface water data were normalized to solid fractions by dividing by the TSS in the individual sample.
- Ecology 2008 centrifuged suspended solids data: The Ecology samples are representative of sediments suspended mid-channel in the Green/Duwamish River that enter the LDW.
- Upper-reach USACE Dredged Material Management Program (DMMP) core data (RM 4.3 to RM 4.75): This dataset is representative of Green/Duwamish River suspended material that settles in the upper section of the LDW.

6 Current and Potential Future Land and Waterway Use

This section summarizes the current and reasonably anticipated future use of the waterway and surrounding watershed. This information forms the basis for the exposure assessment assumptions listed and discussed in Section 7.1.

6.1 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); and 17% is open/undeveloped land and parks.

Residential areas near and on the LDW include the neighborhoods of South Park and Georgetown. These neighborhoods support a mixture of residential, recreational, commercial, and industrial uses. 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 Environmental Justice in Minority Populations and Low-Income Populations*. As noted in EPA's Environmental Justice Analysis (EPA 2013a), 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 higher rates of other chronic diseases such as diabetes than other Seattle neighborhoods and King County as a whole.

6.2 Waterway Use

The LDW supports major shipping activities for containerized and bulk cargo. Approximately 40 berthing areas are located along the LDW. Four marinas permit live-aboard vessels. The LDW is also used for commercial salmon fishing and various recreational activities such as boating, kayaking, fishing, and beach recreation. The LDW serves as a habitat for fish, shellfish, and wildlife, as described in Section 7.2.

Designated uses for the LDW can be found under WAC 173-201A-610 and 612 (Table 612). The LDW is considered marine water under the state's water quality standards regulation because it meets the salinity threshold (vertically averaged maximum daily salinity of 1 part per thousand qualifies as marine) described in WAC 173-201A-260(3)(e). Salinity measurements show tidal condition exists beyond the turning basin. Although the Lower Duwamish Waterway is not specifically mentioned in Table 612, the LDW is considered a continuation of Elliott Bay for the purposes of applying marine criteria. Specifically, the same marine designated uses and standards apply east of a line between Pier 91 and Duwamish Head as long as the salinity threshold is met. The designated uses for the LDW include:

- Aquatic life uses:
    - Excellent: Excellent quality salmonid and other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans, and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning
- Shellfish harvest:
    - Shellfish (clam, oyster, and mussel) harvesting
- Recreational uses:
    - Primary contact recreation
- Miscellaneous uses:
    - Wildlife habitat
    - Harvesting (Salmonid and other fish harvesting, and crustacean and other shellfish (crabs, shrimp, scallops, etc.)
    - Commerce and navigation
    - Boating
    - Aesthetic values

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.

The Washington State Department of Health (WDOH) currently maintains a seafood consumption advisory recommending no consumption of resident fish and shellfish from the LDW. As discussed in Section 7.1, the limited amount of time salmon spend in the LDW results in low site-related salmon body burdens of bioaccumulative contaminants. Consequently, salmon are not included in the LDW fish advisory, although they are included in a South Puget Sound advisory which recommends eating no more than one meal per week to one meal per month depending on the species. 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*. In spite of the seafood consumption advisory, fishers report regularly catching and consuming LDW resident fish and shellfish (LDWG 2014b).

The LDW shoreline is zoned predominantly for recreation, conservancy preservation, and urban industrial land use. A small area on the west side of the LDW between RM 3.1 and RM 3.3 is zoned for single-family residential use. 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. 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 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 (Figure 6). Figure 6 also identifies beach play areas (intertidal areas accessible from shore) and potential clamming areas (areas where clams are present) used in the human health risk assessment.

Although habitat and recreational use, as well as Tribal fishing and shellfishing, may increase at some point in the future, the reasonably anticipated future use of the waterway and surrounding area are anticipated to remain similar to current use.

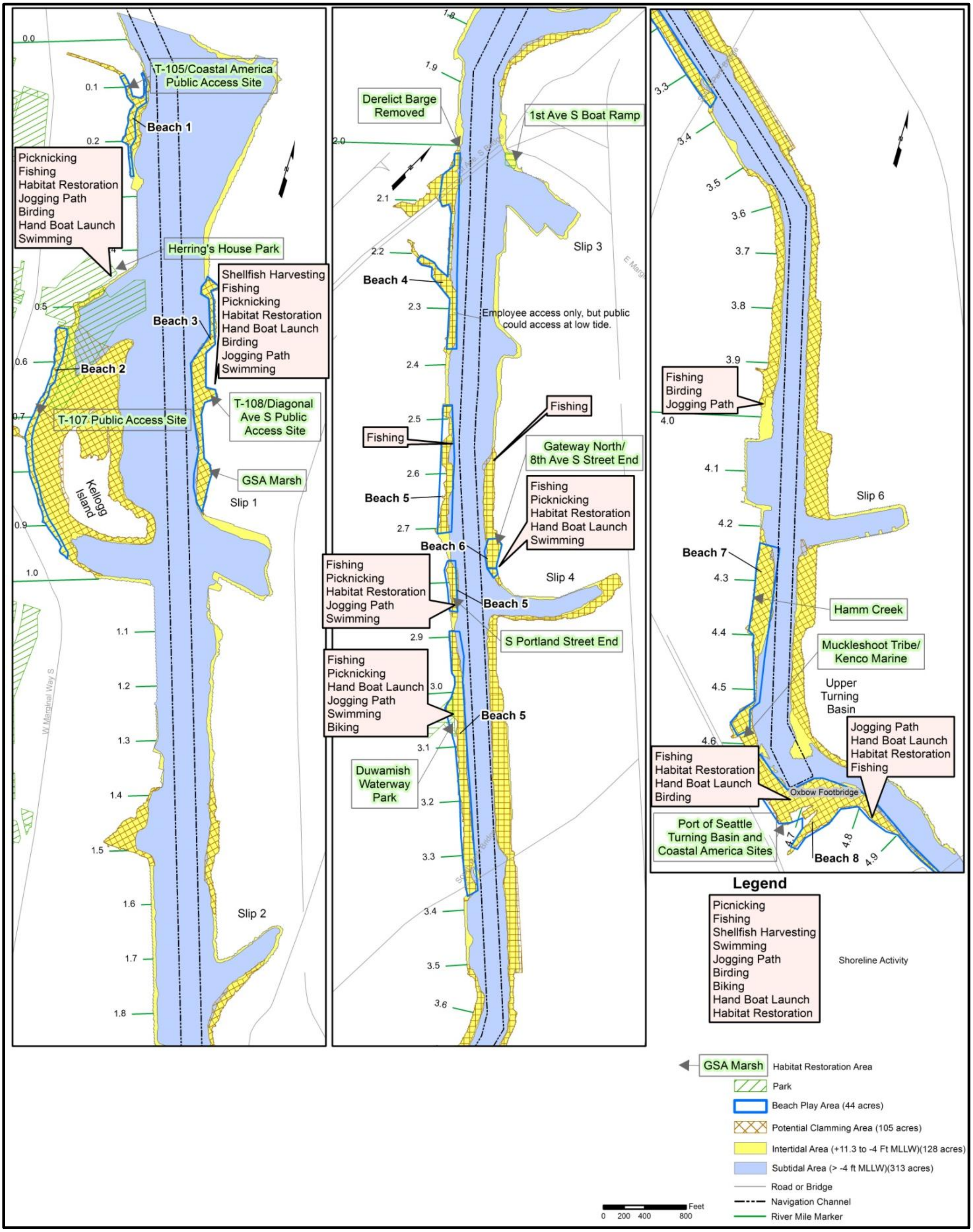


Figure 6. LDW Areas with Parks and Habitat Restoration, Beach Play Activities, and Potential Clamming.

7 Summary of Site Risks

Baseline human health and ecological risk assessments (HHRA and ERA) were conducted during the RI 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 if no action were taken to address contamination at the Site. These assessments provide the basis for taking action and identify the contaminants and exposure pathways that need to be addressed by the remedial action. Multiple exposure pathways by which humans or animals could be exposed to contaminants in the In-waterway Portion of the Site (the "waterway" or LDW) were evaluated. Figure 7 shows the human health conceptual site model. Esitmates of risks remaining after cleanup (Section 10) can be compared against the baseline assessments to determine the amount of improvement that results from a remedial action.

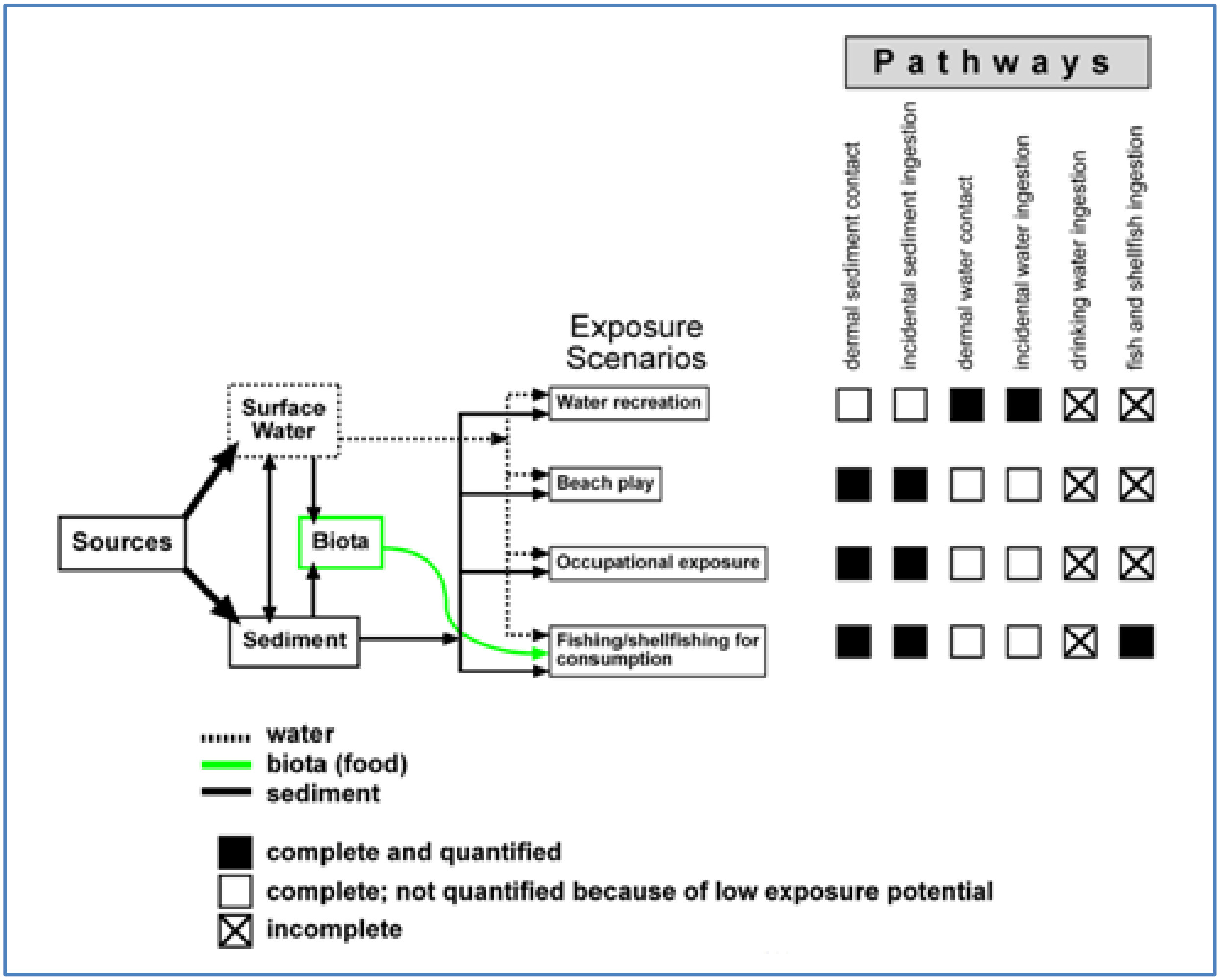


Figure 7. Conceptual Model for Baseline Human Health Risk Assessment

7.1 Human Health Risks

In conducting a human health risk assessment, EPA evaluates the potential for noncancer health effects such as immunological, reproductive, developmental, or nervous system disorders, and the potential for increased cancer risk. Different methods are used to estimate noncancer health effects than cancer risks. EPA estimates human health risks using the following process:

- 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 (called contaminants of potential concern, or COPCs).
- In Step 2, EPA considers the amount of a contaminant that may enter a person's body at the Site (i.e., the dose). EPA considers different scenarios in which people might be exposed to the COPCs (e.g., playing at the beach, fishing, or eating seafood). For each scenario, the concentration of COPCs that people might contact (e.g., in sediment or in fish tissue), and other information such as frequency and duration of fish consumption are used to compute the dose for that scenario. The ways that people might be exposed (pathways) are also considered and there may be more than one pathway in each scenario.
- In Step 3, EPA considers information on cancer toxicity (i.e., cancer slope factors [SFs]) or noncancer toxicity (i.e., reference doses or RfDs) of each COPC, using scientific studies on the effects of these contaminants on people or animals. Toxicity information is not specific to this site, it is from sources that have studied the contaminants to find out how toxic they are no matter where a person gets exposed to them.
- In Step 4, EPA uses the information from the three previous steps to calculate site-related cancer or noncancer risks. A site-related cancer risk is an extra or excess risk, in addition to other cancer risks people are exposed to. EPA evaluates whether these risks are great enough to potentially cause health problems for people at or near the Superfund site. The assumptions EPA uses in calculating risks result in estimates that 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 1,000,000 chance" of developing cancer over the course of a lifetime (in exponential form, 10^{-6}). In other words, for every million people that could be exposed, one extra cancer may occur as a result of exposure to site contaminants. EPA sums the cancer risks for each contaminant included in a particular exposure scenario to develop a total risk value for that exposure scenario (e.g. seafood consumption risks posed by PCBs, arsenic, etc.). EPA is generally concerned when site related risks exceed a range of 1 in 10,000 or 10^{-4} to 1 in 1,000,000 or 10^{-6}. For noncancer health effects, EPA also calculates a noncancer "hazard quotient" (HQ). The hazard quotient is the dose of a contaminant a person might be exposed to, divided by that contaminant's RfD. The RfD is the amount of a contaminant a person could take in over the course of a lifetime without expectation of adverse health effects. For individual contaminants, if the ratio is 1 or less (i.e., the dose received is equal to or less than the RfD), then no noncancer effects are expected. EPA is also concerned about the effects of multiple contaminants with the same noncarcinogenic toxic effect and evaluates this by summing the HQs for each relevant chemical. This sum is called the "hazard index" (HI), and is only of concern if the HI exceeds 1.

In addition to the human health risk assessment, an uncertainty analysis summarizes the assumptions used to compute risks, whether or not these assumptions lead to over- or underestimation of risk, and where possible, quantifies the magnitude of uncertainty.

7.1.1 Identification of Contaminants of Potential Concern

In the LDW HHRA, COPCs are contaminants that were detected in sediments, water[9], fish, and shellfish at concentrations that exceeded risk-based screening criteria and were carried through the risk assessment process. Using the dataset defined for the HHRA,[10] a contaminant was designated a COPC if the maximum detected concentration in sediment or tissue exceeded a health-protective risk-based screening concentration (screening concentration).[11] A contaminant was also designated a COPC if it was not detected at any concentration above its analytical reporting limit (RL) but more than 10% of the samples had RLs that exceeded the screening concentration. In such cases, one-half the maximum RL was the value used to compute risks. The risk-based screening identified the following COPCs, by exposure pathway: 59 COPCs for seafood consumption pathways, 20 COPCs for netfishing, and 28 COPCs for beach play and clamming direct contact pathways. COPCs that were not detected in either sediment or tissue were still included if they had RLs above the screening criteria; however, they were evaluated only in the uncertainty analysis. Consideration of whether the contaminant had been used by industries historically or currently present at the site was an important factor in evaluating whether or not a contaminant with RL above screening criteria was actually present and should be included as a COPC.

The HHRA estimated risks for all COPCs, in order to identify and prioritize those contaminants that were estimated to pose an unacceptable risk and therefore needed to be addressed in the FS. EPA and Ecology regulations and guidance were then used to narrow the list of COPCs to a shorter list of four "contaminants of concern" or COCs, for which risk-based threshold concentrations (RBTCs) were developed for the FS: PCBs, arsenic, cPAHs and dioxins/furans (see text box, "Contaminants of Concern for Human Health in LDW" below). Section 7.1.4 provides information on estimated risks for all COPCs and selection of COCs.

Contaminants of Concern for Human Health in the LDW

Many hazardous substances are found in LDW sediments, fish, and shellfish. Most 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 have immune and reproductive system effects, 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. It is naturally present at low levels in Puget Sound area rock and soil, and industrial activities have spread additional arsenic over much of the Puget Sound Region. Long-term exposure to toxic forms of arsenic may cause nervous and cardiovascular toxicity, liver and kidney disorders, and several types of cancer including skin and bladder.

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 (in either 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, fetal development or early childhood problems, immune system damage, and cancer.

[9] COPCs and risks due to contact with water were evaluated using a 1999 King County analysis for the LDW and Elliott Bay, see Section 7.1.2.1.

[10] The HHRA and ERA datasets are slightly different than the FS datasets summarized in Section 5.3, because additional data were collected after completion of calculations for these reports.

[11] For contaminants with noncancer toxicity, a lower HQ criterion 0.1 was used as a health-protective screening level to ensure that no contaminants were missed for further consideration.

7.1.2 Exposure Assessment

The exposure scenarios considered by EPA are shown in Table 6. Only the scenarios listed in Table 6 as having "numeric" analysis were selected for evaluation in the HHRA; those listed as “qualitative” were excluded from evaluation in the HHRA. The rationale for selecting or excluding each pathway is shown in Table 6.

Consistent with EPA’s Human Health Risk Assessment guidance (EPA 1989) and Executive Order 12898, "reasonable maximum exposure" (RME) scenarios for several populations of interest were used in the HHRA. The HHRA also considered three other scenario types: “central tendency” (CT), “upper-bound” (UB), and “informational” (I). RME estimates are used by EPA for decision-making; they represent the highest exposures that are reasonably expected to occur at a site, and were calculated for all exposure scenarios to avoid underestimating risks. CT exposures were not used in decision-making because they may underestimate exposure for a substantial number of individuals (EPA 1989). CT and UB estimates are used to evaluate the range of uncertainty in risk estimates. “I” risk estimates provide information to the public that they can use to estimate their personal risks (e.g., the risk associated with consuming an 8-ounce meal of fish).

For each scenario, contaminant concentrations specific to an exposure medium that a receptor may contact, called exposure point concentrations (EPCs), were calculated for each COPC; EPCs for COCs in fish and shellfish are shown in Table 7.

Table 6. Rationale for Selection or Exclusion of Exposure Pathways in the Human Health Risk Assessment

Exposure Scenario	Exposure Point	Exposure Medium	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Water recreation	Water recreation areas in LDW	sediment	resident	adult	dermal, ingestion[a]	qualitative	Exposure via swimming less than exposure via beach play.
				child	dermal, ingestion[a]	qualitative	Exposure via swimming less than exposure via beach play.
		surface water	resident	adult	dermal, ingestion[a]	numeric	Most likely direct contact pathway for surface water.
				child	dermal, ingestion[a]	numeric	Most likely direct contact pathway for surface water.
Beach play in intertidal area[b]	LDW beaches	sediment	resident	adult	dermal, ingestion[a]	qualitative	Adult’s exposure during beach play likely to be less than child’s exposure on a per kilogram body weight basis.
				child	dermal, ingestion[a]	numeric	Residents may play at the shoreline near or adjacent to their houses.
		surface water	resident	adult	dermal, ingestion[a]	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared to that from direct contact with bedded sediment.
				child	dermal, ingestion[a]	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared to that from bedded sediment.

Exposure Scenario	Exposure Point	Exposure Medium	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Human consumption of resident seafood	Fishing/ shellfishing locations in the LDW	resident fish and shellfish tissue	resident, visitor, worker	adult, child	ingestion	numeric	Although available data suggest current seafood consumption from LDW is low, tribal members have treaty harvest rights and the public also has recreational expectations for a fishable and swimmable estuary.
Fishing/ shellfishing in intertidal areas	Fishing locations in the LDW	sediment	resident, visitor, worker	adult	dermal, ingestion[a]	numeric	Recreational clamming may occur, given the abundance of clams in some areas. Incidental exposure during fishing is insignificant.
				child	dermal, ingestion[a]	qualitative	Incidental exposure during fishing likely to be less than that assumed in beach play scenario; potential exposure during clamming likely to be much lower compared to adult exposures.
		surface water	resident, visitor, worker	adult	dermal, ingestion[a]	qualitative	Incidental exposure is insignificant.
				child	dermal, ingestion[a]	qualitative	Incidental exposure is insignificant.
Occupational exposure (netfishing)	Commercial netfishing locations in LDW, which potentially include all LDW sediments	sediment	worker	adult	dermal, ingestion[a]	numeric	Commercial fishers are active at the site throughout the fishing season; nets contact the sediment.
		surface water		adult	dermal, ingestion[a]	qualitative	Exposure attributable to resuspended sediment in water column is insignificant compared to that from bedded sediment.
Other occupational exposure[c]	industrial facilities adjacent to LDW	sediment	worker	adult	dermal, ingestion[a]	qualitative	Exposure expected to be much less than that evaluated in other sediment exposure scenarios.
		surface water	worker	adult	dermal, ingestion[a]	qualitative	Exposure expected to be much less than that evaluated in other scenarios.

a. Incidental ingestion associated with sediment contact.

b. Although the beach play scenario is expected to be protective of adults who may participate in beach play activities, they may receive exposure through other activities, such as dog walking. Thus, a dog-walking scenario is evaluated in the uncertainty analysis.

c. Alternative occupational exposure scenarios were evaluated in the HHRA uncertainty section (LDWG 2010), including exposure scenarios for a habitat biologist, habitat restoration volunteers, and King County special operations staff.

Table 7. Exposure Point Concentrations (EPCs) for Contaminants of Concern in Fish and Shellfish Used in Human Health Risk Assessment

	Maximum Detected Concent.	Maximum Reporting Limit	Number Detected/ Total Number of Samples	EPC Value	Statistic[a]	Rationale[b]
Total PCBs, mg/kg ww						
benthic fish, fillet	2.0	NA	33/33	1.2 [c]	UCL95	95% Chebyshev, pooled RL
benthic fish, whole body	4.7	NA	45/45	2.6	UCL95	Approximate Gamma UCL
clams	0.58	NA	14/14	0.60	UCL95	99% Chebyshev (Mean, sd) UCL
crab, edible meat	0.39	0.020	26/29	0.20	UCL95	95% KM (t) UCL
crab, whole body	1.9	NA	25/25	1.1	UCL95	95% H-UCL
mussels[d]	0.060	0.013	18/22	0.041	UCL95	95% KM (Percentile Bootstrap) UCL
pelagic fish, whole body	18.4	NA	53/53	1.9	UCL95	95% H-UCL
PCB TEQ, mg/kg ww						
benthic fish, fillet	1.41×10^{-5}	NA	8/8	1.17×10^{-5}	UCL95	Student's-t UCL
benthic fish, whole body	2.47×10^{-5}	NA	8/8	2.04×10^{-5}	UCL95	Student's-t UCL
clams	5.65×10^{-6}	NA	8/8	3.16×10^{-6}	UCL95	Approximate Gamma UCL
crab, edible meat	2.93×10^{-6}	NA	8/8	2.41×10^{-6}	UCL95	Student's-t UCL
crab, whole body	1.16×10^{-5}	NA	6/6	9.68×10^{-6}	UCL95	Student's-t UCL
pelagic fish, whole body	7.30×10^{-5}	NA	11/11	3.37×10^{-5}	UCL95	Approximate Gamma UCL
Arsenic (Inorganic), mg/kg ww						
benthic fish, fillet	0.006	0.003	6/8	0.0062	UCL95	95% Chebyshev, pooled ½ RL
benthic fish, whole body	0.09	NA	8/8	0.073	UCL95	Student's-t UCL
clams	3.27	NA	8/8	2.0	UCL95	Student's-t UCL
crab, edible meat	0.03	NA	6/6	0.042	UCL95	95% Chebyshev (Mean, sd) UCL
crab, whole body	0.123	NA	6/6	0.11	UCL95	Student's-t UCL
pelagic fish, whole body	0.16	0.01	8/10	0.088	UCL95	95% KM (t) UCL
benthic fish, fillet	0.0013	0.0079	1/11	0.004	one-half maximum RL	Low number of detected samples
Carcinogenic PAH, mg/kg ww [e]						
benthic fish, fillet	0.00064	0.00045	5/8	0.00064	maximum detect	Low number of samples
benthic fish, whole body	0.0028	0.00045	21/24	0.0023[d]	UCL95	95% KM (Chebyshev) UCL

	Maximum Detected Concent.	Maximum Reporting Limit	Number Detected/ Total Number of Samples	EPC Value	Statistic[a]	Rationale[b]
clams	0.044	NA	14/14	0.020	UCL95	approximate Gamma UCL
crab, edible meat	0.00084	0.00065	8/19	0.00065	UCL95	95% KM (t) UCL
crab, whole body	0.0024	NA	19/19	0.00092	UCL95	95% modified-t UCL
pelagic fish, whole body	0.0022	NA	26/26	0.00095	UCL95	95% modified-t UCL
Dioxin TEQ, mg/kg ww[f]						
	NA	NA	NA	NA	NA	NA

a. EPC statistics were calculated as follows: if there were no detected values, one-half of the maximum detection limit was used; if there were 1-5 detected values, the higher of one-half the maximum reporting limit or the maximum detected value were use; if 6 or more detections, ProUCL version 4.0 was used, with nondetected and detected values considered according to its algorithms.

b. Rationales for selecting appropriate statistics for EPC values are described in ProUCL version 5.0 (EPA 2013b)

c. Because of the availability of historical data for English sole from RM 0-1.5, the EPC was calculated as a weighted mean, rather than a mean of all data combined. Means were calculated for each of the four tissue sampling areas, with the historical data for English sole included in Area 1. The mean for the EPC derivation was then calculated as the arithmetic average of the four tissue sampling area means. The upper 95% confidence limit on that mean was estimated using Chebyshev's nonparametric method with a pooled standard deviation from the four areas. Thus, no assumption is made of equal means or variances across tissue sampling areas.

d. No mussel data were available for cPAHs. When calculating the chronic daily intake and risk values, seafood consumption that had been assigned to mussels was divided proportionally among the remaining consumption categories.

e. cPAH concentrations are given in terms of benzo(a)pyrene equivalents. Data used in the risk characterization section of this document are from only 2004 because of high reporting limits in historical data.

f. No dioxin tissue data were available for the HHRA, see discussion Section 5.2.1.

7.1.2.1 Consumption of resident seafood from the LDW

The HHRA considered consumption by groups that eat more fish and shellfish on average than the general population. Table 8 displays the assumptions associated with exposure to contaminated seafood for Tribal members (adults and children), and Asian Pacific Islander (API) adults used to estimate consumption rates.[12] The seafood consumption rates used in the HHRA were based on studies specific to these two groups:

- Tribal members — Puget Sound tribes have been shown to have some of the highest seafood consumption rates of any regional population. To determine a resident-seafood consumption rate for Tribal members, EPA analyzed (EPA 2007) a published survey of the Tulalip Tribes' consumption of fish and shellfish from the Puget Sound region (Toy et al. 1996). Based on that survey, an adult Tribal RME seafood consumption scenario equal to the 95th percentile of Puget Sound seafood consumption was assumed equal to 97.5 g per day (approximately 13 8-ounce [oz] meals per month). This seafood consumption rate does not include consumption of salmon. 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 bioaccumulative contaminants in salmon are acquired during their open ocean feeding, which is a long period relative to their short LDW residence time. Additionally, an upper-bound (UB) Tribal risk

[12] EPA estimates risks based on seafood consumption rates that would be in effect assuming that no contamination was present. It would be inappropriate to use current seafood consumption rates from the LDW, because they are likely suppressed due to general knowledge that the site is contaminated, and published and posted seafood consumption advisories recommending no consumption of LDW resident fish or shellfish.

estimate was derived using estimated Tribal consumption rates based on Suquamish Tribe seafood consumption data.[13]

- Asian Pacific Islanders — Asian Pacific Islanders also have high seafood consumption rates relative to the general population. For adult API, a resident seafood consumption rate of 51.5 g/day (approximately 7, 8-oz meals per month; also excluding salmon) was assumed based on a 1999 EPA study of API seafood consumption rates in King County (Sechena, et al. 1999).

Central tendency (CT) or average risks were also estimated for these groups.

Finally, the risk assessment provided an informational (I) scenario assuming consumption of one meal per month of individual seafood categories. The informational scenario makes it easier to compare scenarios when assessing the risks that would result from consuming one meal per month of different species found in the LDW.

Table 8. Summary of Seafood Ingestion Exposure Parameters for Different Exposure Scenarios

Scenario [a]	Total Ingestion Rate (g/day)[b]	Meals per Month [c]	Exposure Duration (years)
Adult tribal (Tulalip data) - RME	97.5	13.1	70
Adult tribal (Tulalip data) – CT	15	2	30
Adult tribal (Suquamish data) - UB	584.2[d]	78	70
Child tribal (Tulalip data) - RME	39	13	6
Child tribal (Tulalip data) - CT	6.0[c]	2	6
Adult API – RME	51.5	6.9	30
Adult API – CT	5.3	0.7	12
Adult – I[e]	7.5[d]	1	30

a. RME — reasonable maximum exposure. CT — central tendency. UB — upper bound. I — informational.

b. Rates include pelagic fish (shiner surfperch, striped and pile perch), benthic fish (English sole, starry flounder), crabs (Dungeness, slender and red rock), and clams and mussels. They do not include consumption of anadromous fish, which migrate through the LDW and do not reside long enough to be significantly affected by LDW contamination.

c. One meal is assumed to be equal to 227 g (8 oz) for adults and 90.8 g (3.2 oz) for children.

d. Totals of benthic and shellfish categories (and overall total) differ slightly from values provided by EPA (2007), because of significant figure and rounding issues when total consumption was allocated to more specific consumption categories.

e. Adult I (one-meal-per-month) scenario assumed 7.5 g/day for each of the individual seafood categories to reflect different fishing and consumption practices.

7.1.2.2 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 risk associated with exposure to contaminants in surface water while swimming was not evaluated in the same way as other exposure scenarios in the HHRA. Swimming risks were characterized using a 1999 King County analysis (King County 1999) for the LDW and Elliott Bay. Swimming-related excess cancer risks were determined to be low, less than 1×10^{-6}.

[13] The Suquamish Tribe fishes in the vicinity of the LDW and requested that Tribal risks used in the HHRA be based on their consumption rates also, which they report are substantially higher than the rates reported in Toy et al (1996). Suquamish Tribe consumption rates were considered part of a UB scenario. However, they were not used as an RME scenario because Suquamish Tribe members consume a large amount of shellfish, and EPA has determined that the LDW does not contain a large amount of high quality shellfish habitat.

Table 9 displays the exposure parameters used to evaluate exposures related to direct contact with contaminated sediment, which included dermal (skin) contact and incidental ingestion of sediment. Determination of areas associated with exposure was related to how receptors come into contact with contaminants while engaging in a particular activity. It was assumed that netfishers would come into contact with sediments throughout the LDW; for clamming, clam habitat areas accessible by boat or shore were considered. Table 10 shows EPCs for beach play activities over discrete areas of intertidal sediment accessible from the shoreline (outlined in blue in Figure 6). This approach was based on the assumption that small children would contact sediment over limited areas and not all intertidal sediments. EPCs and risks for beach play initially estimated in the HHRA were recalculated in the FS because additional data became available for beach areas following completion of the HHRA. The updated FS dataset was not used to recalculate risks associated with other pathways because the newer data did not significantly alter them.

Table 9. Summary of Exposure Parameters for Direct Contact with Sediment for Different Exposure Scenarios

Scenario[a]	Exposure Frequency (days/year)	Incidental Sediment Ingestion Rate (g/day)	Exposure Duration (years)
Adult netfishing — RME	119	0.05	44
Adult netfishing — CT	63	0.05	29
Child (0-6 yrs) beach play[b] — RME	120	0.2	6
Tribal clamming (Adult) — RME	120	0.1	64
Tribal clamming (Adult) — UB	183	0.1	70
Adult clamming — I	7	0.1	30

a. RME — reasonable maximum exposure. CT — central tendency. UB — upper bound. I — informational.

b. For the beach play scenarios, the LDW was divided into eight areas to assess risks associated with different parts of the LDW.

Table 10. Summary of Sediment Exposure Point Concentrations (EPCs) for Contaminants of Concern Used in Human Health Risk Assessment and Updated in the Feasibility Study

Exposure Point[a,c]	Concentrations Detected (sediment)			EPC	
	Maximum Detected Concent., mg/kg dw	Maximum Reporting Limit, mg/kg dw	Number Detected/Total Number of Samples	EPC Value, mg/kg dw	Statistic Used[b]
Total PCB					
beach play RME, area 1	0.09	NA	2/2 composites	0.05	weighted composite samples
beach play RME, area 2	0.56	0.02	7/8	0.29	95% KM (t) UCL
beach play RME, area 3	0.42	0.02	14/18	0.22	95% KM (Chebyshev) UCL
beach play RME, area 4	2900	0.04	28/29	1100	99% KM (Chebyshev) UCL
beach play RME, area 5	0.86	0.02	34/36	0.25	95% KM (Chebyshev) UCL
Duwamish Waterway Park (subset of beach play area 5)	0.28	NA	1/1 composite	0.28	composite sample
beach play RME, area 6	0.86	NA	1/1 composite	0.86	composite sample
beach play RME, area 7	0.34	0.04	16/22	0.09	95% KM (BCA) UCL
beach play RME, area 8	0.52	0.04	15/22	0.10	95% KM (BCA) UCL
tribal clamming RME/ UB, accessible by bank or boat	110	0.040	415/440	4.00	97.5% KM (Chebyshev) UCL
recreational clamming I, on bankside accessible beaches	23	0.040	142/161	1.50	97.5% KM (Chebyshev) UCL
Netfishing RME/CT, waterway wide	220	0.05	1,205/1,291	2.50	97.5% KM (Chebyshev) UCL

Exposure Point[a,c]	Concentrations Detected (sediment)			EPC	
	Maximum Detected Concent., mg/kg dw	Maximum Reporting Limit, mg/kg dw	Number Detected/Total Number of Samples	EPC Value, mg/kg dw	Statistic Used[b]
PCB TEQ					
beach play RME, area 1	9.08×10^{-8}	NA	1/1	9.08×10^{-8}	maximum detect
beach play RME, area 2	6.69×10^{-6}	NA	1/1	6.69×10^{-6}	maximum detect
beach play RME, area 3	NA	NA	na	na	na
beach play RME, area 4	2.04×10^{-4}	NA	4/4	2.04×10^{-4}	maximum detect
beach play RME, area 5	2.51×10^{-6}	NA	3/3	2.51×10^{-6}	maximum detect
beach play RME, area 6	5.37×10^{-6}	NA	1/1	5.37×10^{-6}	maximum detect
beach play RME, area 7	5.65×10^{-7}	NA	2/2	5.65×10^{-7}	maximum detect
beach play RME, area 8	1.89×10^{-6}	NA	2/2	1.89×10^{-6}	maximum detect
tribal clamming RME/UB, accessible by bank or boat	1.38×10^{-3}	NA	30/30	1.84×10^{-5}	97.5% Chebyshev (MVUE) UCL
recreational clamming I, on bankside accessible beaches	2.04×10^{-4}	NA	18/18	4.19×10^{-5}	99% Chebyshev (MVUE) UCL
Netfishing RME/CT, waterway wide	1.38×10^{-3}	NA	48/48	7.18×10^{-5}	95% Chebyshev (MVUE) UCL
Arsenic (Inorganic)					
beach play RME, area 1	25.3	NA	2/2 composites	16	Weighted composite samples
beach play RME, area 2	20.7	NA	6/6	19	95% Student's t UCL
beach play RME, area 3	18.3	6.6	10/13	11	95% KM (Percentile Bootstrap) UCL
beach play RME, area 4	48.7	NA	25/25	12	95% approximate gamma UCL
beach play RME, area 5	19.1	NA	26/26	10	95% approximate gamma UCL
Duwamish Waterway Park (subset of beach play area 5)	4.3	4.3	1/1 composite	4.3	composite sample
beach play RME, area 6	93.8	NA	1/1 composite	94	composite sample
beach play RME, area 7	13.8	NA	14/14	10	95% Student's t UCL
beach play RME, area 8	15.6	NA	1.0	9	95% approximate gamma UCL
tribal clamming RME/UB, beaches accessible by bank or boat	1,100	31.0	254/275	27	95% KM (BCA) UCL
recreational clamming I, on bankside accessible beaches	20.7	8.8	100/103	10	95% KM (Percentile Bootstrap) UCL
Netfishing RME/CT, waterway wide	1,100	31	755/817	21	95% KM (BCA) UCL
cPAH TEQ					
beach play RME, area 1	0.38	360	2/2 composites	0.38	weighted composite samples
beach play RME, area 2	3.0	NA	6/6	7.0	95% KM (Chebyshev) UCL
beach play RME, area 3	2.80	0.043	10/13	1.5	95% KM (Chebyshev) UCL
beach play RME, area 4	4.80	0.018	23/25	1.4	97.5% KM (Chebyshev) UCL
beach play RME, area 5	0.001	NA	1.0	0.4	95% Chebyshev (MVUE) UCL
Duwamish Waterway Park (subset of beach play area 5)	0.061	NA	1/1 composite	0.27	composite sample
beach play RME, area 6	7.1	NA	1/1 composite	7.1	composite sample
beach play RME, area 7	0.073	0.017	12/14	0.098	95% KM (t) UCL
beach play RME, area 8	0.62	NA	14/15	0.32	95% Students-t UCL
tribal clamming RME/UB, beaches accessible by bank or boat	11.0	0.11	255/264	0.77	95% KM (Chebyshev) UCL
recreational clamming I, on bankside accessible beaches	3.0	0.036	97/103	0.48	95% KM (Chebyshev) UCL
Netfishing RME/CT, waterway wide	11.0	0.1	749/793	0.6	95% KM (Chebyshev) UCL

Exposure Point[a,c]	Concentrations Detected (sediment)			EPC	
	Maximum Detected Concent., mg/kg dw	Maximum Reporting Limit, mg/kg dw	Number Detected/Total Number of Samples	EPC Value, mg/kg dw	Statistic Used[b]
Dioxin/Furan TEQ					
beach play RME, area 1	2.77×10^{-6}	NA	2/2 composites	2.5×10^{-6}	weighted composite samples
beach play RME, area 2	7.45×10^{-5}	NA	1/1	7.45×10^{-5}	maximum detect
beach play RME, area 3	4.31×10^{-6}	NA	1/1	4.31×10^{-6}	maximum detect
beach play RME, area 4	4.12×10^{-4}	NA	4/4	4.12×10^{-4}	maximum detect
beach play RME, area 5	3.57×10^{-5}	NA	4/4 (2 composites and 2 grab samples)	3.57×10^{-5}	maximum detect
Duwamish Waterway Park (subset of beach play area 5)	6.28×10^{-6}	NA	1/1 composite	6.28×10^{-6}	composite sample
beach play RME, area 7	3.73×10^{-6}	NA	1/1 composite	3.73×10^{-6}	composite sample
beach play RME, area 8	3.79×10^{-6}	NA	1/1	3.79×10^{-6}	EPC based on a single grab sample.
tribal clamming RME/UB, accessible by bank or boat	2.1×10^{-3}	NA	11/11	1.42×10^{-3}	95% Adjusted Gamma UCL
Recreational clamming I, on bankside accessible beaches	4.1×10^{-4}	NA	6/6	3.65×10^{-4}	95% Chebyshev (MVUE) UCL
Netfishing RME/CT, waterway wide	2.1×10^{-3}	NA	43/43	6.1×10^{-4}	99% Chebyshev (Mean, sd) UCL

a. Beach play values are based on FS dataset; clamming and netfishing are based on RI dataset

b. The recommended statistical methods used for calculating the EPC for the dioxin contaminants were based on recommendations from ProUCL *(most recent version is* EPA 2013b)

c. RME represents an exposure frequency of 120 days/year; CT represents an exposure frequency of 63 days/year; UB represents 183 days/year; and I represents 7 days/year.

7.1.3 Toxicity Assessment

The toxicity assessment evaluated the relationship between the magnitude of exposure to a contaminant (i.e., the dose) and the risk or hazard posed to humans. Toxicity assessment utilizes human or animal data to predict human toxicity. Scientific estimates of toxicity are adjusted to account for uncertainty so that they are health protective. The toxicity assessment contains two steps: hazard characterization, and dose-response evaluation. The assessment provided, when possible, a numerical estimate of the increased likelihood of adverse effects associated with exposure to a specific dose of a contaminant.

Hazard characterization identifies the types of toxic effects a contaminant can exert. “Toxicity values” are the numerical expressions of predicted toxic effects. Health risks are calculated differently for carcinogenic and noncarcinogenic effects, and separate toxicity values have been developed accordingly. The primary source of toxicity values (cancer slope factors [SFs] and noncancer reference doses [RfDs]) is EPA’s Integrated Risk Information System (IRIS) database. If a toxicity value was not available from IRIS for a given contaminant, then the toxicity value used was from EPA’s Office of Research and Development/National Center for Environmental Assessment, they are called Provisional Peer-Reviewed Toxicity Values. If neither of these sources provided a toxicity value, additional EPA and non-EPA sources of toxicity information were used, including information from EPA regional offices, EPA Health Effects Assessment Summary Tables (HEAST) values, information from California EPA, and Agency for Toxic Substance and Disease Registry (ATSDR) Minimal Risk Levels. Table 11 and Table 12 display the cancer and noncancer toxicity data used, respectively.

The toxicity of cPAHs, dioxins/furans and dioxin-like PCB congeners is expressed as a toxic equivalency factor or TEQ. (Congeners are unique individual chemicals in a group such as PCBs or dioxins/furans.) The TEQ expresses the toxicity of each contaminant in a structurally similar group relative to a reference compound – 2,3,7,8-tetrachloro-p-dibenzodioxin (2,3,7,8-TCDD) for dioxins/furans and benzo(a)pyrene for cPAHs.

Children may be more sensitive to the effects of certain contaminants than adults. For example, EPA accounts for the enhanced toxicity of cPAHs to children by using age-dependent adjustment factors.

The dose-response evaluation examines the level of toxic effect associated with a specific amount of a contaminant. The magnitude of a toxic response to a contaminant depends on the dose to a receptor. The time period of exposure is an important consideration in toxicity studies. For most Superfund sites, EPA is concerned with long term or chronic exposure to contaminants.

7.1.4 Risk Characterization

Results of the exposure assessment (estimated contaminant intakes or doses) are combined with the results of the dose-response assessment (toxicity values established in the toxicity assessment) to provide numerical estimates of potential health effects. The quantification approach differs for potential cancer and noncancer effects, as described below.

Cancer

The potential for cancer effects is evaluated by estimating the excess lifetime cancer risk (ELCR). This risk is the incremental increase in the probability of developing cancer during one’s lifetime in addition to the background probability of developing cancer. Cancer slope factors developed by EPA are considered to be a plausible upper-bound estimate of the cancer potency of a contaminant. By using these upper-bound estimates for the cancer slope factors, there is reasonable confidence that the actual cancer risk will not exceed the estimated risks and may actually be lower (EPA 1989).

For the LDW Site, ELCRs were estimated using the following equation:

$$\text{Risk} = \text{CDI} \times \text{SF}$$

Where:

Risk = Excess lifetime cancer risk (unitless probability)

CDI = Chronic daily intake averaged over a lifetime (mg/kg-day)

SF = Cancer slope factor $(\text{mg/kg-day})^{-1}$

When multiple contaminants are present, cancer risks are added together for each exposure scenario (e.g., fish consumption and clamming). Risks may be summed across exposure scenarios (e.g. seafood consumption risk and clamming direct contact risks). This is consistent with the EPA risk assessment guidelines (EPA 1989).

Table 11 shows cancer toxicity values for the COCs. Accessed dates reflect information available at the time of the risk assessment.

Table 11. Cancer Toxicity Data Summary for Human Health COCs

Contaminant of Concern	Oral/Dermal Cancer Slope Factor, $(mg/kg\text{-}d)^{-1}$	Weight of Evidence/Cancer Guidelines Description[a]	Source	Information Accessed Date
Total PCB	2	B2	IRIS (upper-bound slope factor specified for use with persistent and bioaccumulative PCBs)	3/8/2006
PCB TEQ	150,000	B2	HEAST (slope factor based on 2,3,7,8-TCDD)	3/8/2006
Arsenic	1.5	A	IRIS (surrogate for inorganic arsenic)	3/8/2006
cPAH	7.3	B2	IRIS (benzo[a]pyrene toxicity equivalents)	3/8/2006
Dioxin/Furan	150,000	A (IARC)	HEAST	4/7/2006

a. A = known human carcinogen; B2 = probable human carcinogen (based on sufficient evidence in animals and inadequate or no evidence in humans). The full set of chemicals in each of the classes represented is available at *http://www.greenfacts.org/glossary/def/epa-cancer-classification.htm*.

Noncancer

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular contaminant with the highest level of exposure that is considered protective (i.e., its RfD). When the ratio exceeds 1 (i.e., exposure exceeds RfD), there is a concern for potential noncancer health effects. The ratio of the chronic daily intake (CDI) divided by RfD is termed the hazard quotient (HQ):

$$HQ = CDI / RfD$$

To screen for potential for noncancer effects associated with exposure to multiple contaminants, a hazard index (HI) is used (EPA 1989). This summation approach assumes that the noncancer, multiple-contaminant hazard is additive, which may not always be the case (as when dissimilar organ systems are affected).

The HI is calculated as follows:

$$HI = \sum_{1}^{N} E_i / RfD_i$$

Where:

HI = hazard index

E_i = daily intake of the ith contaminant (mg/kg-day)

RfD_i = reference dose of the ith contaminant (mg/kg-day)

N = number of contaminants

If the overall HI exceeds 1, EPA will evaluate HIs for specific organ systems or toxic effects to determine if exposure to multiple contaminants is truly of concern.

Table 12 shows the noncancer toxicity values for the COCs.

Table 12. Noncancer Toxicity Data Summary for Human Health

Contami-nants of Concern	Chronic[a] or Subchronic[b] Exposure	Oral RfD, mg/kg-day Value	Oral Absorption Efficiency for Dermal Exposure		Primary Target Organ	Combined Uncertainty and Modifying Factors	Sources	Information Accessed Date
			Value	Reference				
Arsenic	Chronic	0.0003	0.03	EPA 2004	Cardiovascular system; Skin (hyperpigmen-tation, keratosis)	3	IRIS (surrogate for inorganic arsenic)	3/8/2006
Total PCB	Chronic	0.00002	0.14	EPA 2004	Development, Immune system, nervous system	300	IRIS (surrogate = Aroclor 1254, the lowest and most protective RfD available for PCBs in IRIS; total includes Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260)	3/8/2006

Source: EPA. 2004. Risk assessment guidance for Superfund, Volume 1: Human health evaluation manual (Part E, supplemental guidance for dermal risk assessment). Final, July 2004. EPA/540/R/99/005. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

IRIS = Integrated Risk Information System

a. Chronic represents exposure of a population (including sensitive individuals) that occurs on a daily basis, which is likely to be without appreciable risk of deleterious effects during a lifetime (EPA 1989).

b. Subchronic represents exposure of a population (including sensitive individuals) between 2 weeks and 7 years, and is likely to be without appreciable risk of deleterious effects (EPA 1989).

Risk Characterization and Selection of Human Health COCs

Table 13 shows estimated cancer and noncancer risks for the human health scenarios. Figure 8 and Figure 9 summarize the baseline excess cancer and noncancer risk related to the number and type of seafood meals consumed per month. Figure 10 summarizes the excess cancer and noncancer risk associated with the RME scenarios for direct sediment contact scenarios. Site seafood consumption RME risks exceed direct contact risks. Seafood consumption risks and direct contact HQs for the RME scenarios exceed risk thresholds established under CERCLA. Under CERCLA, these thresholds are excess cancer risks of 1×10^{-4} and a noncancer HQ (or HI) of 1. MTCA thresholds are also exceeded, which are excess cancer risks of 1×10^{-6} for individual contaminants or 1×10^{-5} cumulatively for multiple contaminants, and a noncancer HQ or HI of 1. For direct contact scenarios, HQs were less than 1, with the exception of beach play at Beach Area 4.

Dioxins and furans were not included in the total excess cancer risk calculation for the RME seafood consumption scenarios because data on dioxin/furan concentrations in fish and shellfish tissue 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. Data from these samples were used to calculate the excess cancer risks associated with dioxins/furans as 6×10^{-5} for the adult Tribal RME scenario. 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 regarding dioxin/furan risks relative to risks from other COCs.

Table 14 summarizes the rationale for selection of human health COCs. 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. Information on whether a contaminant was historically used at the Site was also considered in determining whether these contaminants should be selected as COCs. PCBs, arsenic, cPAHs, and dioxins/furans were identified as human health COCs based on an excess cancer risk greater than 1 x 10^{-6} for carcinogens, or a hazard quotient (HQ) greater than 1 for noncarcinogens. Other COPCs 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.

Table 13. Summary of Cancer and Noncancer Risk Estimates for Human Health Scenarios

Scenario[a]	Medium	Contaminant of Concern	Excess Cancer Risk	Hazard Quotient
Seafood Consumption Scenarios				
Adult Tribal Seafood RME Consumption - Tulalip Survey	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other[c] Total	2 x10^{-3} 2 x10^{-3} 8 x10^{-5} 4 x 10^{-4} 4 x 10^{-3}	40 4 nc 2 nc
Adult Tribal Seafood CT Consumption - Tulalip Survey	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other Total	6 x10^{-5} 7 x10^{-5} 4 x10^{-6} 1 x10^{-5} 1 x10^{-4}	4 0.4 nc 0.2 nc
Adult Tribal Seafood UB Consumption - Suquamish Survey	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other[c] Total	1 x10^{-2} 2 x10^{-2} 8 x10^{-4} 3 x10^{-3} 3 x10^{-2}	274 38 nc 15 nc
Child Tribal Seafood RME Consumption - Tulalip Survey	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other[c] Total	3 x 10^{-4} 3 x10^{-4} 8 x 10^{-5} 8 x 10^{-5} 8 x 10^{-4}	87 8 nc 3 nc
Child Tribal Seafood CT Consumption - Tulalip Survey	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other Total	3 x10^{-5} 3 x10^{-5} 9 x10^{-6} 5 x10^{-6} 7 x10^{-5}	8 0.7 nc 0.4 nc
Adult Asian Pacific Islander RME Seafood Consumption	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other[c] Total	5 x 10^{-4} 7 x 10^{-4} 3 x 10^{-5} 1 x 10^{-4} 1 x 10^{-3}	29 3 nc 1 nc
Adult Asian Pacific Islander CT Seafood Consumption	Fish and Shellfish	PCBs Inorganic arsenic cPAHs Other Total	8 x10^{-6} 1 x10^{-5} 8 x10^{-7} 1 x10^{-6} 2 x10^{-5}	2 0.2 nc 0.1 nc
Adult Informational (one meal per month)[d]	pelagic fish Clam Clam benthic fish (cancer)/ clam (HQ) clam/pelagic fish	PCBs Inorganic arsenic cPAHs Other Total	2 x 10^{-4} 1 x 10^{-4} 7 x10^{-6} 2 x10^{-5} 2 x 10^{-4}	10 0.7 nc 0.3 nc

Scenario[a]	Medium	Contaminant of Concern	Excess Cancer Risk	Hazard Quotient
Direct Contact Scenarios				
Netfishing RME (Direct Sediment Contact)	Subtidal and Intertidal Sediment	PCBs Arsenic cPAHs Dioxins/Furans Other Total	2×10^{-6} 6×10^{-6} 1×10^{-6} 2×10^{-5} 2×10^{-6} 3×10^{-5}	< 1 < 1 nc nc < 1 nc
Netfishing CT (Direct Sediment Contact)	Subtidal and Intertidal Sediment	PCBs Inorganic arsenic cPAHs Dioxins/Furans Other Total	3×10^{-7} 1×10^{-6} 2×10^{-7} 4×10^{-6} 3×10^{-7} 5×10^{-6}	< 1 < 1 nc nc < 1 nc
Clamming RME (Direct Sediment Contact)	Intertidal Sediment	PCBs Arsenic cPAHs Dioxins/Furans Other Total	8×10^{-6} 2×10^{-5} 5×10^{-6} 1×10^{-4} 6×10^{-6} 1×10^{-4}	< 1 < 1 nc nc < 1 nc
Clamming UB (Direct Sediment Contact)	Intertidal Sediment	PCBs Inorganic arsenic cPAHs Dioxins/Furans Other Total	1×10^{-5} 3×10^{-5} 8×10^{-6} 2×10^{-4} 9×10^{-6} 3×10^{-4}	< 1 < 1 nc nc nc < 1
Clamming I (Direct Sediment Contact)	Intertidal Sediment	PCBs Inorganic arsenic cPAHs Dioxins/Furans Other Total	9×10^{-8} 3×10^{-7} 1×10^{-7} 8×10^{-7} 2×10^{-8} 1×10^{-6}	< 1 < 1 nc nc nc < 1
Beach Play RME (Direct Sediment Contact -Ranges for 8 beaches)	Intertidal Sediment	PCBs Arsenic cPAHs Dioxins/Furans Total	3×10^{-8} to 6×10^{-4} 3×10^{-6} to 3×10^{-5} 1×10^{-6} to 8×10^{-5} 1×10^{-7} to 1×10^{-5} 4×10^{-6} to 6×10^{-4}	< 1[b] < 1 nc nc nc

Notes:
General

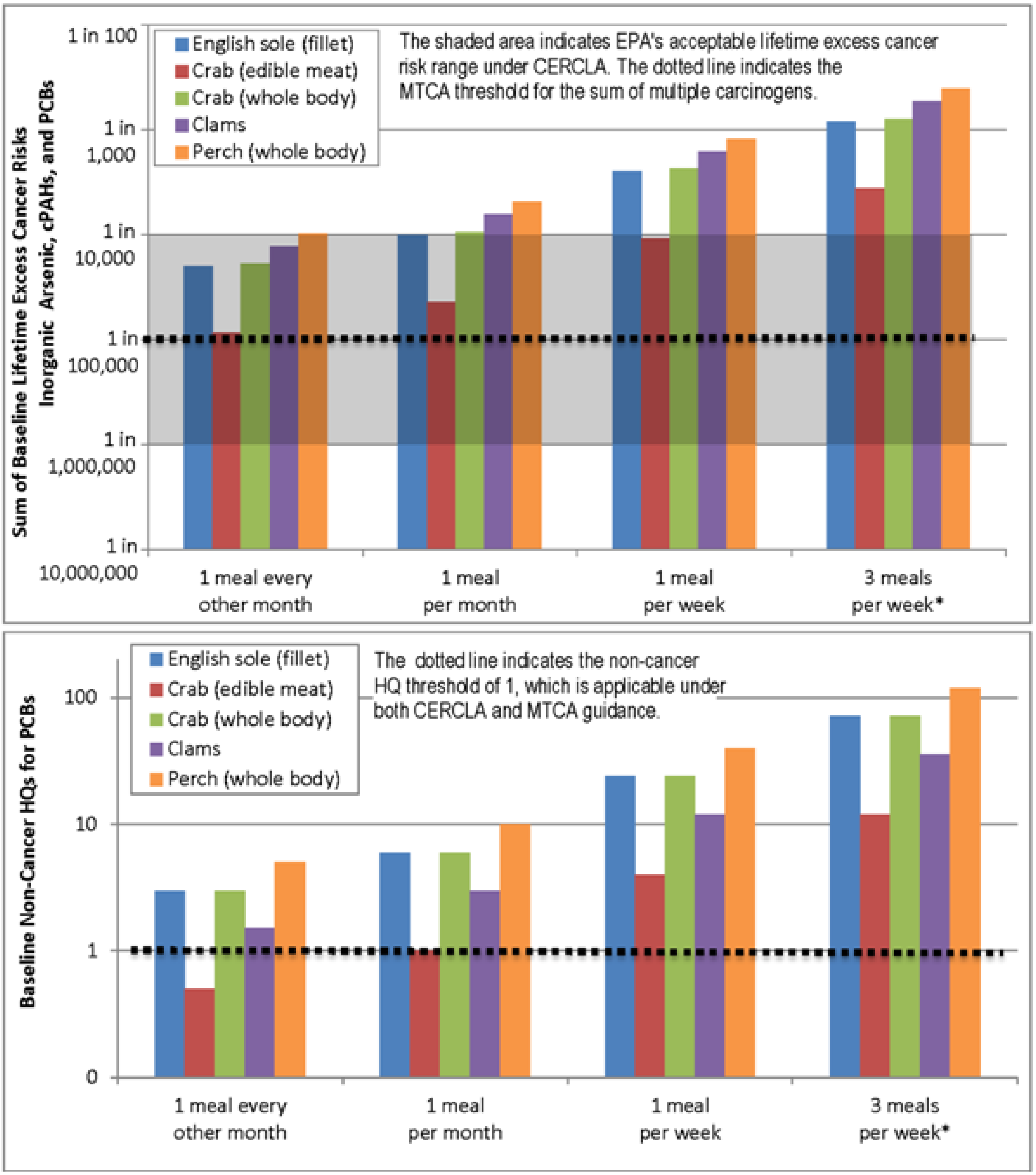
- nc = not calculated
- Baseline lifetime excess cancer risks: calculated as the sum of the risk estimate for inorganic arsenic, cPAHs, and PCBs. Estimates for seafood consumption scenarios do not include risk estimates from dioxins and furans.
- The "Other"' category includes those contaminants evaluated in the HHRA with concentrations greater than screening levels (i.e., both those that exceed risk thresholds and some that do not).

a. For the netfishing and clamming RME scenarios, the total excess cancer risks are based upon data from the Remedial Investigation only. For the beach play RME scenarios, the estimation of total excess cancer risks are based upon data from the Remedial Investigation along with additional data collected during the Feasibility Study.

b. All beaches but Beach Play Area 4 at RM 2.2 have HQs <1. The Beach Play Area 4 HQ of 2 excludes two very high PCB concentrations (see footnote a to Table 1); if the two high PCB concentrations were included, the HQ would be 187. Beach Play Areas are shown in Figure 6.

c. HQ $\geq$ 1 was due to tributyltin (TBT).

d. Informational exposure is presented for the food groups with the highest associated risks.



Notes:

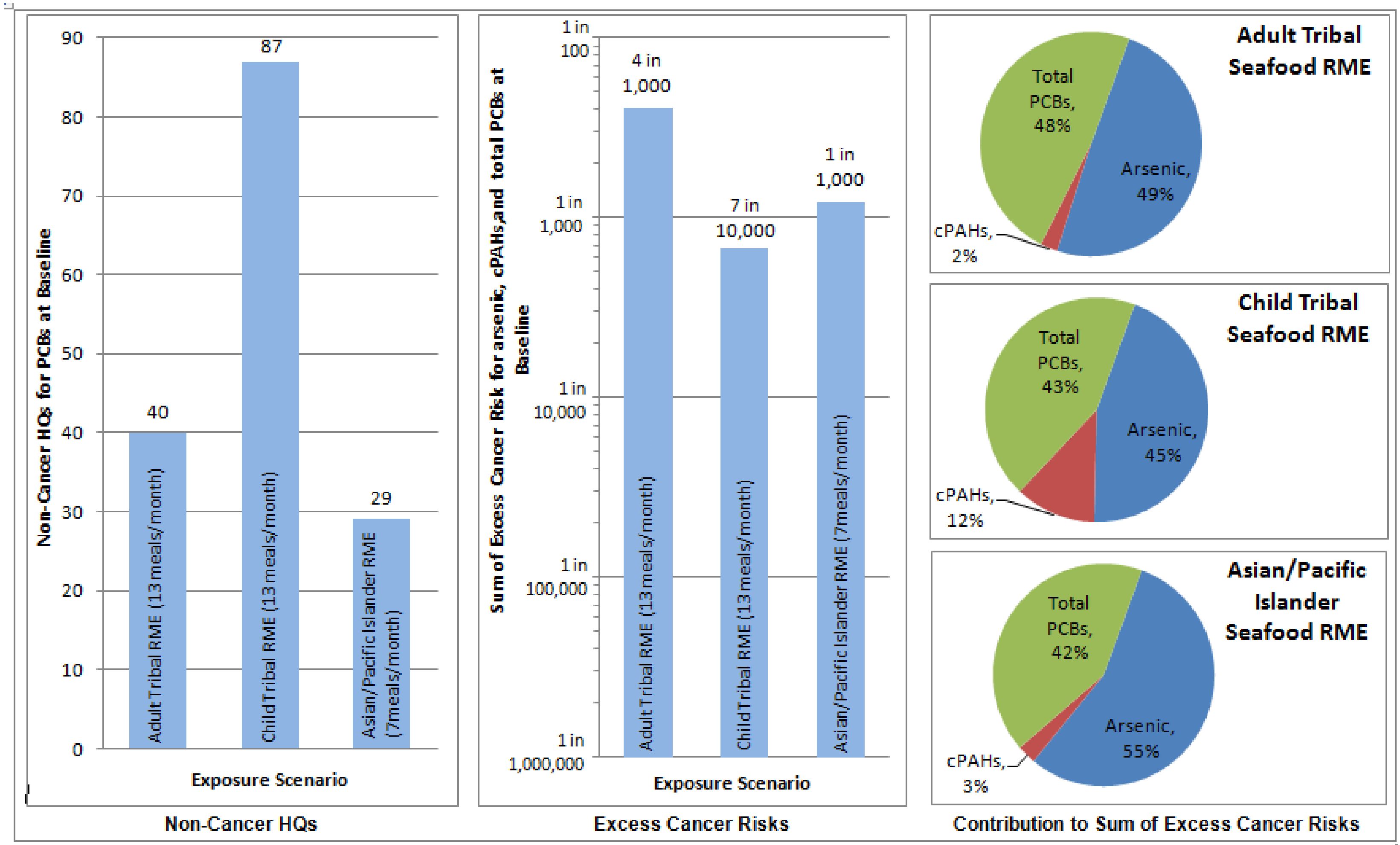
Excess cancer risks and noncancer hazard quotients (HQs) were calculated using the exposure assumptions for the adult tribal RME seafood consumption scenario.

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

Excess cancer risks were calculated as the sum of excess cancer risks for inorganic arsenic, cPAHs, and PCBs. These estimates do not include risk estimates from dioxins/furans, as discussed in Section 7.1.4. 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.

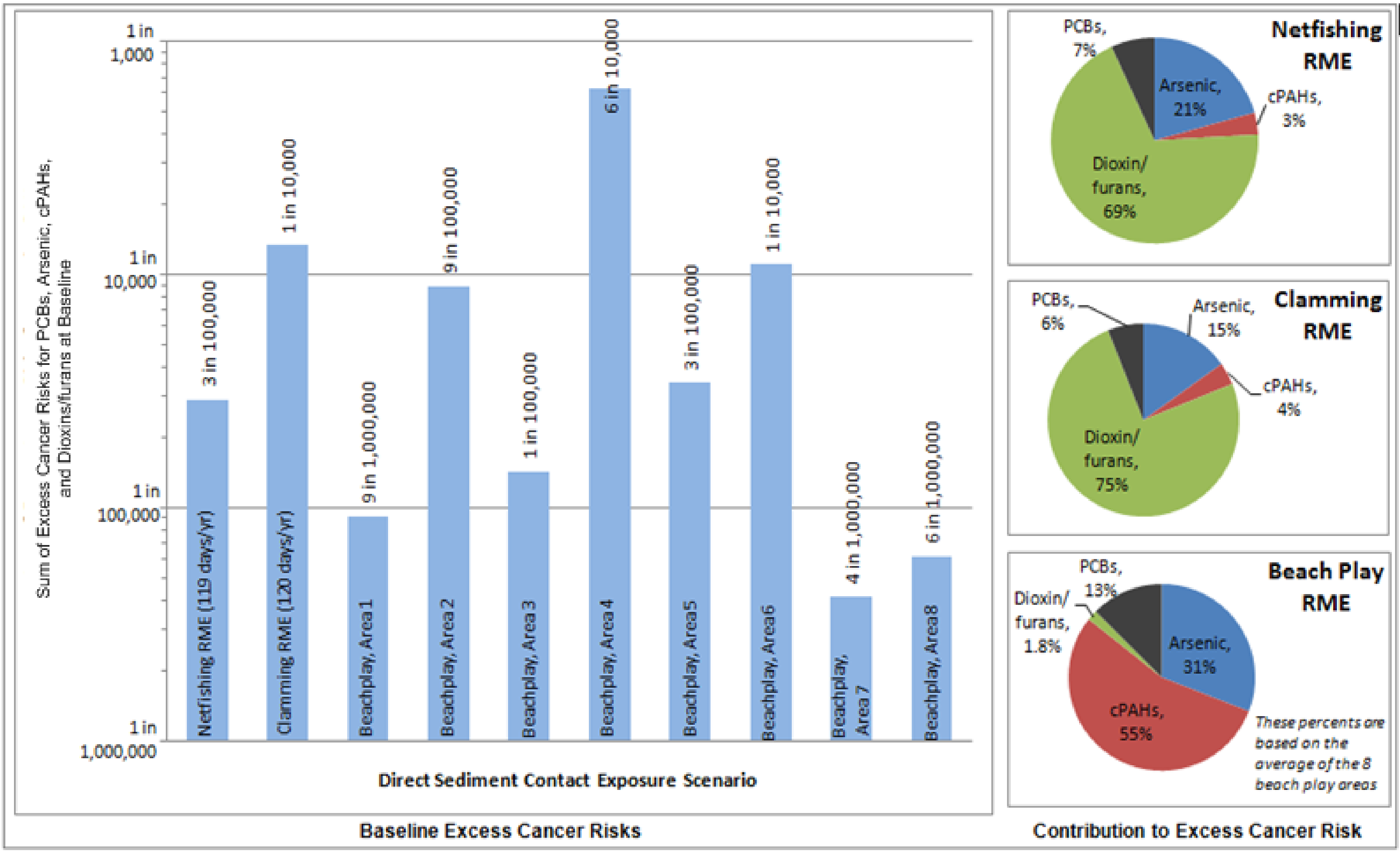
Noncancer HQs for total PCBs are presented because HQs were the highest for PCBs.

Figure 8. Baseline Excess Cancer Risk and Noncancer Hazard Quotients for Consumption of Various Seafood Species as a Function of the Number of Meals Consumed per Month



Notes:
One meal is 8 ounces for adults and 3.2 ounces for children.
Baseline tissue dataset: baseline excess cancer risks and hazard quotients (HQs) are based on the tissue dataset in the RI, and were calculated as the sum of the risk estimates for arsenic, cPAHs, and PCBs, and other contaminants. These estimates do not include risks from dioxins and furans.
The "other" category includes those contaminants evaluated in the HHRA with concentrations greater than conservative screening levels.
For baseline, only HQs for total PCBs are presented because non-cancer HQs were the highest for PCBs.

Figure 9. Baseline Noncancer Hazard Quotients and Excess Cancer Risk for the Seafood Consumption RME Scenarios



Notes:

Baseline datasets: Total excess cancer risks are based upon the RI (LDWG 2010) dataset for the netfishing and clamming RME scenarios, and are based upon the FS (LDWG 2012a) dataset for the beach play RME scenarios.

Non-cancer HQs: HQs are not shown in this figure because they were less than 1 in all cases, except for the beach play area located at the head of the inlet at RM 2.2 west. If these 2 samples are considered, the PCB HQ would be 187; when they are removed, the resulting HQ would be 2.

Figure 10. Baseline Excess Cancer Risk for the Direct Sediment Contact RME Scenarios

Table 14. Summary of COPCs and Rationale for Selection as COCs for Human Health Exposure Scenarios

COPC	COC?	Maximum RME Risk Estimate	Rationale for Selection or Exclusion as COC
Seafood Consumption Scenarios			
PCBs	Yes	2×10^{-3}	Risk magnitude, high percent contribution to the cumulative excess cancer risk (58%), and high detection frequency in tissue samples (97%).
Inorganic arsenic	Yes	2×10^{-3}	Risk magnitude, percent contribution to the cumulative excess cancer risk (29%), and high detection frequency in tissue samples (100%).
cPAHs	Yes	8×10^{-5}	Risk magnitude and high detection frequency in tissue samples (72%).
Dioxins/furans	Yes	nd	No dioxin/furan tissue data were available. However, because excess cancer risks were assumed to be unacceptably high, dioxins/furans were identified as a COC.
Bis(2-ethylhexyl) phthalate	No	6×10^{-6}	Low percent contribution to the cumulative excess cancer risk (less than or equal to 3%) and rarely detected in tissue samples (particularly when samples were re-analyzed to evaluate the effect on RLs of analytical dilutions in the initial analysis).
Pentachlorophenol	No	9×10^{-5}	
Tributyltin	No	HQ = 3	HQs for these metals were only slightly greater than 1 and were driven by the child tribal RME seafood consumption scenario, for which Ingestion rates are uncertain.
Vanadium	No	HQ = 2	
Aldrin	No	5×10^{-5}	All organochlorine pesticides were low contributors to the cumulative excess cancer risk (less than or equal to 3% of the cumulative risk). In addition, because of analytical interference of these contaminants with PCBs, much of the tissue data for these contaminants were qualified JN, which indicates the presence of an analyte that has been 'tentatively identified,' and the associated numerical value represents its approximate concentration. The JN-qualified organochlorine pesticide results are highly uncertain and likely biased high.
alpha-BHC	No	2×10^{-5}	
beta-BHC	No	6×10^{-6}	
Carbazole	No	4×10^{-5}	
Total Chlordane	No	6×10^{-6}	
Total DDTs	No	2×10^{-5}	
Dieldrin	No	1×10^{-4}	
gamma-BHC	No	5×10^{-6}	
Heptachlor	No	1×10^{-5}	
Heptachlor epoxide	No	3×10^{-5}	
Hexachlorobenzene	No	1×10^{-5}	
Direct Sediment Exposure Scenarios			
PCBs	Yes	8×10^{-6}	Lower risk magnitude and percent contribution to cumulative excess cancer risk than the other sediment risk drivers, but selected because of importance in the seafood consumption scenarios.
Inorganic arsenic	Yes	2×10^{-5}	Risk magnitude, percent contribution to cumulative excess cancer risk (14 to 19%), and high detection frequency in surface sediment samples (92%).
cPAHs	Yes	4×10^{-5}	Risk magnitude, percent contribution to cumulative excess cancer risk (3 to 85%), and high detection frequency in surface sediment samples (94%).
Dioxins/furans	Yes	1×10^{-4}	Risk magnitude, percent contribution to cumulative excess cancer risk (35 to 72%), and high detection frequency in surface sediment samples (100%).
Toxaphene	No	6×10^{-6}	Low percent contribution to cumulative excess cancer risk (6% or less) and low detection frequency in surface sediment samples (1%).

Notes:

BHC = benzene hexachloride.

Except for TBT and Vanadium, the maximum RME risk estimates shown are excess cancer risks for the adult Tribal RME seafood consumption based upon Tulalip tribal data. Only RME scenarios were used to designate COCs. The highest risk estimate for any of the RME scenarios is shown in this table (adult tribal RME based on Tulalip data for seafood consumption, and various scenarios for direct contact). Note that the estimates reported here differ slightly from those reported in Appendix B (the HHRA) and Section 6 of the RI (LDWG 2010), based on a 2009 erratum (LDWG 2009) that adjusted the proportion of crabs and clams consumed by the Tulalip Tribe.

The majority of risks for seafood consumption were from PCBs and inorganic arsenic in resident fish, crabs, and clams. 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. Lower risks were associated with activities that involve direct contact with sediment, such as clamming, beach play, and netfishing. The majority of risk associated with adult direct sediment exposure was from dioxins and furans. In contrast, the majority of carcinogenic risks for young 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 (see Section 7.2), were selected as COCs and used to identify areas requiring cleanup in the FS.

7.1.5 Uncertainty Analysis for the HHRA

To be health-protective of all members of the general public, the risk estimates presented in the baseline HHRA were intended to avoid underestimation of risks for individuals with reasonable maximum exposure (RME), and thus are likely to overestimate risks for most individuals for the contaminants that were evaluated. EPA believes this is appropriate, as use of central tendency risk estimates in developing cleanup actions would result in potentially unacceptable exposures following remediation. Central tendency risk estimates were intended to provide information to risk managers involved in remedial planning for the Site but may not reflect actual risks to people currently consuming LDW seafood. Although risk estimates were highest for the seafood consumption scenarios, the uncertainties associated with those risk estimates were also high. There is considerable uncertainty about the applicability of some of the seafood consumption rates to this HHRA under current uses of the Site, particularly for clams, given the degraded quality and quantity of shellfish habitat in the LDW. EPA’s risk analyses must also account for potential future exposure. The Tribes involved in the LDW cleanup have indicated that they would catch and consume more seafood from the LDW if contaminant concentrations were reduced.

Another uncertainty is in the methods used to characterize the excess cancer risks associated with exposures to PCBs. Two methods were used in the baseline HHRA, one method based on total PCB data and the cancer SF for total PCBs and a second method based on dioxin-like PCB congener data and the cancer SF for 2,3,7,8 TCDD and toxic equivalency factors that describe how toxic each individual dioxin-like PCB is relative to TCDD. The issue of concern is how to consider the joint risk posed by total PCBs and dioxin-like PCBs. Some of the risk posed by dioxin-like PCBs is accounted for in the risk calculated using total PCB dose and the PCB slope factor. Consequently, adding the dioxin-like PCB and total PCB risks together could double-count the risk posed by dioxin-like PCBs and overestimate the risk posed by PCBs. On the other hand, the bioaccumulation process may enrich levels of dioxin-like PCBs in seafood relative to the levels of dioxin-like PCBs found in the commercial mixtures used to establish PCB toxicity. Failure to account for this enrichment could underestimate the risk posed by PCBs. The true risk posed by PCBs thus lies between the individual total PCB and dioxin-like PCB risk estimates and the sum of these individual risk estimates. In the HHRA, the total PCB and dioxin-like PCB risk estimates are presented separately along with the points noted above. Risk estimates in Table 13 are based on total PCBs, as the risk accounted was generally greater using that method.

Dioxins and furans were not analyzed in seafood samples, as discussed in Section 7.1.4. This data gap contributes to an underestimation of risk because these contaminants were not included in the risk assessment for the seafood consumption scenarios.

The final risk estimates also reflect uncertainties associated with using data and assumptions from multiple sources, including non-Site related sources such as background contributions of hazardous substances; the combined effect of those uncertainties on risk estimates cannot be quantified. However, the risk assessment tended to overestimate risks more than underestimate them, consistent with the health-protective nature of risk assessment. In spite of these uncertainties, the baseline risk characterization for the LDW site is considered to be protective of human health and sufficient to support risk management decisions.

7.2 Ecological Risks

The baseline Ecological Risk Assessment (ERA) estimated risks for the benthic invertebrate, fish, crabs, and wildlife species that may be exposed to contaminants in sediment, water, and aquatic biota in the LDW. This assessment was based on historical data and sediment and tissue chemistry data collected as part of the RI, as discussed in Section 5.3. The baseline ERA is an estimate of the likelihood of ecological risks if no cleanup action is taken.

7.2.1 Ecological Communities in the LDW

Though much habitat has been lost, the LDW is home to a diverse ecology, with abundant resident and non-resident fish and shellfish, bottom-dwelling organisms, marine mammals, and birds. As discussed in Section 6.2, several LDW habitat restoration projects are planned over the next few years, which, along with reduction of contamination, should result in increased waterway use by these organisms in the future.

Several benthic fish (bottomfish such as sole, sculpin, and flounder) and pelagic fish (water column fish such as 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; juvenile 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.

7.2.2 Problem Formulation

The problem formulation of the ERA established the overall scope of the assessment. It included a description of the data available for conducting the ERA, the suitability of the data for risk assessment purposes, and a risk-based screening process that allowed the risk assessment to focus on contaminants of potential concern (COPCs) and eliminate contaminants that posed minimal risks to ecological receptors from further consideration.

The ERA evaluated risks to four types of ecological receptors of concern (ROC) exposed to the contaminants in the LDW, either directly or via ingestion of prey:

- benthic invertebrates and crabs;
- fish (juvenile Chinook salmon, Pacific staghorn sculpin, English sole);
- birds (spotted sandpiper, great blue heron, osprey); and
- wildlife (river otter and harbor seal).

These ROCs were selected to represent organisms with a range of characteristics that affect exposure, such as habitat, dietary preferences, level in the food chain, and sensitivity to contaminants. Generally, if these species are protected by the remedy, the many species they represent are also protected. Juvenile salmon were selected because they are listed as a threatened species under ESA.

The problem formulation also presented conceptual site models for the ROCs (Figure 11). Conceptual site models identify and describe pathways in which ROCs may be exposed to COPCs within the LDW. The pathways evaluated in the ERA included both direct exposure through sediment and water and indirect exposure through the ingestion of prey from the LDW. The potential exposure pathways of contaminants to higher-trophic-level ROCs in the LDW is discussed in the RI and briefly summarized in Section 5.2.

7.2.3 Identification of Contaminants of Potential Concern for Ecological Receptors

For each receptor of concern (ROC), COPCs were identified through a conservative, risk-based screening process comparing maximum exposure concentrations to the numerical SCO for protection of benthic invertebrates promulgated under the Washington Sediment Management Standards (benthic SCO), (Table 15) or, for other receptors, to no observed adverse effect levels (NOAELs) from the scientific literature.

COPCs identified included: 46 contaminants for the benthic invertebrate community (including tributyltin [TBT], metals, and PCBs and other organic compounds); 2 contaminants for crabs (PCBs and zinc); 6 contaminants for at least one fish ROC (arsenic, cadmium, copper, total PCBs, TBT, and vanadium), and 12 contaminants for at least one wildlife ROC (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, total PCBs, zinc, and vanadium). Contaminants in another subset of COPCs were evaluated only in the uncertainty analysis either because there was uncertainty regarding their presence at concentrations of concern (i.e., contaminants were never detected in tissue, but reporting limits (RLs) were above the screening criteria) or because effect-level toxicity information was not available for them. Otherwise, COPCs were evaluated as discussed below.

7.2.4 Exposure and Effects Assessment

Summaries of exposure pathways determined to be complete for ecological receptors are provided in Table 16. Toxicity reference values (TRVs) used in the effects assessment were derived from the scientific literature using survival, growth, and reproduction as assessment endpoints.

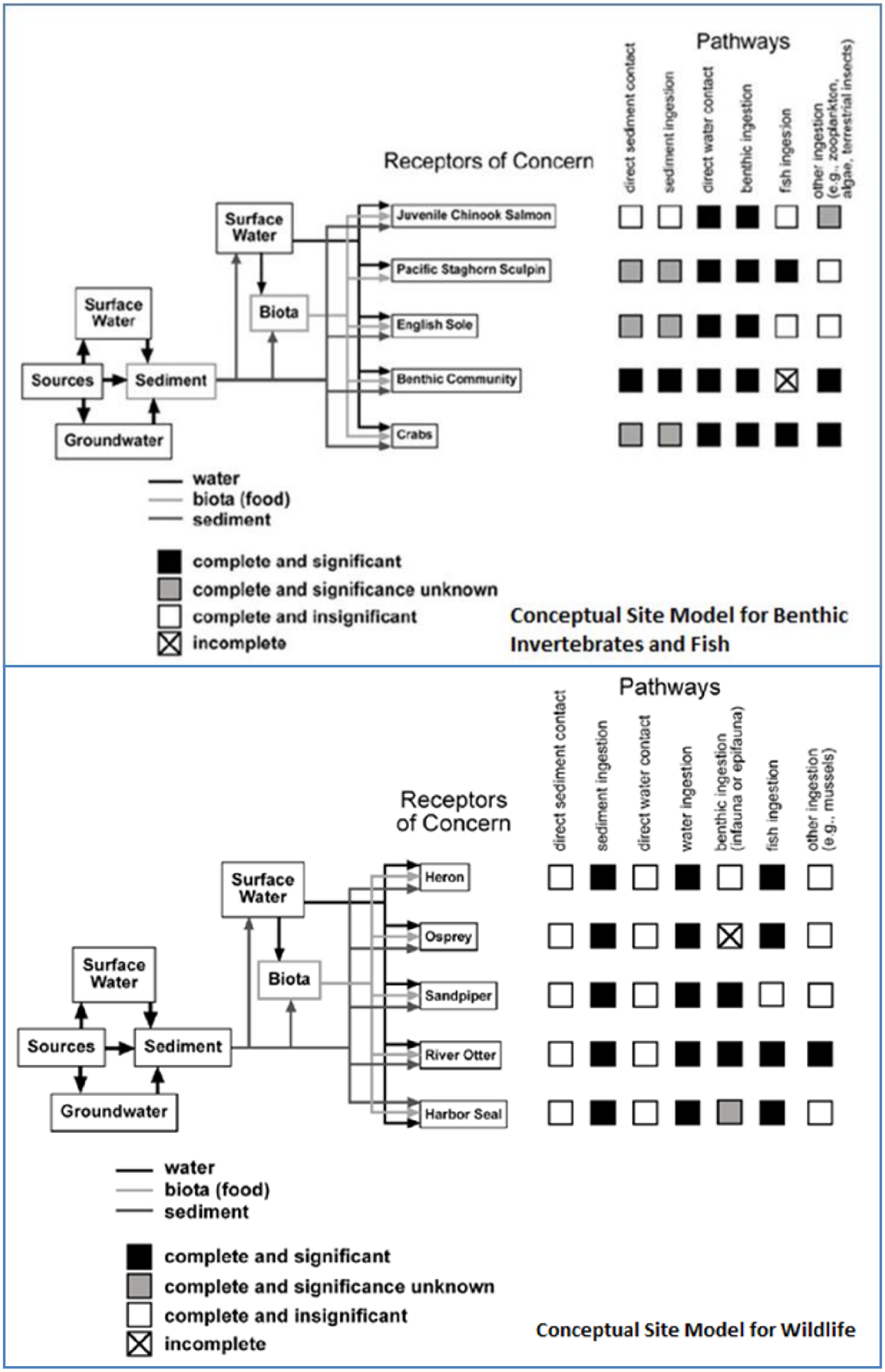


Figure 11. Conceptual Models for the Ecological Risk Assessment

Table 15. Numerical Benthic Sediment Cleanup Objectives and Benthic Cleanup Screening Levels from the Washington State Sediment Management Standards[a]

Contaminant	Units	Basis (dry weight or Organic Carbon)	Benthic Sediment Cleanup Objective	Benthic Cleanup Screening Level
Inorganic Compounds				
Arsenic	mg/kg	Dry	57	93
Cadmium	mg/kg	Dry	5.1	6.7
Chromium	mg/kg	Dry	260	270
Copper	mg/kg	Dry	390	390
Lead	mg/kg	Dry	450	530
Mercury	mg/kg	Dry	0.41	0.59
Silver	mg/kg	Dry	6.1	6.1
Zinc	mg/kg	Dry	410	960
Organic Compounds				
LPAH	mg/kg	OC	370	780
Naphthalene	mg/kg	OC	99	170
Acenaphthylene	mg/kg	OC	66	66
Acenaphthene	mg/kg	OC	16	57
Fluorene	mg/kg	OC	23	79
Phenanthrene	mg/kg	OC	100	480
Anthracene	mg/kg	OC	220	1200
2-Methylnaphthalene	mg/kg	OC	38	64
HPAH	mg/kg	OC	960	5300
Fluoranthene	mg/kg	OC	160	1200
Pyrene	mg/kg	OC	1000	1400
Benz(a)anthracene	mg/kg	OC	110	270
Chrysene	mg/kg	OC	110	460
Total benzofluoranthenes	mg/kg	OC	230	450
Benzo(a)pyrene	mg/kg	OC	99	210
Indeno(1,2,3 c,d)pyrene	mg/kg	OC	34	88
Dibenzo(a,h)anthracene	mg/kg	OC	12	33
Benzo(g,h,i)perylene	mg/kg	OC	31	78
1,2 Dichlorobenzene	mg/kg	OC	2.3	2.3
1,4 Dichlorobenzene	mg/kg	OC	3.1	9
1,2,4 Trichlorobenzene	mg/kg	OC	0.81	1.8
Hexachlorobenzene	mg/kg	OC	0.38	2.3
Dimethyl phthalate	mg/kg	OC	53	53
Diethyl phthalate	mg/kg	OC	61	110
Di-n-butyl phthalate	mg/kg	OC	220	1700
Butyl benzyl phthalate	mg/kg	OC	4.9	64
Bis(2-ethylhexyl)phthalate	mg/kg	OC	47	78
Di-n-octyl phthalate	mg/kg	OC	58	4500
Dibenzofuran	mg/kg	OC	15	58
Hexachlorobutadiene	mg/kg	OC	3.9	6.2

Contaminant	Units	Basis (dry weight or Organic Carbon)	Benthic Sediment Cleanup Objective	Benthic Cleanup Screening Level
n-Nitrosodiphenylamine	mg/kg	OC	11	11
Total PCBs	mg/kg	OC	12	65
Phenol	µg/kg	Dry	420	1200
2-Methylphenol	µg/kg	Dry	63	63
4-Methylphenol	µg/kg	Dry	670	670
2,4 Dimethylphenol	µg/kg	Dry	29	29
Pentachlorophenol	µg/kg	Dry	360	690
Benzyl alcohol	µg/kg	Dry	57	73
Benzoic acid	µg/kg	Dry	650	650

a. SMS biological effects criteria are provided in WAC 173-204-562, Table IV.

Table 16. Assessment Endpoints for Receptors of Concern (ROCs) and Measures of Effect and Exposure

ROC	Assessment Endpoint	Assessment Scale	Measures of Effect	Measures of Exposure
Benthic				
Benthic invertebrate community	survival, growth, reproduction	potential exposure area: small exposure areas for individuals assessment scale: small exposure areas throughout the LDW	SMS and toxicologically based sediment guidelines or TRVs	contaminant concentrations in sediment
			water-based TRVs for VOCs	VOC concentrations in porewater
			site-specific toxicity tests	contaminant concentrations in sediment samples co-located with toxicity test samples
			tissue-based TRVs for TBT (excluding imposex in gastropods)	TBT concentrations in sediment samples co-located with benthic invertebrate tissue collection
			assessment of imposex in field-collected gastropods	TBT concentrations in sediment samples co-located with gastropod collection
Crabs	survival, growth, reproduction	potential exposure area: crabs may forage throughout the LDW assessment scale: LDW-wide	tissue-based TRVs for decapods	contaminant concentrations in crab tissue collected from four tissue sampling areas located throughout the LDW
Fish				
Juvenile chinook salmon	survival and growth	potential exposure area: juvenile salmonids migrate throughout the LDW and forage in shallow areas assessment scale: intertidal areas throughout the LDW	tissue-based TRVs for contaminants evaluated using a critical tissue-residue approach	contaminant concentrations in juvenile chinook salmon tissue collected from middle and lower segments of the LDW
			dietary-based TRVs for contaminants evaluated using a dietary approach	contaminant concentrations in juvenile chinook salmon prey collected from intertidal habitat throughout the LDW, stomach contents collected from juvenile chinook salmon captured throughout the LDW, and sediment collected from intertidal habitats throughout the LDW

ROC	Assessment Endpoint	Assessment Scale	Measures of Effect	Measures of Exposure
English sole	survival, growth, reproduction	potential exposure area: English sole may forage throughout the LDW assessment scale: LDW-wide	tissue-based TRVs for contaminants evaluated using a critical tissue-residue approach	contaminant concentrations in English sole tissue collected from four tissue sampling areas located throughout the LDW
			dietary-based TRVs for contaminants evaluated using a dietary approach	contaminant concentrations in English sole prey and sediment collected throughout the LDW
Pacific staghorn sculpin	survival, growth, reproduction	potential exposure area: sculpin may forage throughout the LDW or small segments of LDW assessment scale: LDW-wide and four modeling areas	tissue-based TRVs for contaminants evaluated using a critical tissue-residue approach	contaminant concentrations in sculpin tissue collected from four tissue sampling areas located throughout the LDW
			dietary-based TRVs for contaminants evaluated using a dietary approach	contaminant concentrations in sculpin prey and sediment collected throughout the LDW and divided into four modeling areas
Wildlife				
Great blue heron	survival, growth, reproduction	potential exposure area: herons may forage in areas of shallow water depths throughout the LDW assessment scale: LDW-wide intertidal	dietary-based TRVs for birds	contaminant concentrations in heron prey collected throughout the LDW and in sediment collected from intertidal habitats throughout the LDW
Osprey	survival, growth, reproduction	potential exposure area: osprey may forage from the top meter of water throughout the LDW assessment scale: LDW-wide	dietary-based TRVs for birds	contaminant concentrations in osprey prey collected throughout the LDW and in sediment collected from intertidal habitats throughout the LDW
Spotted sandpiper	survival, growth, reproduction	potential exposure area: sandpipers predominantly forage within small home range segments of the LDW assessment scale: three intertidal modeling areas	dietary-based TRVs for birds	contaminant concentrations in sandpiper prey and sediment collected from intertidal habitats throughout the LDW
River otter	survival, growth, reproduction	potential exposure area: river otters may forage throughout the LDW assessment scale: LDW-wide	dietary-based TRVs for mammals	contaminant concentrations in river otter prey and sediment collected throughout the LDW
Harbor seal	survival, growth, reproduction	potential exposure area: harbor seals may forage throughout the LDW assessment scale: LDW-wide	dietary-based TRVs for mammals	contaminant concentrations in harbor seal prey and sediment collected throughout the LDW

The following approaches were used in the exposure and effects assessment for the benthic invertebrate community and crabs:

- Risks to the benthic invertebrate community were evaluated by comparing surface sediment contaminant concentrations and site-specific sediment toxicity test results to the SMS chemical and biological criteria[14]; when these were not available, toxicity-based guidelines from the Dredged Materials Management Program (DMMP) or TRVs were used. The SMS chemical criteria for protection of marine benthic invertebrates are 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. The methods used to develop the SMS criteria are consistent with CERCLA ecological risk assessment methodology.
- Risks to the benthic invertebrate community from VOC exposure were evaluated by comparing VOC concentrations in porewater to TRVs.
- Risks to the benthic invertebrate community from TBT exposure were evaluated using results from a site-specific imposex study with gastropods and by comparing TBT concentrations in LDW benthic invertebrate tissue to TRVs.
- Risks to crabs were evaluated by comparing COPC concentrations in LDW crab tissue to TRVs.

Risks to fish were evaluated using two approaches, depending on the COPC. For TBT and PCBs, concentrations in LDW fish tissue were compared with concentrations in fish tissue in the scientific literature associated with adverse effects. For arsenic, cadmium, copper, and vanadium, a dietary approach was used (concentrations in the diet of LDW fish were compared with concentrations associated in the scientific literature with adverse effects) because they are metabolically regulated by fish.

Risks to wildlife ROCs were evaluated by comparing estimated COPC concentrations as a dietary dose for each ROC to dietary doses associated with adverse effects from the scientific literature.

7.2.5 Risk Characterization

A hazard quotient (HQ) was used to quantify ecological risk as the ratio of the estimated contaminant exposure level for the species of concern to the TRV. When the HQ exceeds 1.0, there is a potential for ecological risk.

$$HQ = I/TRV$$

Where:

HQ = Ecological hazard quotient (unitless)

I = Contaminant intake level (mg/kg body weight-day)

TRV = Toxicity reference value (mg/kg body weight-day)

Table 17 compares surface sediment concentrations to benthic SCO criteria. Table 18 shows HQs for crabs, fish, avian and mammalian wildlife, based on TRVs, which are based on no-observed-adverse-effects levels (NOAELs) - and lowest-observed-adverse-effects levels (LOAELs). LOAEL-based HQs of greater than or equal to 1 for PCBs indicated a potential for adverse effects to the benthic invertebrate community, crabs, spotted sandpiper, and river otter. As discussed below, some LOAEL-based HQs

[14] The toxicity tests included: an acute 10-day amphipod (*Eohaustorius estuarius*) survival test; an acute 48-hr bivalve larvae (*Mytilus galloprovincialis*) normal survival test; and a chronic 20-day juvenile polychaete (*Neanthes arenaceodentata*) survival and growth test.

greater 1 were based on highly uncertain exposure or effects data; in that case, the contaminants were not designated as COCs. No quantitative ecological risk estimates were calculated for dioxins and furans due to the lack of tissue data for this compound.

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 criteria (see text box on page 26). Forty-one contaminants were determined to present risks to benthic invertebrates because their concentrations in surface sediments exceeded the benthic SCO chemical criteria. For the subset of 76 samples that were further evaluated using bioassay testing, any sample with a concentration that exceeded the benthic SCO (or CSL) chemical criteria but did not exceed the biological criteria was designated as not exceeding the benthic SCO (or CSL). Based on data from the FS, one or more COCs exceeded benthic SCO criteria in approximately 18%, or 80 acres, of the LDW. In 16 of those 80 acres (4% of the LDW) the CSL was also 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 contaminants, exceedances occurred in 5% or less of the sediment samples (Table 17) in locations dispersed through the waterway.

7.2.6 Identification of COCs

Determination of which COPCs were COCs for ecological receptors was based on consideration of the risk estimates, uncertainties discussed in the ERA, preliminary natural background concentrations, and expected residual risks following planned early actions in the LDW. The COCs from both the ERA and the HHRA were the focus for identifying preliminary remediation goals (PRGs) and cleanup areas in the FS. PCBs were identified as a COC for river otter because they have a higher risk of adverse effects such as reduced reproductive success from the ingestion of seafood contaminated with PCBs. Estimated exposures of river otter were greater than the LOAEL by a factor of 2.9 and uncertainties in the risk estimate were relatively low. In addition, 41 contaminants were selected as COCs for benthic invertebrates because detected concentrations of these 41 contaminants exceeded the benthic SCO criteria of the SMS in one or more locations. Other COPCs that exceeded risk thresholds (LOAEL-based HQ greater than or equal to 1.0) were not selected as COCs because of high uncertainty in the effects or exposure data, comparisons to preliminary background concentrations, or the expectation of low residual risk following remediation in EAAs, as discussed in the ERA.

Table 18 provides detailed rationale for the identification of COCs for ecological risk. COPCs that were not selected as COCs were addressed through focused evaluation in the FS. These contaminants may also be considered in remedial design for specific areas in or near the LDW and in the post-cleanup monitoring.

7.2.7 Uncertainty Analysis for the ERA

Uncertainties in the ERA are summarized below.

- Estimates of the areal extent of surface sediment with concentrations that exceed SMS criteria are uncertain because they were estimated by interpolating from individual points at which sediments were sampled.
- Data from field studies (many of them conducted in the Puget Sound region) were not included in the effects assessment and TRV development because of the difficulty in identifying the cause of toxicity associated with exposures involving multiple chemical and non-chemical stressors.

- The potential for adverse effects is uncertain for all exposure concentrations that are above the NOAEL but below the LOAEL (Table 18) due to lack of data on effects of concentrations between these values.
- Some LOAEL-based TRV values are more uncertain due to uncertainties in the studies reporting the lowest effects concentrations; for example, for the studies reporting PCB TRVs for English sole and Pacific staghorn sculpin and for osprey.
- Some exposure point concentrations (EPCs) are highly uncertain due to a small number of samples driving the estimate; for example, the HQ for lead in spotted sandpiper is driven by a high lead concentration in one benthic invertebrate tissue sample.

No quantitative ecological risk estimates were calculated for dioxins and furans because these compounds were not analyzed in tissues from the LDW. Thus the level of ecological risk from dioxins and furans is unknown. However, background-based remedial goals to reduce what is presumed to be unacceptable human health risk from exposure to dioxins and furans through consumption of seafood from the LDW will reduce exposures (and therefore risk) to higher-trophic-level ecological receptors, as well.

Table 17. Surface Sediment Contaminant Concentrations from FS Dataset, with Comparison to SMS Chemical Criteria for Protection of Benthic Invertebrates

Contaminant	Summary Statistics for Surface Sediments			Total Number of Surface Sediment Samples in FS Baseline Dataset					Exceedances Waterway Wide
	Minimum Detect	Maximum Detect	Mean[a]	Total Samples	Detection Frequency	>Benthic SCO, ≤Benthic CSL, detected[b]	>Benthic CSL, detected[b]	>Benthic SCO or Benthic CSL, detected[b,c]	>Benthic SCO
Metals and TBT (mg/kg dw)									
Arsenic	1.2	1,100	17	916	94%	5	9	14	1.53%
Cadmium	0.03	120	1.0	894	71%	2	12	14	1.57%
Chromium	4.80	1,680	42	906	100%	1	10	11	1.21%
Copper	5.0	12,000	106	908	100%	0	13	13	1.43%
Lead	2.0	23,000	139	908	100%	2	23	25	2.75%
Mercury	0.015	247	0.53	927	88%	20	30	50	5.39%
Nickel	5.0	910	28	836	100%	NA	NA	NA	—
Silver	0.018	270	1.0	875	61%	0	10	10	1.14%
Vanadium	15	150	59	589	100%	NA	NA	NA	—
Zinc	16	9,700	194	905	100%	26	19	45	4.97%
Tributyltin as ion	0.28	3,000	90	189	94%	NA	NA	NA	—
PAHs (µg/kg dw)									
2-Methylnaphalene	0.38	3,300	42	884	19%	1	4	5	0.57%
Acenaphthene	1.0	5,200	65	891	40%	16	4	20	2.24%
Anthracene	1.3	10,000	134	891	73%	2	0	2	0.22%
Benzo(a)anthracene	7.3	8,400	322	891	92%	10	6	16	1.80%
Benzo(a)pyrene	6.5	7,900	309	886	92%	7	5	12	1.35%
Benzo(g,h,i)perylene	6.1	3,800	165	891	86%	10	12	22	2.47%
Total benzofluoranthenes	6.6	17,000	732	885	94%	6	6	12	1.36%
Chrysene	12	7,700	474	891	95%	29	3	32	3.59%
Dibenzo(a,h)anthrecene	1.6	1,500	63	891	56%	18	6	24	2.69%
Dibenzofuran	1.0	4,200	54	889	31%	7	3	10	1.12%
Fluoranthene	18	24,000	889	891	97%	35	12	47	5.27%
Fluorene	0.68	6,800	78	891	48%	11	3	14	1.57%
Indeno(1,2,3-cd)pyrene	6.4	4,300	180	891	90%	16	13	29	3.25%
Naphthalene	3.0	5,300	49	882	21%	0	2	2	0.23%
Phenanthrene	7.1	28,000	429	891	93%	27	3	30	3.37%
Pyrene	19	16,000	723	891	97%	2	6	8	0.90%
Total HPAH	23	85,000	3,809	891	98%	25	6	31	3.48%
Total LPAH	9.1	44,000	696	891	94%	4	3	7	0.79%

Contaminant	Summary Statistics for Surface Sediments			Total Number of Surface Sediment Samples in FS Baseline Dataset					Exceedances Waterway Wide
	Minimum Detect	Maximum Detect	Mean[a]	Total Samples	Detection Frequency	>Benthic SCO, ≤Benthic CSL, detected[b]	>Benthic CSL, detected[b]	>Benthic SCO or Benthic CSL, detected[b,c]	>Benthic SCO
Phthalates (µg/kg dw)									
Bis(2-ethylhexyl) phthalate	5.4	17,000	590	886	79%	46	58	104	11.74%
Butyl benzyl phthalate	2.0	7,100	87	878	54%	80	10	90	10.25%
Dimethyl phthalate	2.0	440	25	878	21%	0	2	2	0.23%
Chlorobenzenes (µg/kg dw)									
1,2,4-Trichlorobenzene	1.6	940	19	871	1%	0	2	2	0.23%
1,2-Dichlorobenzene	1.3	670	19	871	2%	0	4	4	0.46%
1,4-Dichlorobenzene	1.5	1,600	23	871	6%	0	4	4	0.46%
Hexachlorobenzene	0.4	95	17	874	5%	4	2	6	0.69%
Other SVOCs[d] and COCs (µg/kg dw)									
2,4-Dimethylphenol	6.1	290	44	869	3%	0	25	25	2.88%
4-Methylphenol	4.8	4,600	44	883	13%	0	4	4	0.45%
Benzoic acid	54	4,500	238	876	13%	0	9	9	1.03%
Benzyl alcohol	8.2	670	49	867	3%	9	7	16	1.85%
Carbazole	3.2	4,200	82	775	55%	NA	NA	NA	
n-Nitrosodiphenylamine	6.5	230	27	871	3%	0	2	2	0.23%
Pentachlorophenol	14	14,000	122	840	4%	1	1	2	0.24%
Phenol	10	2,800	91	886	32%	19	6	25	2.82%
Pesticides (µg/kg dw)									
Total DDTs	0.72	77,000	462	216	40%	NA	NA	NA	—
Total chlordanes	0.20	230	268	216	13%	NA	NA	NA	—
Aldrin	0.01	1.6	27	216	2%	NA	NA	NA	—
Dieldrin	0.10	280	29	218	4%	NA	NA	NA	—
alpha-BHC	0.14	1.8	1.1	207	1%	NA	NA	NA	—
beta-BHC	0.09	13	1.2	207	2%	NA	NA	NA	—
gamma-BHC	0.05	8.6	27	216	6%	NA	NA	NA	
Heptachlor	0.12	5.2	27	216	3%	NA	NA	NA	
Heptachlor epoxide	0.47	4.9	2.8	207	2%	NA	NA	NA	
Toxaphene	340	6,300	111	205	1%	NA	NA	NA	

Total PCBs (µg/kg dw)									
Total PCBs[e]	2.2	223,000	1,136	1390	94%	336	179	515	37.05%

Source: LDWG (2012)

General: Contaminants identified as risk drivers for the benthic invertebrate community (RAO 3) are those with one or more surface sediment samples with exceedances of the SCO. Three additional contaminants (total DDTs, total chlordanes, and nickel) that do not have SMS criteria were also identified as COCs for the benthic community.

a. Calculated mean concentration is the average of concentrations using one-half the reporting limit substitution for non-detected results.

b. For non-polar organic compounds, comparisons to SCO and CSL were made using organic carbon-normalized concentrations. If total organic carbon (TOC) in the sample was <0.5% or >4%, dry weight concentrations were compared to the Apparent Effect Thresholds: (Lowest Apparent Effects Threshold) and Second Lowest Apparent Effects Threshold. Additional discussion can be found at *http://www.ecy.wa.gov/programs/tcp/smu/sed_pubs.htm#ApparentEffectsThreshold/*. See also Section 15 (Key Terms).

c. Sum of samples exceeding the SCO but not the CSL and samples exceeding the CSL.

d. SVOCs — semi-volatile organic compounds

e. Total PCB statistics and counts were generated with two outliers excluded (2,900,000 and 230,000 µg/kg dw at RM 2.2).

Table 18. Rationale for Selection of Contaminants as COCs for Ecological Risk

COPC	ROC	Maximum NOAEL-Based HQ	Maximum LOAEL-Based HQ	Additional Considerations	COC?
Total PCBs	crabs	10	1.0	Uncertainty in exposure data: whole-body concentrations were estimated Uncertainty in effects data: LOAEL-based HQ was based on a study with Aroclor 1016 and grass shrimp, and NOAEL was estimated using an uncertainty factor; selection of next higher TRV would result in LOAEL-based HQ < 1.0	no
	river otter	5.8	2.9	Uncertainty in exposure data: low uncertainty in diet assumptions and home range Uncertainty in effects data: low uncertainty in TRV (growth endpoint in kits)	yes
	English sole	4.9 – 25[a]	0.98 – 5.0[a]	Uncertainty in exposure data: low uncertainty in tissue concentrations Uncertainty in effects data: high uncertainty in lowest LOAEL TRV because of uncertain statistical significance of the fecundity endpoint for the low dose, a lack of dose-response in the fecundity endpoint, uncertain number of fish used in the experiment, and uncertainties associated with fish handling and maintenance protocols	no
	Pacific staghorn sculpin	3.8 – 19[a]	0.76 - 3.8[a]	Same considerations as listed above for English sole	no
PCB TEQ[b]	spotted sandpiper –Area 2 (high-quality foraging habitat)	15	1.5	Uncertainty in exposure data: low uncertainty in diet assumptions and home range Uncertainty in effects data: high uncertainty in TRV, which was based on study of reproduction with weekly IP injection; high uncertainty in TEFs; effects data for total PCBs are less uncertain than for PCB TEQs and the LOAEL-based HQ for total PCBs was < 1.0	no
Cadmium	juvenile chinook salmon	5.0	1.0	Uncertainty in exposure data: LOAEL-based HQ < 1.0 if empirical juvenile chinook salmon stomach contents data from the LDW are used to estimate exposure, instead of estimating exposure based on ingestion of benthic invertebrates Uncertainty in effects data: high uncertainty in the lowest TRV because selection of next higher TRV would result in LOAEL-based HQ < 1.0, all salmonid-specific studies for cadmium with NOAELs result in NOAEL-based HQs less than 0.01	no
	English sole	6.1	1.2	Uncertainty in exposure data: low uncertainty (LDW-collected benthic invertebrate tissue samples) Uncertainty in effects data: high uncertainty in the lowest TRV because selection of next higher TRV would result in LOAEL-based HQ < 1.0; all other NOAELs and LOAELs were orders of magnitude higher than the selected LOAEL	no
	Pacific staghorn sculpin	5.2	1.0	Uncertainty in exposure data: low uncertainty (LDW-collected shiner surfperch and benthic invertebrate tissue samples) Uncertainty in effects data: high uncertainty in the lowest TRV because selection of next higher TRV would result in LOAEL-based HQ < 1.0; all other NOAELs and LOAELs were orders of magnitude higher than the selected LOAEL	no

COPC	ROC	Maximum NOAEL-Based HQ	Maximum LOAEL-Based HQ	Additional Considerations	COC?
Chromium	spotted sandpiper –Area 2 (high- and poor-quality foraging habitat)	8.8	1.8	Uncertainty in exposure data: high uncertainty because LOAEL-based HQ would be less than 1.0 if the single anomalously high benthic invertebrate tissue sample from RM 3.0 west was excluded; chromium concentrations in sediment were low in this area Uncertainty in effects data: high uncertainty; only one study with reported effects, and study was unpublished and could not be obtained for review	no
Copper	spotted sandpiper –Area 3 (high- and poor-quality foraging habitat)	1.5	1.1	Uncertainty in exposure data: low uncertainty Comparison to natural background: concentration in sediment (Surface Weighted Average Concentration of 57 mg/kg dw) from Area 3 (high- and poor-quality foraging habitat) similar to PSAMP rural Puget Sound concentrations (50 mg/kg dw [90th percentile]) Residual risk: following planned sediment remediation within early action areas, LOAEL-based HQ would be < 1.0	no
Lead	spotted sandpiper –Area 2 (high- and poor-quality foraging habitat)	19	5.5	Uncertainty in exposure data: high uncertainty because LOAEL-based HQ would be less than 1.0 if the single anomalously high benthic invertebrate tissue sample from RM 3.0 west was excluded; lead concentrations in sediment were low in this area Uncertainty in effects data: low uncertainty (reproductive endpoint)	no
	spotted sandpiper –Area 3 (high- and poor-quality foraging habitat)	5.0	1.5	Uncertainty in exposure data: low uncertainty Uncertainty in effects data: low uncertainty (reproductive endpoint) Residual risk: following planned sediment remediation within early action area, LOAEL-based HQ would be < 1.0	
Mercury	spotted sandpiper –Area 3 (high-quality foraging habitat)	5.3	1.0	Uncertainty in exposure data: low uncertainty Uncertainty in effects data: low uncertainty (TRV was based on a growth endpoint) Residual risk: following planned sediment remediation within early action area, LOAEL-based HQ would be < 1.0	no
Vanadium	English sole	5.9	1.2	Uncertainty in exposure data: low uncertainty Uncertainty in effects data: high uncertainty in TRV because only one study was available Comparison to natural background: exposure concentration in LDW sediment (SWAC of 58 mg/kg dw) was less than PSAMP rural Puget Sound concentration (64 mg/kg dw [90th percentile])	no
	Pacific staghorn sculpin	3.2 – 5.9	0.65 – 1.2	Same considerations as listed for English sole above	no
	spotted sandpiper – all exposure areas	2.0 – 2.7	1.0 – 1.4	Uncertainty in exposure data: low uncertainty Uncertainty in effects data: TRV was based on a 4-week growth endpoint, with uncertainty (two available studies: one with reduced body weight in chickens after 4 weeks and the other with no effect on body weight in mallards after 10 weeks) Comparison to natural background: mean exposure concentrations in sandpiper exposure areas ranged from 49 to 57 mg/kg dw, compared to Puget Sound Ambient Monitoring Program rural Puget Sound background concentration of 64 mg/kg dw (90th percentile)	no
41 SMS contami-nants[c]	benthic invertebrates	range of values	range of values	Each of these 41 contaminants had at least one detected exceedance of benthic SCO in baseline surface sediment dataset	yes

COPC	ROC	Maximum NOAEL-Based HQ	Maximum LOAEL-Based HQ	Additional Considerations	COC?
Nickel	benthic invertebrates	6.6	2.5	Uncertainty in exposure data: low uncertainty Uncertainty in effects data: medium uncertainty in the TRV (i.e., the ML) because only no-effects data (amphipod mortality and community abundance Apparent Effects Thresholds) were available; no information was available regarding concentrations associated with adverse effects Residual risk: ML was exceeded at four locations in LDW – all within early action areas with planned sediment remediation	no
Total DDTs	benthic invertebrates	5.1	2.7	Uncertainty in exposure data: medium uncertainty (i.e., likely interference in pesticide analyses from PCBs) Uncertainty in effects data: medium uncertainty; based on a single study with spiked sediment Residual risk: LOAEL was exceeded at only one location in LDW, location is within early action area with planned sediment remediation	no
Total chlordane	benthic invertebrates	82	48	Uncertainty in exposure data: highly uncertain because all total chlordane concentrations in samples from Phase 2 locations were JN-qualified as a result of probable PCB interference; except one location at RM 2.2, all locations with detected total chlordane concentrations co-occurred with elevated PCB concentrations Uncertainty in effects data: TRV is highly uncertain because it was based on a general Canadian sediment guideline (PEL); this guideline is based mainly on field-collected data with complex mixtures of contaminants Residual risk: LOAEL was exceeded at 14 locations in LDW; all but one of these locations are associated with an early action area with planned sediment remediation	no

Note: HQs for fish are the highest HQs in cases where more than one approach was used.

a. LOAEL-based HQs were calculated from a range of effects concentrations reported in Hugla and Thome (1999) because of uncertainty in the LOAEL. The NOAEL TRV range was estimated by dividing the LOAEL TRV range by an uncertainty factor of 5. Ranges reported for Pacific staghorn sculpin also included the range in exposure estimates for areas smaller than the entire LDW.

b. Risk estimates based on TEQs were calculated using only tissue data for dioxin-like PCB congeners because dioxin and furan tissue data were not available. Thus, risks associated with exposure to all dioxin-like contaminants were likely underestimated; the degree of underestimation is uncertain.

c. Arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc, acenaphthene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo (a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3,-c,d)pyrene, naphthalene, phenanthrene, pyrene, total benzofluoranthenes, HPAH, LPAH, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, dimethyl phthalate, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene, 2-methylnaphthalene, 4-methylphenol, 2,4-dimethylphenol, benzoic acid, benzyl alcohol, dibenzofuran, hexachlorobenzene, n-nitrosodiphenylamine, pentachlorophenol, phenol, total PCBs.

NOTE: arsenic and total PCBs are also human health contaminants of concern.

7.3 Basis for Action

The response action selected in this Record of Decision is necessary to protect public health or welfare or the environment from actual or threatened releases of pollutants or contaminants at or from this In-waterway Portion of the Site which may present an imminent and substantial endangerment to public health or welfare or the environment. A response action is necessary for the In-waterway Portion of the Site because:

- Human Health Risk: The risk of an individual developing cancer or noncarcinogenic effects related to exposure to contaminants at the In-waterway Portion of the Site exceeds the acceptable risk range identified in the National Oil and Hazardous Substances Pollution Contingency Plan (National Contingency Plan; NCP). Specifically, seafood consumption risks and direct contact HQs for the RME scenarios exceed CERCLA risk thresholds of an excess cancer risk of 1×10^{-4} and a noncancer HQ of 1. MTCA/SMS thresholds are also exceeded, as discussed in Section 7.1.

- Ecological Risk: Risks to ecological receptors exceed CERCLA risk thresholds. Forty-one contaminants were determined to present risks to benthic invertebrates because their concentrations in surface sediments exceeded the benthic SCO criteria of the SMS. The benthic SCO criteria are based on studies showing the relationship between contaminant concentrations and adverse effects to benthic invertebrates. Risks to river otter (based on an analysis of risks to higher–trophic level species [HTLS]) exceed the LOAEL-based HQ by a factor of 2.9 (Table 18), and uncertainties in the risk estimate were relatively low. MTCA/SMS thresholds are also exceeded, as discussed in Section 7.2.

8 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 7. RAOs help focus the development and evaluation of remedial alternatives and form the basis for establishing cleanup levels in the ROD.

8.1 Remedial Action Objectives

The four RAOs established for the LDW are presented below along with a brief summary of how the Selected Remedy addresses each one:

RAO 1: Reduce risks associated with the consumption of contaminated resident LDW fish and shellfish by adults and children with the highest potential exposure to protect human health. 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 noncancer risks from consumption of resident seafood, which will reduce concentrations of these COCs in tissue. Ongoing source control and the use of seafood consumption advisories and education and outreach programs will provide additional risk reduction.

RAO 2: Reduce risks from direct contact (skin contact and incidental ingestion) to contaminated sediments during netfishing, clamming, and beach play to protect human health. 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 noncancer 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 20 to the chemical or biological benthic SCO.

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, which will reduce PCB concentrations in tissue. Addressing risks to river otters due to consumption of PCB-contaminated seafood, along with addressing risks associated with RAOs 1 – 3, will also address risks to other ecological receptors.

8.2 Cleanup Levels, ARARs and Target Tissue Concentrations

This section describes the selected cleanup levels (see Section 8.2.1), ARARs (see Section 8.2.2), and target tissue concentrations (see Section 8.2.3) for the in-waterway cleanup and key factors that formed the basis for each. The selected cleanup levels are contaminant concentrations that will be used to measure the success of the cleanup alternatives in meeting the RAOs. Cleanup levels 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.

8.2.1 Cleanup Levels

Table 19 lists sediment cleanup levels for RAOs 1, 2, and 4, and Table 20 lists sediment cleanup levels for RAO 3. Sediment cleanup levels for contaminants for RAO 3 are point-based and applicable to any sample location; for the other RAOs, cleanup levels are applied to a specific area (see Table 19). Benthic cleanup levels are based on the benthic SCO in the SMS (WAC 173-204-562). For RAO 3, the SCO numerical chemical criteria can be overridden by the SCO biological criteria (see text box "What are the Sediment Management Standards?" on page 26) unless they are co-located with exceedances of remedial action levels (RALs) associated with human health COCs, which are also point-based. Exceedances of RALs for human health COCs cannot be overridden by toxicity testing.

Table 19. Cleanup Levels for PCBs, Arsenic, cPAHs, and Dioxins/Furans in Sediment for Human Health and Ecological COCs (RAOs 1, 2 and 4)

COC	Cleanup Levels				Application Area and Depth		
	RAO 1: Human Seafood Consumption	RAO 2: Human Direct Contact	RAO 4: Ecological (River Otter)	Basis for Cleanup Levels[a]	Spatial Scale of Application[b]	Spatial Compliance Measure[e]	Compliance Depth[b]
PCBs (µg/kg dw)	**2**	1,300	128	background (RAO 1) RBTC (RAO 2) RBTC (RAO 4)	LDW-wide	UCL95	0 – 10 cm
	NA	500	NA	RBTC	All Clamming Areas[c]	UCL95	0 – 45 cm
	NA	1,700	NA	RBTC	Individual Beaches[d]	UCL95	0 – 45 cm
Arsenic (mg/kg dw)	NA	7	NA	background	LDW-wide	UCL95	0 – 10 cm
	NA	7	NA	background	All Clamming Areas[c]	UCL95	0 – 45 cm
	NA	7	NA	background	Individual Beaches[d]	UCL95	0 – 45 cm
cPAH (µg TEQ/kg dw)	NA	380	NA	RBTC	LDW-wide	UCL95	0 – 10 cm
	NA	150	NA	RBTC	All Clamming Areas[c]	UCL95	0 – 45 cm
	NA	90	NA	RBTC	Individual Beaches[d]	UCL95	0 – 45 cm
Dioxins/Furans (ng TEQ/kg dw)	**2**	37	NA	background (RAO 1) RBTC (RAO 2)	LDW-wide	UCL95	0 – 10 cm
	NA	13	NA	RBTC	All Clamming Areas[c]	UCL95	0 – 45 cm
	NA	28	NA	RBTC	Individual Beaches[d]	UCL95	0 – 45 cm

NOTE: where there are multiple cleanup levels for a cleanup area, the lowest cleanup level is shown in bold.

a. Background – see Table 3 and Section 5.3.4.1; RBTC – Risk-based threshold concentration (based on 1 in 1,000,000 excess cancer risk or HQ of 1)

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

c. Clamming areas are identified in Figure 6.

d. Beach play areas are identified in Figure 6.

e. The UCL 95 is the upper confidence limit on the mean. The determination of compliance with RAOs 1, 2 and 4 cleanup levels will be made by one of two methods: 1) comparison of the UCL 95 of LDW data with the RBTC or background-based cleanup level, or 2) for background-based cleanup levels, a statistical comparison of the distribution of LDW data to the OSV BOLD study background dataset (USACE et al. 2009) may be used. In either case, testing will use an alpha level of 0.05 and a beta level of 0.10. For details, see ProUCL technical manual (EPA 2013b) or most current version). For either method, a sufficient number of samples must be collected to assure statistical power for the test.

Table 20. Sediment Cleanup Levels for Ecological (Benthic Invertebrate) COCs for RAO 3[a]

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

a. Cleanup Levels for RAO 3 are based on the benthic SCO chemical criteria in the SMS (WAC 173-204-562). Benthic SCO biological criteria (WAC 173-204-562, Table IV) may be used to override benthic SCO chemical criteria where human health-based RALs are not also exceeded.

b. PCBs and arsenic are also human health COCs; see Table 19.

No sediment cleanup levels 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 concentrations of arsenic or cPAH in sediment and their concentrations in clam tissue. EPA will define the sediment cleanup footprint based on other cleanup levels, then use the clam target tissue levels (Section 8.2.3) to measure reduction in arsenic and cPAH concentrations in clams. Research will be conducted during the remedial design phase to study the relationships between sediment concentrations for arsenic and cPAHs and concentrations in clam tissue and methods to reduce concentrations of these contaminants in clams. If EPA determines, based on these studies, that additional remedial action is needed to reduce clam tissue arsenic and cPAH concentrations for the purpose of achieving RAO 1, EPA will document and select those actions in a future decision document.

The sediment cleanup levels for PCBs and dioxins/furans (RAO 1) and for arsenic (RAO 2) are set at natural background consistent with the SCO for human health risks (HH SCO). Modeling conducted during the RI/FS could not predict that long term LDW COC concentrations would achieve natural background. 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 current practical limitations on control of sources within the LDW and Green/Duwamish River drainage basins may not allow sufficient future reductions in these incoming concentrations. The term cleanup objective was used in the FS to mean the PRG or as close as practicable to the PRG (sediment PRGs in the FS and Proposed Plan are cleanup levels in the ROD). This ROD uses the term "FS cleanup objective" when referring to the term as it was used in the FS to distinguish it from the new term SCO in the 2013 SMS. 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 COC concentrations predicted by the model are highly uncertain. As discussed in the FS (LDWG 2012a), concentrations of COCs coming in to the LDW from upstream and lateral sources vary over time and are difficult to predict; therefore, the values used to represent these COC concentrations, used as model inputs, are uncertain. In particular, the data used to estimate Green/Duwamish River surface water and sediment inputs to the RI/FS models were relatively sparse and highly variable. In addition, it is difficult to predict what concentrations in upstream and lateral-source sediments will be many years in the future. High and low bounds on these inputs were evaluated in the FS to portray model sensitivity. For example, RI/FS models predict that all alternatives will reduce PCB concentrations in LDW sediments to approximately 40 – 45 µg/kg in 40 years using mid-range model input parameters (Table 5). In contrast, the sensitivity analysis indicates that future PCB sediment concentrations could range from 9 – 100 µg/kg. The great majority of this range is due to varying assumptions about incoming suspended sediment concentrations. 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 coordination with EPA will use this information to further assess upstream source control. EPA is retaining natural background, along with the risk-based values (RBTCs), as the basis for cleanup levels for LDW sediments.

8.2.2 ARARs

ARARs are legally applicable or relevant and appropriate substantive (as opposed to administrative) standards, requirements, criteria, or limitations under any federal environmental law, or promulgated under any state environmental or facility siting law that is more stringent than under federal law. This section discusses MTCA and surface water quality requirements; these ARARs are also discussed in Sections 10.1.2 and 14.2, and a complete list of ARARs is in Table 26.

8.2.2.1 Sediment Quality ARARs

The most significant ARARs for developing cleanup levels during the RI/FS and for the Proposed Plan for the In-waterway Portion of the Site were in MTCA and its rules in WAC 173-340 for Washington cleanup sites generally, and the SMS rules for sediment cleanups in WAC 173-204, which are referred to in the MTCA general cleanup rules (WAC 173-340-760). Major portions of the SMS were revised in September 2013, after the Proposed Plan was issued, in part to update sediment cleanup requirements in Part V (Sediment Cleanup Standards) of the SMS and harmonize Part V requirements with the requirements in MTCA. The 1991 SMS was promulgated under several authorities including both MTCA and the state Water Pollution Control Act. However, Part V of the 2013 SMS was promulgated solely under MTCA. See “What are the Sediment Management Standards?” on page 26 for a summary of the 2013 SMS. As a matter of substance, the MTCA and SMS-based sediment PRGs set forth in the Proposed Plan using the 1991 SMS remain unchanged as cleanup levels in the ROD, though the method for deriving them (applying the substantive requirements of the 2013 SMS) is different, as explained below. This section describes the derivation of the cleanup levels in this ROD in terms of the revised SMS rules.

Sediment cleanup levels for RAOs 1 and 2 (for protection of human health) are calculated at the SCO level – risk-based threshold concentrations (RBTCs) of 1×10^{-6} excess cancer risk for individual carcinogens, 1×10^{-5} excess cancer risk cumulatively for multiple carcinogens, and noncancer HQ or HI of 1, consistent with the NCP and as required by the revised SMS (WAC 173-204-560 and 561). In accordance with the SMS, where RBTCs at SCO levels are more stringent than background levels, the SCO-based cleanup levels are set at the natural background level (see Section 5.3.4.1)[15].

Similarly, consistent with the revised SMS (WAC 173-204-562), cleanup levels associated with RAO 3 (protection of benthic invertebrates) are based on the SCO for the protection of benthic invertebrates (benthic SCO) of the SMS which are defined by chemical and biological criteria for specific hazardous substances as explained in Section 5.3.1.1. The benthic SCO chemical and biological criteria are the same as the 1991 SMS Sediment Quality Standards criteria used in the FS and Proposed Plan. EPA also considered risks to higher-trophic-level species (HTLS) (WAC 173-204-564) in setting a PCB cleanup level for river otter (RAO 4). Cleanup levels for the protection of human health and benthic invertebrates are also protective of HTLS.

The 2013 SMS (WAC 173-204-560) requires initial establishment of cleanup levels at the SCO level, but allows for the cleanup levels to be adjusted upward to CSL levels when it is not technically possible to achieve SCO levels, or if meeting the SCO will have a net adverse impact on the aquatic environment. CSL risk-based cleanup levels are the most stringent of the following: 1) for human health, an excess cancer risk of 1×10^{-5} for individual carcinogens and for multiple carcinogens cumulatively, and a noncancer HQ or HI of 1; 2) for risks to benthic invertebrates, chemical and biological criteria defined in WAC 173-204-562 (which are the same as the CSL criteria in the 1991 SMS); and 3) for risks to HTLS, the same no-observed-adverse-effects threshold as the SCO per WAC 173-204-564. The CSL is the highest of the risk based concentration, PQL, or regional background (a new term created by the 2013 SMS). There is insufficient information at this time to determine whether or not it is technically possible to achieve the SCO-based cleanup levels selected in this ROD, for the reasons discussed in Section 8.2.1. In addition, neither EPA nor Ecology has established regional background for the LDW.

If long-term monitoring data and trends indicate that some cleanup levels or other ARARs cannot be met, EPA will determine whether further remedial action could practicably achieve the ARAR. If EPA concludes that an ARAR cannot be practicably achieved, EPA will waive the ARAR on the basis of technical impracticability (TI) in a future decision document (ROD Amendment or ESD). For SMS SCO-based ARARs, EPA will first consider whether the criteria in the SMS for adjusting cleanup levels from

[15] The SMS also allows upward adjustment for cleanup levels that are below practical quantitation limits (PQLs); however, this is not applicable for the LDW, where natural background- and risk-based cleanup levels are higher than PQLs.

the SCO to the CSL (including regional background) can be met, as discussed above. If these criteria can be met, EPA will evaluate adjusting the relevant sediment cleanup levels upward to regional background or other CSL-based levels described in the SMS.

8.2.2.2 Surface Water Quality ARARs

Surface water quality ARARs consist of applicable promulgated state water quality standards and, in accordance with Section 121(d)(2)(A)(ii) and (B)(i) of CERCLA, federal recommended Clean Water Act Section 304(a) Ambient Water Quality Criteria (AWQC) guidance values where they are relevant and appropriate. The AWQC for human health include values to protect for consumption of organisms only, and those to protect for consumption of organisms and water. For the LDW, the relevant and appropriate AWQC for the protection of human health are those established for the consumption of organisms only because surface water within the In-waterway Portion of the Site is not a source of consumable water. The AWQC also include acute and chronic criteria values for the protection of aquatic life, including benthic organisms. State standards in Washington include those standards promulgated in WAC 173-201A and, for protection of human health, EPA's 1992 promulgated National Toxics Rule (NTR) standards (see Table 26 for legal citations). Consistent with Section 121(d) of CERCLA, the NCP, and MTCA at WAC 173-340-730(3)(b), ARARs are the most stringent of values from WAC 173-201A, NTR, and relevant and appropriate AWQC.

Surface water will not be directly remediated but will be improved by implementation of the Selected Remedy and by source control to be implemented as discussed in Section 4.2. Surface water is a key exposure pathway for consumption of aquatic organisms by humans or wildlife. Surface water quality data will be compared to these ARAR values to measure progress towards achieving RAOs 1 and 4, and evaluated as discussed in Section 8.2.2.1.

8.2.3 Fish and Shellfish Target Tissue Concentrations

EPA has established fish and shellfish target tissue concentrations to measure progress toward achieving RAOs 1 and 4. Controlling sources of contamination to the LDW along with remediating contaminated sediments will reduce COC concentrations in surface water and in fish and shellfish tissue in addition to reducing COC concentrations in sediment. Table 21 lists resident fish and shellfish (crab and clam) target tissue concentrations for RAO 1. They are based on the higher of: the RBTC at 1 x 10^{-6} excess cancer risk or HQ of 1 for the adult Tribal RME scenario; or the current concentrations in non-urban (background) Puget Sound data. Fish and shellfish target tissue concentrations have been developed consistent with the criteria for developing the sediment cleanup levels (which are based on the 2013 SMS) to measure protectiveness for humans, including sensitive subpopulations.

Target tissue concentrations are not cleanup levels; they will be used for informational purposes to assess ongoing risks to people who may consume resident LDW fish and shellfish. Tissue monitoring data will also inform the content or degree of any potential future fish advisories, other ICs intended to minimize risk to the LDW fishing community, or other response actions that may be identified in a ROD Amendment or ESD.

As discussed in Section 5.3.4.2, fish and shellfish target tissue concentrations 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.

The FS used the BCM to predict post-cleanup sediment concentrations for various alternatives and the FWM to predict fish and shellfish tissue PCB concentration associated with these changed sediment concentrations. Together, these models predicted that background-based fish and shellfish target tissue PCB concentrations will not be met in the long term due to the same assumptions subject to the same uncertainties described in the last paragraph of Section 8.2.1. Further, while the same approach was used to develop target tissue concentrations and sediment cleanup levels, it is not known whether achievement of sediment cleanup levels would result in the achievement of target tissue levels. Sediment and tissue background data were not collected concurrently or at the same locations, and food web relationships in the Puget Sound bays where the natural background samples were taken are likely to be different than in the Duwamish estuary.

Table 21. LDW Resident Fish and Shellfish Target Tissue Concentrations

Species Group and Tissue Type	Species[a,b,]	Target Concentration	Source of Target Concentration [c]
PCBs (µg/kg ww)			
Benthic fish, fillet	English sole	12	Non-urban background
Pelagic fish, whole body	Perch	1.8	Species-specific RBTC[d]
Crab, edible meat	Dungeness crab	1.1	Non-urban background
Crab, whole body	Dungeness crab	9.1	Non-urban background
Clams	Eastern softshell clam	0.42	Non-urban background
Inorganic arsenic (mg/kg ww)			
Clams[e]	Eastern softshell clam	0.09	Non-urban background
cPAH TEQ (µg/kg ww)			
Clams[e]	Eastern softshell clam	0.24	Species-specific RBTC[d]
Dioxin/furan TEQ (ng/kg ww)			
Benthic fish, whole body	English sole	0.35	Non-urban background
Crab, edible meat	Dungeness crab	0.53	Non-urban background
Crab, whole body	Dungeness crab	2.0	Non-urban background
Clams	Eastern softshell clam	0.71	Non-urban background

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

b. For non-urban background statistics, see also Table 4. Non-urban background is based on UCL95.

c. The statistic used to compare site data to target tissue concentrations will be based on the UCL95 for each compound listed for fish and crabs collected throughout the waterway; and each compound for clams collected across all clamming areas in the waterway.

d. Species-specific RBTCs were used to determine target concentration when RBTCs exceed background, or background data were not available.

e. Only clam tissue values are shown for inorganic arsenic and cPAH TEQ because most of the risk associated with these COCs was associated with consumption of clams.

9 Description of Alternatives

Remedial alternatives for the LDW were developed to meet the requirements of CERCLA and its regulations, the NCP, which include ARARs such as MTCA and its regulations including the SMS. The NCP requires 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 Selected Remedy and are discussed below.

9.1 Framework for Developing Alternatives

EPA considered several factors in developing remedial alternatives, including: the levels of COCs in surface and subsurface sediments, the likelihood of humans or aquatic organisms coming into 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 6. To support the development of alternatives, EPA developed three criteria: 1) Remedial Action Levels (RALs) (described below); 2) cleanup levels (described in Section 8.2.1); and 3) Recovery Categories, described below.

Remedial Action Levels (RALs) are contaminant-specific sediment concentrations that will be used to identify specific areas 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 vary by alternative and are set by EPA so that, in each area, cleanup levels 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 10.1. The sediment RALs in this ROD are equal to or higher than the sediment cleanup levels 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.

A number of remedial alternatives were developed and are presented in this ROD. Table 22 provides a summary of the alternatives, which are describe in detail in Section 9.4. As shown in Table 22, each alternative has its own set of sediment RALs, from higher concentrations (less active cleanup) to lower concentrations (more active cleanup). Alternatives vary with regard to: which remedial technologies are used; risk reduction projected to be achieved over time; and the extent to which they rely upon natural recovery to reduce contaminant concentrations.

Different RALs were established for surface and subsurface sediments, intertidal and subtidal sediments, and Recovery Category areas.

Contaminant-specific RALs for surface sediments are compared to contaminant concentrations averaged over 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 22) 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 in the top 60 cm (2 ft).[16] Where concentrations exceed the RALs, active remediation technologies are selected based on technology applicability for conditions in the waterway, including relative abilities of the technologies to address contamination given potential for scour, potential for human contact, site constraints (such as docks and navigation), and recovery potential. RALs are applied at each discrete sampling location, not as averaged values applied over the surface area of the waterway sediments. While RALs were used in the FS to identify areas for each altnernative requiring active remediation, the areas of active remediation will be further defined through sampling conducted during remedial design. Sampling results will be used to determine the areal extent and depth of contamination to be addressed by cleanup of the EAAs.

Cleanup Levels are described in Section 8. For each alternative, the projected short-term and long-term sediment COC concentrations after implementation (developed using the RALs and Recovery Categories) are compared to cleanup levels to estimate that alternative's 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 23. 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.

9.2 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, 12 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 LDWG 2012b and LDWG 2013; the modified alternative is called 5C Plus. The Selected Remedy is based on Alternative 5C Plus; however, some additional modifications were made after consideration of public comments on the Proposed Plan. These modifications are summarized in this section and described in more detail in Section 12. An approximation of the locations of sediments addressed by the cleanup alternatives is shown in Figure 13.

[16] The Selected Remedy, developed after completion of the FS and described in Section 13, adds PCB RALs for the top 60 cm (2 ft) in Recovery Category 2 and 3 areas, and adds a requirement that all shoaled areas in the navigation channel that exceed RALs must be dredged.

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Table 22. Remedial Alternatives and Associated Remedial Technologies, Remedial Action Levels, and Actively Remediated Acres

Remedial Alternatives and Technologies[a]	Remedial Action Levels[a] PCBs (mg/kg OC)[b]	Arsenic (mg/kg dw)	cPAHs (µg TEQ/kg dw)	Dioxins/ Furans (ng TEQ/kg dw)	Benthic SMS (41 Contaminants)[b]	Actively Remediated Area (Acres)
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 Alternative 2 with CAD (2R-CAD) – dredge emphasis with contained aquatic disposal/MNR	65 to 110 (LDW-wide); 10-yr post-construction target: 65[c]	93	5,500	50	CSL to 3 × CSL 10-yr post-construction target: CSL	32 acres
Alternative 3 removal (3R) – dredge emphasis with upland disposal/MNR Alternative 3 combined technologies (3C) – ENR/ in situ / cap/ MNR where appropriate, otherwise dredge with upland disposal	65 (LDW-wide)	93 (LDW-wide) 28 (intertidal)	3,800 (LDW-wide) 900 (intertidal)	35 (LDW-wide) 28 (intertidal)	CSL (biological or chemical)	58 acres
Alternative 4 removal (4R) – dredge emphasis with upland disposal/MNR Alternative 4 combined technologies (4C) – ENR/ in situ / cap/ MNR where appropriate, otherwise dredge with upland disposal	12 to 35 (LDW-wide) 10-yr post-const. target: 12[c]	57 (LDW-wide) 28 (intertidal)	1,000 (LDW-wide) 900 (intertidal)	25 (site-wide) 28 (intertidal)	SCO to CSL 10-yr post-const. target: SCO	107 acres
Alternative 5 removal (5R) – dredge emphasis with upland disposal Alternative 5 removal with treatment (5R-T) – dredge with soil washing treatment and disposal/re-use Alternative 5 combined technologies (5C) – ENR/ in situ / cap where appropriate, otherwise dredge with upland disposal	12 (LDW-wide)	57 (LDW-wide) 28 (intertidal)	1,000 (LDW-wide) 900 (intertidal)	25 (LDW-wide) 28 (intertidal)	SCO (biological or chemical)	157 acres
Alternative 6 removal (6R) – dredge emphasis with upland disposal Alternative 6 combined technologies (6C) – ENR/ in situ / cap where appropriate, otherwise dredge with upland disposal	5 (LDW-wide)	15 (LDW-wide) 28 (intertidal)	1,000 (LDW-wide) 900 (intertidal)	15 (LDW-wide) 28 (intertidal)	SCO (biological or chemical)	302 acres
Selected Remedy (5C Plus) – ENR/ in situ / cap where appropriate; otherwise, dredge with upland disposal[e]	**12 (LDW-wide) 65 (intertidal) 195 (subtidal subsurface)**	**57 (LDW-wide) 28 (intertidal)**	**1,000 (LDW-wide) 900 (intertidal)**	**25 (LDW-wide) 28 (intertidal)**	**2 X SCO chemical criteria [d] with 10-year post-construction target to meet SCO**	**177 acres**

a. Areas where remedial action levels (RALs) are applied are as follows: LDW-wide RALs, 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). In intertidal areas, intertidal RALs are applied in the upper 45 cm of sediment (above -4 ft MLLW). Alternative 5C Plus added an intertidal PCB RAL of 65 mg/kg OC in the top 45 cm in intertidal areas, and added a subtidal PCB RAL of 195 mg/kg OC for the top 60 cm in areas of potential vessel scour within Recovery Category 2 and 3 areas. These additional potential vessel 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. See Table 15 for SCO and CSL values. 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. The terms SCO and CSL in this table mean the benthic SCO and CSL; SCO is equivalent to the term "SQS" used in the RI/FS and Proposed Plan. Lower human health-based RALs for PCBs and arsenic in this table take precedence over benthic SCO or CSL values.

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 areas); the lower RALs are used where conditions for recovery are predicted to be limited or less certain (Recovery Category 1 or 2 areas), or where the BCM does not predict recovery to the 10-yr post-construction target concentration.

d. The Alternative 5C Plus RAL of "2 X SQS not to exceed CSL" in the Proposed Plan is modified in the Selected Remedy to "2 X benthic SCO", see Section 12.

e. The Selected Remedy includes additional requirements to address contaminated shoals in the navigation channel, see Sections 12 and 13.

Table 23. Criteria for Assigning Recovery Categories[a]

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	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	< 10 cm
	STM-derived net sedimentation using average flow conditions	Net scour	Net sedimentation	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 it meets all Category 3 criteria
Empirical Contaminant Trend Criteria – used on a case-by-case basis to adjust recovery categories that would have been assigned based on physical criteria				
Empirical Contaminant Trend Criteria	Resampled surface sediment locations Sediment cores (top 2 sample intervals in upper 60 cm)	Increasing PCBs or increasing concentrations of other detected COCs that exceed the SCO (> 50% increase)	Equilibrium and mixed (increases and decreases) results (for COCs that exceed the SCO)	Decreasing concentrations (> 50% decrease) or mixed results (decreases and equilibrium)

a. Recovery categories were not assigned to the Early Action Areas, for which remediation should be complete by the time of the remedial actions addressed in this ROD. At the time of the remedial design, EPA will consider assignment of categories to these areas based upon the logic in this table; this information will inform long term monitoring decisions.

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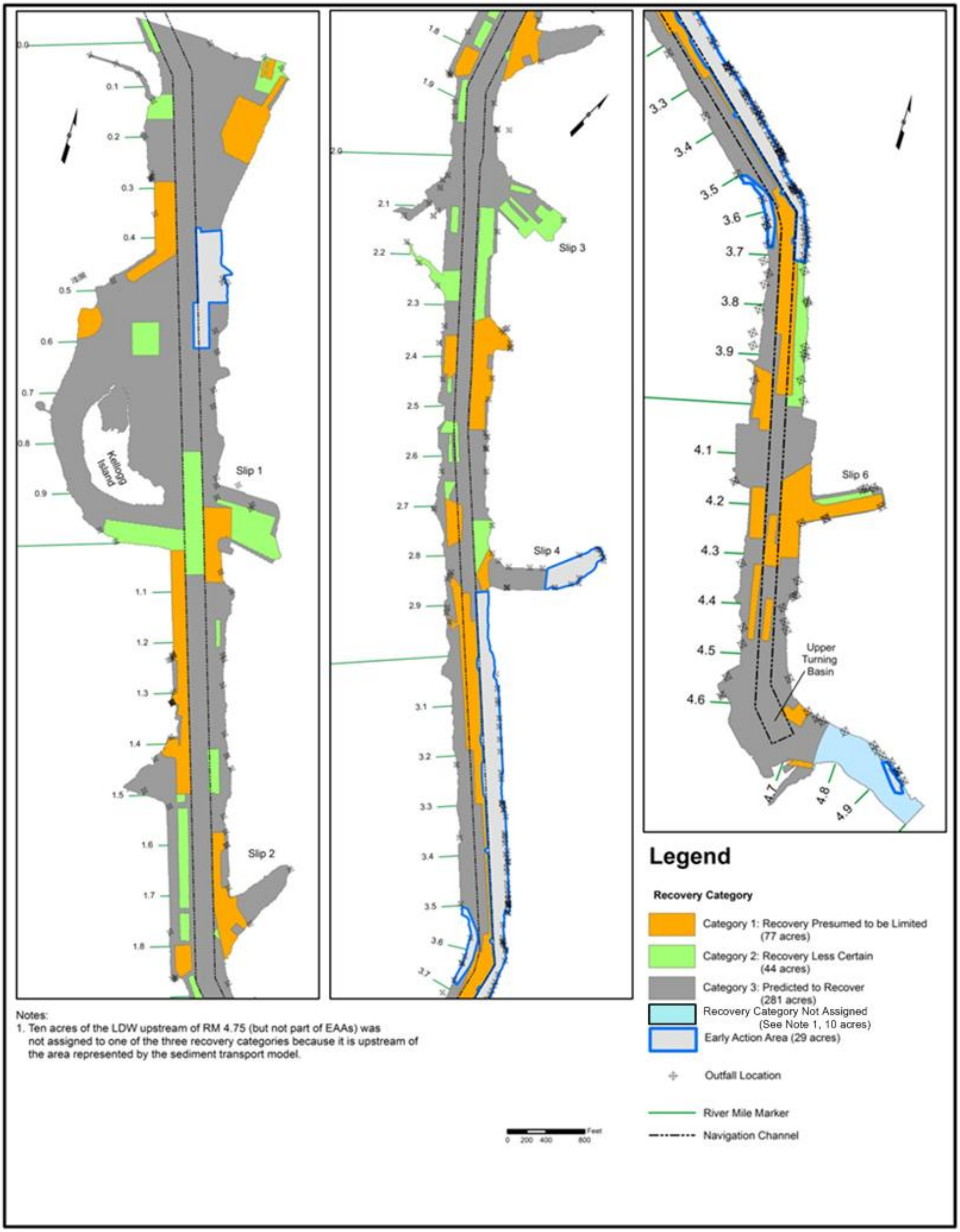


Figure 12. Recovery Category Areas

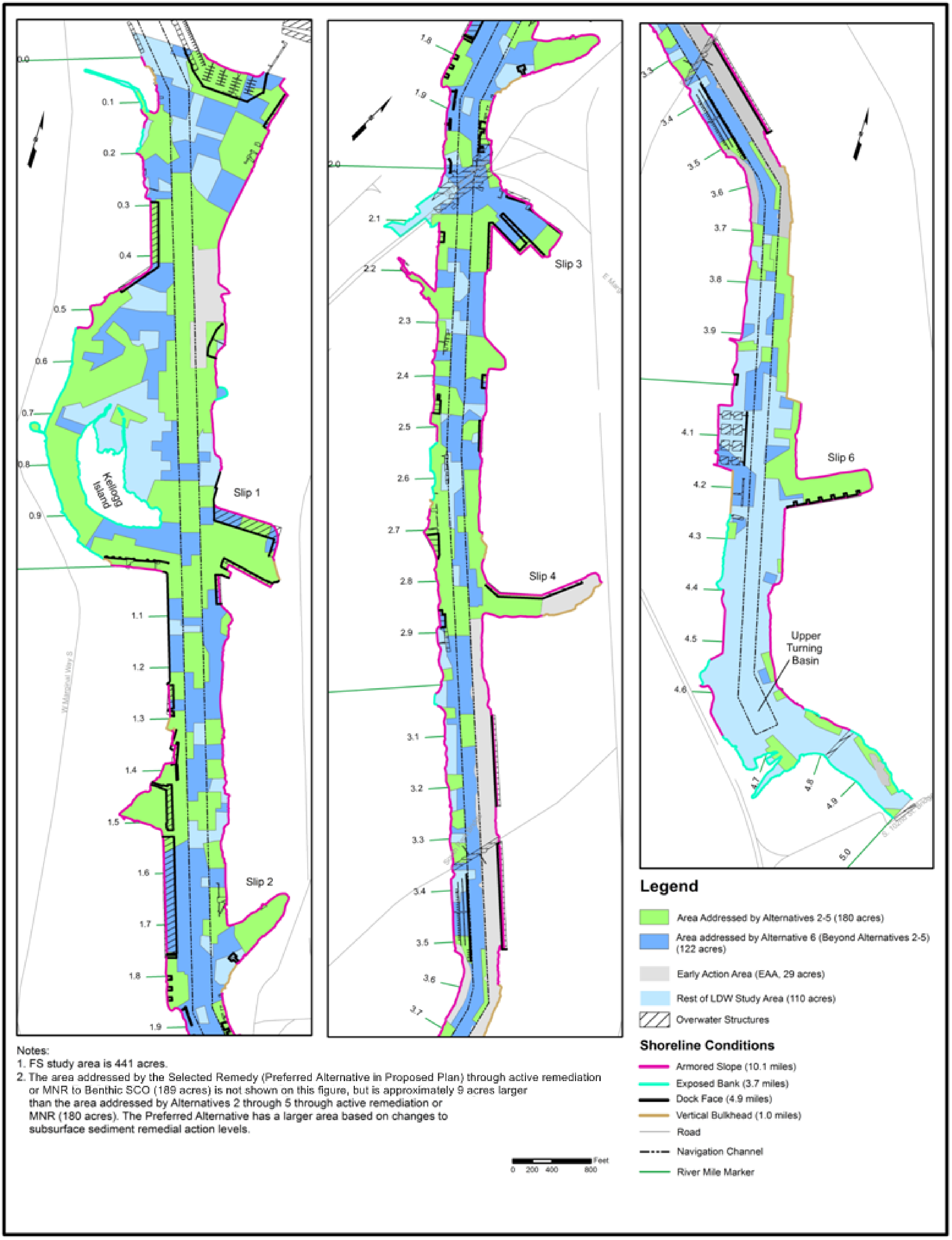


Figure 13. Areas Addressed by LDW Cleanup Alternatives in the FS

9.3 Technologies Common to All Remedial Alternatives

The remedial cleanup technologies described below that were used to develop remedial action alternatives to address contamination in the LDW include 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 completion of cleanup 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 is incorporated into all remedial alternatives except the no action alternative.
- **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 water depth is sufficient for 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. Cap thickness will be determined during remedial design; in the FS , caps were assumed to be 3 ft thick. In habitat areas (see Section 13.2.1.1), the uppermost layers of caps will use 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.
- **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 then 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 used in areas with less sediment contamination than those designated for dredging and capping and only in Recovery Category 2 and 3 areas. In some areas, ENR may be combined with in situ treatment; i.e., 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 before or during remedial design.

The 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.

- **Refinement of MNR as described in the FS:** Terminology used to describe MNR in this ROD for the Selected Remedy 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 concentrations reach RAO 3 cleanup levels (benthic SCOs); that is, MNR would be applied only in areas where concentrations are above the benthic SCO; once benthic SCOs 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 benthic SCOs are not achieved within 10 years after remedial action. Areas where COC concentrations are already below the benthic SCO 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 also continue in those areas.
  - In this ROD (and in LDWG 2012b and LDWG 2013a), the term "MNR" is applied to all areas where reduction of COC concentrations through natural recovery is predicted to continue after cleanup is complete (i.e., in areas where concentrations are above benthic SCOs as well as areas where they are below benthic SCOs). For the Selected Remedy only, this ROD refines MNR, dividing it into two categories: 1) MNR To Benthic SCO, for areas where MNR would be used to achieve cleanup levels for RAO 3 (benthic SCO); and 2) MNR Below Benthic SCO for areas where MNR is used to further reduce COC concentrations to the remaining cleanup levels for RAOs 1, 2, and 4. MNR To Benthic SCO includes additional actions (see Section 13.2.2) to be implemented if the SCO is not achieved within 10 years after remedial action; MNR Below Benthic SCO does not require additional actions in this ROD if cleanup levels are not achieved. This terminology is more fully described in Section 13.
- **Monitoring** – Monitoring includes sampling sediments, porewater, surface water, and fish and shellfish tissue 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 reduction to allow for unrestricted use of the LDW, and to ensure compliance with the MTCA ARAR requiring institutional controls whenever hazardous substances remain above cleanup levels (WAC 173-340-440(4)), all the FS alternatives included institutional controls (ICs). It is important to recognize that even if all natural background-based sediment cleanup levels and tissue targets 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, and other ICs intended to minimize risk to the LDW fishing community, 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 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)).

Governmental controls such as permits required to dredge or fill in the waterway will provide additional protection.

9.4 Remedial Alternatives

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

Each of the twelve remedial alternatives is briefly described. 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 for 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. The C alternatives 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 as it is with a cap. For the FS and this ROD, moderate contamination is defined as 1 to 1.5 times the intertidal RALs (applied over the top 45 cm) and 1 to 3 times the subtidal LDW-wide RALs (applied over the top 10 cm). More aggressive technologies such as 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 water depth constraints preclude capping alone.

The areas addressed by the cleanup alternatives as depicted in the FS and this ROD (Figure 13) 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. Sampling to be conducted during remedial design may establish different sediment contaminant concentrations; for example, some areas may have already recovered naturally within that time 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. ARARs compliance is described in Sections 10.1.2 (for FS alternatives generally) and 14.2 (for the Selected Remedy). All Alternatives, including the Selected Remedy (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 landfill that is compliant with RCRA Subtitle D. 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 landfill compliant with RCRA Subtitle C or TSCA. Alternative 2 used a different disposal technology, contained aquatic disposal, which would have made Section 404 of the Clean Water Act a more important ARAR if that alternative had been selected. Only Alternative 5R-Treatment used soil washing; however, ARARs for disposal or beneficial reuse of treated material would be the same as for disposal of untreated sediments.

Table 22 (above) summarizes the RALs and associated types of actively-remediated areas under each alternative, along with the total area of active remediation for each. Table 24 summarizes the areas and volumes associated with each remedial technology for each of the alternatives as well as costs and construction durations. In the FS, net present values costs for cleanup alternatives were calculated at a 2.3% discount rate based upon guidance from the Office of Management and Budget (OMB).[17,18] Table 25 provides a comparison of costs calculated at discount rates of 0%, 2.3%, and 7%. The cost of implementing in-waterway cleanups at the EAAs is estimated at $95-100 million; this cost is not included in the cost estimates for the alternatives.

For each alternative, Figure 14 shows the construction period and the projected time to achieve a range of risk reduction benchmarks. Figure 14 shows time to achieve RAOs for RAOs 3 and 4, and time to achieve RAOs for all COCs except arsenic for RAO 2. For RAO 1 (all COCs) and RAO 2 (arsenic), as discussed in Section 8.2.1, it was not possible to project the time to achieve cleanup levels using RI/FS models. Instead, Figure 14 shows the time to reach the lowest model-projected concentrations. For informational purposes Figure 14 also shows other information, such as time to achieve 1×10^{-5} excess cancer risk for RAOs 1 and 2, to show when progress would be made towards achieving these RAOs.

[17] Appendix C of Office of Management and Budget Circular A-94 for the Year 2011.

[18] EPA's *Guide to Developing and Documenting Cost Estimates during the Feasibility Study*, (EPA 2000a) recommends that a discount rate of 7% be used for estimating the net present value of cleanups conducted by non-federal parties. The rate of 7% approximates the marginal pretax rate of return on an average investment in the private sector adjusted for expected inflation. The lower discount rate was included because EPA believes a rate derived from interest rates published in Appendix C of OMB Circular A-94 better reflects current economic conditions for safely setting aside money for future cleanup costs. The lower discount rate was also incuded to reflect differing costs of capital for public entities, because, as stated by LDWG in the FS, local governments are likely to be involved in the implementation of the remedy (LDWG 2012a).

Table 24. Remedial Alternative Areas and Volumes

Site -wide Remedial Alternative	Remedial Alternative Technology and Areas								Total Dredge Volume (cy)	Construction Period (years)	Net Present Value Cost ($Millions)
	EAAs (acres)[a]	Dredge (acres)	Partial Dredge and Cap (acres)	Cap (acres)	ENR/ in situ (acres)	MNR To Benthic SCO[b] (acres)	MNR (in Alt 5C Plus, MNR Below Benthic SCO) (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	$220
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
Alternative 5 Combined Technology Plus	29	64	20	24	48	33	223	156	790,000	7	$305
Selected Remedy[c]	**29**	**85**	**20**	**24**	**48**	**33**	**202**	**177**	**960,000**	**7**	**$342**
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 remedial alternatives.

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

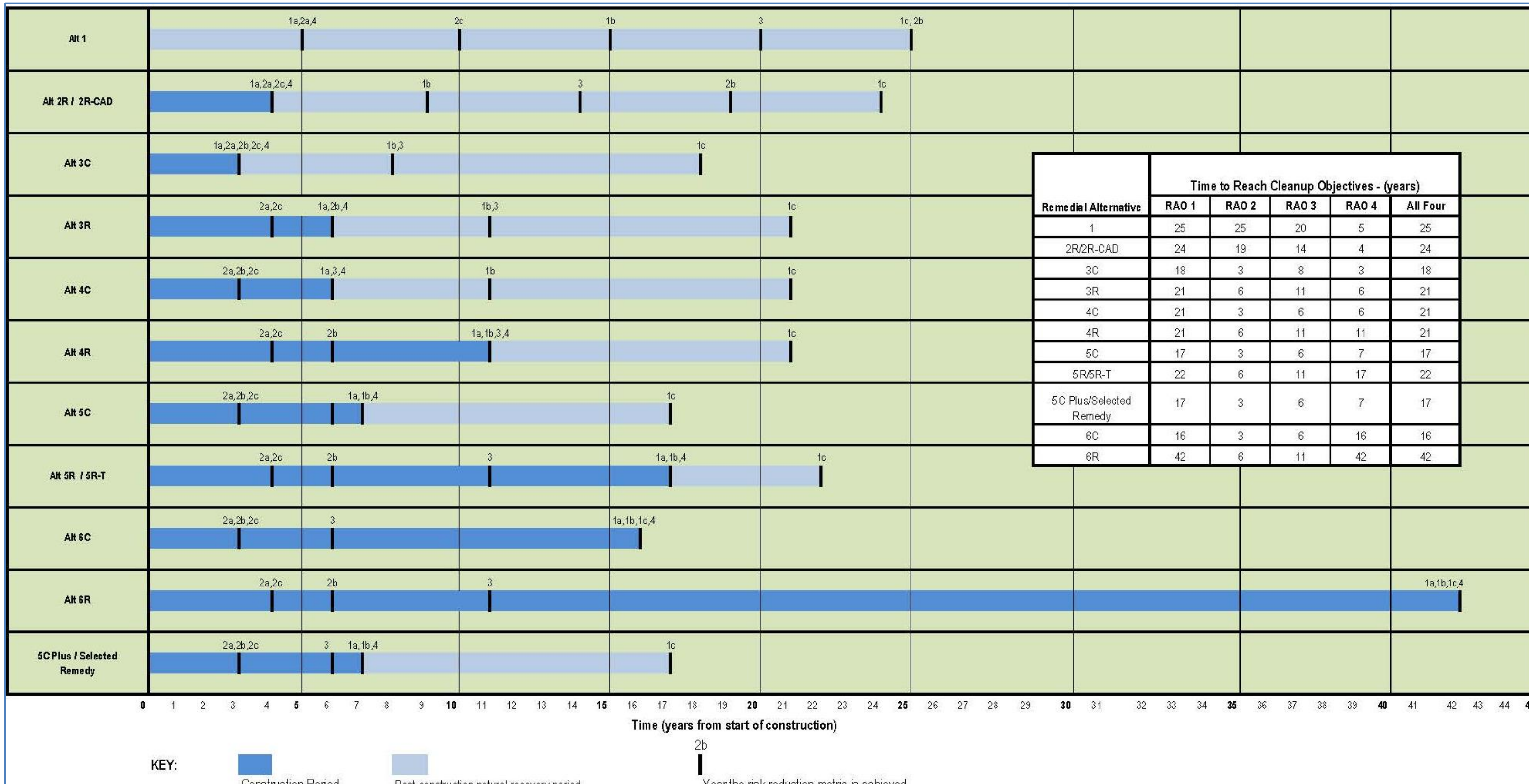
c. Selected Remedy includes changes from the Proposed Plan in dredge areas, volumes, and overall costs based on public comment and other considerations, see Section 12 for details.

Table 25. Summary of Remedial Alternative Costs ($Millions)

Discount Rate	Cost Parameter	Remedial Alternative													
		1	**2R**	**2R-CAD**	**3R**	**3C**	**4R**	**4C**	**5R**	**5R-T**	**5C**	**5C Plus**	**Selected Remedy**	**6R**	**6C**
0% (No discount)	Capital Costs	NA	—	—	—	—	—	—	—	—	—	$280	$327	—	—
	OM&M, Reporting, Agency Oversight Costs	NA	—	—	—	—	—	—	—	—	—	$68	$68	—	—
	Total Cost (2011 dollars)	NA	$250	$230	$310	$230	$430	$300	$580	$630	$330	$348	$395	$1,300	$650
2.3% (30-yr OMB 2011 Real Interest Treasury Rate)	Capital Costs	NA	$169	$148	$224	$156	$324	$221	$430	$473	$250	$258	$295	$771	$478
	OM&M, Reporting, Agency Oversight Costs	NA	$46	$49	$43	$46	$39	$41	$37	$37	$41	$48	$48	$42	$51
	Total Net Present Value Cost	**NA**	**$220**	**$200**	**$270**	**$200**	**$360**	**$260**	**$470**	**$510**	**$290**	**$305**	**$342**	**$810**	**$530**
7% (per EPA's (2000) *Guide to Developing and Documenting Cost Estimates during the Feasibility Study*)	Capital Costs	NA	—	—	—	—	—	—	—	—	—	$220	$243	—	—
	OM&M, Reporting, Agency Oversight Costs	NA	—	—	—	—	—	—	—	—	—	$28	$28	—	--
	Total Net Present Value Cost	NA	$180	$160	$210	$170	$270	$220	$320	$350	$240	$248	$270	$410	$370

Notes:

- Costs are reported in $ million. Total costs are rounded to 2 significant digits.
- Costs for all alternatives do not include costs to conduct cleanup in the EAAs.
- In Appendix I of the FS, monitoring, operations and maintenance, reporting, and agency oversight activities were assumed to occur for a period of 30 years from the start of construction for all of the alternatives except Alternative 6R, for which those activities were assumed to occur for a period of 45 years from the start of construction. In reality, it is not known how long these activities would continue. If they were to occur for more than 30 years (or 45 years in the case of Alternative 6R), the associated costs would be higher than these estimates, although on a net present value basis they may not add appreciably to these estimated costs because they are so far in the future.
- See Table 29 for a detailed cost summary for the Selected Remedy.



Remedial Alternative	Time to Reach Cleanup Objectives - (years) RAO 1	RAO 2	RAO 3	RAO 4	All Four
1	25	25	20	5	25
2R/2R-CAD	24	19	14	4	24
3C	18	3	8	3	18
3R	21	6	11	6	21
4C	21	3	6	6	21
4R	21	6	11	11	21
5C	17	3	6	7	17
5R/5R-T	22	6	11	17	22
5C Plus/Selected Remedy	17	3	6	7	17
6C	16	3	6	16	16
6R	42	6	11	42	42

RAO	Chart Symbol	Metric(s)
1	1a	10^{-4} magnitude risk for Adult Tribal, Child Tribal, and Adult API RME seafood consumption scenarios (only total PCBs)
	1b	10^{-5} magnitude risk for Child Tribal RME seafood consumption scenario (only total PCBs)
	1c	Total PCBs and dioxin/furans reach long-term model-predicted ranges of site-wide SWACs
3	3	RAO 3 achieved (COC concentrations <benthic SCO)
4	4	RAO 4 achieved (river otter HQ <1)

RAO	Chart Symbol	Metric(s)
2	2a	$\leq 1 \times 10^{-5}$ direct contact risk and HQ <1 for all COCs $\leq 1 \times 10^{-6}$ direct contact risk for total PCBs
	2b	RAO 2 achieved (< 1×10^{-6} direct contact risk) for all COCs except arsenic and cPAHs in Beach 3
	2c	Arsenic reaches long-term model-predicted range of site-wide SWAC

Notes:

RI/FS models were unable to predict time to achieve a non-cancer HQ below 1 for three RME seafood consumption scenarios (see Table 9-7 of the FS for details), or sediment cleanup levels that are based on natural background (PCBs and dioxins/furans for RAO 1 [seafood consumption]) and arsenic for RAO 2 (direct contact). Time to achieve model-predicted steady state is shown instead.

For time to achieve cleanup objectives, Alternative 5C Plus and and Selected Remedy have been combined in this table because outputs are the same.

Figure 14. Time to Achieve Risk Reduction for All Alternatives

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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 net present value (NPV) (using a 2.3% discount rate) are estimated to be $9 million for Alternative 1.

Alternatives 2R and 2R-CAD – These alternatives would actively remediate 32 acres with contaminant concentrations above the Alternative 2 RALs (Table 22). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 24. Figure 14 shows the time projected by FS models to achieve risk benchmarks for each remedial action objective. Alternatives 2 and 2R-CAD 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 RAO 3 cleanup levels (benthic SCO criteria) as well as to achieve FS cleanup objectives[19] for RAOs 2 and 4. As noted above, the FS made no distinction between MNR To Benthic SCO and MNR Below Benthic SCO, so these terms are not used for any alternative except the Selected Remedy (5C Plus as modified for this ROD). As discussed in Section 9.3, 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 benthic SCO levels. For simplicity, this ROD uses the term MNR to refer to all areas where reduction in COC concentrations is predicted, regardless of whether levels are above or below the benthic SCO.
- For all alternatives, effective and appropriate ICs will be used to reduce exposure of fish consumers to contamination in fish and shellfish. Examples include seafood consumption advisories, outreach, and education programs.

Remedial Action Objectives

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

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

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.

19. The FS was written before promulgation of the revised SMS, which created a new term “sediment cleanup objective” (SCO). The term "cleanup objectives" was used in the FS to mean the PRG or as close as practicable to the PRG where RI/FS models could not predict acheivement of a PRG. The FS used long-term model-predicted concentrations as estimates of “as close as practicable” to PRGs. This ROD uses the term “FS cleanup objective” when referring to the terminology in the FS and “sediment cleanup objective” or SCO when referring to the terminology in the revised SMS.

The 2R/2RCAD alternatives were 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. RI/FS models predict it will take 24 years after the start of construction to reach lowest model-predicted values (FS cleanup objectives).
- For RAO 2 (human health direct contact): Meet FS cleanup objectives within 10 years following construction completion.
- For RAO 3 (protection of benthic community): Reduce contaminants in sediment to meet the benthic CSL within 10 years following construction, and the benthic SCO within 20 years following construction. (See Section 5.3.1.1 for additional information on the benthic CSL and benthic SCO).
- For RAO 4 (protection of river otter): Meet cleanup level within 10 years following construction.

Alternatives 3R and 3C – These Alternatives actively remediate 58 acres with contaminant concentrations above the Alternative 3 RALs (Table 22). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 24. A greater amount of surface and subsurface contamination is removed by these alternatives than by Alternative 2R/2R-CAD, and they rely more upon 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 benthic SCO within 20 years following construction, with additional COC concentration reduction over time to the FS cleanup objectives.
- ICs would be used as described in Alternative 2R/2R-CAD.

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

- For RAO 1: Achieve greater permanence through actively remediating a larger area, and relying less on natural recovery. RI/FS models predict it will take 18 years (3C) or 21 years (3R) years after the start of construction to reach lowest model-predicted values (FS cleanup objectives).
- For RAOs 2 and 4: Achieve FS cleanup objectives immediately following construction, rather than 10 years following construction.
- For RAO 3: Achieve the benthic CSL immediately following construction, rather than 10 years following construction. The benthic SCO 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 22). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 24. MNR is used in areas with concentrations below the RALs to achieve the benthic SCO within 10 years following construction, with additional COC concentration reduction over time to the FS cleanup objectives. ICs would be used as described in Alternative 2. Alternatives 4C and 4R rely more on active remediation than lower numbered 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 permanence through actively remediating a larger area than lower numbered alternatives, and relying less on natural recovery. RI/FS models predict it will take 21 years (for 4C and 4R) after the start of construction to reach lowest model-predicted values (FS cleanup objectives).
- For RAOs 2 and 4: Same as Alternative 3R/3C.
- For RAO 3: Achieve the benthic SCO 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 22). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 24. These three alternatives do not use MNR to reach the benthic SCO[20]; however, natural recovery is relied upon to further reduce risks to the FS 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 lower numbered alternatives to reduce COC concentrations. These alternatives are designed to achieve, at a minimum, the outcomes of Alternative 4 R/4C, plus:

- For RAO 1: Achieve greater permanence by actively remediating a larger area than lower-numbered alternatives. RI/FS models predict it will take 22 years (5R/5R-T) or 17 years (5C) after the start of construction to reach lowest model-predicted values (FS cleanup objectives).
- For RAOs 2 and 4: Same as Alternative 3R/3C.
- For RAO 3: Achieve the benthic SCO 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 22). The area and volume of contaminated sediments remediated by each technology and estimated costs are provided in Table 24. 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 is completed, rather than relying on MNR. The FS estimates it will take 42 years (6R) or 16 years (6C) after the start of construction to reach lowest model-predicted values (FS cleanup objectives).
- For RAOs 2 and 4: Same as Alternative 3R/3C.

20. Although Table 24 shows 23 acres of MNR, the FS predicts that COC concentrations in these areas will be reduced to the SCO prior to the start of construction.

- For RAO 3: Achieve the benthic SCO immediately following construction as opposed to 10 years following construction.

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

Alternative 5C Plus – Alternative 5C Plus in the Proposed Plan was developed by modifying FS Alternative 5C to include additional remedial elements as described in LDWG (2012b), which 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. These areas are described in more detail in Table 22 footnote a, and in Section 13.
- Additional dredging in shoaled areas of the navigation channel where COC concentrations exceed RALs in the top 2 ft to address the potential that subsurface contamination could be disturbed through maintenance dredging.
- Increased cap thickness to 4 ft in intertidal clamming areas to provide adequate habitat for clams.
- Increased sediment monitoring to evaluate natural recovery progress in areas where COC concentrations are below the SCO but above cleanup levels (designated as MNR Below SCO in this ROD; see Section 13.2.2).

In addition, LDWG (2012b) 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 by LDWG (2012b). EPA, in coordination with Ecology, selected Scenario 5a (referred to as Alternative 5C Plus) in the Proposed Plan.

Estimates of cleanup areas and volumes for Alternative 5C Plus were modified from those in Alternative 5C in LDWG (2013a). Alternative 5C Plus actively remediates 156 acres with contaminant concentrations above the Alternative 5C Plus RALs (Table 22). These RALs are the same as for Alternative 5C, except as follows.

- New RALs for subsurface PCBs were added for potential scour areas within Recovery Category 2 and 3 areas (see Section 13). The new PCB RALs 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 subtidal areas. The PCB RAL, for subsurface sediments in intertidal areas, is 65 mg/kg OC (e.g., 1.3 mg/kg PCBs at 2% TOC) applied as an average over the top 45 cm, and the PCB RAL for subsurface sediments in subtidal areas is 195 mg/kg OC (e.g., 3.9 mg/kg PCBs at 2% TOC) applied as an average over the top 10 cm. No other alternatives have subsurface RALs for PCBs within Recovery Category 2 and 3 areas.
- The RALs for non-human health COCs in surface sediments were increased to 2 times the benthic SCO, not to exceed the CSL, in Recovery Category 2 and 3 areas. The benthic SCO must be met within 10 years of completing remedial action.

The estimated area and volume of contaminated sediments remediated by each remedial technology and the estimated costs are provided in Table 24. Alternative 5C Plus includes 33 acres of MNR To Benthic SCO, and 223 acres of MNR Below Benthic SCO (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 benthic CSL immediately following construction, and the benthic SCO within 10 years following construction.

Selected Remedy - In the Selected Remedy, additional changes were made to Alternative 5C Plus as it was presented in the Proposed Plan to address public comments. These changes are summarized here and discussed in more detail in Sections 12 and 13.

- Estimates of dredging areas and volumes were revised using new data collected after completion of the FS.
- RALs for non-human health COCs were modified to 2 times the benthic SCO (and "not to exceed CSL" was omitted).
- The required space between the authorized navigation channel depth and the top of caps in the federal navigation channel (sometimes called the “buffer”), was changed from 3 ft to 4 ft.
- Additional dredging in shoaled areas of the navigation channel where COC concentrations exceed RALs at any depth that is not at least 2 ft deeper than the authorized channel depth (this allows for over-dredging associated with channel maintenance) This additional dredging addresses the potential that subsurface contamination could be disturbed through maintenance dredging.

Revised area, volume, and cost estimates for the Selected Remedy are shown in in Tables 24 and 25. Although these changes may affect the time to complete the remedial action, EPA retained the 5C Plus estimate of 7 years, because these additional volume estimates are uncertain due to the limited number of cores used to characterize these additional areas, which would need to be addressed during remedial design. Additionally, the time to complete source control activities, length of the fish window and number of dredges operating at the same time may affect construction duration. The Selected Remedy remains sufficiently similar to 5C Plus that the analysis for 5C Plus (Section 10) is also applicable to the Selected Remedy.

10 Summary of Comparative Analysis of Alternatives

EPA used the nine criteria required by CERCLA and the NCP to evaluate and select a remedy 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 Selected Remedy, 5C Plus, compares to the other alternatives. The nine criteria are in three categories: threshold criteria, primary balancing criteria, and modifying criteria. The findings and recommendations in EPA's EJ Analysis (EPA 2013a) were considered as part of the nine criteria analysis, as discussed in Section 10.3.3.

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) — CERCLA Section 121(d) and NCP §300.430(f)(1)(ii)(B) require 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 value costs.

Modifying criteria. Modifying criteria are based on the public comments received on the Proposed Plan, discussions with the state, and consultation with affected Tribes.

State /Tribal acceptance — Assessment of State concerns including (1) The state's position and key concerns related to the Selected Remedy 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.

10.1 Threshold Criteria

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

10.1.1 Overall Protection of Human Health and the Environment

All of the alternatives 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. The objective of Alternatives 2 - 6 is to reach their differing RALs by the end of construction, and cleanup levels in the long term. Alternatives vary in: 1) the extent of reliance on institutional controls to reduce exposure, especially from consumption of resident LDW seafood, 2) the model-projected time to achieve short- and long-term risk reduction (RI/FS models predicted that Alternatives 2-6 would reach the lowest model-predicted concentrations and associated risks in 16 to 42 years, as shown in Figure 14), and 3) the extent to which they depend on potentially less reliable or permanent technologies such as ENR and natural recovery to achieve risk reduction. Alternatives that depend more on ENR and MNR instead of dredging and capping have a greater risk of subsurface contamination becoming exposed and increasing long-term COC concentrations, as discussed in Section 10.2.1. All of these factors provide more certainty that alternatives that rely more on dredging and capping (e.g., Alternatives 5 and 6) will achieve long-term risk reduction than those that rely more on natural recovery (e.g., Alternatives 1 – 3).

As discussed in Section 8.2.1, the RI/FS models (STM, BCM, and food-web model) could not predict that, for any alternative, LDW sediment and tissue COC concentrations would reach the risk- and natural background-based sediment cleanup levels and target tissue concentrations. Although RI/FS data indicated strong evidence for natural recovery in some areas of the waterway, our ability to predict the rate and risk reduction achieved by natural recovery processes 30 – 40 years in the future is limited. EPA is therefore selecting the cleanup levels shown in Table 19 and Table 20 as the long-term objectives for the cleanup.

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. Therefore, it is not discussed further.

10.1.1.1 Protecting seafood consumers (RAO 1)

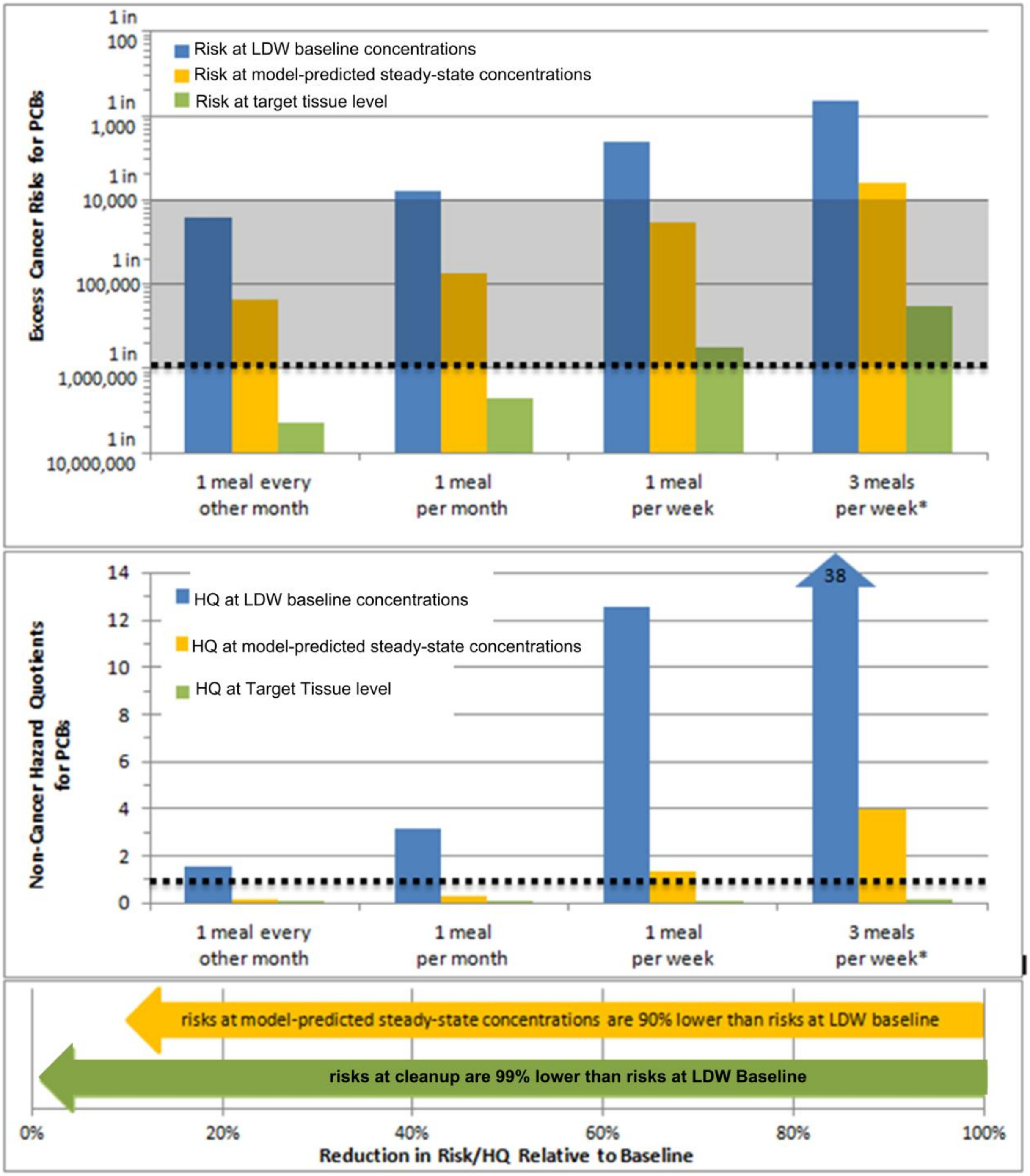
Risks associated with PCBs. Figure 15 shows estimated cancer and noncancer risks for a variety of seafood consumption rates for PCBs at baseline, as predicted by RI/FS models, and at the target tissue concentrations. Only PCBs could be addressed in the RI/FS food-web model because RI data did not provide sufficient information to develop predictive relationships between sediment concentrations and tissue concentrations for other human health COCs; in particular, arsenic and cPAHs did not show close relationships, and there were insufficient tissue data for dioxins/furans to do so. Calculating health risks from eating fish or shellfish is critically dependent on how much and what type of seafood a person may eat. PCB risks for adult Tribal consumers of seafood at RME consumption rates (approximately 3 meals per week) are estimated to be 5×10^{-6} and HQ of less than 1 if target tissue concentrations are achieved. The FS estimated an adult Tribal RME excess cancer risk of 2×10^{-4} and noncancer HQ of 4 - 5, and a child tribal RME excess cancer risk of 3×10^{-5} and a noncancer HQ of 9 - 10 for PCBs only at the model-predicted steady state for all alternatives. These estimates represent a post-cleanup reduction in PCB risks of approximately 90% at the model-predicted steady state and 99% at the target tissue concentration for the adult Tribal RME seafood consumption rate when compared to baseline risks. As shown in Figure 15, PCB-only risks would be lower for those who consume less seafood.

Risks associated with all COCs. Figure 16 shows estimated total cancer and noncancer risks at the target tissue concentrations for PCBs at a range of consumption rates for different seafood types. None of the alternatives would meet MTCA risk thresholds (Section 8.2.1) for consumption of resident fish and shellfish at the consumption rates reported for Tribal or Asian Pacific Islander populations, even if they were to meet the target tissue concentrations, because target concentrations for some COCs are based on natural background levels that are higher than calculated protective risk-based levels (RBTCs-see Table 21). Cancer risks at the adult tribal RME seafood consumption rate (approximately 3 meals per week) if fish and shellfish target tissue concentrations are achieved for all COCs are estimated to be 3×10^{-4}, which is above the excess cancer risk thresholds for both CERCLA and MTCA. Cancer risks at the child Tribal RME seafood consumption rate are estimated to be 5×10^{-5}. The main contaminants contributing to these post-cleanup risks are arsenic and dioxins/furans. The HQ for noncancer risks at both the adult and child tribal RME seafood consumption rate would be less than the CERCLA and MTCA threshold of 1 (based on the risks associated with PCBs, the COC with the highest HQ for adults, and with arsenic, the COC with the highest HQ for children).

At a consumption rate of one meal every other month, seafood consumption risks for all seafood types except crab whole body are estimated to be at or below the MTCA excess cancer risk multiple contaminant threshold of 1×10^{-5} and HI of 1 at target tissue concentrations (if the hepatopancreas were removed, crab edible meat would also be below risk thresholds). At a consumption rate of one meal per month, excess cancer risks for all food types are estimated to be below the CERCLA excess cancer risk threshold of 1×10^{-4} and noncancer HI of 1.

10.1.1.2 Reducing Direct Contact Risks (RAO 2)

For direct contact with sediments in netfishing, clamming, and beach play areas (RAO 2), all alternatives are predicted to result in risks that are within the CERCLA risk range and meet the minimum MTCA risk-reduction requirements: 1) a total excess cancer risk of less than 1×10^{-5} cumulatively for all COCs; 2) excess cancer risks for individual COCs less than or equal to 1×10^{-6} (except for arsenic), and 3) noncancer HI less than or equal to 1. The natural recovery model predicts arsenic will reach an excess cancer risk range below 1×10^{-5} but above 1×10^{-6}. Alternative 2 requires a period of natural recovery to meet these objectives, whereas Alternatives 3 – 6 meet them immediately after construction, and thus there is greater likelihood of a permanent reduction in contamination and risk.

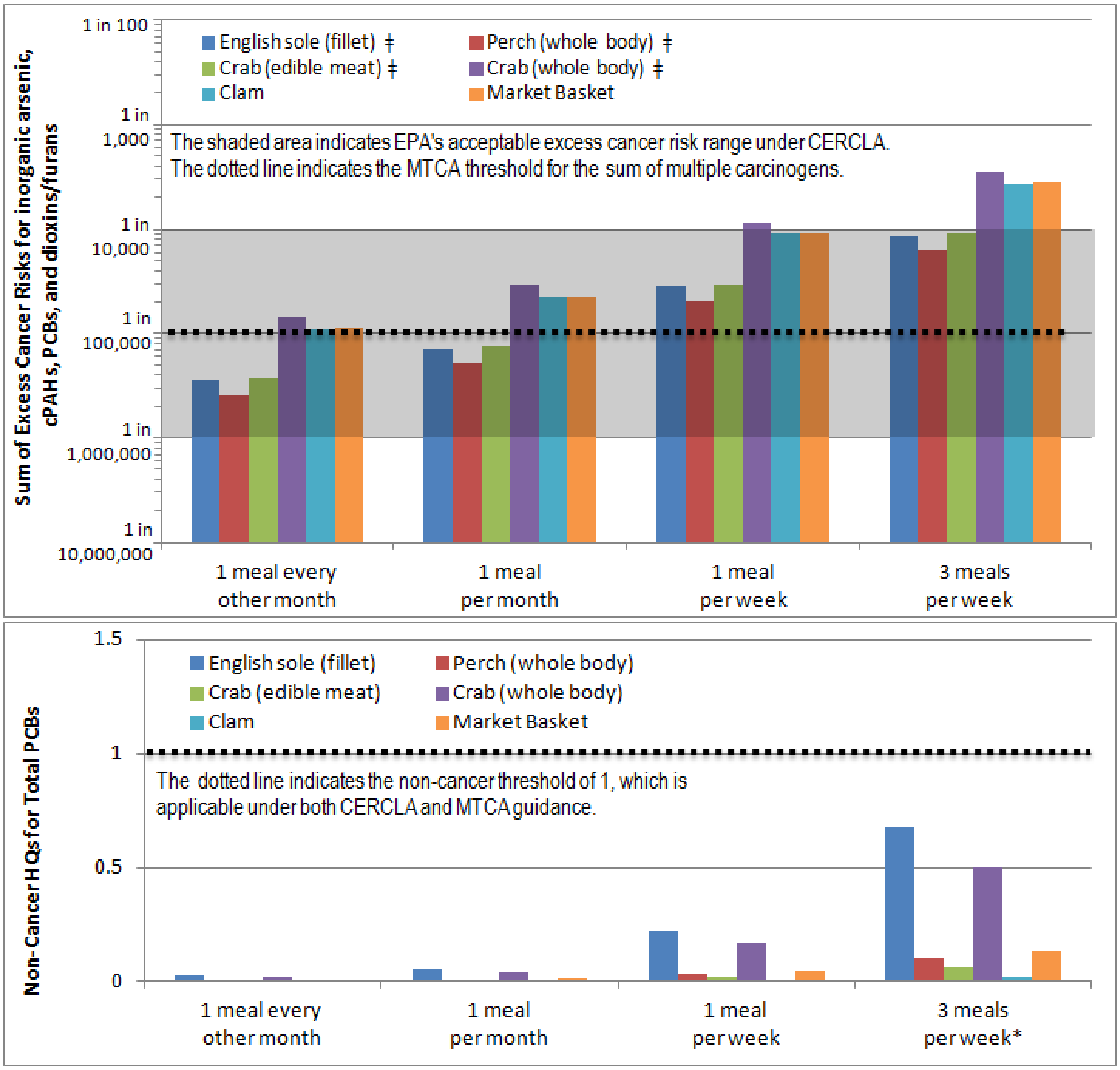


Exposure assumptions: Excess cancer risks and noncancer hazard quotients (HQs) were calculated assuming market basket consumption using the exposure assumptions for the adult tribal RME seafood consumption scenario. Three meals per week is approximately equal to the consumption rate used for the adult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

Excess cancer risks and noncancer 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 noncancer 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) target tissue levels, 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 noncancer HQs, the dotted line indicates the CERCLA and MTCA noncancer threshold.

Figure 15. Comparison of Total PCB Excess Cancer Risks and Noncancer HQs for Seafood Consumption Calculated using LDW Baseline, Model-predicted, and Target Tissue Concentrations



Excess cancer risks and noncancer hazard quotients (HQs) were calculated using the exposure assumptions for the adult tribal RME seafood consumption scenario. One meal is equal to 8 ounces, and 3 meals per week is approximately equal to the rate used for the adult tribal RME scenario in the HHRA.

Target tissue concentrations are the higher of either non-urban Puget Sound tissue concentrations or species-specific risk-based threshold concentrations

Excess cancer risks were calculated as the sum of excess cancer risks for inorganic arsenic, cPAHs, total 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 ǂ 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 tissue 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.

Noncancer HQs for total PCBs are presented because HQs were the highest for PCBs.

Figure 16. Excess Cancer Risks and Noncancer HQs for Seafood Consumption Calculated Using Target Tissue Concentrations

10.1.1.3 Protecting Benthic Communities (RAO 3)

All alternatives are predicted to achieve the RAO 3 cleanup levels for protection of benthic invertebrates (benthic SCO criteria), within 6 to 20 years. Alternatives 2 to 4 and the Selected Remedy (5C Plus) rely on MNR to reduce COC concentrations to the benthic SCO, with more reliance on MNR than in the higher-numbered alternatives and hence a greater likelihood of permanence of contaminant reduction. The FS assumed additional actions would be undertaken if the benthic SCO was not achieved within 10 years of completion of the remedial action. The Selected Remedy differs from Alternatives 2 – 4 in that it relies on MNR with contingency actions as discussed above to reduce COC concentrations only for non-human health COCs.

10.1.1.4 Protecting Wildlife (RAO 4)

All alternatives are predicted to achieve the RAO 4 cleanup levels 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 cleanup levels.

10.1.2 Compliance with ARARs

ARARs for the cleanup alternatives are shown in Table 26. The most significant ARARs for in-waterway remedial action are the MTCA/SMS requirements and federal and state water quality criteria and standards, as discussed in Section 8.2.2. As discussed in Section 10.1.1, the RI/FS models indicate that for all alternatives, the long-term COC sediment concentrations achievable in the In-waterway Portion of the Site 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. Also for all alternatives, the ability to meet surface water quality ARARs will be limited to the extent that all sources, including upstream water quality, can be improved.

Section 14.2 discusses compliance of the Selected Remedy with ARARs. That discussion would apply to all the FS alternatives with respect to MTCA/SMS, surface water quality, and ESA ARARs compliance. See the Project Specific Comments column in Table 26 for discussion of compliance with all other ARARs.

The ARARs selected in this ROD are remedial action requirements for the Selected Remedy. This ROD, like all other CERCLA RODs, is not a decision document for any other purpose and does not establish requirements for implementation of source control by other regulatory agencies.

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Table 26. Applicable or Relevant and Appropriate Requirements, LDW Superfund Site

Topic	Standard or Requirement	Regulatory Citation		Project-Specific Comments
		Federal	State	
Hazardous Substance Cleanup; Sediment Quality	Washington State cleanup standards; Marine Sediment Cleanup Standards; Sediment Cleanup Objectives (SCO); Cleanup Screening Levels (CSL)		Model Toxics Control Act (MTCA) (RCW 70.105D; WAC 173-340); MTCA Sediment Management Standards (SMS) (RCW 70.105D; WAC 173-204)	Substantive MTCA requirements that are more stringent than CERCLA requirements are ARARs. A combination of sediment dredging, capping, enhanced natural recovery (ENR), monitored natural recovery (MNR), and potentially in-situ amendment as treatment, along with the minimally necessary use of fish and shellfish consumption advisories as ICs to reduce fish and shellfish consumption, will be employed to meet the substantive requirements of SCO compliance for the protection of human health, marine benthic invertebrates and higher trophic level species, as set forth in WAC 173-204-560-562, 564 to the extent technically possible, or without a net adverse environmental impact, and at a minimum, the substantive requirements of CSL compliance. Institutional Controls (ICs) will be required as set forth in WAC 173-340-440(4)(a).
Surface Water Quality	Surface water quality standards. Federal recommended Ambient Water Quality Criteria (AWQC); National Toxics Rule (NTR); State Water Quality Standards (WQS)	AWQC per Clean Water Act Section 304(a) (33 U.S.C. § 1314(a)) at http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm; NTR at 40 CFR 131.36(b)(1) as applied to Washington, 40 CFR 131.36(d)(14)	Water Pollution Control Act (RCW 90.48); WQS (WAC 173-201A); Aquatic Life Criteria (ALC) numerical criteria (WAC 173-201A-240)	Sediment remediation described immediately above will improve surface water quality to an unknown degree in combination with source control implementation under state-lead authority. Surface water concentrations shall be at least as stringent as all of the following: 1) all WQS in WAC 173-201A; 2) AWQC unless it can be demonstrated that such criteria are not relevant and appropriate for the LDW or for a specific hazardous substance; and 3) the NTR. See WAC 173-340-730(3)(b), consistent with Sections 121(d)(2)(A)(ii) and (B)(i) of CERCLA and 40 CFR 300.430(e).
Solid Waste Disposal	Requirements for solid waste handling management and disposal	Solid Waste Disposal Act (42 U.S.C. 6901-6992K; 40 CFR 257-258)	Solid Waste Management (RCW 70.95; WAC 173-350)	Substantive requirements for non-dangerous or non-hazardous waste generated during remedial activities unless wastes meet recycling or other exemptions will be complied with.
Waste Treatment, Storage, and Disposal	Dangerous or Hazardous Waste Management	Resource Conservation and Recovery Act, Hazardous Waste (42 U.S.C. §§ 6901-6992K, 40 CFR 260-279)	Dangerous Waste Management (RCW 70.105; WAC 173-303)	Dredged materials contains solid waste subject to solid waste handling requirements above. It would also be hazardous/dangerous waste if it contained a listed waste or displayed a hazardous waste characteristic (e.g., per Toxicity Characteristic Leaching Procedure). Based on the Remedial Investigation (RI), hazardous/dangerous waste is not anticipated in LDW sediments. If it is encountered 40 CFR Part 262 generator rules in Washington at WAC 173-303-17-202 would be complied with for accumulating or managing such waste on-site for up to 90 days. Unanticipated circumstances could require compliance with other hazardous/dangerous waste requirements. State dangerous waste is defined more broadly than Federal hazardous waste.
Land Disposal of Waste	Management and disposal of materials containing polychlorinated biphenyls (PCBs)	Toxic Substances Control Act (15 U.S.C. § 2605; 40 CFR 761.61(c))	Dangerous Waste Management (RCW 70.105; WAC 173-303- 140, 141)	Based on the RI, dredged materials with PCB remediation waste as defined in 40 CFR 761.3 is not anticipated. Any such dredged material will be subject to EPA-approved plans for all cleanup activities, including any sampling, as well as all on-site disposal-related activities. Risk based disposal of PCB remediation wastes must not pose unreasonable risk of injury to health or the environment. Written EPA approval is required for any PCB remediation waste off-site disposal.
	Hazardous waste	Resource Conservation and Recovery Act Land Disposal Restrictions (42 U.S.C. §§ 6901-6992K; 40 CFR 268)		See Dangerous or Hazardous Waste Management project-specific coments above. Any dangerous or hazardous waste land disposal shall meet substantive land disposal requirements.
Dredge/Fill and Other In-Water Construction Work	Discharge of dredged/fill material into navigable waters or wetlands	Clean Water Act Sections 401, 404 (33 U.S.C. §§ 1341, 1344; 40 CFR 121.2 (content of 401 certifications), 230 (disposal sites/mitigation), 232 (definitions/exemptions); 33 CFR 320, 322-3, 328-30 (Army Corps of Engineers 404 Permitting))	Hydraulic Code Rules (RCW 77.65; WAC 220-110) Dredged Materials Management Program (DMMP) (RCW 79.105.500; WAC 332-30-166 (3))	401: EPA will issue the equivalent of state certification assuring water quality standards will not be violated by remedial action discharges along with necessary conditions including any mixing zone parameters consistent with WAC 173-201A-400, as developed in remedial design. 404: Substantive dredge or fill criteria and requirements for discharges will be met, along with substantive mitigation requirements for unavoidable loss of aquatic habitat; mitigation will be assessed and defined as necessary in remedial design. Hydraulic codes provide construction criteria, requirements and limitations, including for dredging, piers, piles, docks, bulkheads and bank protection, specified technical provisions, special concerns. The use of an established open-water disposal site for dredged material for which there is no practical alternative upland disposal site or beneficial use as set forth in WAC 332-30-166(3) will be approved by the designated federal and state DMMP agencies.
	Navigation and commerce	Rivers and Harbor Act Section 10 (33 U.S.C. § 403)		Unauthorized obstruction or alteration of navigable waterways is prohibited. Dredging/capping residual elevations will be designed to preserve navigation and commerce. In-water disposal is not anticipated; any in-water disposal site will not obstruct or alter navigation upon completion.

Topic	Standard or Requirement	Regulatory Citation		Project-Specific Comments
		Federal	State	
Endangered Species and Critical Habitat	Taking or jeopardy to endangered or threatened species; adverse modification of critical habitat	Endangered Species Act (16 U.S.C. §§ 1531-1544; 50 CFR 17 (listings, prohibitions), 402 (interagency consultations), 222-224 (endangered and threatened marine species), 226.212 (critical habitat for Northwest salmon and steelhead))		It is unlawful to take (or possess, deliver, carry, transport or ship) any endangered species, or violate any regulation (promulgated pursuant to Section 4) re endangered or threatened species. EPA in consultation with the Services shall insure any authorized action is not likely to jeopardize endangered or threatened species or adversely modify critical habitat, absent an exemption. EPA shall prepare a Biological Assessment for the Services which will produce a Biological Opinion including any reasonable and prudent alternatives or measures to be taken which will guide remedy implementation, including within specified time periods ("fish windows") for specified activities.
Migratory Birds	Taking or adversely affecting migratory birds.	Migratory Bird Treaty Act, (16 U.S.C §§ 703-712; 50 CFR 10 and 21)		Remedy will be carried out in a manner to avoid adversely affecting migratory bird species as defined in federal regulations, including individual birds and their nests.
Eagles	Taking or harming eagles	Bald and Golden Eagle Protection Act (16 U.S.C. § 668, 50 CFR 22)	Bald Eagle Protection Rules (RCW 77.12.655; WAC 232-12-292)	Taking or harming of eagles, their eggs, nests or young is prohibited; substantive requirements for the protection of bald eagle habitat including nesting, perching and roosting sites will be met.
Floodplain Protection	Adverse impacts; potential harm	Floodplain Management Procedures (40 CFR 6, Appendix A, Section 6, see also Executive Order 11988)		The required evaluation of potential effects of authorized remedial action, to avoid adverse impacts and to minimize impacts for which no practicable alternative exists, followed as necessary by the development of avoidance and/or minimization plans, will be undertaken during remedial design.
Shoreline management	Construction and development		Shoreline Management Act RCW 90.58; WAC 173-26; City of Seattle Master Plan SMC 23.60;King County Master Plan K.C.C. 21A.25)	Master plans within their jurisdiction apply within 200 feet of the shoreline to the extent they impose or establish more stringent requirements. Compliance as may be necessary will be evaluated during remedial design.
Air Emissions	Ambient air quality standards; fugitive emission/fugitive dust	Clean Air Act (42 U.S.C. §§ 7401-7671q; 40 CFR 50)	Washington Clean Air Act (RCW 70.94; WAC 173-400)	Any source of fugitive emissions or fugitive dust must take reasonable precautions to 1) prevent the release of air contaminants, 2) prevent fugitive dust from becoming airborne, and 3) maintain and operate the source to minimize emissions. See especially WAC 173-400-040(4) and (9).
Native American Graves and Sacred Sites	Protections	Native American Graves Protection and Repatriation Act (25 U.S.C. §§ 3001 et seq.); American Indian Religious Freedom Act (42 U.S.C. §§ 1196 et seq.)		Requirements for the protection of Native American remains, funerary objects and associated cultural artifacts when burial sites are encountered; and protection of tribal exercise of traditional tribal religions, including traditional cultural properties, sites and archeological resources. See also Executive Order 13007 which requires federal agencies to avoid physical damage to tribal sacred sites, and interfering with access of tribes thereto. Compliance will be maintained throughout remedy implementation as may be necessary
Noise	Permissible noise levels		Noise Control Act (RCW 70.107; WAC 173-60-040-050)	Maximum levels at specified times for specified durations are in 173-60-040, subject to exemptions in 173-60-050, including 050(3)(a) (sounds originating from temporary construction sites as a result of construction activity) and (3)(f) (sounds created by emergency equipment and work necessary in the interests of law enforcement or for health, safety or welfare of the community).
Historic Preservation		National Historic Preservation Act Section 106 (16 U.S.C. § 470; 36 CFR 800)		The effect if any of remedial activity on any district, site, building, structure or object included or eligible for inclusion in the National Register of Historic Places will be evaluated in consultation with the State Historic Preservation Office during remedial design.

10.2 Balancing Criteria

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

10.2.1 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 10.1.1, 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 Benthic SCO. 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 it were 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 to increase surface sediment 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 would remediate sediments with contaminant concentrations exceeding RALs 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 remediate sediments with contaminant concentrations exceeding the direct contact (RAO 2) RALs for arsenic, cPAHs, and dioxins/furans in the top 45 cm in intertidal sediments to protect people clamming or digging on the beach. However, it is not possible to anticipate every location where disturbance might occur. The Selected Remedy adds remediation of sediments with contaminant concentrations exceeding 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 scour.[21] It also addresses the potential for release of subsurface sediment contamination through navigation dredging. Alternatives 5R, 6C, and 6R would remediate more subsurface sediment contamination in all potentially erosive areas than the Selected Remedy.

[21] LDWG (2012b) evaluated several options for subsurface sediment RALs. EPA selected the 5C Plus RALs listed here because other options would remove less subsurface contamination with an associated increased risk of exposure, or would remove more subsurface contamination but at a higher cost that was disproportional to the increase in long-term effectiveness and permanence. The PCB RAL of 195 mg/kg OC is applied in the top 60 cm (potential vessel scour depths) in Recovery Categories 2 and 3; see Table 22, footnote a and Section 13.1. 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 in intertidal areas.

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

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 were 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 ICs, including the burden placed on Tribes exercising their treaty rights and on other fish consumers in the LDW as the traditional ICs assume there are accessible substitute food sources and that changing behavior is appropriate and acceptable. To address this concern to the extent practicable, the Selected Remedy adopts the EJ Analysis recommendation 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. These outreach efforts include periodic seafood consumption surveys to identify what species are being eaten by whom, as well as understanding the perceptions of risks and benefits of consuming fish from the LDW. The first seafood consumption survey (Fishers Study; LDWG 2014b) is currently underway, with many opportunities for meaningful involvement by the affected fish consuming community, as recommended by the National Environmental Justice Advisory Council (NEJAC). EPA anticipates that the information collected through the Fishers Study may serve as a basis for developing more effective and appropriate ICs, and a more targeted education and outreach program.

Other ICs such as environmental covenants or restricted navigation areas were included to protect caps. Institutional controls in either of these forms regarding ship/vessel use and/or restrictions on anchoring or spudding (sinking vessel-mounted poles into sediment for stabilizing vessels) would have been used under all alternatives to reduce the possibility of releases of COCs in underlying sediments. However, these restrictions may have limited reliability in much of this heavily used waterway.

Alternative 2R-CAD would have the least long-term effectiveness and permanence because it leaves the largest amount of contamination in place. It also would require long-term maintenance of a CAD site in the LDW. Similar to caps, CADs typically maintain their effectiveness as long as they are monitored and maintained. Alternatives that would leave progressively less subsurface contamination in the waterway are progressively more effective for this criterion. The Selected Remedy (5C Plus), 5R, 6C,and 6R would be the most effective, while other alternatives would be comparatively less effective based on the amount of subsurface contamination left behind.

10.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 5R-Treatment would utilize ex situ soil washing to reduce volumes that would be disposed in a landfill. For all alternatives that include ENR, the FS assumed that 50% of the ENR area would 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 would be proportionate to the amount of ENR. Alternative 6C (with 101 total ENR acres) would have the greatest reliance on ENR (with potential in situ treatment); while Alternatives 4C (with 16 total ENR acres), and 3C (with 10 total ENR acres) would utilize this technology significantly less. The Selected Remedy is in the mid-range, with 48 total ENR acres. Both in situ and ex situ treatments would require verification and bench or pilot scale testing during the remedial design phase.

Principal threat waste 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; see Section 11. No direct evidence of any significant amounts of non-aqueous phase liquids has been found in LDW sediment; however, treatment was included for some alternatives.

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

10.2.3 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 would 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 would be reduced to the extent possible using best management practices and performing in-waterway work only when threatened juvenile salmon are not migrating through the waterway. Dredging often leaves residual contamination behind; this would be managed by placing a thin layer of clean sand in areas where RALs are not met after dredging.

The Selected Remedy adopts recommendations from EPA's EJ Analysis (Section 10.3.3) to reduce risks as quickly as possible to minimize impacts to the community and Tribes during construction. As recommended by the EJ Analysis, EPA would work with the community and consult with Tribal representatives to reduce impacts on community and Tribal resources during remedy implementation.

Figure 14 summarizes the construction time and predicted time for each alternative to achieve modeled risk reduction benchmarks associated with each RAO. These estimates were derived from the estimated time to complete construction and the estimated natural recovery periods predicted by the BCM. As discussed in Section 10.1.1, it was not possible to predict the time to achieve all cleanup levels. Generally, the potential for short-term impacts increases as the length of the construction period (based on the area and volume to be actively remediated) increases. Lower-numbered alternatives, with higher RALs, could be implemented faster than higher-numbered alternatives with lower RALs. However, lower-numbered alternatives also relied more on natural recovery and therefore had more uncertainty in their long-term effectiveness.

Alternatives 5C and 5C Plus (the Selected Remedy) provided 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 FS cleanup objectives (17 years). While Alternatives 2R, 3C, 3R, and 4C had shorter construction times, (3 – 6 years), they were projected to take longer to reach all FS cleanup objectives (18 – 24 years) because of the extended time needed for natural recovery. Alternative 6C was projected to take 16 years to reach all FS cleanup objectives, but had a much longer construction time of 16 years. Alternative 6R had a long construction time and time to reach FS cleanup objectives of 42 years.

10.2.4 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 had 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 have been 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 Benthic SCO does not reduce contaminant concentrations as expected. This may have caused an additional administrative burden to determine specific additional actions, and to provide oversight during implementation of such actions. Alternative 2R-CAD had a potentially significant administrative challenge related to locating, using, and maintaining one or more CAD facilities.

Institutional controls were a requirement of all remedial alternatives to manage human health risks from consumption of resident seafood. The primary control mechanisms are seafood consumption advisories, public education and outreach, governmental controls, and environmental covenants pursuant to the Washington Uniform Environmental Covenants Act, which 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 had 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 in finding suitable location(s) and meeting substantive permit requirements for a CAD(s) with sufficient capacity (2R-CAD). Alternatives 4C, 4R, 5C, and 5C Plus (the Selected Remedy) 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.

10.2.5 Cost

Capital, operations, maintenance and monitoring (OM&M), and 30-year net-present value (NPV) costs for each alternative, calculated with a 2.3% discount rate, are provided in Table 25. Table 25 also shows NPV costs using a range of discount rates, from 0% to 7%. The estimated cost of $342 million (NPV at 2.3% discount rate) for the Selected Remedy falls within the low end of the cost range for the FS alternatives ($200 million – $810 million).

10.3 Modifying Criteria

Consideration of Modifying Criteria was based on the public comments received on the Proposed Plan, discussions with the State, and consultation with affected Tribes. The findings and recommendations in and comments on EPA's EJ Analysis were also considered as part of the two modifying criteria.

10.3.1 Community Acceptance

EPA received 2,327 comments on the Proposed Plan from individuals, businesses, interest groups, Tribes, and government agencies. Comments on the extent of cleanup were sharply divided. In general, community groups and individuals wanted stringent cleanup levels, a more extensive cleanup than the Preferred Remedy in the Proposed Plan, and a cleanup that would provide for safe consumption of resident fish and shellfish without fish advisories. The parties who conducted the RI/FS and some businesses in general wanted less stringent cleanup levels for sediments, no cleanup levels for tissue or surface water, and a less extensive cleanup. Businesses also requested that there be flexibility in decision-making. A summary of comments received and EPA's responses are provided in Part 3 of this ROD, the Responsiveness Summary. Community concerns were also considered during the development of and after review of public comments on EPA's EJ Analysis, discussed below.

10.3.2 State/Tribal Acceptance

The Washington State Department of Ecology concurs with the Selected Remedy. A copy of their concurrence letter is provided as Attachment 1.

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. In their comments on the Proposed Plan, both Tribes emphasized the importance of preserving Tribal treaty-reserved resources, and that the cleanup must be adequate to protect the health of tribal fishers exercising their treaty rights in this area and for the protection of the aquatic ecosystem, which contributes to the health of the fishery itself. They also stated that they have been working cooperatively with EPA since the onset of the RI/FS and plan to continue doing so throughout the life of the project.

10.3.3 Environmental Justice Analysis

EPA's EJ Analysis examined the impacts of the Proposed Plan 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 Selected Remedy 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 noncancer 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 recommended additional measures to mitigate disproportionate adverse 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)[22];
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 might be cost savings through a sustainable aquaculture or alternative transportation method;
6. Use green remediation techniques, such as technologies that reduce air impacts, with any cleanup alternative chosen.

The findings and recommendations of the EJ Analysis were incorporated into the evaluation of alternatives and the Selected Remedy, except that EPA did not select any of the offsets described in item 5 as part of the Selected Remedy, as discussed in Section 13.

10.4 Summary of CERCLA Nine-Criteria Evaluation

Alternative 1 was not protective; it was therefore eliminated from further consideration. Alternatives 2 to 6 rely on MNR to varying degrees. They are potentially 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 may also meet ARARs, although whether the Selected Remedy or any of the alternatives, in conjunction with source control, can achieve all ARARs-based human health cleanup levels and water quality ARARs is uncertain. As discussed Section 10.1.2, any of the alternatives may require ARAR waiver(s) in a future ROD Amendment or ESD if ARARs are not achieved.

Alternative 2R-CAD provided the least long-term effectiveness and permanence because it would require long-term maintenance of a CAD site within the waterway and would leave the most subsurface contamination in place. The removal-emphasis alternatives, 2R through 6R, would leave progressively less subsurface contamination in place that could be exposed by vessel scour or earthquakes, and would require fewer use restrictions and less maintenance. They also would have comparatively longer construction times and are more expensive than combined ("C") alternatives with similar RALs. The combined alternatives, 3C through 6C, and especially the lower-numbered combined alternatives, would have more area managed by ENR and MNR (and thus more subsurface contamination left in place), and would have greater monitoring and maintenance requirements. The Selected Remedy adds to Alternative 5C an increased emphasis on removal of high levels of PCBs in shallow subsurface sediments, providing greater permanence because it addresses potential vessel scour, emergency construction, navigation dredging, and other activities that could cause releases of subsurface contamination to the surface and water column. Under the Selected Remedy, MNR is selected only 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 FS cleanup objectives. While Alternatives 5R, 6C and 6R would remove more subsurface contamination, they would disrupt the waterway through releases of contamination dredging over a much longer construction period, and considerably higher cost than the Selected Remedy (Table 24).

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

11 Principal Threat Waste

The NCP establishes the expectation that treatment will be used to address the principal threats posed by a site whenever practicable (40 CFR 300.430[a] [1] [iii] [A]). In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner, or will present a significant risk to human health or the environment should exposure occur.

EPA has determined that the contaminated sediments in the LDW outside of the EAAs are not highly mobile or highly toxic. No direct evidence of any significant amounts of non-aqueous phase liquids has been found in LDW sediments. The maximum concentrations detected for the four human health risk drivers in surface and subsurface sediment outside of the EAAs are:

- 11,000 µg TEQ/kg dw for cPAHs
- 2,100 ng TEQ/kg dw for dioxins/furans
- 890,000 µg/kg dw for total PCBs
- 2,000 mg/kg dw for arsenic

Direct contact risks are low relative to seafood consumption risks (maximum direct contact RME excess cancer risk is 2×10^{-4}, as compared to an excess cancer risk of 3×10^{-3} for seafood consumption). For PCBs and dioxins/furans, the primary threat comes from bioaccumulation through exposure of aquatic receptors (e.g., fish and shellfish). Once contaminated sediment is capped or dredged, exposure through seafood consumption will cease.

Most alternatives, including the Selected Remedy, would utilize ENR/in situ treatment if pilot testing shows that the technology will be effective.

12 Documentation of Significant Changes to the Selected Remedy

In response to comments received on the Proposed Plan, EPA has altered some aspects of the Preferred Alternative (Alternative 5C Plus) in the Proposed Plan in formulating the Selected Remedy. This section briefly describes the changes, which are discussed in more detail in Sections 8 and 13 and in Part 3, the Responsiveness Summary.

- **Cleanup Levels**. EPA received many comments on the PRGs in the Proposed Plan, as described in Part 3. In response to those comments and as discussed in Section 8:
    - The sediment PRGs in the Proposed Plan are cleanup levels in the ROD though they were derived differently due to revisions to the SMS as discussed in Section 8.2 and 14.2.
    - The ambient water quality criterion (AWQC) for PCBs was a proposed ARAR and PRG in the Proposed Plan. For all other COCs, the AWQCs were identified as ARARs but not as cleanup levels. As indicated in the Proposed Plan, PCBs are the most widely distributed of the LDW COCs and may have merited special consideration. After considering comments on the Proposed Plan, as described further in the Responsiveness Summary (Part 3 of this ROD), EPA has decided to address PCBs in the ROD as it did all other COCs in LDW surface water. As a result, the remedial action selected in this ROD identifies the AWQCs (or State WQS or EPA's 1992 National Toxics Rule (NTR) standards, whichever is lower; see Section 8.2.2.2) for all COCs, including PCBs, as ARARs. EPA recognizes that achieving water quality ARARs in the In-waterway Portion of the LDW in part depends on source control actions to be taken under other authorities in addition to the CERCLA remedial action selected in this ROD. Consistent with 40 CFR 300.430(f), this ROD identifies AWQC as ARARs when they are lower than State WQS or NTR, and EPA intends this final remedial action will attain the AWQC, consistent with 40 CFR 300.430(f). See further discussion of surface water quality ARARs in Section 14.2.
    - The fish and shellfish tissue PRGs in the Proposed Plan are called target tissue concentrations in the ROD, and will only be used to assess remedy implementation [40 CFR 300.430(f)(5)(iii)]. This ROD establishes no tissue cleanup levels. EPA decided to use these levels as a means of assessing the success of the Selected Remedy in conjunction with State-led source control. EPA proposed tissue PRGs in the Proposed Plan because people consume fish and shellfish tissue, therefore tissue concentrations are the best and most direct measure of risk to LDW resident fish and shellfish consumers from those COCs. However, fish and shellfish derive their COC concentrations from both sediments and surface water in proportions that at this time can only be approximated and estimates of the degree to which this CERCLA action will reduce fish and shellfish tissue concentrations are highly uncertain. Therefore, EPA decided to identify target fish and shellfish tissue concentrations rather than cleanup levels.
- **Remedial Action Levels.** For the Selected Remedy, benthic protection RALs are 2 times the benthic SCO criteria in Recovery Category 2 and 3 areas; they were 2 times the benthic SCO but

not to exceed the CSL criteria in the Proposed Plan. This change was introduced because many COCs have CSLs that are close to or equal to the SCO, and EPA has determined that setting the RAL at twice the SCO is sufficiently protective of benthic invertebrates during the natural recovery period. This RAL change does not affect the cleanup levels, which remain as they were in the Proposed Plan; the SCO criteria must be met no later than 10 years following construction completion. See Section 13.2.

- **Buffer Depth Above Caps Placed in the Federal Navigation Channel**. The required depth, below the authorized channel depth, for the top of any cap in the federal navigation channel is increased from 3 ft (which was used in the FS) to 4 ft to address concerns raised in comments from the US Army Corps of Engineers (USACE 2013). USACE typically "advance dredges" 2 ft below the authorized depth so that sedimentation in the channel does not interfere with navigation for a longer period and dredging is required less frequently. An additional 2 ft is needed to ensure that navigation dredging does not damage the cap. See Section 13.2.1.

- **Updated Dredging Volume and Cost Estimates**. EPA received several comments on the Proposed Plan suggesting that EPA update volume and cost estimates using data collected after completion of the FS. The Selected Remedy addresses these comments by updating estimated dredged volumes and costs using data from a 2012 USACE characterization of subsurface sediments in shoaled areas in the navigation channel (USACE 2013b). Although other studies have been conducted after completion of the FS, EPA determined that this study would likely have the most significant impact on volume and cost estimates. See Sections 13.2.1 and 13.3.

- **Dredge Contaminated Shoaled Areas in the Navigation Channel**. EPA received several comments from USACE and waterway users about the importance of maintaining the LDW navigation channel at its authorized depth. USACE commented that the Preferred Alternative in the Proposed Plan, by proposing to dredge shoaled areas in the navigation channel only if contaminant concentrations in the top 2 ft exceed RALs, did not sufficiently address contamination in the navigation channel and would impede their ability to maintain the navigation channel. EPA agrees that contaminated sediments in the navigation channel should be removed to provide a remedy that is compatible with current and reasonably anticipated future use of the waterway. The Selected Remedy addresses this concern by requiring that all sediments in the navigation channel be dredged if COC concentrations exceed RALs at any depth above the maintenance depth (2 ft below the authorized depth). See Section 13.2.1.

- **Reevaluate Recovery Categories.** EPA received many comments suggesting that Recovery Categories were incorrectly assigned to specific locations and asking EPA to reevaluate Recovery Categories based on new information collected after the RI/FS was completed. EPA will reevaluate assignment of specific areas to Recovery Categories using information collected after the RI/FS and during remedial design as discussed in Section 13.2.3.

- **Flexibility in Assignment of Cleanup Technologies and Institutional Controls**. Many waterway users and community members emphasized in their comments the importance of maintaining the existing uses of specific areas of the waterway. As part of remedial design, surveys will be conducted to better understand the operational areas and needs of waterway users, and EPA will work with users to minimize conflicts between use restrictions needed to maintain the integrity of caps and other remedy features in light of existing and reasonably anticipated uses of the LDW, as discussed in Section 13.2.4. This may require implementation of dredging in some areas that may otherwise be eligible for capping because capping would require use restrictions that are incompatible with waterway uses.

The changes from the estimate in the Proposed Plan due to modifying the area and volume requiring dredging and cost of the Selected Remedy are as follows:

- Incorporating new data and increasing depth requirements for caps in the navigation channel by 1 ft adds 9 acres, 70,000 cy, of sediments to be dredged, and $18 million.
- Dredging all contaminated sediments in shoaled areas in the navigation channel adds 12 acres, 100,000 cy, of sediment to be dredged, and $27 million. This element can be implemented as part of remedial action or phased in as USACE identifies the need for dredging to address impediments to navigation.
- Total additions: 21 acres, 170,000 cy, and $45 million.

All these estimates are based on limited data and will be refined during remedial design. All changes are within the expected accuracy of FS cost estimates of +50% to -30%, and are less than the 200,000 cy sediment to be dredged that was used as a contingency volume in the FS cost estimates. They are within the range of adjustments that would normally be made during remedial design, and do not significantly change the Selected Remedy.

13 Selected Remedy

Based on consideration of the requirements of CERCLA, the detailed analysis of remedial alternatives, and consideration of public comments, EPA has selected Alternative 5C Plus as the Selected Remedy, with modifications summarized in Section 12, for the In-waterway Portion of the Site. This section provides EPA's rationale for the Selected Remedy, and a description of its anticipated scope, how the remedy will be implemented, and its expected outcomes.

13.1 Summary of the Rationale for the Selected Remedy

The Selected Remedy is protective of human health and the environment, complies with ARARs, 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 to human health through institutional controls.

EPA considered several options for surface sediment and subsurface sediment RALs that determine where active (dredging, capping, ENR) and passive (MNR) response actions will be applied. EPA selected the RALs listed in this ROD because alternatives with higher RALs would remove less subsurface contamination, resulting in less certainty in achieving cleanup goals. Alternatives with lower RALs and more emphasis on dredging would remove more subsurface contamination at higher cost and potentially greater short-term risks, with uncertain associated increases in long-term protectiveness. More than other alternatives, the Selected Remedy emphasizes a combined-technology approach, including removal of shallow subsurface sediments with higher concentrations of PCBs, while allowing MNR in areas with lower concentrations of other COCs. The Selected Remedy provides better long-term effectiveness than other alternatives by adding remediation of sediments in subtidal areas with high concentrations of PCBs in the top 2 ft below the surface of the sediment in Recovery Category 2 and 3 areas, whereas other alternatives propose remediation of subtidal contamination in the top 2 ft below the sediment surface only in Recovery Category 1 areas. This addition provides better protection for releases of contamination that may occur due to infrequent events, such as vessels traveling outside of frequent lanes of operation, vessels operating with excessive propeller power in berthing areas or elsewhere, barge groundings, emergency maneuverings, changes in the patterns of site use, and maintenance of overwater structures. It also addresses contamination in sediments in the navigation channel that may otherwise be released during maintenance dredging.

For all of these factors, the Selected Remedy provides greater permanence in comparison to other alternatives of similar cost and construction duration. Less costly alternatives rely on technologies such as ENR and MNR to address areas with higher COC concentrations, resulting in greater uncertainty as to their long-term effectiveness. In more costly alternatives, the additional costs are not proportional to the overall increase in long-term effectiveness.

The Selected Remedy provides the best balance of minimizing short-term risks due to a comparatively short 7-year construction period, while maximizing long-term effectiveness by dredging or capping the most contaminated sediments. The Selected Remedy 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.

13.2 Description of the Selected Remedy

The Selected Remedy addresses all areas where contaminant concentrations exceed the cleanup levels through a combination of active cleanup technologies, monitored natural recovery, and institutional controls. See Section 8 for a discussion of cleanup levels. The approximate areas that would be remediated through dredging, partial-dredging and capping, capping, or ENR and ENR/in situ treatment, and areas where COC concentrations would be reduced through MNR both above and below the benthic SCO, are shown in Figure 18 on page 137.

In summary, the Selected Remedy consists of the following elements:

Apply active cleanup technologies in a total of 177 acres, as described in Figure 19 and Figure 20**:**

- Dredge or partially-dredge and cap approximately 105 acres of highly contaminated sediments (approximately 960,000 cubic yards).
- Place engineered sediment caps on approximately 24 acres of highly contaminated sediments where there is sufficient water depth for a cap.
- Place a thin layer (6 to 9 inches) of clean material (referred to as enhanced natural recovery [ENR]) on approximately 48 acres of sediments in areas that meet the criteria for ENR.
- Apply location-specific cleanup technologies to areas with structural or access restrictions (e.g., under-pier areas and in the vicinity of dolphins/pilings, bulkheads, and riprapped or engineered shorelines).

Implement monitored natural recovery (MNR) in approximately 235 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 Benthic SCO or MNR Below Benthic SCO, as described in Section 13.2.2 and in Figure 21.

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, and conduct construction, post-construction, and long-term monitoring, as described in Section 13.2.3.

Provide effective and appropriate institutional controls (ICs) for the entire waterway to reduce human 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, as described in Section 13.2.4.

The estimates of areas, volumes, time to reach cleanup objectives, and cost for the Selected Remedy in this ROD are based on RI/FS data and other information included in the Administrative Record. Remedial design sampling will be conducted after cleanups are completed in the Early Action Areas. Results from remedial design sampling will be used to refine delineation of areas to be remediated by varying remediation technologies and the remediation technologies to be applied, and inform source control activities. This section describes how data collected in the future will be used to revise the delineation of areas requiring cleanup and the technologies applied to each area.

13.2.1 Application of Cleanup Technologies

The RALs listed in Figure 22 and Figure 23 (above) and Table 27 and Table 28 (page 125)will be applied in intertidal and subtidal areas in Recovery Category Areas 1, 2, and 3 to identify areas for active remediation, as described and in Figures 19 and 20. Recovery Category areas are shown in Figure 12. Figure 17 shows Recovery Category 1, and potential scour areas in Recovery Categories 2 and 3. All of this information will be used to determine the appropriate compliance depth for application of RALs and technology to be applied at a particular location, as described in this section.

Table 27. Selected Remedy RAO 3 RALs

SMS Contaminant of Concern for RAO 3	RAL for Recovery Category 1 Areas[a] (Benthic SCO)	RAL for Recovery Category 2 & 3 Areas (2 x Benthic SCO)[b]
Metals (mg/kg dw)		
Arsenic	57	n/a
Cadmium	5.1	10.2
Chromium	260	520
Copper	390	780
Lead	450	900
Mercury	0.41	0.82
Silver	6.1	12.2
Zinc	410	820
PAHs (mg/kg OC)		
2-Methylnaphthalene	38	76
Acenaphthene	16	32
Anthracene	220	440
Benzo(a)anthracene	110	220
Benzo(a)pyrene	99	198
Benzo(g,h,i)perylene	31	62
Total benzofluoranthenes	230	4650
Chrysene	110	220
Dibenzo(a,h)anthracene	12	24
Dibenzofuran	15	30
Fluoranthene	160	320
Fluorene	23	46
Indeno(1,2,3-cd)pyrene	34	68
Naphthalene	99	198
Phenanthrene	100	200
Pyrene	1,000	2,000
Total HPAHs	960	1,920
Total LPAHs	370	740

SMS Contaminant of Concern for RAO 3	RAL for Recovery Category 1 Areas[a] (Benthic SCO)	RAL for Recovery Category 2 & 3 Areas (2 x Benthic SCO)[b]
Phthalates (mg/kg OC)		
Bis(2-ethylhexyl)phthalate	47	94
Butyl benzyl phthalate	4.9	9.8
Dimethyl phthalate	53	106
Chlorobenzenes (mg/kg OC)		
1,2,4-Trichlorobenzene	0.81	1.62
1,2-Dichlorobenzene	2.3	4.6
1,4-Dichlorobenzene	3.1	6.2
Hexachlorobenzene	0.38	0.76
Other SVOCs and COCs, (µg/kg dw except as shown)		
2,4-Dimethylphenol	29	58
4-Methylphenol	670	1,340
Benzoic acid	650	1,300
Benzyl alcohol	57	114
n-Nitrosodiphenylamine, mg/kg OC	11	22
Pentachlorophenol	360	720
Phenol	420	840
PCBs (mg/kg OC)		
Total PCBs	12	n/a

Notes:
General:
- PCBs and arsenic are also human health COCs (see Table 28 for RALs for human health COCs), and RALs for the the human health category take precedence over RAO 3 RALs. The surface sediment (10 cm) Recovery Category 1 RALs for PCBs and arsenic are the same for human health and benthic invertebrates, but the 2 X SCO Recovery Category 2 and 3 criteria are not applicable to PCBs and arsenic. Figure 22 and Figure 23 list all RALs for human health COCs.
- Table 23 describes Recovery Categories and Figure 12 shows Recovery Category areas.

a. The RAL applies to the 10 cm and 45 cm depth intervals for intertidal areas and to the 10 cm and 60 cm depth intervals for subtidal areas. See Figure 22 and Figure 23 .
b. For Recovery Category 2 and 3 areas, the RAL applies to the 10 cm depth interval. See Figure 22 and Figure 23.

Relationship Between RALs, ENR Upper Limits, and Cleanup Levels

Remedial Action Levels (RALs) — RALs shown in Tables 27 and 28 will be used during remedial action to delineate areas that require active remediation (dredging, capping, or ENR). Exceedances of RALs are evaluated at each sampling station; they are not averaged over an area. RALs apply to specific locations and depths, as described in the tables.

Enhanced Natural Recovery (ENR) Upper Limits — ENR upper limits (Table 27) are higher concentrations than RALs. They will be used during remedial action to delineate the areas that require capping or dredging, but are not suitable for ENR.

Cleanup Levels — Cleanup levels shown in Table 19 for RAOs 1, 2, and 4, and Table 20 for RAO 3 are generally lower than RALs (but in some cases, RAO 3 RALs are the same as the cleanup levels). Cleanup levels are based on state or federal standards (whichever value is more stringent) and if no standard exists then risk-based concentrations are developed. At this site cleanup levels for sediment are based on Sediment Cleanup Objectives (SCOs) from the State Sediment Management Standards (SMS). See text box on page 26 for more information about the SMS. These levels must to be achieved post-construction, or after a period of monitored natural recovery (MNR). Achievement of cleanup levels for RAOs 1, 2, and 4 is measured by averaging sample results over specific areas using the UCL95 value (see Table 19). Achievement of cleanup levels for RAO 3 are measured at each sampling station (see Table 20).

13.2.1.1 Dredging and Capping

Dredging or partially dredging and capping will be used in areas that have a potential for erosion and where sediments are more highly contaminated (COC concentrations are higher than ENR upper limits; see Section 13.2.1.2 and Table 28), and where it is necessary to maintain water depth for human use and compatibility with current and reasonably anticipated future human use, or to maintain habitat, as described below and presented as flow diagrams in Figure 19 and Figure 20. EPA will gather detailed information during remedial design about COC concentrations, potential for scour or disturbance, and waterway use in specific areas to determine locations for dredging, capping, and ENR. Dredging is required under the conditions described below:

- Shoaled areas in the navigation channel (where the bottom elevation is currently shallower than the authorized navigation depth) will be dredged if COC concentrations exceed human health RALs (for PCBs, cPAHs, arsenic or dioxins/furans) or the benthic SCO at any depth above the maintenance depth (defined as 2 ft below the authorized depth) (Table 28). [23]

- The post-dredging sediment surface must not exceed human health RALs (for PCBs, cPAHs, arsenic or dioxins/furans) or the benthic SCO. If these levels cannot be achieved through dredging, an ENR layer will be applied to the post-dredge surface.

- If the ENR upper limits are exceeded after dredging, the area must be capped. If 1 ft or less of contamination would remain at concentrations greater than the human health RALs or the benthic

[23] Shoaled areas in the navigation channel must be dredged during the implementation of the remdial action where contaminant concentrations in the top 2 ft exceed RALs. Where contaminant concentrations exceed RALs only at depths below the top 2 ft, cleanup may be deferred if USACE determines it is not currently an impediment to navigation, but must be dredged in the future if USACE determines that the area has become an impediment to navigation.

SCO after dredging to sufficient depth to accommodate a cap, all contaminated sediments will be dredged. If greater than 1 ft of contamination would remain after dredging to sufficient depth to accommodate a cap, sediments will be partially dredged and capped.

- All post-remedy surfaces within the federal navigation channel will be maintained at or below their current authorized depths. In order to avoid damage to a cap or ENR layer during federal maintenance dredging, the top of any ENR layer will be at least 2 ft and the top of any cap will be at least 4 ft below the authorized federal navigation channel depth. For areas outside the navigation channel where depths are maintained by private or public entities (called berthing areas in this ROD, but could include slips, entrance channels, or restorations areas) the top of any cap or ENR layer will be a minimum of 2 ft below the operating depth.

- In habitat areas[24], post-remedy surfaces will be maintained at their current depth and backfilled or capped with suitable habitat materials.

- Dredging may be required in some areas that would otherwise be designated for capping if ICs required to prevent damage to a cap (such as prohibitions on tug maneuvering or use of spuds [vessel-mounted poles that are sunk into sediment for stabilizing vessels]) are not compatible with the current or reasonably anticipated future use of that area. See Sections 13.2.3 and 13.2.4. An additional 10 ft (lateral) of dredging outside of the federal navigation channel will be included to assure that side slopes are stable and do not slough into the channel.

Dredged materials will be transported via truck or rail for disposal at a permitted upland off-site landfill facility.[25]

Engineered sediment caps will be placed in areas where sediments are more highly contaminated (COC concentrations are higher than ENR upper limits; see Section 13.2.1.2, and Table 28) where there is sufficient water depth for a cap. Caps in intertidal clamming areas must include a minimum 45 cm clam habitat layer. EPA estimates that caps in intertidal clam habitat areas will generally be 4 ft thick. In other areas, cap thickness will generally be 3 ft. Cap thickness will be evaluated during remedial design in accordance with EPA and USACE (1998). 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.

[24] For the FS, all areas above -10 ft MLLW were assumed to be habitat areas for the purpose of developing remedial alternatives. As part of the remedial design, EPA, in coordination with natural resource agencies and Tribes, will determine what areas are considered habitat areas for the purpose of complying with ESA and Section 404 of the CWA (see Table 26). EPA will also determine what elevations and what substrate materials will be required for caps, ENR, or placement of backfill materials in any identified habitat area.

[25] 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. Sediments that pass the Dredged Materials Management Program's criteria may be disposed at an open-water disposal site.

Table 28. Remedial Action Levels, ENR Upper Limits, and Areas and Depths of Application

			Intertidal Sediments (+11.3 ft MLLW to -4 ft MLLW)				Subtidal Sediments (-4 ft MLLW and Deeper)				
			Recovery Category 1 RALs, ENR ULs, and Application Depths		Recovery Category 2 and 3 RALs, ENR ULs, and Application Depths		Recovery Category 1 RALs, ENR ULs, and Application Depths		Recovery Category 2 and 3 RALs, ENR ULs, and Application Depths		Shoaled Areas[b] in Federal Navigation Channel
Risk Driver COC	**Units**	**Action Levels**	Top 10 cm (4 in)	Top 45 cm (1.5 ft)	Top 10 cm (4 in)	Top 45 cm (1.5 ft)	Top 10 cm (4 in)	Top 60 cm (2 ft)	Top 10 cm (4 in)	Top 60 cm (2 ft)[c]	Top to Authorized Navigation Depth Plus 2 ft
Human Health Based RALs											
PCBs (Total)	mg/kg OC	RAL	12	12	12	65	12	12	12	195	12
		UL[a] for ENR	--	--	36	97	--	--	36	195	--
Arsenic (Total)	mg/kg dw	RAL	57	28	57	28	57	57	57	--	57
		UL[a] for ENR	--	--	171	42	--	--	171	--	--
cPAH	µg TEQ/kg dw	RAL	1000	900	1000	900	1000	1000	1000	--	1000
		UL[a] for ENR	--	--	3000	1350	--	--	3000	--	--
Dioxins/Furans	ng TEQ/kg dw	RAL	25	28	25	28	25	25	25	--	25
		UL[a] for ENR	--	--	75	42	--	--	75	--	--
Benthic Protection RALs											
39 SMS COCs [d]	Contaminant-specific	RAL	Benthic SCO	Benthic SCO	2x Benthic SCO	--	Benthic SCO	Benthic SCO	2x Benthic SCO	--	Benthic SCO
		UL[a] for ENR	--	--	3x RAL	--	--	--	3x RAL	--	--

a. The ENR Upper Limit (UL) is the highest concentration that would allow for application of ENR in the areas described. For areas with no ENR limit listed, ENR is not a currently designated technology (see Section 13.2.1.2 for further discussion).

b. Shoaled areas are those areas in federal navigation channel with sediment accumulation above the authorized depth including a 2 ft over-dredge depth that USACE uses to maintain the channel for navigation purposes. The authorized channel depths are (1) from RM 0 to 2 (from Harbor Island to the First Avenue South Bridge), 30 ft below MLLW; (2) from RM 2 to RM 2.8 (from the First Avenue South Bridge to Slip 4), 20 ft below MLLW; and (3) from RM 2.8 to 4.7 (Slip 4 to the Upper Turning Basin), 15 ft below MLLW. For shoaled areas, the compliance intervals will be determined during Remedial Design; these are typically 2-4 ft core intervals. For areas in the channel that are not shoaled, Recovery Categories 1 or 2 & 3 RALs apply as indicated in the other subtidal columns.

c. Applied only in potential vessel scour areas. These are defined as subtidal areas (i.e., below -4 ft MLLW) that are above -24 ft MLLW north of the 1st Ave South Bridge, and above -18 ft MLLW south of the 1st Ave South Bridge (see Figure 17).

d. There are 41 SMS COCs, but total PCBs and arsenic ENR ULs are based upon human health based RALs only (see Table 20).

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In Recovery Category 1 areas, **dredging, capping, or a combination thereof** is required when any of the conditions listed below have been met:

- In intertidal and subtidal areas, in Recovery Category 1, any sediment COC concentration averaged over the top 10 cm is greater than any of the benthic protection RALs (benthic SCO criteria, see Table 27) or greater than any of the four human health RALs (PCBs, arsenic, cPAHs, dioxins/furans, see Table 28 and Figures 22 and 23).
- In intertidal areas in Recovery Category 1, sediment COC concentrations averaged over the top 45 cm are greater than any of the four human health RALs.
- In subtidal areas in Recovery Category 1, sediment COC concentrations averaged over the top 60 cm are greater than any of the benthic protection RALs or greater than any of the four human health RALs.

In Recovery Category 2 and 3 areas, **dredging, capping, or a combination thereof** is required when COC concentrations exceed the criteria for application of ENR described in Section 13.2.1.2. See Figure 19 and Figure 20.

13.2.1.2 ENR

A thin layer (6 to 9 inches) of clean material will be placed (referred to as enhanced natural recovery [ENR]) in areas that meet the criteria for ENR as described below. 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.

In Recovery Category 2 and 3 areas, ENR with or without in situ treatment will be selected based on sediment COC concentrations and the potential for sediment scour (Table 28 and Figure 17):

- In intertidal areas in Recovery Categories 2 and 3, ENR will be applied when any sediment COC concentration averaged over the top 10 cm is between 1 and 3 times the top 10 cm intertidal RALs (e.g., 12 – 36 mg/kg OC PCBs), 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).
- In subtidal 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 subtidal RALs. In potential vessel scour areas[26] (Figure 17), sediment concentrations of PCBs averaged over the top 60 cm must also be less than 3 times the CSL chemical criterion (195 mg/kg OC). There are no RALs for the top 60 cm in Category 2 and 3 areas in deeper water depths; in these areas, RALs are applied only to the top 10 cm.
- Pilot testing will be performed to determine whether ENR/in situ treatment is effective in reducing toxicity and bioavailability of COCs while avoiding unacceptable impacts to biota. If pilot testing shows that ENR/in situ treatment can meet these objectives, EPA will consider, in coordination with the state and Tribes, the locations where ENR with in situ treatment will be applied. These areas may include some of the Recovery Category 1 areas where it can be

[26] 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.

demonstrated that ENR with in situ treatment will maintain its stability and effectiveness in these areas over time; for example, areas where vessel- and flood-related scour were shown by the STM and FS scour analysis to be minor. EPA may also consider ENR with in-situ treatment in areas with COC concentrations up to the CSL if it can be demonstrated that it will maintain its effectiveness over time.

- ENR will not be applied to Recovery Category 1 areas unless EPA approves it, as discussed above.

13.2.1.3 Other Considerations for Application of Cleanup Technologies

EPA will apply location-specific cleanup technologies to areas with structural or access restrictions (e.g., under-pier areas and in the vicinity of dolphins/pilings, bulkheads, and riprapped or engineered shorelines). Debris and pilings will be removed throughout the LDW as necessary or as required by EPA to implement the remedy, and materials will be disposed at a permitted off-site facility.

13.2.2 Monitored Natural Recovery

MNR will be applied in all areas of the LDW that are not remediated through capping, dredging, or ENR. For all areas where MNR is applied, long-term monitoring of surface sediments (top 10 cm) will be implemented to evaluate whether the RAO 3 cleanup levels (benthic SCO criteria) are being achieved in a reasonable timeframe or are not met within 10 years after remediation. 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. The STM and BCM natural recovery predictions will be reevaluated using data collected during remedial design.

- MNR To Benthic SCO will be applied where the concentration of any of the 39 RAO 3 COCs (i.e., excluding the human health COCs PCBs and arsenic) is less than the RAL but greater than the RAO 3 cleanup levels (benthic SCO criteria; Table 27 and Figure 21), and modeling results indicate the COC will be reduced to the benthic SCO criteria within 10 years of the completion of remedial action. More intensive long-term monitoring will be conducted in these areas, and should MNR not achieve RAO 3 cleanup levels or progress sufficiently toward achieving them in 10 years, additional actions (dredging, capping, or ENR) will be implemented. Those actions will be determined using the same approach set forth in this decision document as described in Section 13.2.1 and illustrated in Figures 19 and 20.
- MNR Below Benthic SCO will be applied where the concentration of all COCs is less than the RAL and the RAO 3 cleanup levels (benthic SCO criteria), but greater than the human health-based (RAO 1 and 2) cleanup levels (which are measured on an LDW-wide or area-wide basis, see Table 19 and Figure 21). Less intensive monitoring will be conducted in these areas. If cleanup levels are not achieved, additional cleanup actions may be considered and selected in a future decision document, see Section 13.4.

13.2.3 Monitoring

The entire LDW will be sampled as part of baseline, construction, post-construction, and long-term monitoring.

- **Remedial design sampling and analysis** will be conducted to establish post-EAA cleanup baseline conditions. Remedial design sampling data will be used to refine the cleanup footprint shown in Figure 18 using the decision criteria described in Figure 19 through Figure 22. Results will also be used to evaluate of the effectiveness of EAA cleanups and the degree to which natural recovery has occurred since the RI/FS sampling, to serve as a baseline for comparison to post-cleanup data, and to aid in the evaluation of source control effectiveness. Remedial design sampling will include:

- Establishing baseline contaminant concentrations in surface and subsurface sediments, surface water, and porewater. Sediment samples will be analyzed for all RAO 1, 2, 3, and 4 COCs (Table 19, Table 20, and Table 21); and a subset of sediment 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 1×10^{-6} or noncancer HQ of 1 at the adult Tribal RME consumption rate (see Table 14), to assess their reduction over time, as well as to determine conventional and engineering parameters. Biological testing (benthic community toxicity and abundance) will be included as determined during remedial design. Surface water samples will be initially analyzed for all analytes in Washington WQS (WAC173-201A), AWQC (CWA Section 304[a]) and NTR (40 CFR 131.36(b)(1) as applied to Washington, 40 CFR 131.36(d)(14)). Following the first few sampling rounds, the surface water analyte list will be reduced to the contaminants that exceeded AWQC, NTR, or Washington WQS values.
- Sampling to better understand the concentrations of incoming suspended sediments from the Green/Duwamish River that deposit in the LDW, in order to refine the RI/FS BCM predictions and inform the long-term monitoring program.
- Measuring contaminant concentrations in fish and shellfish tissue in the LDW to inform fish advisories and to provide a baseline to measure the success of the remedial action in reducing fish and shellfish tissue concentrations (RAO 1). Samples will be analyzed for PCBs, arsenic, cPAHs, and dioxins/furans; and a subset of tissue 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 1×10^{-6} or noncancer HQ of 1 at the adult Tribal RME consumption rates (see Table 14). Additional fish and shellfish tissue data will also be collected in non-urban areas in Puget Sound to refine the non-urban background values (see Table 4) that will be used for comparison to Site data to measure progress in reducing tissue concentrations.
- Conducting research to further assess the relationship between arsenic and cPAH concentrations in sediment and in clam tissue, and to assess whether remedial action can reduce clam tissue concentrations to achieve RAO 1. EPA anticipates that implementation of the Selected Remedy, along with implementation of source control actions, will achieve the RAO 2 (direct contact) cleanup levels for arsenic and cPAHs, which will also result in lower clam inorganic arsenic and cPAH concentrations that will achieve RAO 1 the extent practicable; however, at this time, the amount of reduction is uncertain. If EPA determines, based on these studies, that additional remedial action is needed to reduce clam tissue arsenic and cPAH concentrations for the purpose of achieving RAO 1, EPA will document and select those actions in a future decision document.

- **Recovery Category areas will be re-evaluated during remedial design.** The criteria for Recovery Categories (Table 23) were applied in the FS (LDWG 2012a) based upon best available knowledge using best professional judgment. EPA will use additional information and analysis and the criteria in Table 23 to change Recovery Category assignments in specific areas of the LDW where appropriate. Information EPA will consider in deciding whether to modify recovery categories include the following:

  - o A survey of waterway users, including tribal members exercising their treaty rights, will be conducted to gather detailed information about waterway use, including tribal fishing; maneuvering and anchoring of ships, barges and tugs; use of spuds; and other activities such as berth and wharf maintenance. Information about such activities may change Recovery Categories of some areas.
  - o EPA will also consider other information such as refined sedimentation rates and contaminant trends based upon new data. EPA will also reconsider areas where the Recovery Category designation in the FS appears to have deviated from the criteria in Table 23.

- **Monitoring during and after construction** will include environmental monitoring to ensure compliance with RALs and ARARs, and monitoring of physical as-built conditions (e.g., bathymetry) to ensure compliance with construction standards and project design documents.
- **Long-term monitoring** of sediments, surface water, porewater, fish and shellfish tissue and benthic community toxicity and abundance will be conducted to ensure protectiveness of human health and the environment, to ascertain attainment of cleanup levels and compliance with ARARs, to protect the integrity of the remedial actions, and to aid in the evaluation of source control effectiveness.
- If any habitat areas are constructed as part of the remedial action to comply with CWA Section 404, baseline and long-term monitoring will include appropriate habitat monitoring.

The details of long-term monitoring and maintenance, including performance standards, sampling density and frequency, interim benchmarks, and associated additional actions, as well as maintenance of remedy elements such as caps, ENR areas, and habitat areas, will be provided in a long-term monitoring and maintenance plan to be developed in remedial design. Samples will be analyzed for the analytes listed above for baseline sampling, with the list modified during remedial design based on baseline results.

13.2.4 Institutional Controls

Institutional controls will be required for the entire waterway to reduce human exposure to contaminants, and protect the integrity of the remedy. However, reliance on ICs, particularly seafood consumption-related ICs, will be minimized to the extent practicable. ICs include proprietary controls in the form of Washington Uniform Environmental Covenants Act (UECA)-compliant environmental covenants, and informational devices including fish and shellfish consumption advisories to reduce human exposure from ingestion of contaminated resident fish and shellfish. EPA anticipates relying on the existing WDOH fish and shellfish consumption advisories (see Section 6.2), and information obtained through the ongoing study of fishing and fish and shellfish consumption patterns (Fishers Study: LDWG 2014b) will be used to develop appropriate and effective ICs, which will include other measures to provide additional protectiveness, such as outreach and education programs.

As noted in Section 13.2.3, EPA will gather detailed information in remedial design about waterway use in specific areas, including impacts on tribal treaty rights. EPA will use that information to develop location-specific use restrictions (environmental covenants or governmental controls, such as restricted navigation areas designated by the Coast Guard) that would prohibit activities that may damage caps such as tug maneuvering and spudding. If such ICs interfere with waterway activities required for use of a particular area, dredging may be required instead of capping to allow for fewer restrictions on the use of the area.

13.2.5 Use of Green Remediation Practices

To the extent practicable, the remedial action should be carried out consistent with EPA Region 10's Clean and Green policy (EPA 2009b), including the following practices:

- Use renewable energy and energy conservation and efficiency approaches, including Energy Star equipment.
- Use cleaner fuels such as low-sulfur fuel or biodiesel, diesel emissions controls and retrofits, and emission reduction strategies.
- Use water conservation and efficiency approaches including Water Sense products.
- Use reused or recycled materials within regulatory requirements.
- Minimize transportation of materials and use rail rather than truck transport to the extent practicable.

13.2.6 Role of EAAs in the Selected Remedy

Dredging, capping, ENR, and MNR as described above 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 2.3 and 4.1). EPA has reviewed the EAA cleanup actions subject to implementation under EPA Consent Orders (for the Slip 4, Terminal 117, Boeing Plant 2, and Jorgensen Forge facilities), and has determined that the completed Slip 4 EAA is consistent with the Selected Remedy and requires no further active remediation. The other planned EAA cleanups conducted under EPA oversight 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/SD 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 IC 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 Selected Remedy.

13.2.7 Role of Source Control in the Selected Remedy

The Selected Remedy will be implemented while a comprehensive source control program is managed by Ecology, as described in the Source Control Strategy, which will be updated after completion of the ROD. EPA and Ecology will coordinate before initiating active in-waterway cleanup to ensure that sources have been sufficiently controlled to prevent or minimize the likelihood that sediment will be recontaminated before initiating active remediation in any portion of the waterway (see Section 4.2). The coordination process is further explained in a 2014 Memorandum of Agreement (MOA), and in Ecology's Source Control Strategy. EPA's draft Implementation Plan, which was provided to Ecology in 2013, provides additional details on the coordination process among EPA offices and with Ecology.

This ROD addresses the In-waterway Portion of the Site only and does not impose requirements on or in any way limit Ecology in its implementation of source control under State law, including MTCA and the WPCA. Furthermore, this ROD does not limit Ecology's implementation of Clean Water Act delegated authorities. Over time, the integrated approach of CERCLA and longer-term clean water actions are expected to result in attainment of applicable surface water criteria and uses under the Clean Water Act.

13.2.8 Addressing Environmental Justice concerns

Environmental Justice concerns will be addressed before, during, and after implementation of the remedy through means that include the following:

- Reducing human health risks as quickly as practicable, while also providing for long-term effectiveness and permanence.
- Conducting the Fishers Study (LDWG 2014b) to learn more about the affected community (those who consume LDW resident fish and shellfish) in order to enhance outreach efforts. As noted in Section 10.3.3, EPA has already started implementing this recommendation as part of the RI/FS.
- 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.
- Continuing consultation with affected Tribes on recommendations for the remedy.
- Reducing the impacts of the cleanup on residents through green remediation techniques, as discussed in Section 13.2.5.

13.3 Cost Estimate for the Selected Remedy

The information presented in the cost estimate summary table for the Selected Remedy is based on the best available information regarding its anticipated scope. Changes in the cost elements are likely to occur as a result of the new information and data collected during remedial design. Major changes may be documented in the form of a memorandum to the Administrative Record file, an ESD, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost. Table 25 compares costs for all alternatives and the Selected Remedy, using 0%, 2.3%, and 7% discount rates. Table 29 presents a detailed cost estimate for the Selected Remedy at the 2.3% discount rate.

Table 29. Cost Estimate Summary for Selected Remedy

ELEMENT		UNIT COSTS	UNIT	QUANTITY / SUBTOTAL
PRECONSTRUCTION				
	Mob, Demob & Site Restoration (project)	$ 800,000	Lump Sum	1
	Mob, Demob & Site Restoration (seasonal)	$ 120,000	YEAR	10.5
	Land Lease for Operations & Staging	$ 250,000	YEAR	10.5
	Contractor Work Plan Submittals	$ 100,000	YEAR	10.5
	Barge Protection	$ 80,000	Lump Sum	1
Subtotal:				**$ 5,813,932**
PROJECT MANAGEMENT (CONTRACTOR)				
	Labor & Supervision	$ 62,000	MONTH	48.3
	Construction Office & Operating Expense	$ 21,600	MONTH	48.3
Subtotal:				**$ 4,037,006**
DREDGING				
	Shift Rate	$ 25,963	DAY	924
	Gravity Dewatering (on the barge)	$ 10	CY	950,664
Subtotal:				**$ 33,496,452**
SEDIMENT HANDLING & DISPOSAL				
	Transloading Area Setup	$ 1,000,000	Lump Sum	1
	Water Management	$ 10,000	DAY	924
	Transload, Railcar Transport to & Tipping at Subtitle D Landfill	$ 60	TON	1,425,997
Subtotal:				**$ 95,799,820**
SEDIMENT CAPPING, DREDGE RESIDUALS, DREDGE BACKFILL				
	Debris Sweep	$ 30,000	ACRE	2
	Shift Rate (12 hours)	$ 12,500	DAY	501
	Cap Material Procurement & Delivery (sand)	$ 27	CY	548,103
Subtotal:				**$ 21,121,281**
ENHANCED NATURAL RECOVERY				
	Debris Sweep	$ 30,000	ACRE	5
	Shift Rate (12 hours)	$ 12,500	DAY	46
	Material Procurement & Delivery (sand)	$ 27	CY	28,824
	Material Procurement & Delivery (carbon amended sand)	$ 161	CY	28,824
Subtotal:				**$ 6,143,912**
CONSTRUCTION QA/QC				
	Construction Monitoring	$ 7,925	DAY	924
Subtotal:				**$ 7,322,700**
POST-CONSTRUCTION PERFORMANCE MONITORING				
	Compliance Testing (Dredging)		PROJECT	$ 1,445,267
	Compliance Testing (Capping)		PROJECT	$ 1,141,320
	Compliance Testing (ENR)		PROJECT	$ 1,221,569
Subtotal:				**$ 3,808,157**
CAPITAL COSTS (base)				**$ 177,543,260**
CAPITAL COSTS (present value)				**$ 159,745,069**

ELEMENT	UNIT COSTS	UNIT	QUANTITY / SUBTOTAL
Construction Contingency	35%	PROJECT	$ 62,140,141
Sales Tax	9.5%	PROJECT	$ 16,866,610
Project Management, Remedial Design & Baseline Monitoring	30%	PROJECT	$ 53,262,978
Construction Management	10%	PROJECT	$ 17,754,326
TOTAL CAPITAL COST (base)			**$ 327,567,314**
TOTAL CAPITAL COST (present value)			**$ 294,729,653**
AGENCY OVERSIGHT, REPORTING, O&M, & MONITORING COSTS (base)			
Agency Review & Oversight		PROJECT	$ 10,200,000
Reporting		PROJECT	$ 1,900,000
Operations & Maintenance (Dredging)		PROJECT	$ 1,416,056
Operations & Maintenance (Capping)		PROJECT	$ 5,907,000
Operations & Maintenance (ENR)		PROJECT	$ 6,352,496
Operations & Maintenance (MNR>SCO)		PROJECT	$ 2,250,956
Operations & Maintenance (MNR<SCO)		PROJECT	$ 8,978,076
Long-term Monitoring		PROJECT	$ 5,775,580
Institutional Controls		PROJECT	$ 25,000,000
Subtotal (base):			**$ 67,780,164**
Subtotal (present value):			**$ 47,504,279**
TOTAL COST (Net Present Value) at 2.3% discount rate			**$ 342,233,932**

13.4 Estimated Outcomes of Selected Remedy

The intent of the Selected Remedy is, in conjunction with cleanup of the EAAs and with Ecology-led source control activities, to be protective of human health and the environment and to attain ARARs, although some ARARs may not be achieved for the foreseeable future. It is consistent with current and reasonably anticipated future uses of the waterway. It is intended to minimize reliance on fish and shellfish consumption-related institutional controls to the extent practicable; however, such controls will have to remain in effect to ensure protectiveness for the foreseeable future.

The goal of this CERCLA cleanup action and the Ecology-led source control program is to reduce in-waterway contamination and sources to the waterway to levels needed to achieve all cleanup levels and ARARs described in Section 8 and Table 19 and Table 20. RI/FS modeling results conclude that it may not be possible for any alternative to do so; however, as discussed in Sections 8 and 10, it is difficult to predict long-term Site conditions with any degree of accuracy.

The active remedy components of the Selected Remedy are expected to take 7 years to implement after completion of the EAAs and remedial design, and after sources have been sufficiently controlled to minimize recontamination (see Section 4.2). The Selected Remedy will be designed to maintain sufficient water depth for human use and habitat function and allow for future navigation dredging. During and after remediation current and anticipated future land and waterway uses, including industrial, residential, commercial and recreational uses, are expected to be able to continue, subject to the institutional controls and so long as sources of contamination are controlled or eliminated. EPA expects that direct contact risks (RAO 2) and risks to higher trophic level species (RAO 4) will be reduced to the cleanup levels (except as noted in Section 10.1.2) and risks to benthic invertebrates (RAO 3) and human seafood consumers (RAO 1) will have been significantly reduced at the completion of active components of the remedy. EPA anticipates that another 10 years of natural recovery will be required to reduce COC concentrations sufficiently to meet RAO 3 and RAO 1 to the extent practicable.

The lowest contaminant concentrations in fish and shellfish tissue are predicted by modeling to be achieved in 17 years following the start of construction. 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 RAO 3 cleanup levels (benthic SCO criteria) and human health-based RALs (see Table 27 and Table 28) are exceeded, additional actions will be taken to reduce COC concentrations to these levels. If monitoring shows that contaminant concentrations have reached a steady state at levels below the benthic SCO criteria or human health-based RALs but above the human health risk reduction or background-based cleanup levels, EPA will review the data and consider whether additional technically practicable cleanup actions would further reduce contaminant concentrations in sediments, tissue, or surface water.

EPA expects that, once the active components of the Selected Remedy (dredging, capping, ENR, and any additional actions needed to meet the benthic SCO criteria and human health-based RALs) have been completed and long-term monitoring shows COC concentrations have reached a steady state, COC concentrations will either be at cleanup levels for sediment and ARARs for water quality, or will represent practicable limitations in implementation of source control and active remediation. Data collection and analysis during long-term monitoring is intended to test this expectation.

However, if EPA determines that additional remedial action is appropriate for the In-waterway Portion of the Site, EPA will select such action in a ROD Amendment or ESD. If EPA or the State determines that further source control is appropriate, EPA or the State will address such sources with source control response action decisions separate from this ROD. If EPA determines that no additional practicable actions can be implemented under CERCLA to meet ARARs, EPA may issue a ROD Amendment or ESD providing the basis for a technical impracticability waiver for specified sediment and/or surface water quality based ARARs under Section 121(d)(4)(C) of CERCLA.

Implementation of the Selected Remedy, along with the EAA cleanups 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. It should also address the key Environmental Justice concerns as discussed in Section 13.2.8.

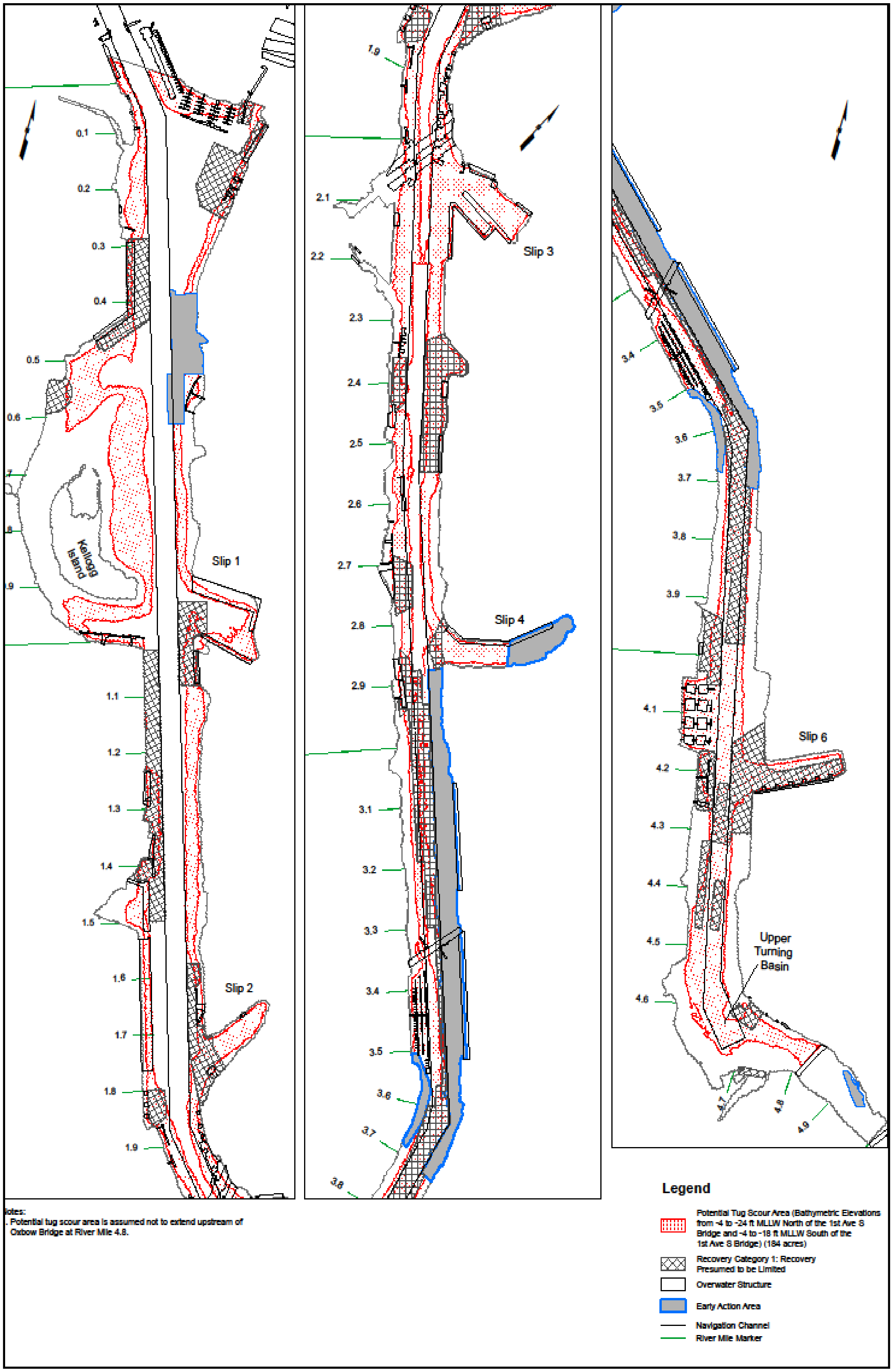

Figure 17. Recovery Category 1 and Potential Tug Scour Areas in LDW

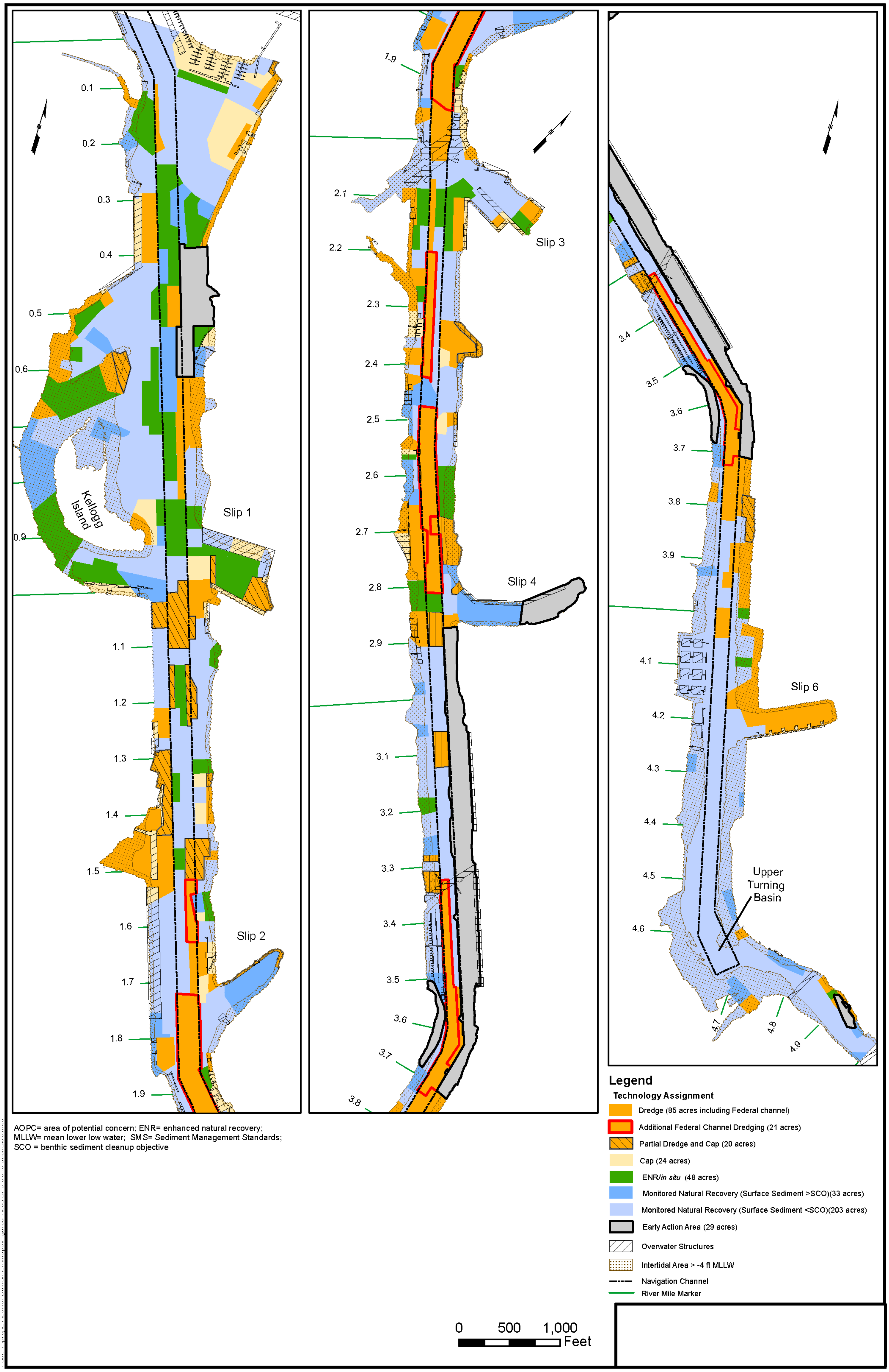

Figure 18. Selected Remedy

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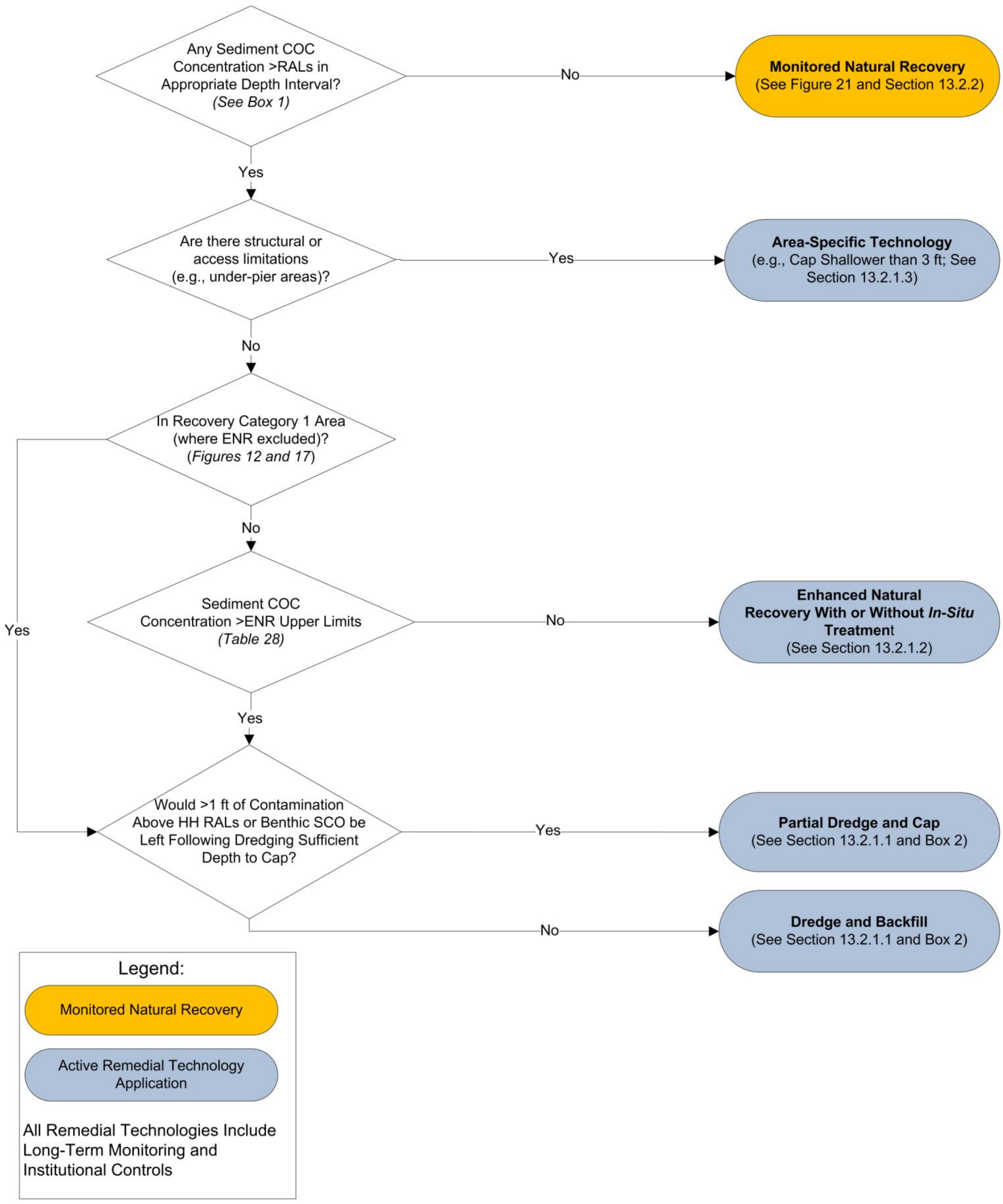

Box 1. Intertidal Sediments (+11.3 ft MLLW to -4 ft MLLW)

Remedial Action Levels (RALs) and Depth Interval to Which They Apply

Contaminant	Units	Recovery Category 1 Areas: 4 in (10 cm) depth interval	Recovery Category 1 Areas: 1.5 ft (45 cm) depth interval	Recovery Category 2 and 3 Areas: 4 in (10 cm) depth interval	Recovery Category 2 and 3 Areas: 1.5 ft (45 cm) depth interval	Risk Reduction Associated with RALs
PCBs (Total)	mg/kg-OC	12	12	12	65	Human Health [a,b,c,e]
cPAH	µg TEQ/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	
39 SMS COCs	Varies by COC	SCO (see Table 27)	--	2xSCO (see Table 27)	--	Ecological [d,e]

Notes:

1. The average concentrations in depth Interval (e.g., vertically composited samples) are compared to RALs.
2. Human Health RALs and RAO 3 RALs must be met immediately following construction.

[a] RAO 1 - Human health seafood consumption

[b] RAO 2 - Human health direct contact includes 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] There are 41 SMS COCs, but PCB and arsenic are principally RAO 1 COCs. SMS also lists toxicity test-out criteria using bioassays. Test-out is not allowed for PCBs or arsenic.

Box 2. Habitat Areas
Elevations of intertidal habitat areas are assumed to be unaffected by addition of 6-9" of suitable materials (i.e., ENR)
Cap,dredge and backfill,or partial dredge and cap to pre-construction grade; finish with suitable habitat layer
In clam habitat areas (Figure 6), caps will generally include 4 ft of suitable clean material Including a minimum 45 cm clam habitat layer

Figure 19. Intertidal Areas – Remedial Technology Applications

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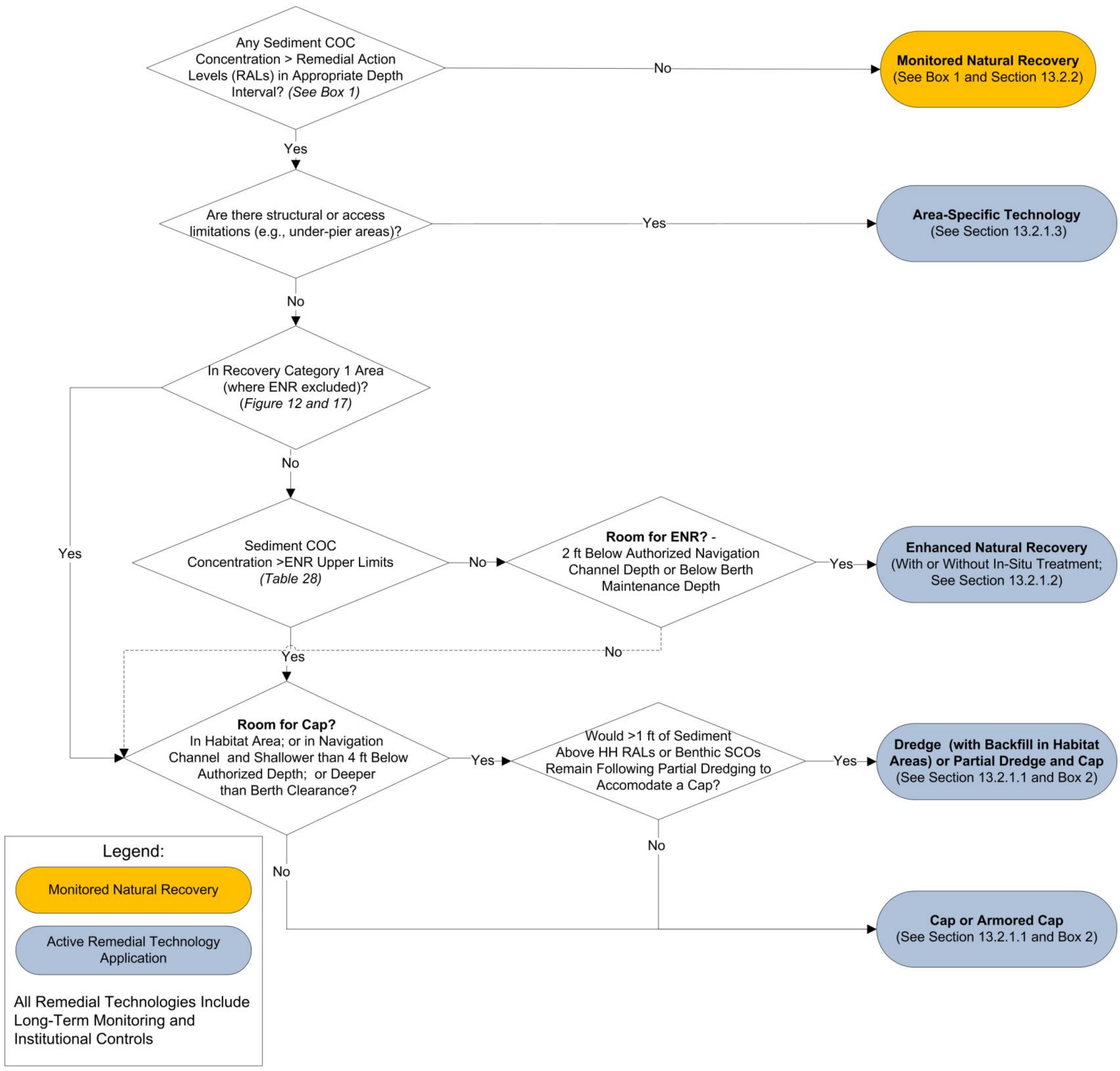

Box 1. Subtidal Sediments (-4 ft MLLW and Deeper)

Remedial Action Levels (RALs) and Depth Interval for Application of RAL

Contaminant	Units	Recovery Category 1 Areas		Recovery Category 2 and 3 Areas		Shoaled Areas of the Federal Channel	Risk Reduction Associated with RALs
		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; See *Footnote 2* and Figure 16	See *Footnote 3*. To a depth of 2 ft below the authorized depth for waterway reach[f]	
PCBs (Total)	mg/kg-OC	12	12	12	195	12	Human Health [a,b,c]
cPAH	µg TEQ/kg-dw	1000	1000	1000	--	1000	
Dioxins/Furans	ng TEQ/kg-dw	25	25	25	--	25	
Arsenic (Total)	mg/kg-dw	57	57	57	--	57	
39 SMS COCs	Varies by COC	SCO (see Table 27)	SCO	2xSCO (see Table 27)	--	SCO (see Table 27)	Ecological [d,e]

Notes

1. The average concentrations in depth interval (e.g., vertically composited samples) are compared to RALs.
2. Potential Tug Scour Areas are Subtidal Elevations Potentially Susceptible to Propellor Wash (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).
3. Shoaled areas are those areas in federal navigation channel with sediment accumulation above the authorized depth including a 2 ft over-dredge depth; see Table 28. For areas in the navigation channel that are not shoaled, Recovery Categories 1 or 2 & 3 RALs apply. Authorized depths are: (1) from RM 0 to 2, 30 ft below MLLW (from Harbor Island to the First Avenue South Bridge); (2) from RM 2 to RM 2.8, 20 ft below MLLW (from the First Avenue South Bridge to Slip 4); and (3) from 15 ft below MLLW from RM 2.8 to 4.7 (Slip 4 to the Upper Turning Basin).
4. Human Health RALs and RAO 3 PRGs (Benthic SCOs) Must Be Met Immediately Following Construction.

[a] RAO 1 - Human health seafood consumption

[b] RAO 2 - Human health direct contact includes 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] There are 41 SMS COCs, but PCB and arsenic are principally RAO 1 COCs. SMS Also lists toxicity test-out criteria using bioassays. Test-out is not allowed for PCBs or arsenic.

[f] Depth intervals to determine compliance will be determined during Remedial Design; typically, 2-3 ft core intervals are used.

[g] Caps were assumed to be 3 ft for cost estimating purposes; cap thicknesses will be evaluated by EPA during Remedial Design in accordance with EPA and USACE (1998)

Box 2. Habitat Areas (see Section 13.2.1.1)
Elevations of intertidal habitat areas are assumed to be unaffected by addition of 6-9" materials (i.e., ENR)
Cap, dredge and backfill, or partial dredge and cap to pre-construction grade; finish with suitable habitat layer.

Figure 20. Subtidal Areas – Remedial Technology Application

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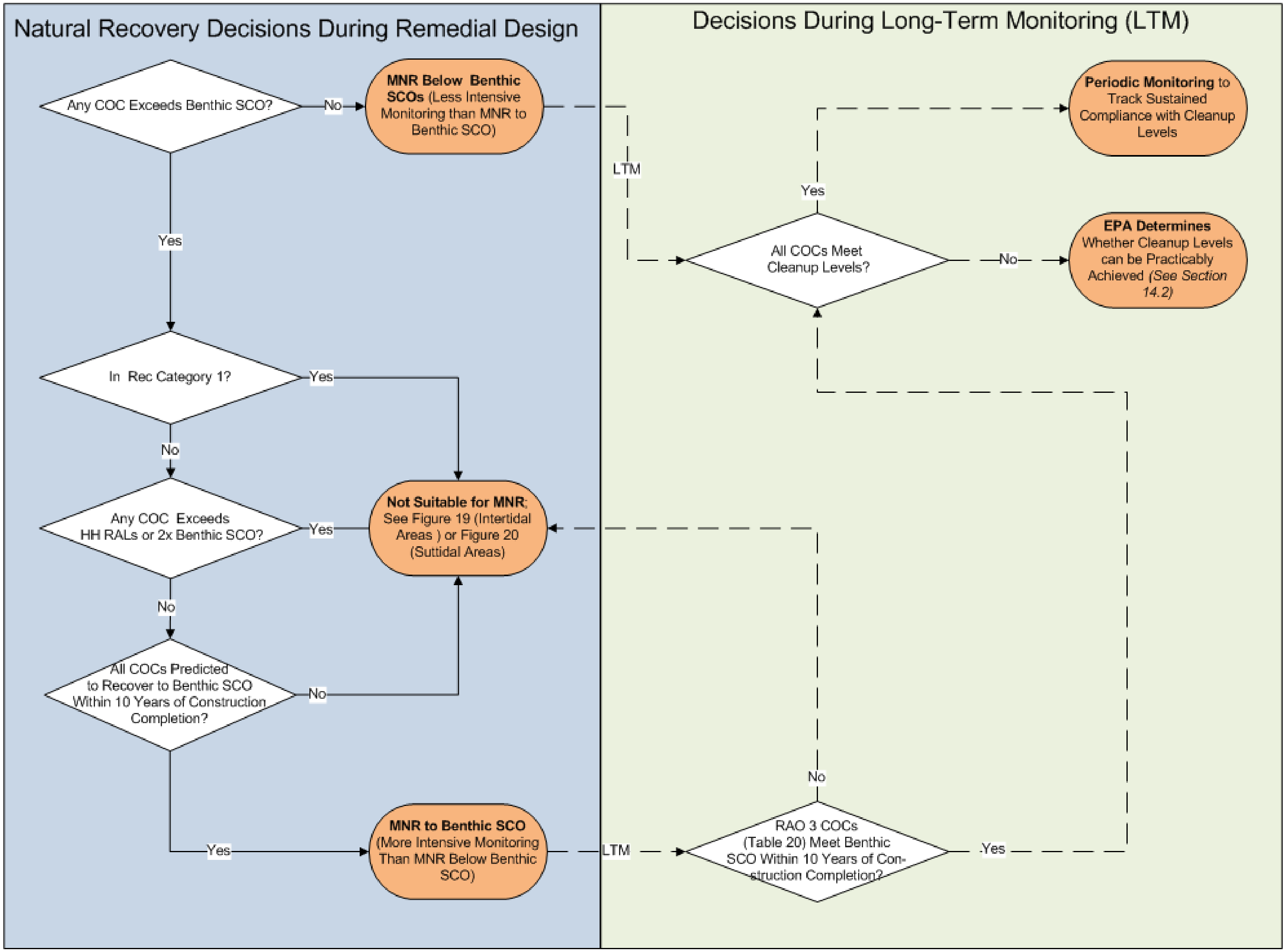


Figure 21. Intertidal and Subtidal Areas – Natural Recovery Application

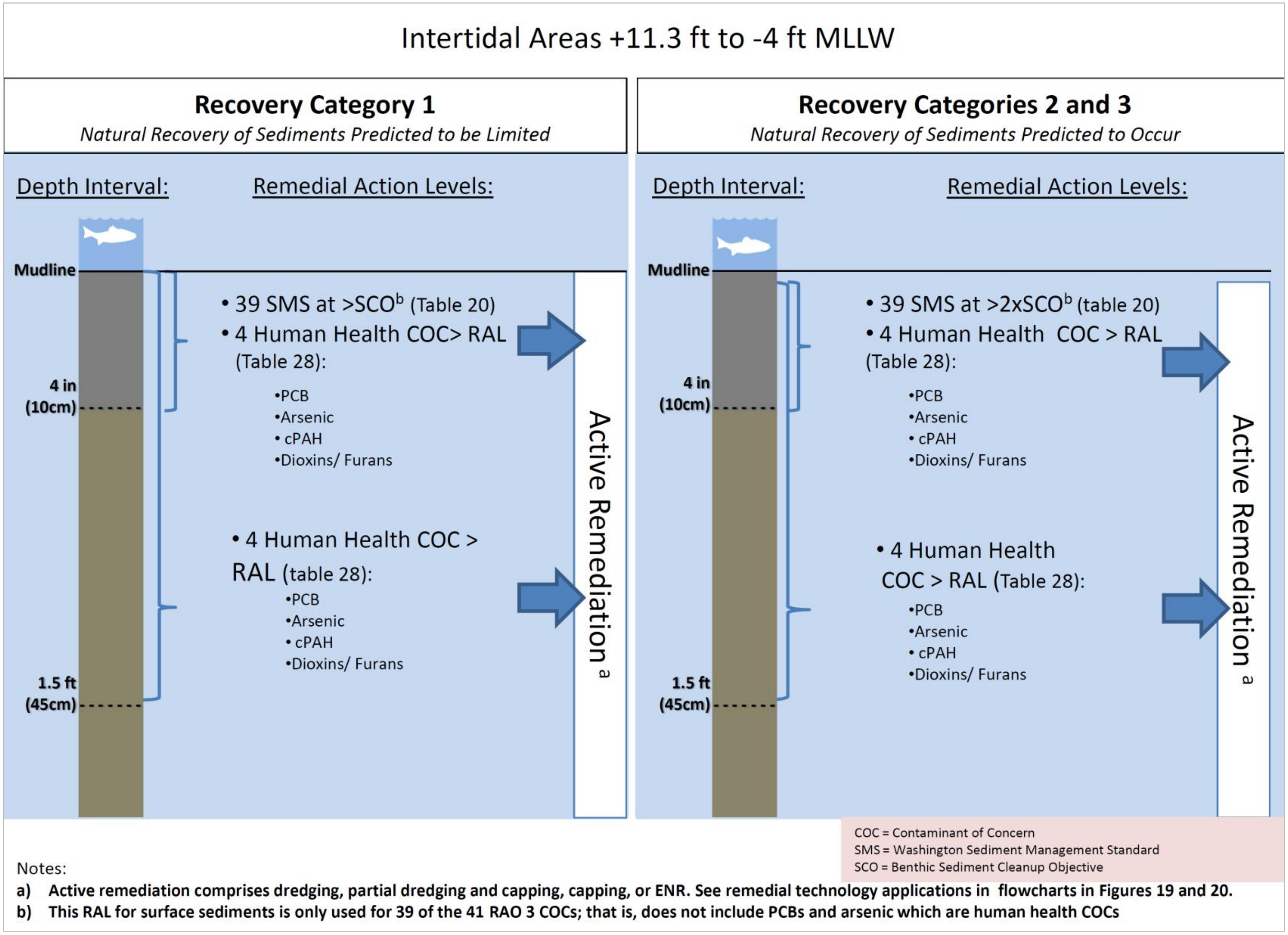
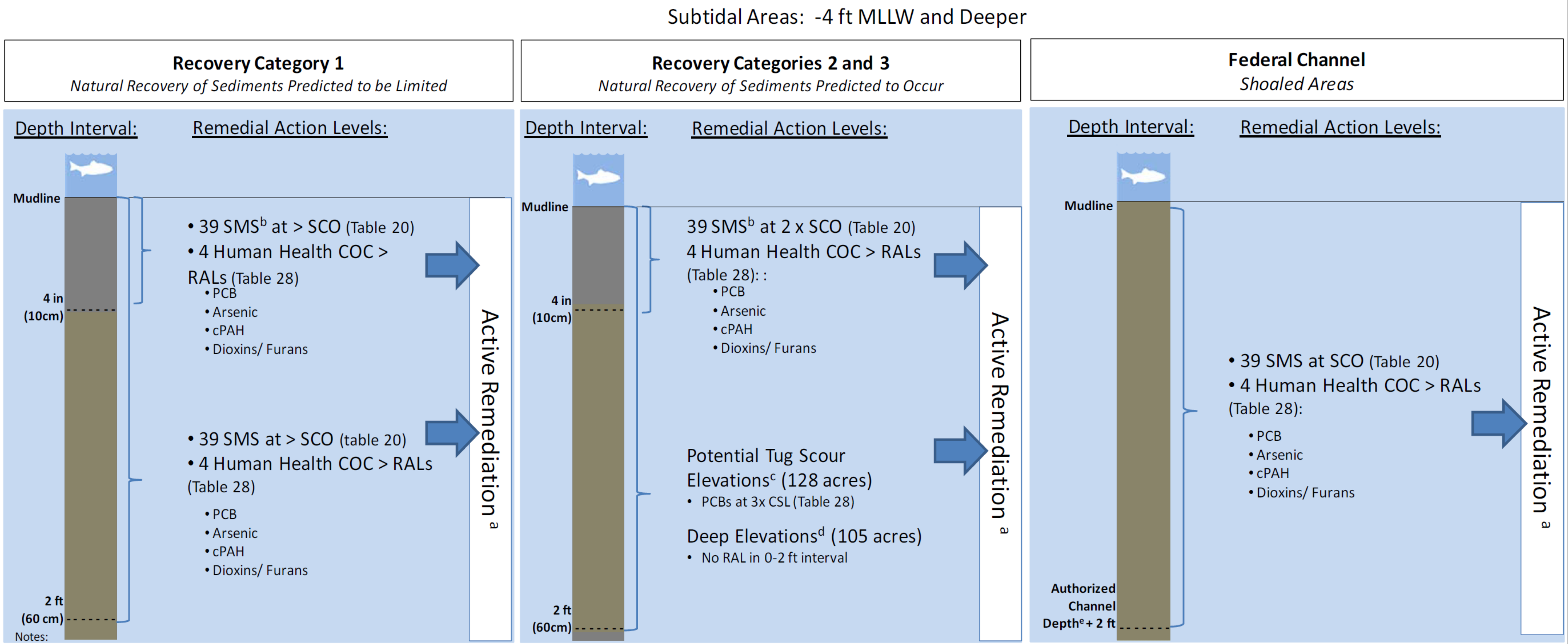


Figure 22. Intertidal Areas - Remedial Action Levels Application



Notes:

a) Active Remediation comprises dredging, partial dredging and capping, capping, or ENR. See remedial technology applications in flowcharts in Figures 19 and 20.
b) This RAL for surface sediments would only be used for 39 of the 41 COCs, and is not used for PCBs or arsenic.
c) Potential tug scour elevations are shown in Figure 17. These are defined as -4 to -24 ft MLLW north of 1st Ave S Bridge and -4 to -18 ft MLLW south of 1st Ave S Bridge.
d) Deep elevations are defined as deeper than -24 ft MLLW north of 1st Ave S Bridge and deeper than -18 ft MLLW south of 1st Ave S Bridge.
e) Shoaled areas are those areas in navigation channel with sediment accumulation above the authorized depth including a 2 ft over-dredge depth, see Table 28. For areas in the navigation channel that are not shoaled, Recovery Categories 1 or 2 & 3 RALs apply. Authorized depths are: (1) from RM 0 to 2, 30 ft below MLLW (from Harbor Island to the First Avenue South Bridge); (2) from RM 2 to RM 2.8, 20 ft below MLLW (from the First Avenue South Bridge to Slip 4); and (3) from 15 ft below MLLW from RM 2.8 to 4.7 (Slip 4 to the Upper Turning Basin). To these depths, 2 ft overdredge depth should be added

COC = Contaminant of Concern
SMS = Washington State Sediment Management Standards
SCO = Benthic Sediment Cleanup Objective

Figure 23. Subtidal Areas – Remedial Action Levels Application

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14 Statutory Determinations

CERCLA Section 121 and the NCP Section 300.430(f)(5)(ii) require selection of a remedy or remedies that are protective of human health and the environment, comply with ARARs (unless a statutory waiver is justified), are cost-effective, and use permanent solutions and alternative treatment technologies to the maximum extent practicable. In addition, CERCLA includes a preference for remedies that employ treatment that permanently and significantly reduces the volume, toxicity, or mobility of hazardous substances, pollutants, or contaminants as a principal element.

As discussed below, EPA has determined that the Selected Remedy meets these statutory requirements.

14.1 Protection of Human Health and the Environment

The Selected Remedy will protect human health and the environment through dredging or capping the most contaminated sediments, using ENR to reduce COC concentrations in moderately contaminated areas, and using MNR to further reduce concentrations in less contaminated areas.

Long-term model projections of risk reduction achieved by the Selected Remedy 30 - 40 years in the future are uncertain. The FS estimated an adult Tribal RME excess cancer risk of 2×10^{-4} and noncancer HQ of 4 and a child Tribal RME excess cancer risk of 5×10^{-5} and noncancer HQ of 9 for PCBs at the model-predicted steady state after implementation of the cleanup. As discussed in Section 8.2.1, model projections in the FS may underestimate the long-term risk reduction achieved by the Selected Remedy. If the target tissue concentrations in Table 21 are achieved, excess cancer risks for PCBs are estimated to be 5×10^{-6} for the adult Tribal RME scenario and 1×10^{-6} for the child Tribal RME scenario and noncancer HQs are estimated to be less than 1 for both adult and child Tribal RME scenarios. Compared to the adult and child Tribal RME seafood consumption rate baseline risks presented in Section 7.1, 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 target tissue concentration.

Long-term projections of risk at the model-predicted steady state could only be made for PCBs. Estimated cancer and noncancer risks for the adult Tribal RME seafood consumption rate if fish and shellfish target tissue concentrations are achieved 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 21) are estimated to be 3×10^{-4} , and the HQ for noncancer risks would be less than 1 (based on PCBs, the COC with the highest HQ).

As discussed in Section 4.3, and other places in this document, institutional controls limiting seafood consumption will be needed for the foreseeable future. The intent of the remedy is to reduce contaminant concentrations in sediments, surface water, and fish and shellfish tissue to the extent practicable, and to minimize reliance on seafood consumption advisories to attain protectiveness.

14.2 Compliance with Applicable or Relevant and Appropriate Requirements

ARARs for the Selected Remedy are shown in Table 26. The most significant ARARs for this remedial action are the MTCA/SMS requirements and Federal and State water quality criteria and standards, as discussed in Section 8.2.2. The objective of the Selected Remedy is to meet ARARs throughout the In-waterway Portion of the Site.

MTCA/SMS

The sediment cleanup levels in this ROD are based on the SCO criteria in the SMS. The SCO-based sediment cleanup levels for protection of human health are set at natural background concentrations or at the RBTCs[27], whichever is higher. The SMS allows for selection of higher CSL-based cleanup levels when it is not technically possible to achieve SCO levels, or if meeting the SCO will have a net adverse impact on the aquatic environment (WAC 173-204-560). EPA has determined that there is insufficient information at this time to determine whether it is technically possible to achieve the SCO-based cleanup levels selected in this ROD, as described in Section 8.2.2.1. The selected cleanup levels for the protection of benthic invertebrates (RAO 3) are the SCO chemical and biological criteria set forth in WAC 173-204-562. The SMS also requires protection of HTLS; cleanup levels for the protection of human health and benthic invertebrates are also protective of HTLS.

The Selected Remedy is predicted to reduce contaminant concentrations to the RAO 3 cleanup levels (the benthic SCO) within 10 years after the completion of active cleanup. Additional actions (see Section 13.2.2) will be implemented if they are not achieved within 10 years. However, as discussed in Section 10.1.1, the RI/FS models indicate that the long-term COC sediment concentrations achievable in the In-waterway Portion of the Site 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, implementation of the Selected Remedy is not predicted to achieve the SCO-based sediment cleanup levels required by the SMS for PCBs, dioxins/furans (for RAO 1), and arsenic (for RAO 2).

As discussed in Sections 8.2.1 and 8.2.2, the Selected Remedy could potentially meet ARARs notwithstanding these RI/FS model projections. See Section 8.2.1 for a discussion of RI/FS modeling uncertainties. The objective of the Selected Remedy and Ecology's source control program under its authorities is to reduce COC concentrations to cleanup levels protective of human health, HTLS, and benthic invertebrates, as required by the SMS and to meet water quality ARARs. EPA will monitor progress of these actions, including measuring long-term contaminant concentrations in sediment and surface water for ARAR compliance. EPA will also monitor fish and shellfish tissue concentrations to inform decision making with respect to protectiveness of human health and the environment, including the need for and content of institutional controls. Institutional controls are required by MTCA, WAC 173-340-440(a)(4), when hazardous substances above cleanup levels remain at a site, which is wholly consistent with EPA policy and guidance. This MTCA rule is an ARAR.

If long-term monitoring data and trends indicate that some ARARs cannot be met, EPA will determine whether further In-waterway remedial action in conjunction with source control could practicably achieve the ARAR. If EPA concludes that an ARAR cannot be practicably achieved, EPA will either waive the ARAR on the basis of technical impracticability (TI) in a future decision document (ROD Amendment or ESD), or for SMS SCO-based ARARs, EPA will consider whether the criteria in the SMS for adjusting cleanup levels upward from the SCO, to no higher than the CSL, can be met as discussed above. If these

27. MTCA/SMS require a total excess cancer risk of less than or equal to 1 x 10^{-5} and excess cancer risks for individual COCs less than or equal to 1 x 10^{-6} and a noncancer HQ or HI of less than 1 for protection of human health.

criteria can be met, EPA will evaluate adjusting the relevant sediment cleanup levels upward to regional background or other CSL-based levels described in the SMS.

Because EPA cannot know whether or to what extent the SMS ARARs for various COCs will be achieved upon completion of remedial action (including natural recovery), consideration of such waiver(s) prior to the collection of monitoring data sufficient to inform TI waiver decisions, or upward adjustment of cleanup levels under the SMS, is neither warranted nor justifiable at this time.

Surface Water Quality ARARs

Surface water quality ARARs consist of applicable promulgated state water quality standards and, in accordance with Section 121(d)(2)(A)(ii) and (B)(i) of CERCLA, federal recommended Clean Water Act Section 304(a) Ambient Water Quality Criteria (AWQC) guidance values where they are relevant and appropriate, as discussed in Section 8.2.2.2. Current concentrations of PCBs in the upstream Green/Duwamish River surface water are higher than the selected ARARs (discussed above and in Section 8.2.2.2). RI/FS model projections assumed no future decrease in the current upstream surface water COC concentrations. Implementation of the sediment remedy in combination with source control implementation under State-lead authority will improve surface water quality to an unknown degree. If appropriate, waiver of surface water quality ARARs will be considered only after the improvement from these combined actions is assessed based on long-term water quality monitoring. As discussed above, if long-term monitoring indicates that surface water quality ARARs cannot be met, EPA will review the data and consider whether additional technically practicable cleanup would further reduce contaminant concentrations in surface water. If EPA determines that additional remedial action is appropriate for the In-waterway Portion of the Site, EPA will select such action in a ROD Amendment or ESD. If EPA or the State determine that further source control is appropriate, EPA or the State will address such sources with source control response action decisions separate from this ROD. If EPA determines that no additional practicable actions can be implemented to meet ARARs, EPA may issue a ROD Amendment or ESD providing the basis for a technical impracticability waiver for water-quality based ARARs under Section 121(d)(4)(C) of CERCLA.

ESA

To protect threatened or endangered species under the ESA, including Puget Sound Chinook salmon, Puget Sound Steelhead, and bull trout, 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 salmon are minimal, largely because juvenile salmon are not migrating through the waterway during that period. EPA will consult with the National Marine Fisheries Service and the U. S. Fish and Wildlife Service (Services) to ensure protection of threatened or endangered species. EPA will prepare a Biological Assessment (BA) for the Services in accordance with Section 7(c) of ESA; and EPA anticipates that the Services will evaluate the BA and produce a Biological Opinion (BO) in accordance with Section 7(b) including any reasonable and prudent measures to be taken, which will guide implementation of the Selected Remedy with respect to the protection of listed species.

14.3 Cost-Effectiveness

The Selected Remedy is cost-effective and represents a reasonable value for the costs incurred. In making this determination, the following definition was used: “A remedy shall be cost-effective if its costs are proportional to its overall effectiveness." (40 CFR 300.430(f)(1)(ii)(D)). EPA evaluated the "overall effectiveness" of those alternatives that satisfied the threshold criteria (i.e., were both protective of human health and the environment and ARAR-compliant) by assessing three of the five balancing criteria in combination (long-term effectiveness and permanence; reduction in toxicity, mobility, and volume through treatment; and short-term effectiveness). Overall effectiveness was then compared to costs to determine cost-effectiveness. The relationship of the overall effectiveness of this remedial alternative was determined to be proportional to its costs and hence this alternative represents a reasonable value for the money to be spent.

The total estimated capital costs (net present value) to construct the Selected Remedy are $295 million, and the total estimated operation, maintenance, and monitoring costs (net present value) are approximately $48 million for a total of $342 million (excluding the cost of source control, which is not part of the In-waterway Portion of the Site, and excluding the cost of the Early Actions). Less costly alternatives rely more on technologies such as ENR and MNR that have greater uncertainty as to their long-term effectiveness. In more costly alternatives, the additional costs are not proportional to the overall increase in protectiveness.

14.4 Utilization of Permanent Solutions and Alternative Treatment (or Resource Recovery) Technologies to the Maximum Extent Practicable

EPA has determined that the Selected Remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the Site. Of those alternatives that are protective of human health and the environment and comply with ARARs, EPA has determined that the Selected Remedy provides the best balance of trade-offs in terms of the five balancing criteria, while also considering the statutory preference for treatment as a principal element and bias against off-site treatment and disposal and considering State and community acceptance.

14.5 Preference for Treatment as a Principal Element

The Selected Remedy does not satisfy the statutory preference for treatment as a principal element of the remedy because there is no cost-effective means of treating the large quantity of contamination present at the In-waterway Portion of the Site. The NCP establishes the expectation that treatment will be used to address the principal threats posed by a site whenever practicable, (40 CFR 300.430[a] [1] [iii] [A]). In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be contained in a reliable manner, or will present a significant risk to human health or the environment should exposure occur. As discussed in Section 11, EPA has determined that the contaminated sediments in the LDW outside of the EAAs are not highly mobile or highly toxic. However, the Selected Remedy does include potential treatment through ENR/in situ treatment using activated carbon or other sequestering agents if pilot tests are successful. In situ carbon amendment works best at relatively low levels of contamination.

14.6 Five-Year Review Requirement

Because this remedy will result in hazardous substances, pollutants, or contaminants remaining on-site above levels that allow for unlimited use and unrestricted exposure, a statutory review will be conducted within five years after initiation of remedial action to ensure that the remedy is, or will be, protective of human health and the environment.

15 Key Terms

Apparent Effects Threshold (AET) – the concentrations of a specific contaminant in sediment above which an adverse biological effect always occurs for a particular biological indicator. The lowest AET (LAET) refers to the most sensitive assay, and a second lowest AET (2LAET) refers to the next most sensitive assay.

Applicable or Relevant and Appropriate Requirements (ARARs) – ARARs are substantive (as opposed to administrative) standards, requirements, criteria, or limitations under any federal environmental law, or promulgated under any state environmental or facility siting law that are more stringent than under federal law, which must be met or formally waived upon (or before) completion of final remedial action. See Section 121(d) of CERCLA.

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.

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, pollutants, or contaminants that may endanger public health or welfare or the environment.

Chronic Daily Intake (CDI) – intake of a contaminant averaged over a lifetime, often adjusted for absorption efficiency.

Cleanup Screening Level (CSL) – see text box "What are the Sediment Management Standards?". The level used to identify cleanup sites and the maximum level for establishing sediment cleanup levels under the Washington State Sediment Management Standards.

Congener – structurally related chemical substances. For example, there are 202 chemical congeners in the suite of polychlorinated biphenyls that share the generalized biphenyl organization and differ according to location of the chlorine.

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 mathematical model to estimate the relationship among sediment, water, and tissue contaminant concentrations including higher trophic levels (such as fish).

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 noncarcinogenic hazardous substances with similar modes of toxic action.

Hazard Quotient (HQ) – a method to summarize the relative level of risk for a single noncarcinogenic 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.

Imposex- A condition of gender alteration (masculinization) in mollusks associated with exposure to butyltins.

In situ Treatment – an active remedial technology conducted in place (e.g., without removing sediment). It includes reactive caps and ENR 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 cleanup 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 criteria 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 concentration of a hazardous substance consistently present in an environment that has not been influenced by localized human activities. For some hazardous substances such as PCBs, background conditions may be influenced by global-distribution patterns.

No Adverse Effects Level (NOAEL) – the level of exposure to an organism at which no biologically or statistically significant effect is found in exposed test organisms in comparison to a control.

Organic Carbon (OC) Normalized Values –the bioavailability and toxicity of some organic contaminants in sediments are expected to correlate with the OC in sediment. Accordingly, some SMS criteria divide the dry weight value by the fraction of OC present in the sample (e.g., 12 mg/kg OC is the benthic SCO for total PCBs).

Preliminary Remediation Goals (PRGs) – contaminant concentrations that are developed during an RI/FS and proposed as Cleanup Levels in a Proposed Plan. 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. PRGs may become cleanup levels in the ROD.

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.

Propeller Wash, Propeller Scour – (see Vessel Scour)

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

Reference Dose (RfD) – an estimate of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs may be adjusted for uncertainties related to the type of test organism or organ system selected for the criterion; often this adjustment is by an order of magnitude.

Recovery Categories – categories used in the LDW FS to assign remedial technologies to specific areas based on information about the potential for sediment contaminant concentrations to be reduced through natural recovery and/or for subsurface contamination to be exposed due to erosion or scour. As used in this ROD, Category 1 refers to recovery that is presumed to be limited; Category 2 refers to recovery that is uncertain, and Category 3 refers to recovery that is predicted to occur with some confidence.

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.

Sediment Cleanup Objective (SCO) – see text box "What are the Sediment Management Standards?". SCO represents the level that is the environmental goal for establishing sediment cleanup levels under the Washington State Sediment Management Standards.

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.

Slope Factor (SF) - An upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent. This estimate, usually expressed in units of proportion (of a population) affected per mg/kg-day, is generally reserved for use in the low-dose region of the dose-response relationship, that is, for exposures corresponding to risks less than 1 in 100.

Spatially Weighted Average Concentration (SWAC) – a means of interpreting data across a surface (such as the LDW), using interpolation methods to generate a mosaic of concentrations which may then be averaged over the area.

Spud/Spudding – as applied to marine navigation, a spud is a metal pole that is dropped into the sediment by its own weight and is used for temporary anchorage or stabilization of vessels.

Toxic Equivalent (TEQ) – a single value used to express the joint toxicity of a mixture of compounds with a similar toxic action, e.g., dioxins/furans or carcinogenic PAHs.

Tug Scour – (see Vessel Scour)

Upper Confidence Limit (95%) on the Mean (UCL95) – 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.

Vessel Scour – erosion and movement of sediment due to propeller thrust or due to grounding of vessels. Vessel scour may cause subsurface contamination to reach the surface.

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Part 3 Responsiveness Summary

[separate volume]

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Attachment 1
Washington State Department of Ecology
Concurrence Letter

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

November 21, 2014

Dennis McLerran, Regional Administrator
U.S. Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101

RE: **Lower Duwamish Waterway Superfund Site Record of Decision**

Dear Mr. McLerran:

This letter communicates the State of Washington's (State) concurrence in the selected remedy for the in-waterway portion of the Lower Duwamish Waterway (LDW) Site, as described in the United States Environmental Protection Agency's (EPA) Record of Decision (ROD).

The ROD embodies a workable approach and an appropriate balancing of the unique factors present in this urban estuary with its long history of alteration and industrialization. The ROD represents a step forward in the restoration of the LDW's environment, but does not encompass the full extent of activities required of EPA or the State to clean up the contaminated sediment and control sources of additional contamination to the waterway. Accordingly, the State and EPA have memorialized our mutual expectations and understandings concerning the remedy in the Lower Duwamish Waterway Memorandum of Agreement, dated November 20, 2014.

Source control work may overlap with the CERCLA site boundary. The State agrees that the ROD does not impede state requirements or in any way limit the State in implementation of state law, including the Model Toxics Control Act, the Water Pollution Control Act or the State's implementation of Clean Water Act delegated authorities.

We have appreciated working in partnership with you on issues concerning the remedy and source control, and look forward to seeing progress made. If you have any questions or would like to discuss any aspect of this letter further, please contact me at (360) 407-7001 or via email at maia.bellon@ecy.wa.gov.

Sincerely,

Maia D. Bellon

Maia D. Bellon
Director